New Frontiers in Regional Science: Asian Perspectives 47

Soushi Suzuki
Roberto Patuelli *Editors*

A Broad View of Regional Science

Essays in Honor of Peter Nijkamp

Springer

New Frontiers in Regional Science: Asian Perspectives

Volume 47

New Frontiers in Regional Science: Asian Perspectives

This series is a constellation of works by scholars in the field of regional science and in related disciplines specifically focusing on dynamism in Asia.

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Editors

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Foreword: A Lifetime of Leadership in Regional Science

Peter Nijkamp and I first met in the mid-1970s when both of us were in our late twenties and in the early stages of our academic careers. We came from quite different backgrounds. In my case I had trained as a geographer–planner and had recently moved from a post in local government to a lectureship in planning at Liverpool University. Peter's career had already taken off most impressively with his appointment to a chair in Regional Economics at the Free University in Amsterdam. His regional economics textbook, a major work co-authored with Jean Paelinck, had just been published.

Both of us were excited by the opportunities offered by the nascent field of regional science. We were profoundly influenced by the efforts of American economist Walter Isard to develop a spatial dimension to inter-disciplinary social science and to create an institutional structure that would allow this new field to blossom and, in time, become an international organization. For this purpose, Isard had founded the Regional Science Association in 1954 and, after building a strong base in North America, had turned his attention to other parts of the world. He took full advantage of the burgeoning interest among economists, geographers, and planners to "plant" national sections of the Association, led by academics who shared his vision of regional science as the rigorous analysis of cities and regions.

By the early 1960s, Isard had initiated an annual Regional Science Congress in Europe. For nearly twenty years, however, the whole operation was run from RSA Headquarters in Philadelphia with a congress program largely put together by Isard who prided himself on identifying and nurturing new talent. To a degree, the congresses were successful, valued particularly by those for whom this was their first taste of international networking.

Inevitably there eventually came a time when European regional scientists began to resent what they quite rightly regarded as a paternalistic approach. Why was it necessary for Americans to organize our activities? Surely, we thought, this was something we could and should do for ourselves. Feelings were running high, especially among younger academics. The solution was to create a European Core Group charged with the task of organizing the first genuinely European congresses.

Peter and I share the distinction of being founder members of the Group, Peter as the chair and myself as the local organizer for the 1979 London European Congress. It is probably fair to say that none of us in the Core Group had much relevant experience of organizing international conferences. We found ourselves literally in the position of making it up as we went along. Peter, as our leader, played a crucial role in devising sensible (and sensitive) ways of working and, most important, finding key people who were reliable and willing to put in the time and effort needed to deliver a major international event of this kind.

From these humble beginnings there developed ERSA, the European Regional Science Association. Forty years on, the ERSA we now know organizes a very successful range of activities including congresses, summer institutes, lecture series, as well as providing an umbrella for the national and language-based sections.

I have always regarded that early experience gained working with Peter as some of the most valuable in my whole career. The story, of course, does not end there. Over the years, in ways I would never have imagined, he and I have collaborated on innumerable occasions: as RSAI Presidents, in editing books and journals, in organizing conferences, workshops, and summer institutes and, most recently, in The Regional Science Academy, our virtual think tank. Peter always brings to these activities boundless energy, excellent judgement, and the ability to constantly enthuse those around him, whether they be established academics, younger scholars, or Ph.D. students. While most academics ultimately reach a point when they want to slow down, Peter remains as keen as ever to generate and embrace new ideas and to ensure that regional science continues to be that exciting inter-disciplinary field we both encountered for the first time all those years ago.

University of Liverpool, Liverpool, UK Peter Batey

Foreword: For Peter Nijkamp's Festschrift Volume

I am honored to have the opportunity to provide some insight into the impact of Professor/Dr. Peter Nijkamp on Regional Science both as a discipline and as a world organization. Next to the Founder of Regional Science, Walter Isard, no one has had a greater impact on the field than Professor Nijkamp. His history of research activity and publications is without peer. His continued development of advanced quantitative skills and support of new analytic developments and new methodology is at the forefront in the field. His focus on students and his continuing efforts to develop and support them are widely recognized and appreciated. His commitment and leadership in international development and the internationalization of the organization is another reflection of his long-term commitment to guiding and strengthening the organization. His guidance in making the field both analytically rigorous but also committed to operational consideration in planning and policy makes him a leader that understands the importance of implementation of research in the real world. Below I will take a few lines to introduce you to these various issues.

Peter holds his Ph.D. (cum laude) from Erasmus University in Rotterdam, the Netherlands with a specialty in econometrics and nonlinear programming applied to industrial planning. He has been a Professor of Urban Economics and Economic Geography at the Free University (VU) in Amsterdam since 1975 with teaching and research interests in transportation, planning, quantitative analysis, migration, technology and innovation, spatial systems, and sustainable development.

Peter has written a thousand books and book chapters and hundreds of articles. His scholarship is perhaps the strongest and most extensive of all living regional scientists. What is most striking about it is its cutting-edge character, high quality and empirical research base as opposed to discursive characterization. In topical terms, his work has ranged from environment (Theory and Applications of Environmental Economics, Elsevier, Amsterdam, 1987) to housing and from planning and policy (Multi-criteria Analysis of Physical Planning, Elsevier, Amsterdam, 1990) to exploration of innovation and regional economics (Handbook of Regional Economics, Elsevier, Amsterdam, 1986). His original interests in spatial interaction and the gravity model were extended to incorporate advances in mathematical programming and optimization. His work on migration and transportation supported the use of these spatial interactions models. He then worked extensively on environmental issues both as they relate to urban development and design and as they suggest impacts on regional economic structure. He pioneered regional sciences' social science leadership in inter-disciplinary research activities (Handbook of Regional Science (3 vol.) Springer Verlag, Berlin, 2013) and most recently has committed himself to strengthening the growth and the internationalization of regional science research and student and young faculty involvement through his development of the Academy of Regional Science.

He has supervised over 100 Ph.D. students and has or is serving on over 40 editorial and advisory boards in the different fields of regional science and holds visiting and contributing professorships in numerous countries.

Besides his recognition by Regional Science with the Founder's Medal and his election as an International Fellow of Regional Science, there he has received many honors outside his discipline. These external recognitions of his academic and research prowess are clear in his national and cross-national honors. In 1996, he was awarded the Spinoza Prize in the Netherlands to support his creation of a Center for Quantitative Research. He is the past chair of the Netherlands Social Science Council (SWR) and the past Vice-President of the Royal Netherlands Academy of Sciences (KNAW). He was the first social scientist to serve two terms as the President of the Netherlands Research Council (NOW) in the years 2002–2009 and he is the past President of the European Heads of Research Councils (EUROHORC). He was on the Council of the International Institute for Applied Systems Analysis (IIASA) in Vienna and an honorary scholar at the same Institute. He has been awarded honorary doctorates (honoris causa) from the Free University of Brussels (Belgium), the National Technical University of Athens (Greece), the Adam Mickiewicz University of Poznan (Poland), the University of the Algarve Faro (Portugal), and the Academy of Economic Studies Bucharest (Romania). I think this gives the reader an appreciation of the breadth and depth of recognition of this outstanding scholar, academic leader, and international academician.

For the purpose of this volume, the notes above provide some indication of his outside recognition but for us, in Regional Science he has been a central figure. He is the past President of the European Regional Science Association (1979–1989) and President of the Regional Science Association International (1990–1992). He inaugurated and chaired the Network on European Communications and Transport Activity Research (NECTAR) in the years 1987–2001 and chaired the Board of Trustees for the collaborative transportation research institute (TRAIL) at Delft University of Technology. He is the past chair of STELLA (the Transatlantic Research Network on Sustainable Transportation Research) operating jointly between Europe and North America. All this has been done as part of his contributions to regional science. He represents a model that includes scholarship, international academic and research collaborative leadership, and a commitment to the next generation of scholars and students.

He is my friend and colleague and one of the people I admire most in terms of regional science and academic leadership. This volume is an appropriate recognition of some of his many accomplishments.

George Mason University, Arlington, VA, USA

Kingsley E. Haynes

Foreword: Peter: Congratulations and Thank You!

This book is a tribute by the students and colleagues of Peter Nijkamp to celebrate the life and works of this outstanding scholar on the occasion of his 75th birthday. It is no exaggeration to say that Peter Nijkamp has been the most active scientist in the international regional science community since his graduation with a Ph.D. from Erasmus University Rotterdam in 1972. He has been a groundbreaker in regional science for 50 years, as well as the most productive professor in energy and environmental economics, spatial science, and sustainability science at Vrije Universiteit Amsterdam, the Netherlands. While the origins of his scholarly activity were in Europe, his contributions and accomplishments are known and acknowledged globally. As a zealous advocate of regional science, he has contributed to the establishment of regional science associations throughout the world. He has had advisory roles in various national and international organizations as an expert in regional development policy, transportation policy, sustainable development policy, etc. A detailed account of his activities and accomplishments would fill another book.

I first came across his name by reading his book entitled *Theory and Application of Environmental Economics* (North-Holland, 1st ed. 1977). The book was the first to consider the three fundamental balances—namely the balance of value, materials, and energy—jointly. These balances have become key principles in my research and were also adopted by my former Ph.D. students. Personally, Peter Nijkamp has been a mentor and good friend to me, going as far back as the 1980s.

I met Peter first in 1983 during the 8th Pacific Regional Science Conference Organization (PRSCO) meeting held in Keidanren-Kaikan, Tokyo, through the introduction of Professor Hirotada Kohno, who was the chair of the Local Organizing Committee (LOC) and President of the Japan Section of the Regional Science Association International (JSRSAI). I was still a Ph.D. student of Professor Kohno at the University of Tsukuba, and serving as Assistant Director in the LOC. At that time, Peter Nijkamp had already achieved a lot as a brilliant scientist despite still being relatively young. Just after returning from the 7th PRSCO meeting held in Surfers Paradise, Australia in 1981, where Prof. Kohno met Peter Nijkamp for the first time, he said to me “Prof. Nijkamp is young and will be definitely one of the people through who regional science and the regional science communities will be stimulated from now on.” This prediction has clearly turned out to be correct.

Peter Nijkamp is a trustworthy person. He is considerate of the feelings of others. He is a good communicator, full of wit, as well as a brilliant elocutionist. Our first collaboration consisted of organizing the International Symposium linked to the Annual Meeting of JSRSAI. After I had started my own career as a regional scientist and began networking internationally, our collaboration expanded to international meetings and workshops—including social events—mainly in PRSCO regions and but also in other parts of the world. In terms of social events, the one held at the InterContinental Hotel in Rome after the 1997 European Meeting is legendary. Everyone who participated in this event can still vividly and fondly remember what a fun night it was, with Peter assuming his usual role of impromptu master of ceremony.

I, as Editor-in-Chief of New Frontiers in Regional Science: Asian Perspectives, took the initiative to suggest to Dr. Soushi Suzuki to plan a Festschrift in honor of Peter Nijkamp. As some readers will know, the monograph series was launched around six years ago by the Japan Section of the Regional Science Association International together with the Asia-Pacific Journal of Regional Science (Springer) in cooperation with colleagues in international regional science communities.

It is now more than a half-century ago that JSRSAI was established. For most of the years since then, in fact, for almost 40 years, Peter Nijkamp has participated in all of the annual meetings of JSRSAI and in the international meetings held in Japan. His participation has broadened their views and encouraged young JSRSAI members to look beyond the border. He has advised JSRSAI executives to organize international meetings and projects with remarkable ideas and insightful views. Peter has been an Honorary Fellow of JSRSAI since 2001 and was awarded the Outstanding Achievement Prize in commemoration of 50 years of JSRSAI in 2012. He is now serving as a Chief Advisor for two JSRSAI projects, namely the monograph series and the international journal. He has made substantial contributions to the development of JSRSAI, which has now achieved a pivotal role in the global regional science communities. We cannot discuss the history of JSRSAI without mentioning Peter Nijkamp's valuable contributions. Consequently, it is a great honor for the members of JSRSAI and the broader regional science community when this book is accepted as a token of their appreciation of Peter Nijkamp's long friendship and outstanding contributions to this association and to regional science generally.

University of Tsukuba, Tsukuba, Japan Yoshiro Higano

Foreword: Professor Nijkamp, 75 and Going Strong

This edited volume includes some of the world's top regional scientists and celebrates Professor Peter Nijkamp for his 75th birthday. I am quite honored to participate with this Foreword. Professor Nijkamp is likely the world's best-known regional scientist with the possible exception of Walter Isard himself, the founder of regional science. Professor Nijkamp's contributions are widespread as he has authored or co-authored several hundred manuscripts if not more. A common theme in Professor Nijkamp's work is his belief that regional science, and good science in general, can promote a more prosperous, just, and fair society that provides opportunities to all, with its growth being sustainable and environmentally friendly. In all, one of the things that stand out in Professor Nijkamp's vision is an optimistic view that people, their institutions, and governments can improve the life for all of the world's citizens if they are guided by good science. Peter's vision is not just "technocratic" but it is also inspired by social justice, aiming to be inclusive to for all people from the world's races, ethnic groups, and religions. Although all of his work has made a mark, I speculate that his most enduring work will be linking environmental sustainability with regional science—an area that regional science has so much to contribute.

Professor Nijkamp has left his mark on regional science and scholarship around the world in so many ways. Perhaps with a couple exceptions, Professor Nijkamp has recruited the most scholars into regional science. Because of that, we have more influence as a field and we have more people reading and citing our work. I admire how Peter can sit down with young researchers in Africa, Central Asia, Western Europe—i.e., everywhere—and compliment their work, while at the same time constructively critiquing the work, helping shape it into a contribution to regional science. His genuine affection for young scholars and his general charm lift the quality of their research and often forge a lifelong commitment to regional science. Professor Nijkamp likewise has been the supervisor for dozens if not hundreds of Ph. D. students—many of which are now among the world's leading regional science scholars. His footprint will live on for generations.

Professor Nijkamp's contributions to regional science extend to forging a strong world community. Of course, he has done the "official" duties such as serving as the President of Europe's and the world's major regional science organizations and he remains active in his service to them. He has edited hundreds of books and special journal issues, promoting regional science's vision to audiences that would have never been exposed. He has organized hundreds of workshops and symposiums for both junior and senior scholars, creating a family of regional scientists as well as promoting good science. Professor Nijkamp has served as a mentor to scores of researchers and scholars, including myself. My professional standing owes so much to Peter's good judgement and sound advice. Overall, I cannot see that regional science would be the same without Professor Nijkamp's tireless contributions and lifelong work for regional science. Whatever it would be, it would certainly not be the academically vibrant worldwide community that has been a great part of my life.

Congratulations Peter on your 75th birthday and I am sure you will have many many more! I cannot think of a better way to celebrate than with a volume written by many of your closest collaborators and students. This volume is filled with the papers at the envelope of regional science and will certainly be an important resource for years to come. A fitting testimonial to Peter's lifelong work!

Ohio State University, Columbus, OH, USA

Mark Partridge

Foreword: Peter Nijkamp—A Gentleman and a Scholar

When Soushi and Roberto invited me to write this Foreword, I was delighted, honored, and humbled. I first met Peter Nijkamp in Sao Paulo, Brazil in 2008, at the 8th World Congress of the Regional Science Association International. It was Geoffrey Hewings who introduced me to Peter, over lunch one day. I am sure that Peter does not remember that meeting (but I do). Since then I have spent hundreds of hours with Peter in conferences and workshops in a wide array of spectacular settings from Santa Fe, New Mexico to Stockholm, Sweden. In 2017, I even had the opportunity to spend time with Peter in the place of his birth; Dalfsen in the Netherlands.

When I first met Peter, I was aware of his prowess and reputation as an academic. To date, he has published over two thousand scientific papers. According to Google Scholar, his work has over 65,000 citations. His contributions to Regional Science span the theoretical, methodological, and the applied. The range of the topics to which he has applied his knowledge and expertise is vast—regional and urban modeling, multi-criteria analysis, transport systems analysis, entrepreneurship, environmental and resource management, methods of policy analysis, etc.

His excellence in scholarship has been recognized by the receiving of numerous prestigious awards and recognitions such as the Dutch Spinoza Prize (highest scientific award in the Netherlands), the Founders Medal of the Regional Science Association International, the Walter Isard Award for Scholarly Achievement in Regional Science, and Doctor honoris causa degrees from a number of universities, including the Free University (Brussels, Belgium), National Technical University (Athens, Greece), and Adam Mickiewicz University (Poznan, Poland).

Peter is much more than a scholar, however. He understands the vital importance of stepping outside of the ivory tower and making his knowledge and expertise work for the betterment of society. Over the years, he has advised dozens of public and private sector entities, including the World Bank, the European Union, the Asian Development Bank, and numerous Dutch ministries.

In addition, Peter has been an outstanding servant to academia in general and to Regional Science in particular. He currently serves on approximately twenty-five editorial boards for scientific journals. He is the past President of both the European Regional Science Association and the Regional Science Association International.

While these achievements are impressive, it is important to understand that they only paint a partial picture of Peter Nijkamp. Part of Peter's greatness is to be found in his ability to bring people together. If you peruse Peter's publications, you will see that he has co-authored papers with literally hundreds of different individuals. Not only that, every year he organizes numerous workshops and conferences all over the world. These are small-scale events, in that most of them comprise between 25 and 50 participants. However, these are mega-scale events when it comes to the ideas discussed and the scientific progress that is made. Many of these events are organized under the auspices of The Regional Science Academy (TRSA), of which Peter, along with Karima Kourtit, is a co-founder. While the scientific content of TRSA meetings is a critical component of their success, these are also events where social networking is prized. Peter has an uncanny ability to bring together just the right mix of people in just the right setting.

As I write this Foreword, we are in the middle of the COVID-19 global pandemic. Conferences have been canceled and travel restricted. We are all being asked to practice social distancing. I can only imagine how difficult this must be for Peter. Peter is a natural-born social networker, He loves being with people and engaging in face-to-face scientific dialogue with his colleagues. I am sure that, like many of us, he is looking forward to the day when he can board a plane and travel to his next international conference.

Finally, thank you to Soushi and Roberto for organizing this magnificent volume, in celebration of Peter's 75th birthday. Thank you to all the contributors who agreed to share their insights on a variety of Regional Science issues. But most of all, thank you to Peter for his decades of outstanding scholarship and friendship. You have touched the lives of so many people, who are proud to call you a colleague and a friend. I hope that you agree with me Peter, when I say that this volume is a fitting tribute to one of Regional Sciences pre-eminent scholars.

The University of Toledo, Toledo, OH, USA

Neil Reid

Foreword: Peter Nijkamp and Developing World

When Soushi Suzuki informed me that he and Roberto Patuelli are preparing an edited book for Peter Nijkamp celebrating Peter's life contributions in enhancing regional science, as well as Peter's 75th birthday, I think that it is a great idea and well deserved. Peter has endlessly contributed to the science of regional science and has been one of the major pillars in the establishment and growth of the Regional Science Association International (RSAI). It is a privilege to learn of Peter's endurance and creativity in providing these rich contributions. With this note, allow me to convey a big congratulation to Peter for his lifetime achievement on many aspects in the academic world; and not less pertaining to regional science.

I also appreciate Peter's energetic activities in pushing the frontiers of regional science moving forward. His willingness to organize seminar series with unconventional topics throughout the years is amazing. In these seminars, he keeps challenging participants to think beyond what are known. Peter is a true academic. In the RSAI organizational meetings, Peter often leads discussions with his insightful ideas. His energy and creativity certainly have had a significant role in shaping the organization of the association.

I am even more appreciating of his contributions to the association in his eagerness to support the development of regional science in the developing world. Without any hesitation and despite his overbooked schedule, Peter accepted my invitation to attend the 2013 Pacific Conference of RSAI held in Indonesia that I co-convened. His presence at the conference contributed to the success of the conference as well as validating the quality of the RSAI Indonesian Section. The Indonesian Section grew strongly after that event. Peter was also a strong supporter in the 2018 RSAI World Congress in India which has strengthened our sections in South Asia. He has also been very supportive of the idea of having our upcoming World Congress in Morocco. While maintaining our achievement in Europe and North America, it is crucial for our association to extend our presence and further expand the knowledge of regional science in Asia and Africa. Our association and the science of regional science should be able to contribute and support an improved and more rapid development in these regions.

Peter, developing countries' academics are in debt for your tireless efforts to further introduce the knowledge of regional science in these areas. I personally appreciate your support and attention to regional scientists in the developing world. I wish you a happy birthday and looking forward to more of your ideas and contributions in regional science; particularly their applications for developing countries.

Australian National University, Budy P. Resosudarmo
Canberra, ACT, Australia

Foreword: A Tribute to the Modern Flying Dutchman

Back in 1962, the American singer-songwriter Marvin Gaye recorded a song that few people cared about, but strange things happen in show business. When the British singer Paul Young two decades later recorded a rearranged version of the song, it became the UK No. 1 single. I do not think that Peter Nijkamp ever met Marvin Gaye or Paul Young (although with Peter you never know) but the title of the song fits few people as well as Peter Nijkamp: “Wherever I lay my hat, that’s my home.”

This should not be misunderstood. Even if Peter Nijkamp is “the type of boy who is always on the roam” (as the song text says) he is certainly not an idle tramp, roving around wherever his nose points and sleeping in the haystacks he finds (there are also very few of them nowadays). Peter is a traveler with a mission and the mission is to spread and develop Regional Science across the world. He fulfills this mission better than anybody else of us. There are persistent rumors that KLM plans to give him an exclusive platinum version of their “Best Customer Award.”

The contents of Peter’s CV could be the collective CV of a full university: He has published well over 1000 scientific articles, more than 40 monographs, and over 100 edited volumes. He is an Honorary Doctor of five universities and a member of a number of academies. He has supervised about 100 Ph.D. students, several of them today holding a professorship in different countries. He has been an advisor to a large number of national and international organizations and has been chairing a number of different scientific committees and councils. On the RePEc worldwide ranking list of economists, he has the highest ranking of all Dutch economists and he has the highest ranking of all regional scientists globally. Does the man never sleep?

Most of all, Peter Nijkamp is The Regional Scientist. During the whole 1980s, he was the President of the European Regional Science Association and thereafter he became the President of the global Regional Science Association International for three years. He has been one of the two main editors of the giant work Handbook of Regional Science, which second and extended edition was published in 2020, and he is the founder of the Regional Science Academy (for which I served as the first President).

Nowadays, being an Emeritus Professor, one might expect that he, like Candide, would cultivate his garden and otium cum dignitate. Nothing could be more erroneous. Candide has to wait while Peter is organizing still another ABC (Advanced Brainstorm Carrefour!), editing a new paper together with one of his many colleagues or giving a speech at a conference. For Mr. Regional Science there are always more exciting things to deal with than garden work!

This book is a homage to Peter from colleagues, associates, former doctoral students, and guest researchers. I am happy to be one of them!

KTH Royal Institute of Technology, Hans Westlund
Stockholm, Sweden

Preface

This book celebrates the life and work of Peter Nijkamp, as well as his strong research focus on regional science. His work follows a rigorous and wide approach, centered around analytical modeling and methodological innovation. This edited volume, like Prof. Nijkamp's research, covers a wide range of topics in regional science, analyzed through multi-criteria evaluation, evaluation modeling, econometrics, and simulations, among other methods. These tools are applied to the analysis of society, culture, tourism, information, cities, environment, and sustainability.

Professor Nijkamp is one of the founding members of the Regional Science Association International (RSAI). For several years, he has played a leading role in this research community, also covering the roles of President of the European Regional Science Association (ERSA) (1979–89) and of the RSAI (1990–92). He is a member of approximately 30 editorial or advisory boards of scientific journals in the field. He is also the past President of the European Heads of Research Councils (EUROHORCs), and he is the 1996 recipient of the Spinoza Prize, the most prestigious scientific award in the Netherlands. He received the 2004 Founder's Medal of the RSAI, the highest international scientific award in the area of regional science, and he is also an RSAI Fellow. On the (RePEc) ranking list of economists worldwide, he has the highest ranking of all Dutch economists, and also the highest ranking of all regional scientists. His body of work forms a valuable reference for researchers, scholars, policymakers, and students in the field of regional science and in other disciplines.

This volume, timed to coincide with his 75th birthday, celebrates Prof. Nijkamp's great contribution to regional science. He also promoted and participated in the education and development of many young researchers, not only in regional science, but also in other fields, supervised about 100 Ph.D. students, and hosted even more as guests at the Vrije Universiteit Amsterdam. Contributors to this volume include Prof. Nijkamp's former doctoral students and guest researchers, as well as longtime research associates and colleagues. We have edited this volume guided by feelings of sincere gratitude and respect for him.

> Peter Nijkamp is not only our academic father, but also a mentor in our lives
> Soushi and Roberto

This book is organized as follows.

Part I: New perspectives, modeling, and methodology in Regional Science
Part I of the book is devoted to reflections on regional science research and the showcase of how different methods may be used to improve its societal impact.

This part starts with a contribution by Roberta Capello and Andrea Caragliu (Chapter 1: The Cost of Missed EU Integration), in which they measure the cost of a missed EU integration. They do so by comparing the GDP growth expected for two scenarios: a reference one of greater future integration and one of missed integration. They find that the more integrated scenario suggests faster economic growth across all EU countries.

Subsequently, Amitrajeet A. Batabyal and Hamid Beladi (Chapter 2: On the Existence of an Equilibrium in Models of Local Public Good Use by Cities to Attract the Creative Class) develop a representative-agent model of competition between two cities that use a local public good (LPG) to attract members of the creative class. In this framework, they obtain equilibrium conditions based on the behavioral rules of the agents (artists and engineers).

Eric Vaz (Chapter 3: Canadian Regional Science 2.0) follows, which a chapter exploring new research directions in Regional Science, and using Canada as a basis of discussion for the potential of new methods which could be able to address unprecedented challenges for humankind. He concludes that regional science and the analysis of the spatial/geographical dimensions remain central for exploiting the explosion of digital data happening today.

Moving into the realm of sustainability and urban peripheries, the authors of the subsequent chapters, Teresa de Noronha, Eric Vaz, and Waldemar Ratajczak (Chapter 4: Dynamic Sustainability: Back To History To Advocate For Small And Medium Size Towns), discuss the real "net" value of agglomeration economies generated when in the presence of volatile assets such as history, strategic planning, knowledge creation, trust, shared innovation, and advanced specific skills at the global level.

On a similar note, Gabriella Vindigni, Teresa Graziano, Vito Martelliano, and Bruno Messina (Chapter 5: Peripheral Urban Areas: Perspectives on Sustainable Regeneration) scrutinize some theoretical and methodological approaches in urban planning of peripheries through an explanatory place-based case study. They conclude that multi-method frameworks may allow to achieve a participative approach to the urban regeneration of peripheries.

Finally, in the last chapter of Part I, Karima Kourtit (Chapter 6: Cities and Spatial Data in the New Urban World—A Data-Analytic Exploration) seeks to address the emerging research and policy challenges regarding cities, their definition, and their role, as the result of the presence and use of extensive spatial data and statistics in the digital society.

Part II: Society and Culture

Part II of the book tackles a number of socio-economic issues, from residential sorting and segregation to the integration of migrants, to urban social capital and cooperation. All these issues are among the most frequently analyzed topics in regional science.

In the first chapter of this part, Mohana Mondal, Michael P. Cameron, and Jacques Poot (Chapter 7: Group-Size Bias in the Measurement of Residential Sorting) discuss a common issue with popular indices used for measuring residential sorting, that is, the extent to which a subgroup of the population is spatially distributed (sorted or segregated) differently from the remainder of the population. They identify a positive bias in indices of residential sorting, identifying the entropy index of systematic segregation as the preferable one to use to avoid group-size induced bias.

Looking at related issues, Tüzin Baycan (Chapter 8: Entrepreneurial Interest of University Students in a Multicultural Society) investigates the diverse attitudes, career motivations, and perceived leadership skills of university students in the Netherlands. She analyzes and compares their entrepreneurial interest, inter alia on the basis of gender and ethnic differences, finding that motivating factors differ for immigrants and natives, and for males and females.

In Chapter 9 (How Can Small-Scale Measures of Human Development Index (HDI) Be Used to Study the Local Potential for Sustainable Economic Growth?), Umut Türk, Marina Toger, and John Östh propose the computation of the HDI index at the local/regional level. They show that geographical HDI patterns in Sweden, computed at the municipality level, agree with commonly used segregation measures.

Subsequently, Annie Tubadji (Chapter 10: Ceteris Paribus and Fixed Effects in Regional and Cultural Economics) takes a new look at a stable of current econometric practice and argues that individual fixed effects have the same interpretation of the ceteris paribus assumption and hamper the extraction of important implications from empirical results in regional analysis, especially regarding cultural relativity in economics.

Finally, in Chapter 11, Roberto Patuelli, Eveline van Leeuwen, Lorenzo Zirulia, and Aura Reggiani (Horizontal Transmission of Civic Capital and the Emergence of Cooperation: An Agent-Based Modeling Approach) introduce a theoretical agent-based model to analyze the horizontal transmission of civic capital (e.g., its transmission among peers) within the context of the so-called threshold models. They show that the average outcomes in terms of civic capital depend strongly on the model parameters and on the assumptions on the spatial extent of peer influence, which drives conditional cooperation.

Part III: Tourism and Information

Part III of this book focuses mostly on tourism research. It first provides a discussion of Peter Nijkamp's contribution to the field and to its integration with regional science. Subsequently, the focus moves to the use of information technologies (IT) in tourism and not only, ranging from the analysis of online reviews to website analytics, to the use of GIS.

In Chapter 12, João Romão (Peter Nijkamp on the Move: Crossing Borders between Regional Science and Tourism Studies) discusses how different academic disciplines contribute to the creation of synergies between tourism studies and regional science, by analyzing research objectives, methodologies, and approaches developed or applied by Peter Nijkamp and his extensive global network of collaborators.

Bart Neuts (Chapter 13: Revisiting Bruges: Investigating the Importance of Tourist Crowding Perception in the Visitor Experience through Computational Text Analysis) evaluates tourist crowding perception in Bruges by applying computational text analysis on TripAdvisor reviews. He finds that while crowding is perceived as stable over time, it has a small but statistically significant negative effect on review scores.

Still within the topic of tourism and IT, Maria Francesca Cracolici and Furio Urso (Chapter 14: Exploring User Behavior in Destination Websites: An Application of Web Mining Techniques) explore the information-seeking behavior of those who log on to a website promoting the island of Sicily, a well-known tourist destination in the South of Italy. Website visitors from Western countries and from China are compared, highlighting widely different approaches to the exploration and use of information.

Finally, Maria Giaoutzi and Chrysaida-Aliki Papadopoulou (Chapter 15: The Role of Visualization in Spatial Planning: A GIS-Based Approach) move on more general grounds and discuss the added value that visualization provides in spatial planning by integrating GIS technology into the planning process. In this regard, they focus on the extension of multi-criteria decision analysis (MCDA) to incorporate visualization through GIS techniques.

Part IV: City, Environment, and Sustainability

The final part of the book (Part IV) focuses on sustainable growth, green investments, and the circular economy.

In Chapter 16, Luigi Fusco Girard (Towards the Implementation of the Circular Economic Model in Metropolitan Cities: The Case of Naples) focuses on the benefits of the circular economy and circular city model. A multidimensional and multicriteria assessment method is experimented in the city of Naples, Italy.

Subsequently, Marina van Geenhuizen, Razie Nejabat, Pieter Stek (Chapter 17: Large Cities as the Cradle of Sustainable Energy Innovation) address the question as to what extent innovation in sustainable energy is concentrated in large cities and how its performance is connected to agglomeration factors and network factors, as well as concomitant entrepreneurial advantages, in the presence of different path dependence.

In Chapter 18, Martina Siskova and Jeroen van den Bergh (Are CO2 Emission Targets of C40 Cities Realistic in View of their Mayoral Powers Regarding Climate Policy?) evaluate the level of a number of cities' ambition in setting emission targets and implementing policies, as well as factors explaining it. They find that richer countries tend to set less ambitious objectives in the short run, but more ambitious ones for the long run, and that population size is correlated with less challenging objectives.

Remaining within the wider topic of reducing emissions and improving energy efficiency, Yoshifumi Ishikawa (Chapter 19: Economic Impact Analysis of Installing Renewable Energy: A Multiregional Input–Output Model for a Small Region and the Rest of the Country) proposes a versatile multiregional input–output model for estimating regional economic effects of installing renewable energy. His simulations show that installing such infrastructure and supplying the remaining energy resulting from conventional sources to the rest of the country have large effects on the regional economy.

Finally, in Chapter 20, Soushi Suzuki (A Performance Assessment of Japanese Cities by Means of Data Envelopment Analysis) provides an assessment of the relative economic performance of 16 large Japanese cities by means of an extended super-efficient Data Envelopment Analysis model. His results show a statistically significant relationship between city performance and population density.

We wish to express our thanks to all contributors of this volume.

Sapporo, Japan
Bologna, Italy
September 2020

Soushi Suzuki
Roberto Patuelli

Contents

Part I
New Perspectives, Modelling and Methodology in Regional Science

Chapter 1
The Cost of Missed EU Integration

Roberta Capello and Andrea Caragliu

Abstract The 2016 referendum held in the UK about the possibility to quit EU membership as well as a wave of populistic movements sweeping all over European Countries seem to suggest that less integration could be an outcome for the European Union. This paper has the aim to measure the cost of a missed integration, by highlighting what GDP growth would be in case of a missed integration. It does so by building a scenario of missed integration and compares it with a reference scenario. Scenarios are based on the Macroeconomics, Social, Sectoral, Territorial (MASST) model that has recently been updated to its fourth generation, whereby regional economic relations are tested econometrically. The estimated cause–effect chains are then the basis to build new scenarios simulated under complex sets of internally coherent assumptions in a simulation stage. The reference scenario presented is not a simple extrapolation of past trends; the post-crisis period registered structural changes to be taken into account for the future. In the integration scenario, we assume further integration within the EU to take place through the following changes: (1) higher trade flows among EU countries ("production integration effect"); (2) higher decrease in non-tariffs barriers ("proximity effect to larger markets"); (3) higher trust within and among countries ("social effect"); (4) higher quality of government ("institutional effect"); (5) stronger cooperation networks among cities ("cooperation effect"); and (6) higher exports ("market integration effect"). Results show that a more integrated scenario leads to faster economic growth across all EU countries. Territorial disparities are also initially lower in the case of more integration, although this difference abates over time. Lastly, the gains from integration are not spatially even and some regions gain more than others.

Both authors acknowledge Peter Nijkamp's intellectual legacy. In fact, their scientific development would have not been the same without Peter Nijkamp's guidance in the first years of their intellectual journey.

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JEL Classification Codes R11 · R12

1.1 Introduction

The recent economic crisis, the 2016 referendum held in the UK about the possibility to quit EU membership as well as a wave of populistic movements sweeping all over European Countries open to a different future for EU regional economies, and call for a possible interpretation of their effects, if they drastically pervade Europe, leading to a "failure" of the integration dream for the European Union.

This paper aims at presenting a scenario exercise of missed integration. The final goal of such exercise is to raise awareness of the costs of such missed integration for Europe as a whole, for its countries, and its regions. The costs will be calculated in terms of missed GDP growth compared with a reference scenario that cannot simply represent a linear extrapolation of past tendencies. The 2008 crisis brought about structural changes in the economy; consequently, the after-crisis period cannot be compared to the pre-crisis period in the macroeconomic and industrial structures of the economies, as the econometric estimates of macroeconomic and industrial relations show.

The scenarios are built based on the Macroeconomics, Social, Sectoral, Territorial (MASST) model (Capello 2007; Capello and Fratesi 2012; Capello et al. 2017), that has recently been updated to its fourth generation (Capello and Caragliu 2020), whereby regional economic relations are tested econometrically. The estimated cause–effect chains are then the basis to build a new scenario simulated under complex sets of internally coherent assumptions in a simulation stage.

In particular, in the integration scenario, we assume further integration within the EU to take place through the following changes: (1) higher trade flows among EU countries ("production integration effect"); (2) higher decrease in non-tariffs barriers ("proximity effect to larger markets"); (3) higher trust within and among countries ("social effect"); (4) higher quality of government ("institutional effect"); (5) stronger cooperation networks among cities ("cooperation effect"); and (6) higher exports ("market integration effect").

Results show that a cost of missed integration does exist. In fact, a more integrated scenario leads to faster economic growth across all EU countries, although two interesting results emerge. The first one is that the gains from integration are not spatially even and some regions gain more than others. Secondly, the gains are not a constant result from integration. Some regions register a lower GDP growth in an integration scenario, a signal of the weakness of their economy, unable to cope with an international competition. This result may also explain (even if not justify) in some cases the tendency towards autarchy and closeness of some parts of Europe.

Another interesting result of the scenario exercise is the change in regional disparities. The empirical analysis shows that regional inequalities initially lower in the case of more integration, although this difference decreases over time.

This chapter is structured as follows. In Sect. 1.2 we provide a synthetic description of the methodology for building quantitative scenarios, which represents the basis of the MASST model. Section 1.3 describes the first scenario: a reference scenario whereby some major structural changes, also described in the section, taking place in the EU economies in the aftermath of the 2007–2008 economic crisis are taken into account. Section 1.4 presents instead a different scenario, modeling the possible benefits stemming from further integration among EU economies, as a deviation with respect to the results obtained in the reference scenario. Lastly, Sect. 1.5 concludes by illustrating some possible future research avenues, mostly related to the need to take an additional (and presently ongoing) further structural change in EU economies, namely the COVID-19 medical emergency which will likely reshape many of the relations modeled in this work.

1.2 Scenario Building Methodology and the MASST4 Model

The aim of the paper is to provide territorial scenarios on how the future of Europe will look like under the assumption of a more intense degree of integration. Quantitative results obtained through the model are not meant to be forecasts. The aim of a forecast is to obtain precise values of specific economic variables in the future, on the basis of extrapolations of a system of past socio-economic relations, and since they extrapolate from past tendencies, forecasts yield the best results in a short-term perspective.[1] However, the aim is not to build foresights either, i.e. an image of the future based on radical breaks, on structural effects which destroy past tendencies like a new technological paradigm, new socio-cultural models, new political regimes. A foresight is a possible, probable, and even desirable image of the future based on a structural and radical break with the past, and assuming in general a long-term perspective (usually decades).[2]

The goal is to provide what can be defined as a *quantitative foresight* in that it is the result of three major steps.

In the first step, we build a scenario whereby an image of the future is constructed on the assumption that a discontinuity will emerge in the main elements or driving forces that influence and regulate the system. In our case, the main assumption representing a discontinuity is the degree of integration that takes place in regional

[1] On forecasting methodologies see, among others, Armstrong (1985), Hawkins (2001), Hendry and Clements (2001), and Loomis and Cox (2000).

[2] On foresight methodologies see, among others, CEC–European Commission (2004), Miles and Keenan (2000), and United Nations Industrial Development Organisation (2004).

economies, presented in Sects. 1.3.2 and 1.4.1, for the reference scenario and the integration scenario assumptions, respectively.

In the second step, a theoretical structure linking relations among economic variables modeling the structural relations in the regional economies included in the analyses, thanks to a macroeconometric regional growth forecasting model, called MASST, now in its fourth version (Capello and Caragliu 2020). This structure, based on a Keynesian set of quasi-identities for the national model, and on various strands of the regional economics literature for the regional component is shown in Fig. 1.1 for the present generation of the model (MASST4).

Figure 1.1 shows that the MASST model is based on the interrelation between a national sub-model, depicted on the left-hand side of the figure, and a regional model, visible on the right-hand side. The link between the two sub-models is based on the regional differential shift, which identifies deviations of regional GDP growth rates with respect to national mean growth rates as defined in Eq. (1.1):

$$\Delta Y_r = \Delta Y_N + s; r \in N \tag{1.1}$$

where N represents the Country to which each region r belongs, while ΔY indicates the GDP growth, and, lastly, s stands for the regional differential shift.

In the MASST model, growth is explained mostly by national features. National competitiveness stems from institutional (such as government efficiency), organizational (for instance, transport infrastructure), and economic (price competitiveness) characteristics, while at the same resting on competitiveness on international markets. The national model also explains national economic performance as a result of global demand for local products. The capacity of regions to grow depends instead on the local endowment of specific tangible and intangible assets, which we label *territorial capital*. These include static and dynamic features of territorial innovation patterns, static and dynamic agglomeration economies, regional productivity, regional institutions, trust and sense of belonging, and industrial composition. Thus, while the national model is geared towards capturing demand-side elements, the regional sub-model mostly deals with supply-side elements.

The relations among national and economic variables are estimated with different econometric techniques depending on the availability of shorter or longer time series for each data vector and the preferred specification chosen on the basis of standard econometric testing for each equation. While the interested reader is referred to Capello and Caragliu (2020) for additional details on the advances presented in the fourth generation of the MASST model, it here suffices to mention that the model presently works on the basis of six national equations, nine regional equations, and two urban equations, with yearly data covering the period 2000 through 2016 for the national sub-model and three period average data for the pre-crisis (2004–2008), crisis (2008–2012), and after-crisis (2012–2015) periods for the regional sub-model. A panel structure for both the national and regional sub-models allows therefore to exploit cross-sectional and time variation across all Countries (27 + the UK) and NUTS2 regions (276) of the European Union.

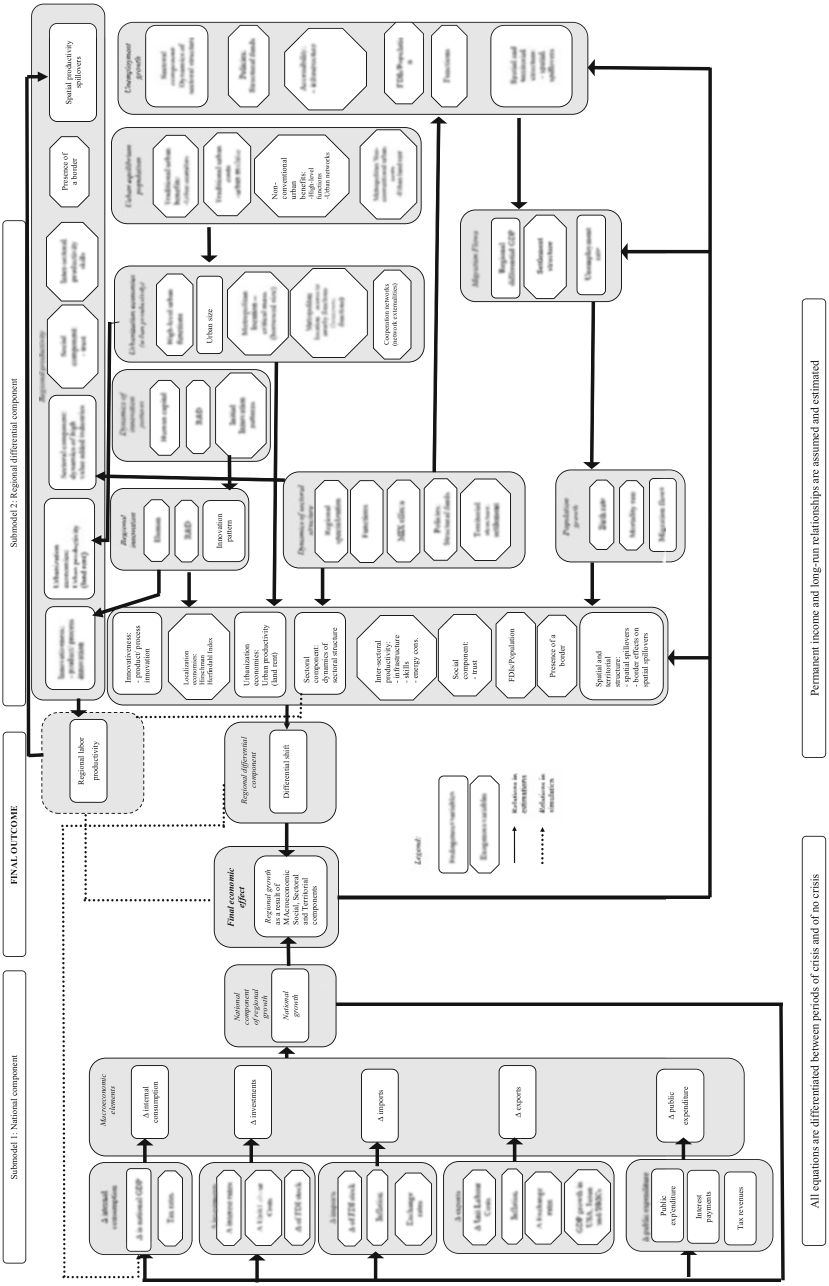


Fig. 1.1 Logical scheme of the MASST4 model. Source: Capello and Caragliu (2020)

Lastly, *in the third step of the procedure*, estimated relations are used in a so-called simulation stage, that produces quantitative forecasts for a period ranging between 15 and 20 years. The fourth generation of the model, for instance, produces forecasts for the 2018–2035 period.

This stage is based on dividing model variables in endogenous (i.e., determined within the model on the basis of the equations illustrated in Fig. 1.1) and exogenous, i.e. not explained by the model. The latter represent model levers, i.e. strategic regional and national characteristics for which target values can be decided by the modeler. The choice of targets depends on assumptions that, within the quantitative foresight approach, are based on scenarios, i.e. internally coherent sets of conditions that define possible future growth paths. These scenarios do not need to be more or less likely to happen; on the contrary, extreme conditions are often sought, so as to highlight major bifurcations in future growth patterns, which ultimately allows the model to steer towards a cluster of conditions that target variables are assumed to fully or partially reach within the simulation period.

This process is regulated by Eq. (1.2), which defines the process of adjustment of target variables towards their goals:

$$x_t = x_{t-1} + S(T - x_{t-1}) \tag{1.2}$$

where x represents a model lever, t stands for each time period, T is the variable target, and, lastly, S represents the speed of adjustment.

When $T = 1$ the adjustment of the variable is instantaneous (i.e. it takes place in the first year). Values of T lower indicate more gradual adjustments, and the choice of S is in itself a lever for the modeler. Typically, faster adjustment speeds are chosen for policy variables, while slower adjustment speeds are selected for structural variables, such as demographic characteristics. In the MASST model, targets can be unique for all regions, as well as selected for groups of regions or even be region-specific.

Results obtained will not be precise estimates of future GDP levels, but rather the main tendencies, major adjustments to change, relative behavioral paths that will be at work, given some conditional assumptions about the influence of the main driving forces.

1.3 A Reference Scenario

1.3.1 Structural Changes in EU Economies After the 2008 Crisis

In the aftermath of the financial crisis starting on Sep. 15, 2008, with Lehman Brothers filing for bankruptcy, several relations founding the structure of both national and regional economies has changed for good. Consequently, the reference scenario cannot be the simple extrapolation of past tendencies, and has to consider the structural changes that occurred in the 2008 crisis.[3] This section describes some stylized facts leading to a better understanding of the way the new structure of the MASST4 model was built, on the basis of the way European economies emerged from the end of the greatest economic contraction of the past two decades.[4]

The variable of interest in the scenario exercise is the GDP growth. Its past trend after 2008 shows the growing divide in terms of aggregate economic performance across three clusters of Countries, witnessing a different reaction to economic crisis by European countries. Countries can statistically be grouped by performing a cluster analysis[5] (see Table 1.4 in Annex 1) on the performance of EU Countries across three indicators of aggregate economic activity (unemployment levels, job creation, and real GDP growth) in 2015.

Figure 1.2 shows 2000–2016 real GDP growth rates in the three Country clusters identified, setting the value of each Country cluster in 2000 as 100. Figure 1.2 highlights that, rather strikingly, despite identifying clusters with the after-crisis economic performance only, patterns of GDP growth remained fairly stable for more than 15 years. In other words, the crisis exacerbated long-run trends that were already present in EU economies: Countries displaying sluggish GDP growth before the crisis hit (blue line in Fig. 1.2) also tended to be outperformed by Countries with middle (red line) and fast (green line) GDP growth both before, as well as during and after the crisis ended.[6] For the rest of this subsection, we will maintain the same color code so as to better highlight the different performance of these groups of Countries across many different economic indicators.

Not surprisingly, most Countries belonging to the third cluster are located in the Eastern part of Europe, with the exception of Ireland, Luxembourg, and Sweden—all Countries located in the core and Northern part of the Continent. All countries located on the Southern and South-Western tip of the continent have instead been

[3]This work has been carried out before the 2020 COVID-19 pandemic, and therefore does not take its economic consequences into account. However, the aim of the paper remains valid. In fact, under the realistic assumption that the new crisis has to be taken into consideration in both the reference and the integration scenarios, its existence does not affect the relative results.

[4]Once again, while precise forecasts are not yet available at the time this is being written, the medical emergency due to the pandemic diffusion of the COVID-19 virus in the first half of 2020, and the ensuing lockdown measures taken in many Countries is likely to cause an even worse contraction of GDP in many EU countries than the 2007/2008 crisis. In fact, the IMF presently foresees a likely contraction of world GDP in 2021 for the first time in decades (World Economic Forum 2020).

[5]The cluster analysis has been performed on the basis of the k-means method setting the target to obtaining three groups of Countries. Dissimilarity across groups has been defined in terms of Euclidean distance (Minkowski with argument 2). Lastly, centers of cluster have been identified with the first k observations from those to be clustered.

[6]Our working definition of the end of the crisis sets it to 2012, the first year in which EU GDP resumed pre-2008 levels. This does not imply that in 2012 all EU Countries achieved this goal; in fact, in purchasing power standard per capita terms, in 2012 Greece, Spain, Croatia, Italy, Cyprus, the Netherlands, Portugal, Slovenia, Finland, and the UK were still off target.

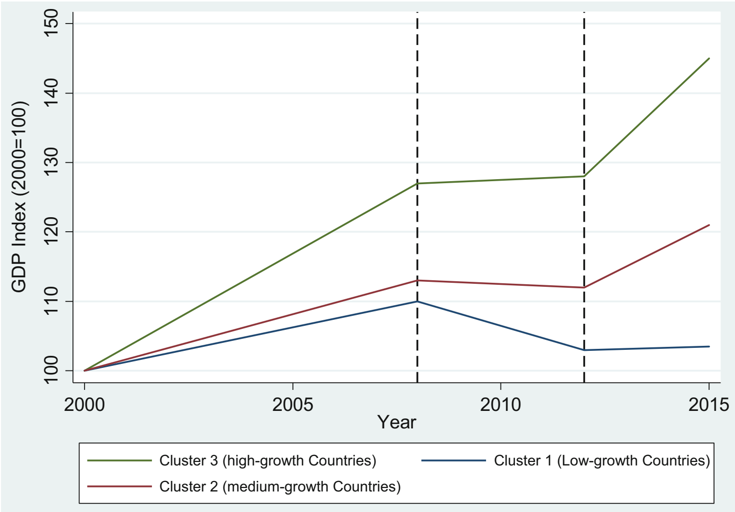


Fig. 1.2 2000–2016 real GDP growth rates in the three Country clusters identified, 2000 = 100. Source: Authors' elaboration on the basis of EUROSTAT data

experiencing rather poor economic performances, especially when compared to the prior decades characterized by robust GDP growth. This is in particular true of Greece, Spain, Portugal, Cyprus, and, to a minor extent, Italy. This piece of evidence has prompted many to stress the emergence of a new North-South economic divide within the EU, adding to the traditional Old VS. New Member States one (Iammarino et al. 2017).

Different reasons hide behind such different performance. A first convincing explanation for these diverging trends lies in the different investment behavior in these three groups of Countries. To this aim, Fig. 1.3 shows for the low-growth (Fig. 1.3a; blue line in Fig. 1.2), medium-growth (Fig. 1.3b; red line in Fig. 1.2), and fast-growth (Fig. 1.3c; green line in Fig. 1.2) EU Countries the following indicators:

- in red color, the pre-crisis (1995–2008) investment trend;
- in green color, the after-crisis (2012–2017) investment trend;
- in blue color, raw annual investment rates.

Figure 1.3 shows that after-crisis investment trends differ with respect to before the crisis in that Countries with sluggish GDP growth are characterized by similar investment trends, in all such Countries slower than in the other two groups of countries. At the same time, in medium-growth countries investment trends have been steeper, and this effect is even stronger for fast-growth Countries. It is also important to stress that in the aftermath of the crisis, reactivity of investment growth to GDP growth becomes three times as large with respect to the period before the crisis, which likely suggests higher cumulative effects of investment on GDP. Lastly, as investment remained structurally more volatile, this means that it also is

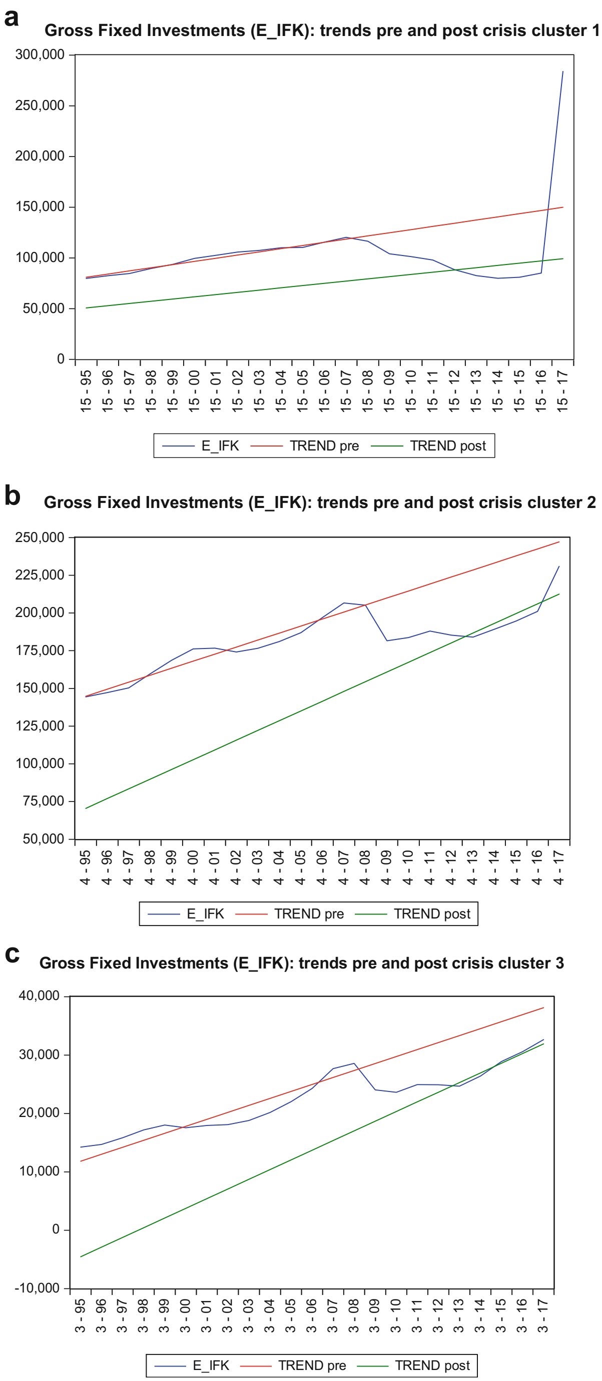


Fig. 1.3 Pre-crisis and after-crisis investment trends. (**a**) Pre-crisis and after-crisis investment trends in low-growth Countries. (**b**) Pre-crisis and after-crisis investment trends in medium-growth Countries. (**c**) Pre-crisis and after-crisis investment trends in fast-growth Countries. Legend: Red—

less directly linked to its long-term trend, thus making reasonable forecasts ever more complicated.

A further implication of the different performance of Country groups in terms of wealth creation (GDP) and investment propensity is also the different level of opening to international trade. This is evidenced in Fig. 1.4, showing the ratio of exports to GDP in Country clusters for the period 2000–2016.

Figure 1.4 offers a rather staggering picture. While Countries characterized by low GDP growth rates across the 16 years (2000–2016) represented on the graph display a rather poor performance in terms of opening up to international trade, Countries in the fastest growth cluster increased their export to GDP ratio by 45% (an average compound increase of 2.3% per year over the 16 years observed in these analyses). This is in line with evidence presented in classical works such as Dollar and Kraay (2004), suggesting that trade openness is conducive to faster GDP growth rates.

Countries experiencing poor economic performance also offer a similarly sobering picture when analyzing another indicators of economic performance such as innovation expenditure (as proxied by R&D expenditure over GDP; Fig. 1.5). Figure 1.5 suggests that towards the goal set by the 2020 Agenda for the EU to reach the celebrated 3% of R&D expenditure, only Countries belonging to Cluster 3 (that experiencing fastest growth rates) are getting substantially closer to the target set.

Additional evidence, discussed more in detail in Capello and Caragliu (2020), of the changes taking place in the aftermath of the crisis include the following major adjustments:

- While before the crisis a process of deindustrialization of the European economy was taking place, an initial launch of high-tech industries in Europe, under the influence of the new technological paradigm "Industry 4.0" followed suit;
- By the same token, an initial shift from a specialization in low-value added services taking place before 2008, an increase in high-value added services took place across many EU Countries as a reaction to the economic contraction.

Not unexpectedly, these staggering differentials in national growth patterns exert a major impact on territorial disparities. To provide evidence of this last statement, we first calculated a Theil index decomposing GDP disparities into overall, within-Countries, and between-Countries disparities for the three groups identified above. While prior to the crisis a major process of within-EU convergence in per capita income levels took place, mainly because of the substantially faster economic performance of New Member States, the crisis imposed a halt to this process (Borsi and Metiu 2015; Barrios and Strobl 2009). Yet, as Countries re-emerged from the global contraction at different speeds, so did the process of divergence, with

Fig. 1.3 (continued) pre-crisis (1995–2008) trend; Green—After-crisis (2012–2017) trend; Blue—annual investment. Source: Authors' elaboration on the basis of EUROSTAT data

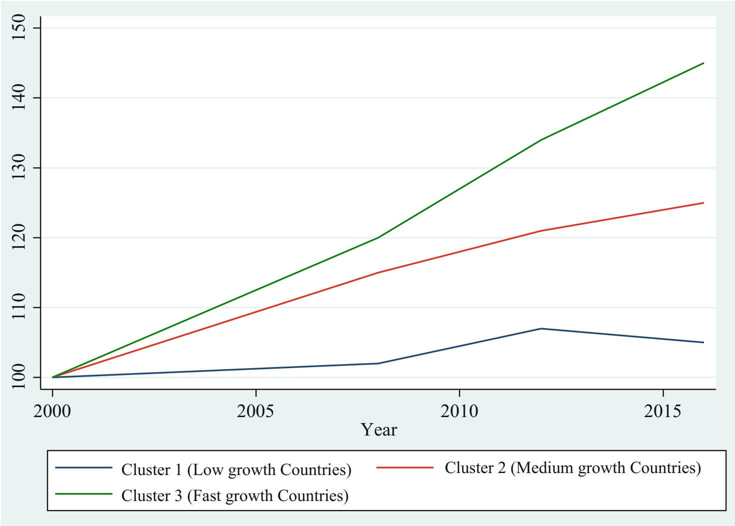


Fig. 1.4 2000–2016 export/GDP in Country clusters. Source: Authors' elaboration on the basis of EUROSTAT data

Countries experiencing fastest growth displaying (Fig. 1.6) the most severe increase in within-Countries disparities. On the other end, and precisely because of their less rapid economic growth, Countries in the other two clusters suffered from smaller increases in the within-Country Theil index.

While being far from conclusive and not yet taking cause–effect mechanisms into account, the evidence presented so far does suggest that structural relations among economic variables changed as a consequence of the contraction. This last point needs to be taken into account when shaping a reference scenario (Sect. 1.3.2) that goes beyond simply extrapolating long-run trends, but rather aiming at capturing the long-run consequences of such structural changes. The simulation exercise will also provide an evidence-based educated guess on the above mentioned goal of identifying cause–effects linkages, thereby shedding light on the most important structural relations in the analyzed economies.

1.3.2 Reference Scenario Assumptions

The reference scenario is based on the assumptions that the structural changes previously discussed will remain valid in the medium run future. Thus, in this subsection we discuss the main assumptions made on the most important macroeconomic and territorial trends characterizing the reference scenario.

First, we start by listing a few pre-crisis conditions assumed to being more or less likely to remain valid in the after-crisis period:

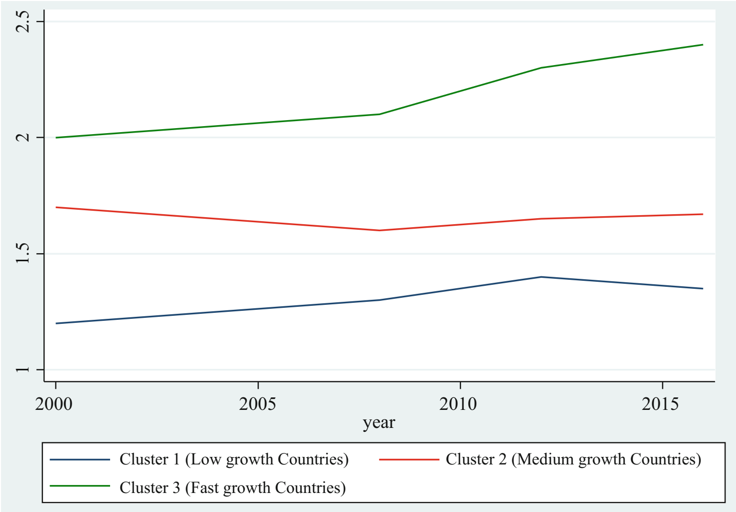


Fig. 1.5 2000–2016 R&D expenditure/GDP in Country clusters. Source: Authors' elaboration on the basis of EUROSTAT data

- a high reactivity of investment growth to GDP growth, although decreasing in the long term;
- high volatility of investments of the post-crisis period will continue;
- free international trade between the USA and EU is replaced by a risk of protectionist measures between the US and the EU, causing a lower increase in exports with respect to the previous long-term trend.

We then include several trends emerging during the crisis that are in their turn likely to continue in the future:

- permanent controls on national deficits and debts;
- some controlled exceptions of public expenditures for low-growing and indebted countries (due to political risks, like several recent elections in Italy, the UK, Spain, and Greece showed);
- low inflation rates;
- expansionary monetary policy (quantitative easing) ending soon, as implied by the European Central Bank.

Moreover, the reference scenario is also based on several assumptions on industrial trends:

- a halt in the deindustrialization of the European economy, with an initial launch of high-tech industry in Europe, under the influence of the new "Industry 4.0" technological paradigm;
- an increase in high value-added services related to the adoption of Industry 4.0 related technologies.

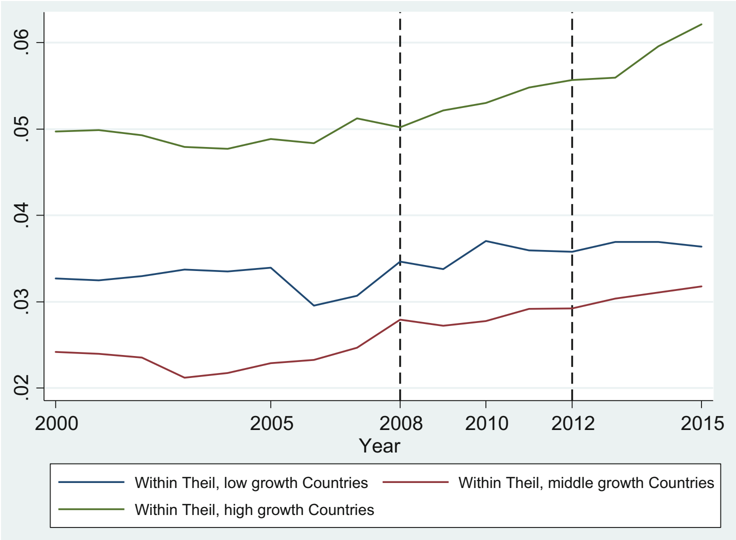


Fig. 1.6 Within-countries regional disparities by groups of countries. Source: Authors' elaboration on the basis of EUROSTAT data

The reference scenario also revolves around a few crucial assumptions on institutional changes:

- Brexit becomes effective in 2020. The way in which the UK leaves the EU is not differentiated in the scenario exercise. What is of interest in this approach is that the UK leaves, and an institutional and trade barrier is put in place between the UK and the rest of the EU countries;
- even though some regional independency requests take place, no regional independence follows;
- there is a redistribution of the European budget in favor of new topics, such as security and migration, thereby decreasing the share of budget devoted to cohesion policies and Common Agricultural Policy (CAP). National shares are set at the levels decided in EC (2018), and maintaining regional shares as in the 2014–2020 programming period.

Lastly, from a territorial perspective, two additional assumptions are further formalized:

- urban amenities in Western countries are assumed to further increase;
- high quality functions are assumed to be upgraded and cooperation among cities fostered.

1.3.3 Reference Scenario Results

When inserted into the MASST model in quantitative terms, the above mentioned assumptions provide interesting results, presented in Table 1.1 for the EU28 as a whole (both with and without the UK as a member state) as well as by the major sub-continental aggregates (EU15 Countries, comprising all Member States joining the EU prior to 2004, and CEECs, joining from 2004 and after).

Table 1.1 suggests that the EU will benefit from a stable relaunch after the great contraction of 2007–2008. More in detail, the model predicts that CEECs still an average growth rate higher than Old 15 Countries (1.75% against 1.58%); however, the difference between the two major blocks of Countries in the EU has consistently decreased. The acceleration in the rate of economic expansion following the 2007/2008 crisis is in line with the expected impact of various procyclical fiscal policies here included in the reference scenario assumptions and found to be positively associated to GDP growth (Nijkamp and Poot 2004).

While results at the Country level are left to the interested reader upon request,[7] it is here worth focusing on the rich picture emerging from the analysis of regional GDP growth. To this aim, Map 1.1 shows average regional yearly GDP growth rates between 2018 and 2035 for all 276 NUTS2 regions of the EU. The colors portray positive GDP growth with increasingly darker blue tones and the (admittedly few) regions registering negative GDP growth in yellow.

In general, Map 1.1 shows that large cities and metro areas, despite maintaining an overall positive economic performance, are not necessarily the most dynamic in their countries. Also, the map shows a vast diffusion of new technologies and organizational innovations especially towards mid-income regions and medium-size cities. Lastly, the reference scenario foresees a slowdown in the process of convergence of CEECs, already suggested in recent works (see, e.g. Hagemejer and Mućk 2019).

1.4 An Integration Scenario

1.4.1 Scenario Assumptions

The integration scenario is based on the general assumption that economic integration among European member countries will strengthen over the next 18 years, despite Brexit taking place.

More in detail, this generic assumption is broken down into five main levers that define this scenario:

[7]It here suffices to mention that inside the Old 15 group, the best performance in terms of GDP growth is found for Luxembourg, Belgium, Denmark, The Netherlands and Austria, while among CEECs top performers include Estonia, Slovakia, Bulgaria, Hungary, and Lithuania.

Table 1.1 Aggregate results of the reference scenario

	Average GDP growth rate	Average productivity growth rate	Average total employment growth rate
EU28	1.60	0.29	0.27
EU27 without the UK	1.63	0.30	0.28
United Kingdom	1.40	−0.04	0.16
Old15	1.58	0.15	0.24
CEECs	1.75	0.63	0.38

Source: Authors' elaboration on the basis of the MASST4 model

- an increase in the integration of global value chains among EU countries (*production integration effect*);
- an elimination of non-tariffs barriers among European countries (*market integration effect*);
- a decrease in non-tariffs barriers (*proximity to larger markets effect*);
- an increase in trust within and among countries (*social effect*);
- higher quality of government (*institutional effect*);
- stronger cooperation networks among cities (*cooperation effect*).

These assumptions are translated into quantitative hypotheses described in Table 1.2.

1.4.2 Scenario Results

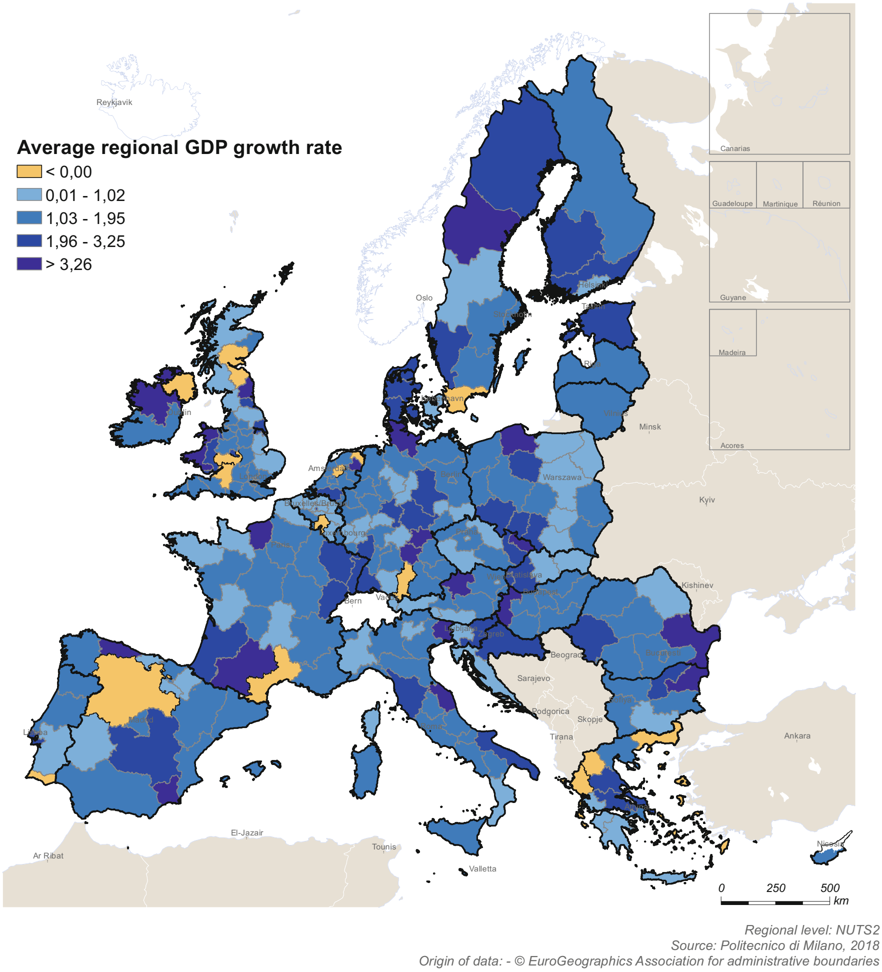
In this section, all results are presented against the backdrop of the reference scenario described in Sect. 1.3.

At the aggregate level, Table 1.3 shows average yearly GDP growth rates simulated by the MASST model within the integration scenario for the period 2018–2035 as a difference with respect to the reference scenario.

Table 1.3 presents two main highlights:

- While in the integration scenario both CEECs and Old15 Countries seem to benefit from a further deepening and broadening of the process of economic integration within the EU, it is important to stress that CEECs are the ones benefitting the most. Within a more integrated EU economy, countries receiving a substantial share of within-Europe Foreign Direct Investment, mostly targeting manufacturing activities, and exploiting thicker and more efficient labor markets, would reap the largest benefits.
- At the same time, while the EU as a whole benefits from a more integrated scenario rather uniformly, as suggested by advocates of free trade,[8] the UK is

[8]See Rodrik (2018) for a thorough review of the literature on trade openness.



Map 1.1 Regional results of the reference scenario. Source: Authors' elaboration on the basis of the MASST4 model

forecasted as a net loser in this game, its benefit being less than half[9] the gains obtained by the EU as a whole. In this simulation, the UK is he single Country benefitting the least from the EU's further integration, which is likely due to its severing the several free trade and labor mobility agreements signed with European partners over the last five decades.

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[9]UK's percentage gain w.r.t. the EU is obtained as the ratio + 11%/+25%.

Table 1.2 Quantitative assumptions for the integration scenario

Qualitative assumptions	Model levers	Quantitative assumptions (targets in 2035)
Higher trade flows among EU countries ("production integration effect")	Trade matrix	Doubling of interregional trade flows intensity
Higher decrease in non-tariffs barriers ("proximity to larger markets effect")	Border effects (interaction between border region dummy and FDI effects on regional DIF)	Elimination of the border effect
Higher trust within and among countries ("social effect")	Trust	Increase in trust (everywhere, stronger in Old15 Countries and in metro areas)
Higher quality of government ("institutional effect")	Quality of Government	Spatially-neutral increase in Quality of Government
Stronger cooperation networks among cities ("cooperation effect"	Diffusion and thickness of inter-urban scientific cooperation networks (FP projects co-participation)	Spatially-neutral increase in inter-urban networks
Higher exports ("market integration effect")	Constant in national export equation	Increase in the constant in national export equation

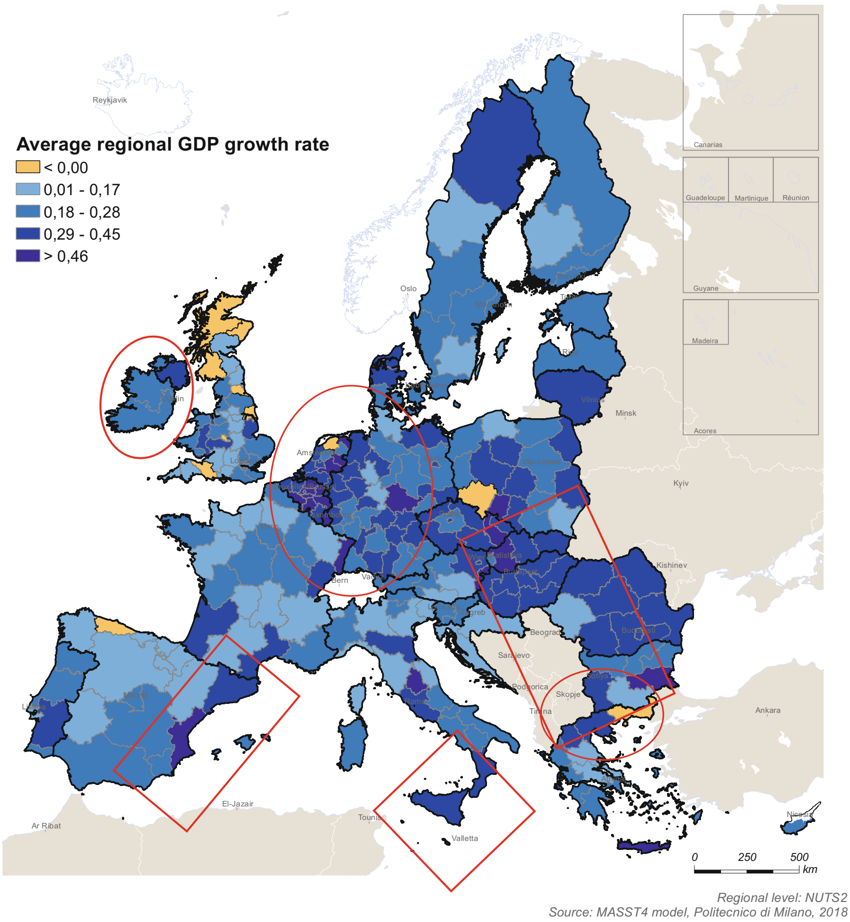
Table 1.3 Aggregate GDP growth in the integration scenario, difference w.r.t. the reference scenario

	Average GDP growth rate
EU28	0.24
EU27 without UK	0.25
United Kingdom	0.11
Old15	0.23
CEECs	0.29

Source: Authors' elaboration on the basis of the MASST4 model

At a more disaggregate level, Map 1.2 shows average yearly GDP growth rates for all EU28 regions in the integration scenario, and again as a difference with respect to the reference scenario. In Map 1.2, oval shapes identify areas where the increased performance of EU regions can be explained by the proximity to larger market effect; in other words, these regions gain mostly because the removal of interregional trade and administrative barriers allows them to gain access to rich markets.

Regions marked with rectangles represent instead areas where a combination of the *production integration effect* and the *proximity to larger market effect* takes place. With respect to areas gaining mostly from their location in proximity to large markets, these areas also benefit from positive spillovers from areas specialized in manufacturing activities or characterized by high regional productivity levels.



Legend:

	"proximity to larger market effect"
	areas where a combination of "production integration effect" and "proximity to larger market effect" takes place

Map 1.2 Regional results of the reference scenario. Source: Authors' elaboration on the basis of the MASST4 model

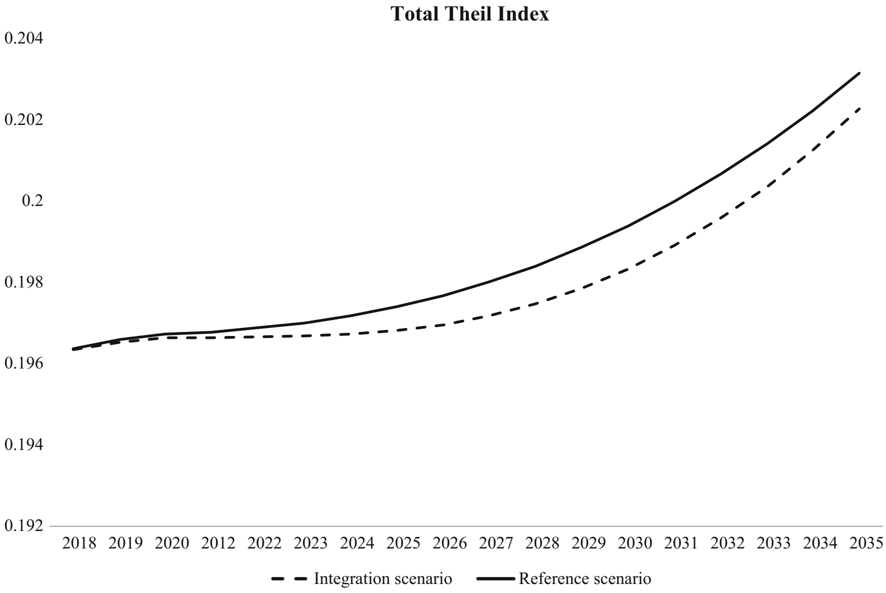


Fig. 1.7 Total Theil index for the reference and integration scenarios, 2018–2035. Source: Authors' elaboration on the basis of the MASST4 model

Lastly, Fig. 1.7 shows the results of calculating the Total Theil index for both the reference (continuous line) and integration (dashed line) scenarios.

While both scenarios suggest a likely increase in international income disparities, following the recent re-emergence of divergence in the EU, it also suggests that this trend could be partially offset by fostering further integration in the EU; in fact, the Theil index of the integration scenario remains uniformly lower with respect to the line representing the reference scenario (although the difference slightly decreases as we approach the end of the simulation period). In other words, we find that a scenario where integration is fostered leads EU regions to be on average more competitive, while at the same time enhancing cohesion.

1.5 Concluding Remarks

This paper presented an application of the MASST4 model to the simulation of two scenarios, viz. a reference scenario procrastinating the structural changes induced by the 2007/2008 crisis for the medium run, and an integration scenario, based instead on the assumption that the forthcoming 18 years will witness a further deepening and broadening of the economic integration within the EU.

Our results suggest that a reference scenario leads to a reduction of the macro-regional patterns present in the recent past (e.g. the celebrated East-West divide and the North-South differentials that emerged in the early stages of the crisis), while also prompting the case for a likely club convergence type of regional growth (Fischer and Stirböck 2006). In fact, in the reference scenario regional growth rates converge around the Country averages, and diverging behaviors involve some regions (like Castilla Leon, Algarve, Languedoc-Roussillon, Croatia, North-Western regions in Greece and the Aegean islands and southern Sweden).

An integration scenario leads instead to a more expansionary economy, with nevertheless remarkable spatial heterogeneity in these effects. While on the one hand integration further increases the costs of Brexit for the UK, on the other it may also cause losses in some regions less endowed with crucial assets.

An integration also tends to increase cohesiveness. This is a rather striking result, that goes against the traditional debate characterizing the alleged trade-off between competitiveness and cohesion (Mancha-Navarro and Garrido-Yserte 2008). Fostering the emergence of a more integrated EU market leads in fact to a more homogeneous distribution of the benefits thereby obtained, in particular enhancing growth rates in Accession Countries; this in turn allows a faster process of catching-up.

Despite the relevant findings obtained with these two simulations, a major research challenge awaits the MASST model in the months to come. The medical emergency due to the global diffusion of the COVID-19 virus has triggered policy responses that implied severe lockdown measures in most EU Countries. While in the short run this has caused major contractions in consumption patterns, the economic effects of these measures will likely be felt for decades, because public expenditure is going to be financed by increasing public deficits, with particularly severe consequences in debt-burdened Countries. The MASST model will provide a good toolbox to include all the measures undertaken in EU Countries within an internally coherent logic, thereby allowing a first-hand, evidence-based estimate of the likely territorial effects of the epidemic.

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Annex 1

Table 1.4 List of countries belonging to the three clusters

1 (low-growth countries)	Countries
	Cyprus
	Finland
	Greece
	Italy
2 (medium-growth countries)	Austria
	Belgium
	Croatia
	Denmark
	France
	Germany
	Netherlands
	Portugal
	Spain
	UK
3 (fast-growth countries)	Bulgaria
	Czech Republic
	Estonia
	Hungary
	Ireland
	Latvia
	Lithuania
	Luxembourg
	Malta
	Poland
	Romania
	Slovakia
	Sweden
	Slovenia

Source: Authors' elaboration on the basis of EUROSTAT data

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Chapter 2
On the Existence of an Equilibrium in Models of Local Public Good Use by Cities to Attract the Creative Class

Amitrajeet A. Batabyal and Hamid Beladi

Abstract We analyze a stylized model of competition between two cities that use a local public good (LPG) to attract members of the creative class. The creative class consists of *artists* and *engineers* and we study the behavior of a *representative* artist and an engineer. The level of the LPG in each city is determined by majority voting of the two representative creative class members. If both representative members choose to live in the same city, then the LPG provision is the average of the preferred quantities of the two members. In this setting, we perform three tasks. First, we ascertain the preferred quantity of the LPG for the representative artist and the engineer. Second, assuming that the representative artist and the engineer accurately predict the outcome of living in a particular city, we describe a scenario in which there is *no* equilibrium in our model. Finally, we show that if the representative artist and the engineer treat the LPG provision levels in each city as *exogenous,* then an equilibrium does *exist* in the model.

Keywords Artist · Creative class · Engineer · Equilibrium · Local public good

JEL Codes R11 · H40

2.1 Introduction

Regional scientists and urban economists are both very familiar with two notions that have been introduced into the literature by the urbanist Richard Florida. The first is the notion of the *creative class* and the second is the notion of *creative capital*. The

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creative class, according to Florida (2002, p. 68), is composed of "people who add economic value through their creativity." This class is made up of specialists such as doctors, engineers, lawyers, scientists, university professors, and, markedly, bohemians such as artists, musicians, and sculptors. What distinguishes members of the creative class from other people—who are not members of the creative class—is the fact that they possess creative capital which is postulated to be the "intrinsically human ability to create new ideas, new technologies, new business models, new cultural forms, and whole new industries that really [matter]" (Florida 2005, p. 32).

From the standpoint of the economic development of cities and regions, what is special about the creative capital possessing members of the creative class? In his copious writings on this question, Florida (2002, 2003, 2008, 2014), Florida et al. (2017), and some of Florida's supporters such as Stolarick et al. (2011) and Lobo et al. (2014) have argued that city and regional planners ought to focus seriously on the activities of the creative class because the collection of people making up this class gives rise to ideas, information, and technology, outputs that are salient for the growth and development of cities and regions. Put differently, cities and regions that want to flourish in this age of globalization need to do all they can to draw in and then hold on to members of this creative class who are, for all intents and purposes, the primary drivers of economic growth and development.

One question that economists—see Glaeser (2005)—have raised when pondering the concept of creative capital is the following: What is the difference between the well-known and time-honored notion of human capital and Florida's newer concept of creative capital? The recent work of Batabyal and Beladi (2016, 2018) and that of Batabyal et al. (2019) is pertinent in answering this important question. These researchers have helpfully explained that there is little or no difference between the notions of human and creative capital when the accretion of this creative capital is contingent on the successful completion of many years of formal education. In contrast, there can be a lot of difference between the concepts of human and creative capital when creative capital is either present naturally or when it is based on the accretion of business and professional experiences but *not* on the successful completion of a formal education.

The discussion in the preceding paragraph tells us that creative capital is of two types. Therefore, as pointed out by Porter and Batabyal (2016), it is a *more general* concept than the mainly formal instruction based notion of human capital. Batabyal and Beladi (2018) and Batabyal et al. (2019) refer to members of the creative class who have creative capital either naturally or mostly by collecting business and professional experiences as *artists* and to those whose acquisition of creative capital is the outcome of many years of formal instruction as *engineers*. This bipartite classification—also see Marlet and van Woerkens (2007)—implies that the aggregate creative class in either a city or more generally a region is the *sum* of the artists and the engineers in this city or region. We shall make use of this two-part classification of the creative class in the ensuing analysis in this chapter.

We now concentrate on cities specifically in the remainder of this chapter. In this context, suppose one accepts Florida's (2002) basic point that cities that would like to flourish economically need to draw in and then hold on to members of the creative class. The obvious next question is: “How are cities to do this?” Florida (2002, 2008), Buettner and Janeba (2016), and Batabyal et al. (2019) have responded to this question by explaining that local public goods (LPGs) such as cultural amenities, quality schools, and public transit are a key means by which cities can efficaciously carry out the dual “draw in” and “hold on to” functions.[1]

The idea mentioned at the end of the preceding paragraph about the usefulness of LPGs is now recognized by researchers. Even so, we would like to emphasize the following two points. First, to the best of our knowledge, Batabyal et al. (2019) is the only paper to have conducted a theoretical analysis of the effect that the provision of LPGs by two cities has on their ability to draw in and hold on to members of the creative class.[2] However, to conduct their analysis and obtain concrete results, these researchers work with a model with (1) *linear* functional forms and (2) *actual numbers* for many of the model variables. Therefore, the results obtained by these researchers in their paper are specific and we know relatively little about the existence of an equilibrium in theoretical models in which two cities use LPGs to compete with each other to draw in and hold on to members of the creative class. Second and given this lacuna in the literature, our goal in this chapter is to provide the *first* analysis of some of the circumstances that determine when an equilibrium does and does not exist in models of LPG use by two cities to attract and retain members of the creative class.

The remainder of this chapter is organized as follows. Section 2.2 describes our stylized model of an aggregate economy that consists of two cities. We use this model to analyze competition between the two cities when each city uses a LPG to draw in members of the creative class. As pointed out previously, the creative class consists of artists and engineers and we concentrate on the behavior of a *representative* artist and a *representative* engineer. The amount of the LPG that is provided in each city is determined by majority voting of the two representative creative class members. If both representative members choose to live in the same city, then the LPG provision is the average of the preferred quantities of these two members. Section 2.3 ascertains the preferred quantity of the LPG for the representative artist and the engineer. Assuming that the representative artist and the engineer accurately predict the outcome of living in a particular city, sect. 2.4 describes a scenario in which there is no equilibrium in the model under study. Section 2.5 demonstrates that if the representative artist and the engineer treat the LPG provision levels in each city as *exogenous* or given, then an equilibrium does exist in the model. Finally, sect. 2.6 concludes and then suggests four ways in which the research delineated in this chapter might be extended.

[1]See Hansen and Niedomysl (2009), Richardson (2009), and Audretsch and Belitski (2013) for a discussion of related issues.

[2]For theoretical studies of other questions about the creative class, the reader should consult Batabyal (2017a, 2017b), Batabyal and Beladi (2016), Batabyal and Nijkamp (2016), Batabyal and Yoo (2018), and Usman and Batabyal (2014). That said, we stress that there is *no* overlap between the topics we study in this chapter and the questions analyzed in these cited journal articles.

2.2 The Theoretical Framework

Consider an aggregate economy that consists of two cities denoted by the superscript $i = 1, 2$. Real world examples from the USA of the kind of cities we have in mind are (1) Rochester and Syracuse in the state of New York, (2) Minneapolis and Saint Paul in the state of Minnesota, and (3) Dallas and Fort Worth in the state of Texas. Our analysis focuses on the creative class, i.e., on the sum of the artists and the engineers, in the two cities. Rather than model the entire creative class in a city, for expositional ease, in the remainder of this chapter, we shall focus on the behavior of a representative artist and a representative engineer. The superscript $k = a, e$ denotes these two representative creative class members. Specifically, "a" denotes the representative artist and "e" denotes the representative engineer. The utilities or payoffs representing the preferences of the representative artist and the engineer are given by the quasi-linear functions[3]

$$U^k = 1 - T^i + \beta^k \log\left(L^i\right), k = a, e, \tag{2.1}$$

where U^k denotes the *kth* representative member's utility, T^i denotes the tax levied by city i $(=1, 2)$ to pay for the LPG L^i provided in this city, β^k is a representative member specific parameter, and we assume that the inequality $\beta^e > \beta^a > 0$ holds. In words, this assumption means that relative to artists, engineers place a higher value on the LPG on offer in each of the two cities.[4]

The amount of the LPG provided in each city is determined by majority voting of the two representative creative class members (artist and the engineer). If a particular city happens to draw in both representative creative class members, then we suppose that the supply of the LPG in this city is given by the *average* of the preferred quantities of the two representative members. With this description of our aggregate economy of two cities out of the way, our next task is to ascertain the preferred quantity of the LPG for the representative artist and the engineer.

2.3 Preferred Levels of the LPG

Suppose that there are n^i residents in city i. Then the tax T^i levied by city i when representative member k selects LPG level L^k is given by L^k/n^i. In symbols, we have $T^i = L^k/n^i$. Substituting this expression for the tax in Eq. (2.1), the *kth* representative member's utility function can be written as

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[3]See Hindriks and Myles (2013, pp. 555–558) for a textbook exposition of such functions.

[4]There is a precedent for this assumption in the extant literature. See Batabyal et al. (2019) for additional details.

$$U^k = 1 - \frac{L^k}{n^i} + \beta^k \log\left(\frac{L^k}{n^i}\right). \tag{2.2}$$

As pointed out by Hindriks and Myles (2013, pp. 208–209), a LPG is typically *not* a pure public good because exclusion is frequently possible. One kind of exclusion arises from the fact that in order to enjoy a LPG, an individual must be resident in a particular geographical area. In addition, a resident individual who refuses to pay local taxes that fund the provision of a LPG can also be excluded from enjoying the benefits of the relevant LPG. What this means in our case is that the last term in the utility function on the right-hand side (RHS) of Eq. (2.2) is appropriately written as $\log(L^k/n^i)$ and not as $\log(L^k)$.

To determine the preferred value of L^k, we solve

$$max_{L^k}\left[1 - \frac{L^k}{n^i} + \beta^k \, log\left(\frac{L^k}{n^i}\right)\right]. \tag{2.3}$$

The first-order necessary condition for an optimum is

$$\frac{\beta^k}{L^k} - \frac{1}{n^i} = 0, \tag{2.4}$$

which tells us that the preferred level of the LPG that we seek is given by[5]

$$L^k = \beta^k n^i. \tag{2.5}$$

Inspecting Eq. (2.5), it is easy to confirm that if either the parameter β^k or the number of residents in city i or n^i increases, then the *kth* representative member's preferred level of the LPG also *increases*. Now suppose that the representative artist and the engineer accurately predict the outcome of living in a particular city. Given this supposition, our next task is to delineate a situation in which there is no equilibrium in the model under study.

2.4 Non-Existence of an Equilibrium

Some thought ought to convince the reader that only two types of equilibria are possible in the model that we are studying. In the first or "type I" equilibrium, the representative artist and the engineer choose to reside in *separate* cities and in the second or "type II" equilibrium, the representative artist and the engineer both choose to reside in the *same* city. Now recall from the discussion in sect. 2.2 that

[5] It is straightforward to verify that the second-order sufficiency condition in this maximization problem is satisfied.

Table 2.1 Utilities from staying in and moving from a city in the type I equilibrium

Stay in city	Move from city
$U^a = 1 - \beta^a + \beta^a \log(\beta^a)$	$U^a = 1 - \frac{\beta^a+\beta^e}{2} + \beta^a \log(\beta^a + \beta^e)$
$U^e = 1 - \beta^e + \beta^e \log(\beta^e)$	$U^e = 1 - \frac{\beta^a+\beta^e}{2} + \beta^e \log(\beta^a + \beta^e)$

Table 2.2 Utilities from staying in and moving from a city in the type II equilibrium

Stay in city	Move from city
$U^a = 1 - \frac{\beta^a+\beta^e}{2} + \beta^a \log(\beta^a + \beta^e)$	$U^a = 1 - \beta^a + \beta^a \log(\beta^a)$
$U^e = 1 - \frac{\beta^a+\beta^e}{2} + \beta^e \log(\beta^a + \beta^e)$	$U^e = 1 - \beta^e + \beta^e \log(\beta^e)$

the level of the LPG provided in each city is determined by majority voting of the representative artist and the engineer.

Therefore, accounting for this voting and the possibility that either the representative artist or the engineer may, in principle, want to move to the other city, the utilities obtained by the two agents in our model in the first or type I equilibrium are given in Table 2.1. To interpret the payoffs specified in the bottom four cells of Table 2.1, consider the *second row* first. In this row, the U^a payoff under the "Stay in city" column describes the utility obtained by the representative artist when he or she chooses to reside in one city and the representative engineer decides to reside in the other city. Now recall that $T^i = L^k/n^i$ and that $L^k = \beta^k n^i$. Substituting the second of these two equations into the first gives $T^i = (\beta^k n^i)/n^i = \beta^k$. This explains why the tax term T^i can be written as β^k in the equation for U^a. Similarly, the U^a payoff under the "Move from city" column delineates the utility obtained by the representative artist when he or she and the representative engineer both choose to reside in the *same* city. In this case, because both representative members live in the same city, the supply of the LPG is the *mean* of the two preferred quantities. This explains why the tax term in the expression for U^a is given by $(\beta^a + \beta^e)/2$. Finally, observe that since $L^k = \beta^k n^i$, we obtain $L^a = 2\beta^a$ and $L^e = 2\beta^e$. Therefore, $(L^a + L^e)/2 = \{2(\beta^a + \beta^e)\}/2 = \beta^a + \beta^e$. This last result explains why the concluding term in the expression for U^a is $\beta^a \log(\beta^a + \beta^e)$ and not $\beta^a \log\{(\beta^a + \beta^e)/2\}$. A similar interpretation applies to the two payoffs in the *third row* of Table 2.1 except that these payoffs now refer to the representative engineer.

Moving on to the second or type II equilibrium, the four possible utilities accruing to the representative artist and to the engineer are shown in Table 2.2. To interpret these payoffs, let us, once again, focus first on the *second row* of this Table. In this row, the U^a payoff under the "Stay in city" column describes the utility obtained by the representative artist when he or she and the representative engineer both choose to live in one city. Similarly, the U^a payoff under the "Move from city" column delineates the utility obtained by the representative artist when he or she decides to live in one city and, as a result, the representative engineer ends up living in the other city. A similar interpretation applies to the two payoffs in the *third row* of Table 2.2 except that these payoffs now refer to the representative engineer.

After observing the eight payoffs accruing to the representative artist and the engineer in Tables 2.1 and 2.2 and the structure of our model, we deduce that an equilibrium will *not* exist if at least one representative creative class member (artist or engineer) wishes to *move* in the two possible types of equilibria. That said, let us concentrate on the type I equilibrium for the time being. With regard to this kind of equilibrium, observe that it is *not* possible to satisfy the inequalities

$$1-\beta^a+\beta^a\log\left(\beta^a\right)<1-\frac{\beta^a+\beta^e}{2}+\beta^a\log\left(\beta^a+\beta^e\right) \tag{2.6}$$

and

$$1-\frac{\beta^a+\beta^e}{2}+\beta^e\log\left(\beta^a+\beta^e\right)<1-\beta^e+\beta^e\log\left(\beta^e\right) \tag{2.7}$$

simultaneously. Why not? To answer this question, observe that if the inequalities in Eqs. (2.6) and (2.7) hold simultaneously, then an implication of Eq. (2.7) is that the inequality

$$\frac{\beta^e-\beta^a}{2}<\beta^e\{\log\left(\beta^e\right)-\log\left(\beta^a+\beta^e\right)\} \tag{2.8}$$

is satisfied. However, since $\beta^e>\beta^a>0$, some thought and the properties of the logarithm function together tell us that the left-hand side (LHS) of Eq. (2.8) is positive but the RHS is negative. Therefore, the inequality in Eq. (2.8) clearly cannot hold which, in turn, means that the inequality in Eq. (2.7) also *cannot* hold.

The above finding informs us that the direction of the inequality sign in Eq. (2.7) needs to be flipped. Once this is done, the implication of the flipped inequality is that the utility from moving exceeds the utility from staying and therefore the representative engineer ought to *move* to the other city and live jointly with the representative artist. The inequality in Eq. (2.6) tells us that the utility from staying in a city for the representative artist (the LHS) is *less* than the utility from moving to the other city in which the representative engineer is resident (the RHS). Therefore, the representative artist also ought to *move* and live jointly with the representative engineer. Putting these two results together, we see that both representative creative class members would like to move from the posited equilibrium. Therefore, we *cannot* have a type I equilibrium in the model under study.

Having discussed the type I equilibrium, let us now focus on the type II equilibrium. In this case, consider the inequalities given by

$$1-\beta^a+\beta^a\log\left(\beta^a\right)>1-\frac{\beta^a+\beta^e}{2}+\beta^a\log\left(\beta^a+\beta^e\right), \tag{2.9}$$

and

$$1-\frac{\beta^a+\beta^e}{2}+\beta^e \log\left(\beta^a+\beta^e\right) > 1-\beta^e+\beta^e \log\left(\beta^e\right). \tag{2.10}$$

Straightforward algebra reveals that the inequality in Eq. (2.10) always holds. Manipulating the individual terms in the inequality in Eq. (2.9) gives us the following parametric condition

$$\frac{\beta^e}{\beta^a} > 1+2\,log\left(1+\frac{\beta^e}{\beta^a}\right). \tag{2.11}$$

When the parametric condition in Eq. (2.11) is satisfied, the inequality in Eq. (2.9) holds for sure. In addition, since the inequality in Eq. (2.10) always holds, we can say that both the inequalities given in Eqs. (2.9) and (2.10) hold when the above parametric condition is satisfied. From this discussion, we can deduce that when the parametric condition in Eq. (2.11) is satisfied, the representative artist will want to move away from a type I equilibrium (see Eqs. (2.6), (2.9), and the payoffs in Tables 2.1 and 2.2) and the representative engineer will want to move away from a type II equilibrium (see Eqs. (2.7), (2.10), and the payoffs in Tables 2.1 and 2.2). On the basis of this deduction we conclude that when the parametric condition given in Eq. (2.11) is satisfied, there is *no* equilibrium in the model under study. We now proceed to our final task in this chapter. This involves showing that if the representative artist and the engineer treat the LPG provision levels in each city as *exogenous* or given, then an equilibrium does exist in our model.

2.5 Existence of an Equilibrium

In this case, the representative artist and the engineer both take the provision levels of the LPG or L^k in each of the two cities as exogenous or given and *not* as something that either one of them can influence with their own actions. In this situation, the utilities obtained by the representative artist and the engineer will change and no longer be given by the payoffs specified in Tables 2.1 and 2.2. In particular, to analyze the type I equilibrium, the analog of Table 2.1 is now given in Table 2.3.

Comparing Tables 2.1 and 2.3, we see that the payoffs to the representative artist (U^a) and to the representative engineer (U^e) in the "Stay in city" column are unchanged in Tables 2.1 and 2.3. However, because the LPG provision levels are now treated as exogenous by the two representative creative class members, relative

Table 2.3 Utilities from staying in and moving from a city in the type I equilibrium

Stay in city (exogenous LPG provision)	Move from city (exogenous LPG provision)
$U^a = 1 - \beta^a + \beta^a \log(\beta^a)$	$U^a = 1 - \beta^e + \beta^a \log(\beta^e)$
$U^e = 1 - \beta^e + \beta^e \log(\beta^e)$	$U^e = 1 - \beta^a + \beta^e \log(\beta^a)$

Table 2.4 Utilities from staying in and moving from a city in the type II equilibrium

Stay in city (exogenous LPG provision)	Move from city (exogenous LPG provision)
$U^a = 1 - \frac{\beta^a + \beta^e}{2} + \beta^a \log(\beta^a + \beta^e)$	$U^a = -\infty$
$U^e = 1 - \frac{\beta^a + \beta^e}{2} + \beta^e \log(\beta^a + \beta^e)$	$U^e = -\infty$

to Table 2.1, the payoffs (U^a) and (U^e) in the "Move from city" column in Table 2.3 do change.

Similarly, in the type II equilibrium, we observe that the payoffs to the representative artist (U^a) and to the representative engineer (U^e) in the "Stay in city" column are unchanged in Tables 2.2 and 2.4. Even so, for the same reason as the one mentioned in the preceding paragraph, relative to Table 2.2, the utilities (U^a) and (U^e) in the "Move from city" column in Table 2.4 are different. In this regard, note that the specification $U^a = U^e = -\infty$ for the two utilities in this column makes sense because we are assuming that if there are *no* representative creative class members residing in a particular city, then the level of the LPG provided in this city is zero.

Now, inspecting the payoffs in Table 2.4, it is straightforward to verify that *both* representative creative class members will want to stay in the city in a type II equilibrium and not move. However, the same cannot be said about a type I equilibrium. Inspecting the four payoffs in Table 2.3, we see that we cannot make a definitive statement about whether a type I equilibrium will exist. This is because at least one representative creative class member may want to move from the city in a type I equilibrium. So, we have just demonstrated that in contrast to the situation examined in sect. 2.4, a type II equilibrium *will* always exist when the representative artist and the engineer take the provision levels of the LPG or L^k in each of the two cities as exogenous or given. This concludes our analysis of the existence of an equilibrium in models of LPG use by cities to draw in the creative class.

2.6 Conclusions

In this chapter, we examined a stylized model of competition between two cities that used a LPG to draw in members of the creative class. The creative class consisted of artists and engineers and we analyzed the behavior of a *representative* artist and an engineer. The amount of the LPG provided in each city was determined by majority voting of the two representative creative class members. If both representative members chose to live in the same city, then the LPG provided was the average of the preferred quantities of the two members. In this setting, we performed three tasks. First, we ascertained the preferred quantity of the LPG for the representative artist and the engineer. Second, assuming that the representative artist and the engineer accurately predicted the outcome of living in a specific city, we described a scenario in which there was no equilibrium in our model. Finally, we demonstrated that if the representative artist and the engineer treated the LPG provision levels in each city as exogenous, then a type II equilibrium existed in the model.

The analysis conducted in this chapter can be extended in a number of different directions. In what follows, we suggest four possible extensions. First, instead of using quasi-linear utility functions to describe the payoffs obtained by the two representative creative class members, it would be useful to study the equilibrium existence question with general utility functions that are both increasing and concave in their arguments. Second, since the decision about which city to live in is typically made on more than one occasion in a creative class member's lifetime, it would be useful to analyze a multi-period game between representative creative class members and an apposite city authority where it is possible to change a member's residence decision at different points in time. Third, it would be useful to explore the extent to which cities benefit by drawing in and retaining diverse sets of people within the creative class as opposed to specific subsets such as artists or engineers only. Finally, it would be helpful to study the equilibrium existence question of this chapter in a setting in which city authorities are able to draw in and hold on to members of the creative class with an expanded set of policies that includes LPGs as one particular policy. Studies that analyze these aspects of the underlying problem will provide additional insights into the range of circumstances in which equilibria exist in models of interactions between creative class members and city authorities.

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Chapter 3
Canadian Regional Science 2.0

Eric Vaz

Abstract This chapter takes a retrospective approach to the advances and contributions of regional science. It further argues that regional sciences are currently on the verge of a remarkable change resulting from the growing pressures, social, environmental, and economic felt in the Anthropocene. Regional Science, however, offers ubiquitous methods that together with economics and geography may well revolutionize the status quo of decision making and governance. The strongest aid is found in the evolution of geo-computation and artificial intelligence, which paves a new way for regional science to define itself as a fundamental field within the social sciences. The example of Canada is brought as an outstanding witness to the Zeitgeist of the regional science revolution. By framing the importance of regional science, as well as the integration of novel techniques that have strengthened the field over the recent decades, I further explore new directions Regional Science may take when considering the contributions to the present and future of times facing unprecedented challenges for humankind.

Keywords Regional science · Canada · Canadian regional science · Geo-computation · Spatial analysis · Artificial intelligence · Machine learning · Regional science 2.0

3.1 Introduction

The advent of the fifties brought the cradle of regional science as we know it today (Isard 1956). As a multidisciplinary toolkit of several methods intertwining economics, geography, and most of social science, it leveraged quickly from the need to understand space and place-based models intertwined with the rationale of

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innovation and the growing demand of transportation efficiency for development of entire regions (Vaz 2016). The Isardian vision of transdisciplinary focus led to a natural extension of understanding spatial interactions within a consequence for economists and geographers (Isard et al. 1998). While the field significantly grew, the dominating schools of regional economic thought (Martin and Sunley 2006) leveraged the already well-established industrial allocation models (Putman 1967) to create deterministic interpretations of quantitative models for regional development (Kacprzyk and Straszak 1980). The territorial size and shape of regions, however, as well as the oftentimes homogenous distributions of policy and governance throughout geographical space, led to a set of well-established methods that allowed regional science to blossom as applied research simultaneously for many European countries (Fingleton 2013). The stronger focus in the United States of regional science within urban cores, transportation, and metropolitan areas, however (Small 1997), brought different assumptions than the European counterparts of regional development, and thus the contribution of integrating transportation efficiency into the discourse of regional science created a growing field in the eighties and nineties of a ubiquitous approach of testifying the future of development of regions. Regional science grew leaps and bounds in the last couple of decades, and created as a consequence a field that extends from planning and urbanization to economics and geography, without failing to integrate sociology and finally, addressing the complex structures of local governance and government (Stimson 2019). For that reason perhaps, did the very father of regional science consider in his later years to advent his work further into peace science instead (Isard et al. 1998).

Regional science reached its height of optimism along the fringe of its development in the mid-1990s to early 2000 (Isserman 1993). The growing economies of Europe and America, the consolidated industrial models peaking in growth before the several economic recessions (Martin 2011), made regional science and regional economics the new standards allied to the upcoming computational methods to better explore the robust quantitative frameworks of industry, governance, and economic development (Fischer and Getis 2009). In fact, computation of the 1990s and early-2000 create a relationship of reconsidering interacting and relations of spatial decision, enhancing the scope of location analysis to regional analysis with pervasive methods for interpreting the value of territorial decision making (Wilson 2014). Regional problems became the centerfold of governance and policy ideation, and the new hope of future sustainable regional development (Field 2018). By 2007, however, with the downturn of several economies throughout the world, territories became fragmented, and the asymmetries at national boundaries led to misinterpretation of regional understanding having a profound impact on the economy and thus an underlying skepticism concerning adequate governance (Hadjimichalis and Hudson 2014). The once robust methods within regional science became questioned, and fields such as geography, sociology, and economics witnessed a rebirth of their non-multidisciplinary framework for social sciences since (Stimson 2019). In recent years, however, largely due to the availability of large data structures within social sciences (Snijders et al. 2012), an astonishing regrowth within the regional science has taken shape (Lohr 2012). New paradigms, beyond industrial allocation, focusing on hybrid models and significantly smaller scales of interaction have started to emerge (Vaz and Aversa 2013). Regional science is thus changing into a new accord of reinventing itself as a multidisciplinary field that substantiates the integration of sociology, geography, economics, and planning (Massey 1979) within highly robust computational (and geo-computational) models brought forth from the advances of spatial science and artificial intelligence coupled with spatio-temporal resolutions that answer regional issues. (Rey and Janikas 2006). This paper attempts to better understand the development of regional science within the Canadian context, and define an upcoming definition for regional science that considers the technological innovation brought by big data and artificial intelligence—defined as regional science 2.0. Canada benchmarks a unique opportunity to address large data and offers an ideal laboratory for the development of modern regional science given its data availability, intrinsic regional dimension, and territorial differences throughout the importance of structured governance and divergent provincial decision making (Polèse 1999). While the data is out there to be assessed, the challenges of applying regional science in the context of Canada are an important driver for its future sustainability (Vaz and Arsanjani 2015), and an opportunity for the advent of Regional Science 2.0.

3.2 Regional Science and Artificial Intelligence

During a similar timeframe as regional science itself, in the mid-1950s, the interest in developing self-sufficient models by means of computation nested the birth of artificial intelligence (Norvig 2012). The integration of the component of machine learning (Michie et al. 1994) led to a fundamental growth of understanding conceptually at the time the possible complexity of offering large scale territorial solutions (Gahegan 2000). The computational capabilities, which we are, however, reaching only at the present, were not available to the extent of much of the theories developed during the extend of the 1960s to the 1980s could leverage the field and make artificial intelligence an applied research stream beyond the fiction ideas of science fiction. With the advent in recent years, however, of artificial neural networks (Fischer 1992), clustering techniques (Murray and Estivill-Castro 1998), and agent based models (Gimblett 2002), the classic machine learning theories are now capable of rewiring the very core of application of computational science. This has as such become the first generation of applied artificial intelligence, where the integration of big data into novel views of understanding the world around us, and reshaping several scientific fields Vaz and Noronha (2020). Artificial intelligence as such, has developed beyond the Asimovian idea of a competing robot (Haddadin 2013), into a leveraging technique of competitive science where the goal of artificial intelligence now relies in robust models to address the complexity of decision making, a much needed avenue in a rapidly changing world where regions are an important aspect of future development dynamics The increase of computational capacity and the integration of learning algorithms, for instance, mimic nicely unpredictable behaviors, particularly when enriched with big data, and leading to optimal solutions for territorial governance. Artificial intelligence, somewhat explored in recent years in spatial sciences, has seldomly been explored in the field of regional science and governance. This is, however, a natural evolving step from the tradition of the growth of the discipline of social science (King 2011). Fostered by the availability of specific data sets, neatly hosted within open data structures, for the first time in human history, we have the opportunity to assess multi-temporal standardized data structures that show demographic, geographical, and economic evolutions over periods of time that allow us to assess the evolution of patterns leading to predictive and scenario based modelling (Vaz et al. 2012). The increment of neural networks and the capacity of geo-computation is leveraging the territorial interpretation of these findings (Hewitson and Crane 1994), lending the explicitly spatial driven characteristics of regional models to answer territorial divergences that allow the very same calculated optima to be applied for governance and industrial allocation decision (Tang et al. 2018). The advent of artificial intelligence as such, is remitting to a new hope for the evolution of regional science Vaz (2018), in its multidisciplinary convergence as a structure field of knowledge and contributor for modern regions throughout the world (Brunette et al. 2009).

3.2.1 Geo-computation and Artificial Intelligence

Spatio-temporal dynamics, particularly when assessing regional change have gained a significant amount of attention in recent years due to its inherent complexity, resulting from the interaction of environmental and economic interests, as well as the need for consequential sustainable development (Arsanjani et al. 2013). The existence of different data sets that depict economic, environmental, and social phenomena have led to growing amount of data infrastructures that support multiple scales of regional analytics. Regional sciences, as such, have challenged the status quo of conventional computation techniques to address transdimensional data to assess regional problems. The territorial nature of these tools have led to the integration of geospatial and spatial analytical toolboxes within the field of geo-computation that (1) leverage the understanding of static modelling of territorial interaction (Vaz and Bandur 2018), (2) demonstrate the capability to assess past behaviors to integrate governance and policy opportunity costs (Vaz 2014), and (3) predict the future changes and impacts at regional based on past and present territorial decision (Vaz and Nijkamp 2015; Vaz 2020). The integration of spatial sciences, regional modelling, computational technologies, as well as the stochastic opportunity to model time as well as geographical extend, has leveraged what can be defined the field of geo-computation, with a direct impact on the way we handle and monitor regional change. The opportunity of regional data storage systems at different scales throughout has made particularly in the last couple of years the existing data sets inherently rich, and multi-temporal, maximizing the prospect of multi-temporal analysis within the predictive spatial frameworks of regions. These instruments can nowadays be applied for decision making through Geographic Information Systems interfaces, where visualization of prospected regional data, as well as results of direct prediction ease the integration of strategy as well as community knowledge transfer of regional decision processes. The advent of geo-computation is further fueled by the capacity of volunteered data integration from the community itself, where criteria of data satisfaction and system integration satisfaction permits to establish knowledge transfer where regional toolboxes for governance decision become more society-centric as we advance towards smarter regions. Both the data richness (in terms of spatial and temporal resolution) as well as the community integration of quality assurance directly contribute towards the potential of artificial intelligence to have a determinant role in several fronts of regional geo-computation Vaz et al. (2020).

3.2.2 Machine Learning for Regional Sciences

One of the key aspects where regional geo-computation benefits mostly from artificial intelligence is the growing demand of machine learning algorithms to prospect the ever increasing data sets and gear towards robust predictive models of classification techniques as is the case of the contribution of global data sets of land use and land cover, that would have been unthinkable a decade ago with similar coverage and resolution. Expanding machine learning towards the incorporation of artificial neural networks, such as self-organizing maps, idealizes a new perception of integrating strategic decision and enables spatial planning to rethink the role of spatial interaction between communities, cities and even the efficiency of transportation. The remarkable contributions of such tools allow to assess big data as well as understand spatial interaction for large to very large geographical extents. This particular field of advances within machine learning has allowed the integration of a geographical perspective into the governance and policy application framework. The territorial heterogeneous nature within regional systems can largely benefit from the taxonomy of spatial autocorrelation that assesses at a fine level of granularity different spatial and remote sensed data. This permits the foundation for artificial intelligence and machine learning to blossom in the multidisciplinary field of regional science where the convergence of high resolution data is incrementally relevant for fine resolution governance issues. A growing body of literature is dominating the spatial science ecosystem with such methods. From classification of land use at finer scales, to the possibility to predict commuting times for transportation, has direct impacts on the regional sphere of our cities, vulnerable ecosystems, and the aesthetics of our landscape. The final operability of such methods lies in the positioning of governance structures utilizing novel geoinformatics for regional decisions. It is necessary thus that regional scientists think holistically, and consider geography, economics, as well as the skyrocketing advances of machine learning into the frameworks of regional decision and monitoring. Machine learning is a promising contribution which fits very well in the application of spatial data, and leverages traditional statistical models to a new dimension of spatial understanding within the regional perspective. The exploration of social, economic, and territorial dimensions within a regional system allows to address complex questions that otherwise would be impossible to assess. Issues such as (1) industry location, (2) corporation dynamics, (3) land use transitions, (4) endogenous growth and specialization, (5) social impact, (6) urban and rural interactions, and (7) innovation and invention dynamics, are all issues that may be tackled within a regional complexity science framework and largely benefit from instruments found in artificial intelligence. It is the geographical scalability that allows for a mixed science approach and a convergence of multidisciplinarity. Within the structure of policy and governance, the role of computational methods holds the potential to (1) monitor, (2) assess, (3) predict, the current state of complex regional interactions, that otherwise would be impossible to measure. In this sense, the future development of regional science will use the significant advances of computational and geo-computational methods. Fundamentally, regional science is an open science, where despite its tradition, a central methodological framework has to be defined as to create an epistemology for its field. The dispersal of regional science as a field in itself is a result of the growing literature in other more traditional fields such as sociology, geography, and economics. It should be noted, however, that regional science has a tremendous potential when considering the Anthropocene, and it can well be expected that it will continue to grow in the next decades, as we face increasingly complex problems that intertwine computational decision systems with governance and policy integration. The availability of spatial (and not so spatial) data and particularly, the advent of high-granularity data, responds well to the growth of regional science as a field. As the subject data become available for more precise (or local) decisions, one can consider the articulation of the field as a macro-regional science 2.0 and a micro-regional science 2.0. Where the field will leverage new scales to address regional issues, from perspectives that otherwise, without the computational aspects of data availability, would not be achieved.

3.3 The Opportunity for Canada

Canada presents quite a unique challenge in regard to its regional understanding. Its significant geographical extent makes the country hold a unique complexity formed by cultural, physical, and economic characteristics. While there is a single Canadian identity, at provincial level economic, historical, and policy characteristics are very distinct. This grants Canada a unique profile of richness and diversity, which leads to differentiated sectors of economic activity to blossom in different provinces. This is a result of the historic path tendency tied to the traditional production circuits of provinces, but also to the availability of natural resources given the heterogeneous profile of the spatial unit of Canada itself. Six geographic regions can be distinguished for regional purposes: (1) Atlantic Canada, (2) Quebec, (3) Western Canada, (4) British-Columbia, (5) Territorial North. The remarkable variation on key variables such as population concentration and economic activity (both the industry and the service sector) make Canadian provinces a highly interesting regional proxy. Southern Ontario, for instance, where population density is one of the greatest in Canada, shows a substantially low population density in northern Ontario. A crucial example is the unavailability of certain demographic and land use indicators in the less population dense regions. Canada's spatial data structure, and geographical information—despite the significant investment in technological integration and data in the recent decades as well as the fact that Canada has been the pioneer for geoinformation—presents some significant gaps when outside the population dense regions. Added to this, the regional challenges of population dynamics, with immigration playing a key role on the distribution and redistribution of spatial interactions of the economy, applied politics, and governance initiatives, lead to a regional dynamic structure for Canada's geographical regions and provinces. These transitions throughout regional space as well as the emergence of large urban cores that function as economic hubs for Canadian economies continuous growth, leverage the importance of regional models that handle large data, and understand the spatial interaction from a spatio-temporal perspective. This is the unique opportunity that Canada has to merge novel regional spatial methods in its forum of current monitoring techniques. While governance structures largely recognize monitoring of regional dynamics as one of the most relevant aspects for sustainable decisions in line of an increasingly vulnerable environment, it is the added territorial complexity of (1) size, (2) economy, (3) land use, that makes Canadian provinces benefit greatly from the upcoming regional methods such as machine learning and artificial intelligence in its planning structure.

3.4 Regional Science 2.0 in Canada

In its long tradition, regional science has become a beacon for development in a globalized world, where issues such as land use change, fresh water resources, immigration, and sustainable development are critical factors for guaranteeing a sustainable future. Regional science has reached its septuagenarian existence, and with the ongoing trends of globalization, where immigration, heritage, environment, and urbanization gain a new dimension, regional science boasts yet again, the charm and youth of a teenager. The reinvention of regional science has mostly been brought forward with the advances of computation and technology, where never like before, toolsets become available to end-users (both from science as well as from the community) to dwell in the questions of regional dynamics. The open source community enabling methods, tools, and techniques in forums and discussion boards alike, have allowed through open source software such as Geoda, GWR4, and QGIS, to name a few, to establish a new network of multidisciplinary communities that enable the continued success of major conferences such as the RSAI, ERSA, and NARSC to flourish. The incremental amount of workshops that are offered in such conferences are far from different than the 1954 call for an association of regional scientists, that stood still well-established in the ivory tower. It has been the evolution of this great regional scientist, and later the quasi-evolution of computing, that allowed brick-and-mortar scientists to become the second generation of innovative and creative thinkers of regional science. It was the generation of well-established academics in the 1990s, that through inquisitive minds, and still active nowadays as the legacy passes on to the next generation of regional scientists, laid the cumbersome task of creating the digital divide, when computational processes in the mid-1990s still presented from a programming and geo-computational standpoint several hardware and software implementation challenges. Far from the original blackboards from the Isardian vision of contemplation of geography and regions, the 1990s so bustling challenges of computation and contribution to more extensive data dealing with firm allocation, and the sentient and rapid transformation of the urban landscape and firms allocation. I would consider that we are now in the third paradigm of Regional Science. The Regional Science 2.0, standing in the shoulders of giants, regional science stands now as a renewed frontier of understanding the contexts of the startling absence of geographical space for commercial activity, the ethereal nature of services through sharing economies, and the frontier of verticalization of cities in the urban divide. These issues are becoming inquisitively explored by a new set of scientists and research toolkits, that find contemplation far beyond the blackboards from the 1950s, the conference rooms from the 1990s, but in the short posts of Facebook, the witty lines of Twitter, and the encompassing forums on Reddit. Regional science is witnessed unprecedented growth in the potential to address new paradigms that aid in understanding the complexity of territories and land use interactions. As the rumors of fractal cities travel farther along the dissonant walls of cyberspace, we ask ourselves the question if regional science extends to complex systems, and if our models are not a reflection of a single scale of a much more complex and naturally forming systems. Is the urban footprint similar to the mutation of cells biological systems are transportation networks that different from a nervous system. The new generation of regional scientists will be engaged in working further with complex computational models that set up through quantum computing an integrative vision of macro, microeconomics. While Regional Science will continue to be a not so well definable discipline, it will continue to flourish through the many multidisciplinary realms it can integrate. The geographical dimension remains thus, the next frontier as our digital data elaborates further on the complexity of territorial and multi-scale integration of spatially-explicit frameworks that only regional science allows to further to have a positivist truth within a framework of regional intelligence.

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Chapter 4
Dynamic Sustainability: Back to History to Advocate for Small- and Medium-Sized Towns

Teresa de Noronha, Eric Vaz, and Waldemar Ratajczak

Abstract A debate related to the "net" value of agglomeration economies created in the long run is proposed. Some volatile assets such as strategic planning, knowledge creation, shared innovation, and advanced skills are identified. The perspective of urban dynamics adds a glimpse over the potential capacity of medium- and small-sized towns (SMTs) to be capable participants in the development process throughout extensive periods.

The concept of agglomeration economies, pointing out to efficiency gains due to the proximity among agents, is an "unrefuted truth" to be revisited: Immediate efficiency gains are frequently suggested by policymakers whose good intentions for regional development have aggravated discrepancies with shrinking effects for SMTs. Costly consequences must be mentioned: pollution, loss of biodiversity, climate change, pockets of social stress, and extreme poverty are long-term impacts. Not often are impacts directly measurable, for example: The recent pandemic of COVID-19 has shown the fragility of large urban cores to immediately address complexity.

This chapter is composed of (1) introduction, an insightful approach, (2) case studies, illustrating the empirical capacity of SMTs to survive long-term challenges, (3) discussion, highlighting some theoretical insights from the case studies analyses, and, finally, (4) conclusion.

Keywords Small- and medium-sized towns · Sustainability · Territorial revenue distribution · Governance · Rural areas · Redistributive public policy · New urban architecture · Long-term negative externalities

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4.1 Introduction: Dynamic Sustainability for SMT

The dramatic changes faced in the last couple of decades brought a general trend of populations moving from SMTs in the rural world to intensively urbanized contexts and eventually to mega towns. Migratory movements have since long been at the origin of spatial transformations that altered urban areas. Inside established limits, there has been a tendency evolving together with a systematic asymmetric distribution of opportunities to rural areas and their small or medium-size towns which, meanwhile, have become associated with peripheries and low-potential areas (O'Brien and Ahearn 2016).

Small- and medium-sized towns (SMTs) have shown a potential for high-tech agriculture, their increasingly important role as a playground for creative and innovative small business activities, and their sustainability function in ecologically protected areas as well as a recently new role in the spread of multiculturalism (Woods 2018). Rural regions have brought new hope towards a sustainable opportunity for growth. The socio-economic potential of towns in rural areas is also evident, as they are often the anchors for new developments (Grunwell and Ha 2014). SMT also forms a bridge between social community capital and landscape cultural heritage (Vaz 2020) and, on the one hand, abridge the new growth and creativity trends which must be accepted and enhanced (Vaz and Bowman 2013).

What we will try to prove during the development of this chapter is that rural medium-sized towns are not irrelevant players in the protected and stagnating rural areas (Hospers 2013). They always have been agents of change throughout history; thus, a long-term observation with a historical "bird's eye" is of utmost importance. Future will expose increasingly to internationalization, social networks, modern information and communication technologies (ICTs), and many other possible technological developments. In other words, the primary goal of this study is to discuss and eventually find out, if there are pathways that may link the historical growth of SMTs to the challenges of a high-technological society. We recognize that, in the context of an open space-economy, towns must gather all their capabilities to be able to survive. Thus, depending on how innovative each one can be and enhancing their own potential, they can reach a complex combination of rurality and modernity, in a new understanding of urban networking architecture.

In a democratic context, solutions require a consensus and the capacity of citizens to be aware and act in times of change. We believed that policymakers are no longer free to act independently from public opinion. However, the results of recent elections across the world are proving unclearness about what citizens wish of democracies and their decision processes. Clear is that, if democracy is supposed to consolidate, citizens (even those located in remote and peripheral areas) expect better local living conditions and better amenities for quality living. In general, the population is reluctant to let small towns vanish, as they are part of poetic imagery of childhood and enchantment (de Noronha and Nijkamp 2015)—a historical view of hope and expectation of glory that demonstrates social development and well-being. Some literature (Kourtit et al. 2015) points to market forces that would probably slowly shrink rural environments and their towns. However, some recent scientific arguments classify such environments as guardians of a redistributive model wishing we should not lose, thus calling the attention for alternative strategies of survival and possible reinforcement of SMTs vitality (de Noronha and Vaz 2015). Technological innovation and new products combined with improved transportation systems may, indeed, facilitate a new concept of distance for which distant places are much near than we have considered them to be. Although we think that necessary public policies will most likely fail in the design of successful SMTs (Halseth and Ryser 2016) we do trust that there are other, different forms, most of them tailor suited, for which the self-reliance and self-organization capacity of these towns optimized.

Repeating what has already been questioned by us, sociologists, economists, and architects seems to be in favor of assets concentration in and around the large cities (Kourtit and Nijkamp 2013). Also, new technologies are available and able to manage agglomerations efficiently to the point that cost reductions become unbeatable. Still, why do we assume that, in a context of limitless spreading of the networking systems, the rural world will stay apart from technological innovation and knowledge sharing? Some authors have confirmed that the rise of urban network externalities, defined as external economies—from which firms and households can benefit by being located in agglomerations on networks that connect with other agglomerations—could bring new advantages and positive influences upon urban performances of SMTs. This poses the following question (Fertner et al. 2015): Why should it not be assumed that any innovative inputs can be available outside the big agglomerations as much as inside, thus, allowing smaller towns to undertake or participate in novel social functions? Most probably, many citizens are ready to learn further to contribute to different conditions for their rural environments. Multitasking is possible in the rural word, indicating that small- and medium-sized towns do have a precise and essential role in promoting economic activities outside big urban agglomerations (de Noronha Vaz and Nijkamp 2009). Simultaneously, reflecting the past and envisioning the future, policymakers should, in any case, act to consider the potential major role of small towns (de Noronha and Vaz 2015; Vaz et al. 2012a). We claim that SMTs have a strategic position for rural development. They may become, for example, hotspots for knowledge creation and diffusion, such a significant condition for business life and innovation, and social networks and community bonds, as they can better handle the processes of socio-economic decline and promote a geographically balanced income distribution and sustainable production structure, meaning they are able to become much more resilient and stop shrinking (Panagopoulos et al. 2015). We should face such urban structures as potential nuclei for change and balance of extended rural areas. The goal of our suggestion is to prove that SMTs should be a target as instruments of regional balance and development. To launch the idea, the authors have recently published a theoretical framing to justify how this has a solid theoretical ground (de Noronha and Vaz 2020). This chapter sheds some light on the vast potential offered by SMTs, addressing specific cases where competitiveness and economic activity have been stimulated after long periods of historical constricted industrial progress.

4.2 Methodology: Historical and Critical Approach of SMTs

Our theoretical main framing was briefly described in the previous introductive chapter and deeply explained in the previous reference, which due to open access can be followed by the readers. In this discussion, we expect to call the attention to the effective role that history has played along town and city development. Only time has decided their path either for progress or decay. Many towns have been the birth of prosperous activities, given the needed time to consolidate their most efficient activities, others kept resilient for a long time, and many have not resisted to the many shocks of unexpected evolutive processes. We have chosen a methodological approach based on an evolutionary (historical) analysis of three successful towns. These three case studies will be presented, and similar situations compared from an analytical point of view, to better identify the main socio-economic advantages generated by the small urbanized populations that SMTs can provide. We will not be able to escape the critical characteristic of most of SMT, since most are in rural areas and have, or had, in their history, a dominant position within the agricultural sector. None of them is today a rural small town. But in the past, they have been, they have moved from their fundamental role and have become today advanced cities with valid and independent urban contexts. All of them were critical providers of specific services to large cities. But it is undeniable that not only is the production process of farms different from that of organizations but also the lifestyle of those persons active in the agricultural sector often differs from the rural lifestyle of those who are engaged in other non-farm activities (van Leeuwen et al. 2007).

Historically, the decreasing economic importance of agriculture and fisheries has been substituted by new economic activities that may be directly connected to related activities, and yes, pointing to cluster dynamics. By studying the maritime clusters across Europe, there is a connection between fisheries that are developing exciting activities related to biotechnology, actively promoting the sector in advanced research environments of their regional universities (Monteiro et al. 2013). Such kind of case studies can be identified across many different countries.

Moreover, and just before we describe our case studies, we would like to add that rural areas and their SMTs are places increasingly appreciated by the different experiences of the idyllic rural landscape (de Noronha Vaz et al. 2013). In this regard, the esthetics of the landscape plays a fundamental role in well-being and touches the very core of the subjective well-being of humans (Vaz and Agapito 2020). SMT should take advantage from their very precious, frequently unusual, cultural, and architectural heritages that contribute to the richness of their legacy, landscape, and esthetics. The international accreditations of such historical or modern outstanding environments allocate different economic activities and attract people, as residents or tourists, pulling further development opportunities such as investments and jobs. As suggested, labels must be created to emphasize the cultural attributes of such towns (Akgun et al. 2013). In other words, the "idolization" of towns depends not only on their qualities but also on their creative capacity and openness to today's network society.

4.3 The Case Studies

In this section, we have chosen to observe, describe, compare, and enhance the pillars of sustainability and eventual growth of some medium-sized towns. Our observation set is composed of Oeiras in Portugal, Markham in Canada, and Poznan in Poland. Furthermore, in all cases, we call their historical roots to grasp some of their patterns of change better. With similar conditions related to their inclusion in the proximity of great cities, the first two medium towns take advantage, rather than long-term costs (happening if they had persisted as oversized satellites) from their proximity to Lisbon and Toronto, respectively. Though, part of their progress has been justified by well thought and carefully designed growth strategies. The second remarkable feature of these two towns is the fact that there is a clearly defined path dependency arriving from very well-established historical contexts. The same can be reported about our third case study. The case of Poznan is also quite interesting, but, contrary to the previous two, it does not locate in the vicinity of a big city. Warsaw, the Polish capital, is about 300 km away. Thus, Poznan benefits from nurturing a significative network of dozens of small towns, which populate its surroundings. In common, all the cases have emerged from agricultural and rich historical pasts.

4.3.1 Oeiras, Portugal

The proposed comparison was carefully composed having in mind the different general conditions in both countries: A very different population history (the oldest country in Europe, surpassing poverty with emigration waves and the new world still in expansion with immigration factors as the most critical determinant to economic growth), clearly different dimensions, and quite the opposite climates. Even though frequent similar traces in the functioning and survival strategies of these SMTs have been found.

From an overly broad perspective, the two parliamentary systems, at the country level, differ: Fiscal obligations extremely regulate one and a three-level public policy context (national, regional, and municipal) affects citizens and firms. The other offers a non-interventionist background for companies and different agents. The significant difference between the two countries that we could emphasize, however, is that in the case of Canada, the selected town is located in the province of Ontario, thus submitted to a provincial legislative context, adding to the fact, an inexistent public policy for regional development and cohesion. However, at the national level, there is a reliable support system to firms, namely de-bureaucratizing the creation and consolidation of SMEs (small and medium enterprises).

Contrarily, in Portugal, firms must deal with a weighty legal and fiscal context, although this situation improved in recent years. This is partially compensated by the considerable effort of the European Union to leverage as much as possible the different regions within the EU, creating similar opportunities for citizens and business, accordingly, simplifying processes and achieving a better social balance. Many programs launched by the EU have focused on lagging areas, and the incentives to promote growth at the micro-level have been significant. So, in general, SMTs in Portugal, if located in rural areas make profit from an active public policy, either directed towards regional development or business innovation. Despite this, it took a significant amount of time for regions, towns, and business to be able to fully absorb the support that has been made available for Portugal by the EU (Vicente-Galindo and Noronha Vaz 2009).

We have selected for the present chapter the cases of Oeiras, in Portugal, and Markham, in Canada, due to the several similarities these towns have, establishing a common ground to the analyses: Both belong to the excellent areas of the countries' most significant cities, Lisbon and Toronto; Both having significant historical roots based upon narrow but flourishing segments of agricultural activity; Both have been important points of passage for travelers; Both have been the reason that the rural world has become a significant environment for high-tech, eventually, even potential high-tech hubs soon have suggested how such can become possible (Knoke et al. 2017).

Towards the middle of the last century, after significant housing prices increases in both capitals, Toronto and Lisbon, citizens used these towns as dormitory alternatives. Transportation, via train, has been improved to allow a more frequent connexon between both country capitals and these two SMTs, increasingly intensifying as their land prices increased. In both cases, this first significant growth period took place between 1970 and 2000.

Strategically, a different approach was carried out by the stakeholders in charge of these two municipalities' development. In Oeiras, and despite the heavy national interventionist context emerging from a recent integration of Portugal in the, then called, European Community so well accompanied by several agendas to renew and reshape skills and industry in the whole country, growth took place at its own speed, and very little long-term planning was done. Most of the first set of investments was oriented, at a national level, towards firms' support to innovation, new business creation, and governmental social needs such as the creation of new universities, advanced schools, logistic platforms, financing of commercial centers, and health care improvements. However, and despite the rise of many new opportunities, there was not the will, or capacity, to plan a structured strategy able to redefine how the urban areas should develop under such new conditions for the decades to come. Oeiras was a clear example of this general attitude. Although for the municipality, there was an effort to improve the town life quality, basically profiting from the natural proximity of the Tagus river, from very easy accessibility to the oldest highway in the country, most of the urban agglomeration did not change almost until the 2000s.

One of the most important data to follow a SMT dynamic capacity is related to its population composition and growth. It is expected that this SMT (at municipality level) will reach 180.000 inhabitants by 2021, having grown up about 80,000 inhabitants in the last 50 years. Population density grew significantly from 3500 to 3800 per square km in the last 15 years.

The historical context of Oeiras municipality is largely marked by its heritage based upon the remarkable construction of Palacio do Marques de Pombal, built in the second half of the eighteenth century. The building is remarkable, an imposing palace with its long, curved stone staircases and its austere Baroque style, the summer residence of King D. José and his royal family during the summer periods. Observing the palace, one can get an idea of the immense wealth of Sebastião José de Carvalho and Melo, for this is a building of very palatial dimensions, ornate as a royal palace. It is today one of the best examples of the eighteenth-century Portuguese manor house, following the Baroque and Rococo styles. Beyond the palace, the magnificent gardens of fantasy inspirations also extend to the right bank of Ribeira da Lage. Symbol of their deep culture, typical of a Europe of Lights, the gardens retain architectural landmarks of rare beauty. The owner, Prime Minister and Secretary of State, the second prelate and also holding various essential positions and titles, employed their income also to benefit Quinta de Oeiras, inherited fertile farmland from his first wife consisting of farmland with vineyards, olive groves, and fruit trees. In the second half of the twentieth century, this property was sold and fractioned, purchased by the State and replaced by the National Agronomic Station. The property belongs to Oeiras City Hall since 2004.

Another important legacy of this SMT is its early industrial activity, starting with the construction of the Oeiras Metallurgy and Metallurgical Construction Factory, commonly known only as of the Fundição de Oeiras, one of the most important, imposing and interesting historical traces of the industry in the Oeiras Municipality, producing at a national scale since its start. It is one of the few survivors of the hundreds of industries that existed in Portugal and that significantly supported its development. It was undoubtedly one of the largest factories in the county and one that employed the most significant number of workers. It has a long history and constitutes a relevant heritage. It was built in the nineteenth century, in the wake of the movement caused by the Industrial Revolution. Perhaps it began only as a metallurgist foundry, later expanded its area, and embarked on metalworking, expanding its facilities. The company was founded in 1921 as a public limited company, the Foundry of Oeiras from early on gained significant socio-economic importance in the municipality. With an initial area of 6500 m^2 and 60 workers, the main activity in the early days was the casting of ferrous metal to support the electrical installations and, generally, the entire national industrial foundry.

As pointed out earlier, economic activities are an excellent indicator to follow the vitality of cities. The specialization profile, business location patterns, and positioning in international markets not only reflect the opportunities that urban agglomerations create for their people and organizations but do also indicate their capacity to survive to future challenges related to years to come. From this point of view, the Lisbon metropolitan area has, just like most of all the other Great Metropolitan areas across the world, unique advantages at the national level: it is the country's capital with a significant geographical accumulation of strategic resources for development and can attract qualified people and activities from other regions and countries, thus a relevant presence in supranational networks of cooperation and exchange.

The municipality of Oeiras, representing a center of economic activity and consumption of international value, thereby plays an essential role of intermediation between the whole country and the world, made good use of this advantage, but only in the last decades. Meanwhile, Portuguese business location patterns start to indicate the beginning of overcoming a metropolitan model excessively dependent on a central pole, with the consolidation of new peripheral centralities capable of attracting and incubating innovative initiatives as well, a kind of services decentralization mostly resulting from intensive knowledge creation combined with lower costs in the real estate market. Also, the strengthening of openness abroad reflects an expansion of international investments and activities. Stakeholders confirm that Oeiras is a municipality with a postmodern profile with its spot in the international economic environment.

Today, the town and the municipality are both able to attract not only the most extensive national companies but the largest advanced services and technology companies, which are usually owned by external entities mostly in the services sector, namely commerce, information and communication technologies, financial and real estate activities, leasing and business services. Following a historical strategy, Oeiras is finally awaking for a wide range of research and technology areas of knowledge that guarantee a good offer of this kind of business support services. Just to name some of them: Technology Transfer Center, Welding and Quality Institute; Technology Transfer Center of Universities—UMIC—Agency for the Knowledge Society I.P.; Research Institutions—Institute of Experimental Biology and Technology and the Gulbenkian Institute of Science; Institute of New Technologies—Institute of Experimental Biology and Technology; Associated Laboratory—Institute of Chemical and Biological Technology; State Laboratory—General Directorate of Crop Protection; Research Units—Center for Developmental Biology, Genetics and Natural Tolerance Development, Institute of Biomedical Technology and Life Cycle R&D Unit for Welded Industrial Components and Products. Also, to mention the existence of four large industrial parks in that municipality: Arquiparque (Miraflores), Lagoas Park (Porto Salvo), Quinta da Fonte (Paço de Arcos), and Taguspark (Porto Salvo).

4.3.2 Markham, Ontario, Canada

Our next observed case is in Ontario, Canada. Markham is a SMT of large size, located 30 km away from Toronto, approximately the same distance that Oeiras is from Lisbon. This SMT has already been classified as the City of Markham and just like our previous case also benefits from a powerful historical legacy. In 1791, John Graves Simcoe was appointed the first Governor of Upper Canada, and his actions strongly influenced Markham urban evolution. Concerned in improving the military security of the new territory, he conceived a system of free land grants, which promoted the growth of what became later the Township of Markham. The first European settlement in Markham took place when William Berczy, a German artist, and developer guided a group of about 64 German families to North America. After their arrival around New York State, they moved further by negotiating 64,000 acres in Markham Township. So that Markham has its roots in the so-called German Company Lands. The settlement was difficult. 64 families arrived in 1794, and their start was limited by the harsh winters and many crop failures. Some settlers moved back to Niagara, but those who stayed, finally, managed to succeed. Later, other settlers arrived (French Revolutionary Émigrés, United Empire Loyalists, Pennsylvania Germans, and migrants from the British Isles) in the search for improved life quality.

From 1794 to 1830, growth in Markham was described by the difficulties of homesteading and the expansion of some agricultural trades. The township's many rivers and streams facilitated water-powered energy such as Woollen Mills. Small towns such as German Mills, Almira, Buttonville, Cedar Grove, and Unionville flourished in those mill sites, favoring the building of new transportation routes such as Yonge Street, expending urbanization increase. Around 1860, most of the surrounding lands were cultivated, and new villages such as Thornhill and Unionville expanded to share with Markham growing specialized industries such as wagon works, farm instrument builders, and furniture factories, for example.

The expansion of the railway system in the surrounding small towns pressured Markham to start the Toronto and Nipissing Railway Company. At first, the railway brought renewed prosperity and rapid development and Markham increased its population to 1100 at the end of the nineteenth century.

It was after this period that the exchanges with Toronto intensified and soon after were enhanced by the rail line, the telegraph, telephone, and automobile. At the same time, after the turn of the century, a local business could not easily fight with suppliers in the city, and the township stagnated to an agricultural community. Its next growth phase occurred as a post-war urban advance from Toronto. Industrialized by the war effort and experiencing a strong baby boom, it became the host for many immigrants from all over the world. The Regional Municipality of York was established in 1971 by the Province of Ontario. A large portion of the municipality was incorporated into the Town of Markham. The second connection system-initiated Highway 404 and rapid urbanization. Markham has served as an example of environmental protection and restoration to accommodate 150,000 people (Gordon and Tamminga 2002). It holds one of North America's largest concentration of new communities planned with traditional neighborhood design principles—part of an exercise to confirm whether New Urbanism could collaborate with pre-emptive ecosystem planning. The results of the comparison indicate that the plans met or exceeded most objectives for environmental protection.

Today, Markham is considered Canada's High-Tech Capital secured by more than 1500 technology companies and creating about 37,000 jobs. This significant development and consequent growth had its origin not only on the rich heritage earlier described but, and above all, on a set of very well-planned communities whose stakeholders and policymakers saw the huge opportunity arising from proximity to Toronto.

As land prices in Toronto started to rise, urban planners and real estate companies set together to define priorities and a long-term agenda for the region calling before all for high-quality infrastructure and talented workforce to design a pro-business environment. That was about 20 years ago, but today's Markham's business community includes companies and organizations able to excel by providing globally competitive banking, financing, engineering, design, technical, and commercialization services. Of the 10,400 companies located in Markham, there is a high concentration of Canadian head offices, including industry leaders such as IBM, AMD, Redline Communications, Real Matters, OnX Enterprise Solutions, Huawei Technologies, Nightingale Informatix, Lenovo, GE Energy, Nexeya, Toshiba, Adastra, CDI, Qualcomm, and Genesys.

Moreover, and due to this substantial economic activity, Markham is booming in terms of real estate prices, seconding Toronto and as one of the most active municipalities of the Great Toronto Area (GTA). The rise of housing prices has a significant impact on the population educational level moving to Markham and on the number of investors who are engaging in acquiring properties within the municipality. The process triggers a new cycle of fast but risky growth. Markham has become one of the most diverse residential areas in Ontario, and many of the investors are Indian residents or Chinese, some of these foreigners. Some of these houses were bought and stay empty, waiting for increase in their values, a typical situation related to fast growth that requires national public policies of control and contention. Prices may reach an unsustainable maximum and fall fast to a loss for many resident families.

From a strategic point of view, the City of Markham adopted a 10-year Economic Strategy—Markham 2020 | Markham's Global Future in 2008. This strategy is a design of Markham for the future, bringing up plans with important details. So far, this strategy has proven to be successful, protecting, and orienting city's economic development towards a robust and growing local economy. In 2015, the City Council approved a four-phase performance review of Markham 2020: In phase 1, the research performance data was monitored, and consultation with stakeholders was done; phase 2, concerning community engagement, thus a series of open house-style public meetings and webinars were organized in 2015 and the start of 2016; further, in phase 3, in the Spring of 2016, within an open house concept Keynote Speakers, a webinar was organized counting with the participation of industry experts from TD Bank, York University, Seneca College, Scotia Bank. Lastly, phase 4 presented findings and recommendations to the Economic Development Council and published a publish report in Open House Meeting Series.

Before passing the last case study, a few additional considerations would improve the understanding of the reason why from many other SMTs these two have been selected to be discussed together. Their different ecosystems have been mentioned, but their similarities still remain to be shown. Both Oeiras and Markham have progressed and have within a similar timeframe become classified as cities. Their fast growth and patterns towards sustainability and landscape integration allowed to provide most of those services necessary to keep the population satisfied, attracting further business and activities, and leading to economic growth. Their proximity to large urban cores facilitated this process. However, not all towns next to large cities can deal with the gravitational pull that large urban cores exert. Most of them weaken and become semi-functional suburban regions.

Both cases started with an impressive historical legacy, where the existence of dominant families. Their power brought the capacity of creating networks of influences able to spread the significant characteristics of the growing small towns, even in rural settings. This legacy further emphasizes the potential of branding a historically present product, where both in the cases of agricultural and manufactured products, a strong identity prevails. Branding products, together with their origin and pushing town development, at those times, also deserve a significant emphasis in this study. Local or regional knowledge growing from such circumstances developed much faster in Oeiras than in Markham. This indicates that we could have to expect a much earlier growth in that case. However, that did not occur because, under no circumstances, advanced knowledge was such an essential tool for growth at the end of the nineteenth, beginning of the twentieth century, as 100 years later. Thus, not surprising that Oeiras stagnated at a more advanced level than Markham.

Two vital advantages promoted a real change in Markham, around the 1970s. Firstly, the vastly expanding immigration in Canada, seconded by the capacity to develop early on a very sophisticated vision of urban planning that stayed remained an essential tool of growth for the region since then. Within the Greater Toronto Area, around the 1980s, several municipalities joined together to create a significant critical mass that led to the capacity to generate agglomeration economies. The fast zoning of land and the architected design and construction of many complementary buildings pushed towards benefits for industrial location, bringing a considerable number of new firms, linked to the emerging sector, such as information and communication technologies. The growth was much slower in the case of Oeiras. A similar foresight did not exist in the case of Oeiras, and it did take the town approximately four decades to surpass that phase of the dormitory for demographics employed in Lisbon.

Despite the different trajectories, significant similarities between the two pathways followed by this growing SMTs are noticeable. The historical legacy of both towns played a fundamental role in planning and supporting local firms to cluster. This agglomeration economy building led to diversified economic activities. Furthermore, SMTs have managed to go beyond being considered as dormitories from major cities. In this process, these towns leveraged independent promotion. In Oeiras, this occurred as soon as Portugal became eligible for structural funds supporting skills and innovation in corporations (de Noronha Vaz et al. 2015; Vaz et al. 2014). Hence, we must consider that, in this case, the primary driver for urban growth was due to the incoming external funds, a very distinct situation of what occurred in Markham. In Markham, foreign investors were attracted by the existing skills of the growing demographics of immigration arriving predominantly from India and China. Canada's history and strategic development are, still today, based upon immigration trends. Markham used this opportunity well by facilitating the concept of living and working on a high-tech hub, with all benefits of education, culture, and economic activity fostered by the proximity to North America's second-largest financial market, Toronto.

4.3.3 Poznań, Poland

To better observe the dynamics of growth of SMTs across the world, we have searched for another, different, but also a remarkably interesting case. The city of Poznan located in Poland. The reason why we have selected this case for our publication is that it was once a medium-sized town, today emerging to a city and aspiring to be a smart city. It grew from historical legacy into modernity, and, such as the other two cases, it has created specific knowledge circuits to develop its agricultural and industrial capacities further into technological innovation and quality living. However, differently from the recent development of the previous two case studies, Oeiras and Markham, Poznan took a long time to become the city it is today, developing at a much regular and steady pace.

Poznan legacy dates from a long time ago as this historic town is one of the oldest in Poland. Its roots go back to the beginnings of the Polish state, formally established in 966. It was in Poznan that the first Polish bishopric was created, as early as 1000. That was also the year when the Holy Roman emperor, Otto III, passed through Poznan with his suite on a pilgrimage to the tomb of St. Adalbert in Gniezno, the first capital of Poland, situated 50 km from Poznan. Otto III planned to restore the Roman empire through the association of four kingdoms: Gaul, Germany, Rome (Italy), and Sclavinia, the main part of which was Christian Poland, already well organized politically at that time. A thousand years later, this idea of a universal community of European states was invoked by the 11 fathers of European integration. Then, in the twelfth century, Poznan became the second capital of Poland. The sixteenth and early seventeenth centuries were the city's golden years; it was then one of the richest, if not the richest, city in Poland. This was due to the many royal privileges it had been granted to.

The history of Poznan has seen many events that stimulated the city's socio-economic development. For this case study description, we have considered that one of the most significant dates from 1650, when its Jesuit College has been transformed into a university by King Sigismund III Vasa, an act later confirmed by kings John Casimir in 1650 and John III Sobieski in 1678. Because of its location in the western borderland of old Poland and on the main West-East axis, Poznan has often been an object of fights, attacks and plunders by Czech, Brandenburg, Swedish, German, and Russian armies. However, each act of destruction and humiliation stimulated its inhabitants to rebuild their city even more beautiful and better organized. This is a feature that people living in Poznan and the region also display today by showing a strong sense of unity and pride in their urban environment.

An essential part of the Poznan urban environment is the interesting green spaces as part of a city layout unique in Europe. They are known as the Poznan Green Wedges. There are five of them, and their conception was worked out by Prof. Władysław Czarnecki between 1895 and 1983. The green spaces occupy a total of 68.1 km^2 (26% of the city area). Woodland predominates among them, at 37.5 km^2 (14.3% of city area), followed by housing-estate green spaces, at 0.2 km^2 (4%) and then gardens, parks, cemeteries, sporting grounds, etc. There are 24 parks and 7 gardens in the city. As much as 15% (39.2 km^2) of the green spaces are legally protected areas. They include Natura 2000 areas, protected landscape areas, ecologically valuable sites, and nature reserves. The city has a highly diversified hydrographic network. Its main river is the Warta (third in terms of length in Poland, at 808 km). Other rivers include the Główna and Bogdanka. In all, the city features six rivers and more than 30 lesser streams. Because it is situated in the Wielkopolska Lakeland, Poznan also has many lakes and ponds. The largest are Lakes Kiekrz, Malta, Rusałka, and Strzeszyn, while lesser water bodies exceed 60 in number.

In 2010, PricewaterhouseCoopers made an analysis of types of development of different Poland's capitals of 11 biggest cities: institutional-democratic capital, technical and infrastructural capital, quality-of-life capital, human and social capital, the capital of culture and image, the capital of investment attractiveness, and the capital of financing sources. In the case of Poznan, the assessment of its position confirmed that the city favored five major factors shaping self-organizing innovative complexes that were able to promote and shape the future of Poznan and its evolution till today.

The geographical infrastructure of Poznan is a junction of seven roads of international and inter-regional importance. One of them, the A-2 highway, joins Warsaw with Berlin and Lisbon. The international airport at Ławica meets the aerotropolis criterion and is located 10 min away from the center of Poznan. It serves 1.5 million passengers a year and has connections with 22 European cities. Also, the railway offers passenger links with the biggest cities in Poland and Europe. About 130 trains are stopping daily at the Poznań Główny Central station. They are served by the Integrated Communication Centre opened in 2012. Freight trains go through the Poznan Franowo station, which is one of the largest freight-service stations in Poland. Poznan is a participant in the European Union's Rail Baltica Growth Corridor project.

Among the Polish cities, Poznan counts as one that is highly advanced economically. In 2011, its per capita GDP was 71% of the European Union average. The productive structure of the Poznan economy is diversified on the basis of services (about 70% of gross added value) and industry and construction (more than 29%). There are over 100,000 economic agents based in Poznan. Among them, some have global reaches such as Bridgestone Poznań, GlaxoSmithKline Pharmaceuticals, Nivea Poland, Volkswagen Poznań, Wrigley Poland, Kompania Piwowarska, and Cegielski S.A. Poznań. Also, Poznań is a city of high-tech and clustering activities such as: Wielkopolska Chemical Cluster, Wielkopolska Cluster of Advanced Automation Technologies, Wielkopolska Cluster of Furniture Design, Wielkopolska ICT Cluster. No surprise that the unemployment rate is under 4%.

Poznan pursues and develops those fields of knowledge and activity which serve to generate technological progress, especially based on higher-level education. There are 28 higher education schools in Poznan, both public and private, with a total enrolment of more than 131,000 students, producing yearly more than 40.000 graduates. Higher schools employ an academic staff of 8.500, including 1.100 full professors. A special role in Poznan is played by 79 R&D units, employing 5500 workers. Of special significance in creating new technological systems are the two scientific-technological parks: the first and oldest one in Poland, viz. the Poznan Science and Technology Park, and the first non-public one in Poland, viz. the Nickel Technology Park Poznan. Also based in Poznan are Business Process Offshoring (BPO) centers of such well-known global firms as Microsoft, Bridgestone, Carlsberg, Arvato-Bertelsmann, GlaxoSmithKline, and others.

The systematic effort of the Poznan authority to support and reinforce the leading role of the creative sector in the city also manifests itself in its unique Academic and Scientific Poznan program. Its chief, though not the only, aim is arranging open lectures by eminent scholars, artists, and specialists from all over the world in such fields as nanotechnology, mathematics, renewable energy, molecular genetics, spatial management, philosophy, architecture, design, graphics, contemporary art, early music, and others. Poznań has a rich social superstructure, which is a foundation for its creative milieu because it possesses a wealth of information connected with creativity and transmits it to the world outside (Törnqvist 1983); it creates productive knowledge; it engages in a variety of creative activities. In 2005, one in six firms operating in Poznan was registered in the creative sector. In particular: one in three, in the sector of the legal service of firms, one in six, in financial intermediation, one in eight, in the architectural sector, and one in ten, in the trade of works of art and artistic articles.

This high level of development of social supra-structure in Poznan has been recognized both at home and abroad. The city has taken first place in 39 competitions organized by domestic and international organizations, associations, and government institutions. Poznan does not lie in a central place of the European Union, but rather on its eastern periphery. In its 1000-year-long history, with the tradition of persistent organic work and talents of its inhabitants, the city has managed to develop a specific climate of tolerance, coexistence, and cooperation, organizational skills, and the ability to look forward to the future.

4.4 Discussion

The presented case studies of three distinct SMT stem from settlements with critical historical roots. These roots provide a solid foundation for discussion. Human settlement patterns have shown great diversity globally. Despite this diversity, however, a common foundation on the spatial allocation in urban and rural areas exists. The literature has explored mostly urbanized regions throughout the world, neglecting the scholarly observations of the rural world. The rural world, however, is a common phenomenon, interlinking major urban regions to hinterlands, and SMT correspond to the scope that abridges both these very distinct silos of the Anthropocene. In this sense, SMT are the tool that connects two different spheres of reality. By focusing on the possible contribution of SMTs to development, and better understand how sustainable these regions are.

It is important to emphasize that towns, even the smallest, can resist processes of the structural decline of regions by acting as catalysts for geographically balanced income distribution and for a sustainable, productive structure.

In contemporary societies, SMT is an essential element of the global settlement system. In terms of the most significant proportions of the world's population, large cities are followed by small- and medium-sized towns. Big cities, as well as SMT result from different specificities of human nature: big cities, resulting from the human propensity to live in a group. Conversely, small towns reflect the human desire to live in harmony with nature. Nature's rhythm makes individuals and groups pursue their goals in the most effective way possible. Small towns gain particular importance in this respect.

Towns continue to be important places for local households, economic activities, and employment. In countries such as Poland and Portugal, households are still very dependent on the local economy. However, it is also in these countries that economic diversity is relatively low. In particular, the Polish rural areas still have a large share of total employment in agriculture. This means that new developments, such as novel farming regulations, new technologies, or modernization, will have strong local effects. People that lose their jobs will have little opportunities to find a new one and thus will have less money to spend in the local economy. In such cases, SMTs are essential places from which to start new economic activities and local development projects and, at the same time, to preserve the vital ecosystem services. In this sense, they form a bridge between social community capital and ecological, cultural heritage, on the one hand, and the new growth and creativity trends, on the other.

One of the most intriguing issues in the discussion of SMT concerns the potential of supporting their sustainability. The complexity and the variety of methods to achieve sustainable development in SMT fluctuate, however, depending on different factors that build on their success.

It is not possible to harmonize comparable information for these three case studies, but hereby we provide some interesting remarks of evolutive accents common to all of them: (1) In all three case studies, the ability to engage in knowledge creation during recent decades was crucial. The generation of precise knowledge spots that emerged has always played an essential role in their growth while fostered with the collaboration between stakeholders and government match the previously defined needs of the towns. It is in such cases that public–private partnerships could facilitate achieving pre-established goals.

Another important factor in rural environments is the transfer of knowledge to SMTs within rural environments. The literature demonstrates that the key features that relate to a town's innovative capacity depend on complementarities and networking systems between internal and external knowledge sources. (2) The ability for technological transfer grows with the increasing number of entrepreneurs, particularly when linked to the creative industries as well as knowledge-intensive business services. Additionally, it may be concluded that the presence of several small firms in different sectors has a positive effect on new firm formation in all industries. (3) These small towns have reinforced their innovation processes by extending ICT, creating infrastructure, developing the agri-food chain, and cooperating in R&D related to the specific fields or sectors with specific and applied know-how. This means that the central governments must consider them as full partners in the knowledge sharing process and call them to active participation, which in most cases does not happen. It is frequent to see regional universities being put aside from the significant discussions in their specific fields of competences, for example, and much less will be the involvement of professional schools. There is an urgent need to alter such governmental attitudes, they delay solutions that benefit the overall sustainability of regions.

The affordability of ICT is redefining the productive models based upon diffusion of information. Web 2.0 has made the usage of e-learning, e-commerce, e-production, and social-networking highly adaptable, ubiquitous, and efficient. For more significant gains of efficiency, the effectiveness of actions focusing on the transfer of knowledge and innovation through the development of internet technologies should consider the functional typologies of small towns. These typologies have the distinction between peripheral, agricultural, tourism, or residential/industrial towns that have different critical historical and landscape characteristics in which ICT cooperates. For instance: Labor force allocated to local businesses; higher rates of self-employment in tourism-recreational communities; better diffusion of information about cities surrounding areas and towns; increases in access to data from SMT and rural communities; profiting farmers who are searching for new technologies or markets and wish to search for seasonal non-agricultural jobs, or even in support of home-based work in residential-rural areas.

When considering sustainability, one cannot escape a grounding thought: Today's peri-urban areas cannot be regarded as a stock for future urban expansion. The green belt surrounding the town represents a strong economic and ecologic asset to be protected (de Noronha Vaz et al. 2011; Vaz 2016). Small towns may manage such areas even better than other urban structures and can guarantee their protection. For that, the most necessary requisite is the survival of professional actors with conditions to support a sustainable multifunctional economy. A fair alternative being the development of new eco-friendly neighborhoods (Eric Vaz and Bowman 2013; Vaz et al. 2012b), with the purpose to save natural resources, adequately address energy consumption, to decrease traveling.

4.5 Conclusion

One of the goals of this chapter is to discuss the real "net" value of agglomeration economies generated when in the presence of volatile assets such as history, strategic planning, created knowledge, trust, shared innovation, and advanced specific skills at the global level. This chapter, however, provides just a glimpse of the potential capacity that SMTs must be full participants in the development process throughout longer observed periods. The concept of agglomeration economies has been pointing out to efficiency gains due to the proximity of agents. We argue that this "irrefutable truth" should be revised and assessed from a long-term perspective.

The efficiency gains of agglomeration economies have received significant attention from stakeholders towards immediate efficiency gains. Particularly when intertwined with policymakers that promote strategies that albeit worthy intentions have caused aggravating discrepancies with shrinking effects for SMT (Kourtit and Nijkamp 2012) as well as negative externalities from intensive resources exploration to use of urban infrastructures (Vaz and Jokar Arsanjani 2015).

Agglomeration economies further add to pollution, loss of biodiversity, climate change, as well as a loss of livability and social justice. A very recent example is the impact of COVID-19. Rapid spread within urban cores leads to a stringent effort in planning, making management and policies challenging to implement, directly resulting in a potential hazard of incremental cases.

Finally, our analyses claim for the observation of new innovative processes and products as tools for development in SMTs. It is also emphasized that by promoting networking, consolidation of the triple helix model of innovation, or increase in resilient modes, for instance, these urban structures can recombine natural assets and innovation in more productive and sustainable ways. Although "one size fits all" development policies are not recommended (Donnermeyer and Hollifield 2003), this is conducted by the creation of new activities, clustering of startups within the economic landscape, landscape designing for regenerative cities (Girardet 2017), and employing innovative ecosystems by enhancing high-tech in small and medium enterprises as suggested by Song et al. (2020).

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Chapter 5
Peripheral Urban Areas: Perspectives on Sustainable Regeneration

Gabriella Vindigni, Teresa Graziano, Vito Martelliano, and Bruno Messina

Abstract The last decades have witnessed a rapid modification of existing urbanization patterns, which have progressively modified the concept of peripheries. The considerable heterogeneity in types and number of urban peripheries and their diverse set of dimensions (spatial, social, and economics) go beyond the concept of the distance from a city core. Urban peripheries are increasingly characterized by discontinuity, heterogeneity, spatial and social fragmentation. At the same time, new economic opportunities and innovation emerge from peripheral areas. The complexity and the dynamism of these areas require new strategies of sustainable urban regeneration. In this framework, urban planning is a critical instrument to address specific demands or challenges in addition to building community-based approaches. This work employs a place-based case study, the project G124 carried out by the Renzo Piano Foundation, in order to evaluate its first outcomes. The project is aimed at "mending" Italian peripheries by involving the community and local stakeholders, as well as enhancing local resources and self-construction for micro-interventions. It is based on the idea of the "beauty" of peripheries, regarded as value through which it is possible to improve sense of belonging and affection. In so doing, the research provides new perspectives about innovative planning approaches based on innovation in decision-making processes finalized to improve urban sustainability in peripheral areas.

Keyword Urban peripheries · Urban regeneration · Participatory design · Place-based approach · Creativity

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5.1 Introduction

In recent years, urban periphery has become a fuzzy concept. At the global scale, urban peripheral areas have been undergoing bewildering changes due to a wide repertoire of transcalar processes and territorial dynamics which have completely transformed the long-established dualism between core and suburbs. The worldwide increasing rates of urbanization (UN-Habitat 2013), mostly in countries of the "Global South," have been nurturing unparalleled socio-economic disparities. The very concept of peripheries has become controversial to the point to make it challenging to trace its conceptual evolution. As a result, in several disciplines, ranging from regional economy to urban studies and social sciences, heated debates have been focused on the challenges, advantages, and critical aspects of urban renewal programs in complex and multifaceted territories such as urban peripheries.

This chapter aims at scrutinizing some theoretical and methodological approaches in urban planning of peripheries through a place-based case study approach (Yin 2018) which, as Stake (1995) puts it, provides some predictions to be texted in other contexts of study: namely, the Mazzarona neighborhood in the Southern Italian city of Siracusa, selected by Renzo Piano for the second edition of his program of "mending" peripheries.

Data were collected according to multiple methods in order to provide different perspectives. We spent considerable time in the case study context, taking extensive field notes, reflections, and comments in order to provide an in-depth understanding of the processes which the selected neighborhood was undergoing. We carried out extensive fieldworks during the several stages of the project, ranging from the preparatory phase to participatory planning meetings and events open to the local community. In order to achieve the most objective positionality about ongoing dynamics, we also used a triangulation of methods by using additional data collection methods such as the critical discourse analysis (Waitt 2005) both of planning documents and manifestos, retrieved from a variegate set of informational sources ranging from institutional reports and data collection to perceptions and point of view of the stakeholders involved and community participation.

The work is organized as follows. The second part reviews the theoretical evolution of peripheries with the aim of exploring conceptualizations related to the challenges of spatial planning in "marginalized" places. Theoretically inserted at the interplay between critical urban geography and the planetary urbanism framework, the paragraph deepens the interwoven urban processes deriving from urban sprawl and shrinkage, in order to pinpoint the key elements for a sustainable community-led participatory planning of urban peripheries.

The theoretical section also encompasses analyses of several flexible and adaptive approaches for urban regeneration planning by taking into account the traditional stakeholder-based participatory methods as well as Artificial Intelligence (AI) and participatory design theory for urban planning.

Finally, the last section retraces the evolution of planning approaches in Italy, with a specific focus on a recently developed urban regeneration program of peripheries implemented since 2014 by the star architect Renzo Piano. As a "senator for life," the architect decided to devolve his salary to some small-scale urban regeneration programs in selected Italian peripheries, by involving several young Italian designers and urban planners.

Although some controversial implications of the motto-style architectural manifesto, as underlined by Boano and Astolfo (2015), it is interesting to evaluate the renewal program of "mending" peripheries due to the challenges and achievements of such hyper-local approaches to urban planning. In particular, the final paragraph synthetizes the experience gained in an urban periphery of a Southern Italy city, Syracuse, selected within the last edition of the Renzo Piano's "mending" program and used as an exploratory case study in this chapter in order to highlight potentialities of participatory planning in peripheral areas.

5.2 Planetary Urbanism, Uneven Spatial Development, and Contemporary Peripheries

Over the last few decades a widespread awareness has been raising that the urban dimension is one of the main controversial issues for pursuing the goal of environmental, social, and economic sustainability.

According to the seminal work of Brenner and Schmid (2015) on planetary urbanism, which arouses heated debates and intellectual disputes (Brenner 2018), some macro-trends are spreading at the global level which have been challenging long-lasting assumptions about the epistemology of the urban.

Firstly, growing rates of urbanization have been shaping unpredictable forms of marginalization, stagnation, and shrinkage which foster unprecedented geographies of uneven spatial development. Secondly, territorial inequalities molded by the previous cycles of industrialization were easy to capture because of the typological differentiation of dialectical spaces they produced (urban/rural, center/periphery, and so forth). Nowadays, on the contrary, the "poles" of long-entrenched dualisms mutually create one another at the different scales, continuously rewritten by capitalism-led spatial development. Thus, poverty and wealth, centrality and marginality, development and decline reciprocally produce one another at the different scales, ranging from the neighborhood to the global level.

Thirdly, the so-called cityness has become a more complex and differentiated concept compared to the previous capitalist industrialization cycles. As a result, a proliferation of urban forms and functions is incorporated in polymorphic, increasingly variegated and multiscalar geographical spaces and institutional frames.

Brenner and Schmid (2011, 2015) emphasize that the transformation of urbanizing landscapes at the global scale is also fostered—among the other things—by the ongoing development of megacities and polynucleated metropolitan regions, notably in the Global South; the increasing densification of inter-metropolitan networks and the related infrastructural investments; the large-scale resource extraction systems (for water, energy, and so forth); land grabbing due to the expansion of large-scale industrial agriculture; and the enduring reorganization and functional shifting of traditional outer edge settlements owing to the creation of fresh export processing zones, delocalized factory implantations, back office sites, knowledge-based high-tech clusters, data processing facilities, and intermodal logistics terminals.

These land use changes fostered by urbanization processes are incorporated within new geographies of a growingly multiscalar and polarized urban governance which has emerged from the several waves of market-oriented neoliberalism and the related projects of deregulation, privatization, and austerity, notably in the aftermath of the 2007–2009 crisis.

In line with the most recent critical urban studies, the risk of universalizing ideologies of "the" city is embedded in technocratic, entrepreneurial, neoliberal visions of mainstream global urban policies, which foster a proliferation of "smart," "creative," "sustainable" cities without taking into account the (re)-production of new geographical inequalities due to the financialized accumulation by dispossession (Swyngedouw and Kaika 2014).

Although criticizing the "city-centric" singular visions that underpinned at length the major urban theories, Brenner (2018) emphasizes the wide-ranging consequences of the increasing processes of capitalist agglomeration, which have been molding increasingly variegated and uneven spatial developments. It is crucial to go beyond the idea of "the" city as a monolithic spatial agglomeration by completely reframing the socio-spatial lens through which urban development can be read. In order to achieve this, it should be necessary to go through a critical reconceptualization which should overcome long-entrenched geographical dualisms.

Furthermore, planetary urbanization is not produced by the same causes nor it encompasses the same implications in the Global North and Global South. Thus, it is crucial to use specific conceptual tools and frameworks as well as place-based planning strategies which could deconstruct traditional visions of urban/rural relations, core–periphery, and so forth, according to the deeply-rooted spatial features at the local and even micro-local scale.

Contemporary place-based planning strategies should face the challenges that cities have been dealing with, by overcoming the long-entrenched "obsession" with establishing a neat boundary between "city" and "non-city spaces" in a world of increasingly generalized urbanization and rapidly imploding/exploding urban transformations (Brenner 2018).

As urbanization is a constantly changing phenomenon of varying intensity and functions at the global scale, the epistemological effectiveness of concepts such as center and periphery should be indeed completely reframed.

As a matter of fact, contemporary peripheries appear to increase in number, typology, and assumptions in terms of sustainable urban planning. Retracing their conceptual evolution does not mean to oversimplify them, but rather, on the contrary, to mirror their inherent complexity and multiscalar character. As La Rosa et al.

(2017, p. 172) put it, "it is crucial for planning research to increase understanding of how urbanisation processes in peripheral contexts might improve sustainability of peripheries and their wider metropolitan contexts."

5.3 Peripheries: A Multifaceted Concept

In the last decades, urban peripheries have been experiencing deep transformations owing to a tangle of interwoven factors at the different scales. As already underlined, the growing rates of urbanization at the global level (UN-Habitat 2013), mostly in "emerging" countries, have been fostering unprecedented socio-economic inequalities, by shaping new forms and functions of urban peripheries. The apparently conflictual processes of urban sprawl and urban shrinkage have increasingly transformed the concept of peripheries to the point to make it difficult to trace in a single way its assumptions (Taylor and Lang 2004).

To start with, there are even differences in their definition. Although they can be generally described in terms of geographical, socio-economic, and political distance from a core, following a traditional epistemological dialectics center/periphery, in Europe urban peripheries are generally regarded as disadvantaged spaces, strictly dependent on core areas, which suffer from marginality and disconnection (Geneletti et al. 2017). They usually refer to urban settlements grown up at the edge of the inner city, often within a social housing program development, thus being marked by lack of basic services, effective infrastructure networks, and inclusive public spaces.

On the contrary, in the North American scenario, extra-edge urban settlements, which are usually the outputs of a long-lasting urban sprawl, are commonly identified with suburban, rurban, and exurban areas not necessarily characterized by socio-economic disadvantages.

In their comprehensive review about urban peripheries, Geneletti et al. (2017) emphasize the terminological variety and the related implications in terms of semantic assumptions.

Due to its undefined character, the term "suburbs," very common in the Anglo-Saxon context, is usually followed by further specifications to emphasize the specific location or a distinctive functional feature: inner-ring, outer, high-density, low-density suburbs, and so forth.

Furthermore, negative implications are often embedded in terms of landscape deprivation, social marginalization, poor housing stocks, socio-economic and environmental vulnerability, unplanned and chaotic spatial development fostered by urban sprawl (Epprecht et al. 2014).

Apart from the widely-used "suburb," other terms are commonly used to indicate peripheral areas, ranging from "peri-urban" to "fringe" and "edge." Finally, the term "peripheries" has a multiscalar connotation, since it can be referred both to a more or less well-defined center/ring relationship within a city–region and to a wider a meso/macro scale. So, "peripheries" can include not only the local level (namely, urban settlements at the outer skirts of an urbanized area), but also the meso/regional and macro level of those urban nodes which are peripheral compared to “world,” “global” cities (Hall 1966; Sassen 1991) or first-rank cities, that is to say the financial and economic hubs within a worldwide urban hierarchy.

As causes and factors are concerned, the rise of urban peripheries can be connected to a variegated and multifaceted repertoire of processes and dynamics which entails both the peripheralization regarded as a synonym of socio-economic and cultural marginalization, regardless of its pure geographic localization from the core, and the emergence of new urban agglomerations, included the informal ones, in the outskirts of already existing urban nodes (Bernt and Rink 2010).

These processes are interwoven with apparently opposed dynamics which have been shaping new forms and functions in central areas, such as the so-called back-to-the-city movement that has transformed the relations between core and ring since the post-war era in the Anglo-Saxon contexts (Glass 1964). As a matter of fact, several transformations have concurred in the residential rediscovery of inner cities, embedded in the postindustrial and postfordist transition, which counterpart the middle class’s contemporary suburbanization in North America and North Europe. These changes, which foster processes labeled under the name of gentrification, include the economic (re)production of capitals in inner cities—according to Smith’s rent gap theory (Smith 1979)—; changes in consumption behaviors of the baby boomers or new “creative classes” (Florida 2002; Ley 2003); and the shift from a “managerial” city to an “entrepreneurial” city due to neoliberal waves (Harvey 1989).

Finally, at the European level, scholars and institutional actors have recently put emphasis on the so-called inner areas, namely marginal territories usually located in the most “internal” zones which have experiencing growing rates of depopulation, outgoing migration, unemployment, and lack of basic services. In the Italian scenario, they have been classified according to a set of socio-economic and cultural indicators within the SNAI Strategy framework (*Strategia Nazionale Aree Interne*, Inner Areas National Strategy) aiming at reducing the divide between “richest” areas and “poorest” ones. Well, these inner areas are actually defined according to a variegated set of indicators mirroring their different levels of peripheralization, not regarded as the pole of the urban dialectics between inner city and outer edges, but rather as a sub-national level of different grades of marginalization.

As a result, very different concepts of peripheries have recently emerged at the global, regional, and local scales. Before dealing with the role of planning in addressing challenges related to the sustainable, inclusive development of urban peripheries, it is, therefore, necessary to scrutinize the differences in conceptualization and methodological frameworks related to peripheries:

As Geneletti et al. (2017, p. 232) put it,

> The adequacy and effectiveness of the existing sustainable planning approaches for tackling the various, complex and dynamic systems represented by con-temporary peripheries should be understood to improve current planning practices and identify needs for future research.

In advanced city–regions the territorial organization has become growingly asymmetric, polycentric, fragmented and often uneven in terms of non-place-bounded networks which have completely reconfigured and rescaled territorially nested urban systems. This has traditionally implied an increased attractiveness of some selective activities in core areas and the mounting marginalization of more peripheral areas.

According to critical urban studies, large-scale development projects, such as museums, parks, business centers, and waterfronts have been embedded in the last decades in urban branding strategies aimed at re-enforcing the competitive positions of the related metropolitan economies in a global context of fast changing hierarchies. These projects of urban restructuring often foster new geographies of exclusion and social polarization within market-driven urban policies, by reflecting global pressures as well as incorporating local, regional, and/or national deregulation of governance (Swyngedouw et al. 2002, p. 550, 551):

> The new urban policy, developing in parallel with the new neoliberal economic policy, squarely revolved around re-centering the city. Old forms and functions, traditional political and organizational configurations, had to give way to a new urbanity, a visionary urbanity that would stand the tests imposed by a global and presumably liberal world order. Repositioning the city on the map of the competitive landscape meant reimagining and recreating urban space, not just in the eyes of the master planners and city fathers and mothers, but primarily for the outsider, the investor, developer, businesswoman or -man, or the money-packed tourist.

However, the privileged urban areas attracting new investments are not limited to inner cities. According to Salet and Savini (2015, p. 448),

> The planning of new metropolitan centralities entails significant political challenges as these territories are in a critical geopolitical position. outer areas are the target of increased attention and urgency as spaces where urban growth has to be addressed in the 21st-century city.

As a matter of fact, in the most advantage city–regions, quite unexpectedly outer segments of some peripheral areas, particularly those enclosed by the first city rings at the intersection of big infrastructural networks, have increasingly experiencing spatial changes due to public and private market-led investments.

Polycentrism in metropolitan development has shaped different spatial manifestations over the last few years. While urban policies have been usually addressed to the city cores (Swyngedouw et al. 2002), nonetheless in some cases government and/or private-led investments have been recalibrated towards areas located outside the urban cores, which have resulted to be more attractive for low land values and profit opportunities after development, such as, for instance, university campuses or startup incubators, conference centers, retail and entertainment complexes, and so forth:

> "These have dominated the spatial planning agendas of areas that in the past were called 'the periphery', and these areas have thus been excluded from mainstream urban agendas" (Savini et al. 2015, p. 457).

While this shift can be interpreted as a revitalized interest for less attractive areas, in the meantime this could be explained through the lens of gentrification which, far from being confined to central areas, has been shaping new uneven spatial developments also in peripheral and/or rural areas. As a result, spatial planning and urban policies should be addressed towards a wider strategy encompassing social mix policies, housing affordability, strategy to support traditional retail and consumptionscapes.

Since periphery is not just a disadvantaged fringe as it is often depicted, as the authors (*ivi*, 457) put it,

> The spatial, social, environmental, and economic results of these interventions show large variety, and it is difficult to establish general patterns in this changing development geography. Yet, despite the limit of generalization for research, the increased variety of ways to address the uncertain and variegated change of the urban fringe poses an important challenge for urban policy making: how can smart growth, environmental sustainability, and the achievement of balanced socioeconomic development be supported in politically and territorially splintered metropolitan areas? (Grant 2009; Raco and Street 2012; Wilkinson 2012)

As a consequence, an increasing awareness is spreading on the need to develop new conceptual and methodological tools for sustainable urban planning, management, and design, particularly in fast changing peripheral territories (La Rosa et al. 2017). In particular, at the "metropolitan" scale, the cross-administrative boundary, which entails a fragmentation of several urban policies among municipalities belonging to the same metropolitan area, needs to be reframed conceptually and methodologically in order to address the related complex spatial relations (Geneletti et al. 2017).

Furthermore, the ongoing waves of neoliberalization, which have encompassed a stepping back of public intervention in favor of public–private actions, have fostered the narratives of urban regeneration at the different scales as a spur for local economic growth.

As Parés et al. (2014) underlined, these kinds of narratives often imply oversimplified generalizations about tools, strategies, and scopes of urban governance, neglecting, for instance, long-entrenched dynamics of continuity and even resistances to change.

As Salone puts it (Salone 2018, p. 133),

> the international debate about urban regeneration has so far privileged large-sized interventions in "deprived" inner areas, mainly conceived as an application of conventional measures of physical rehabilitation and socio-economic development according to a blue-print global model. In this kind of experiences even the claim for an active participation of local residents tends to be reduced to ritual mechanisms that do not seem able to stimulate the rise of an enlarged decision-making and a real bottom up process.

According to Kallin and Slater (2014), the rhetoric of Smart Growth underpins an anti-sprawl anti-modernist attitude, and mixed-use urban settlement is now twinned with the New Urbanism approach which is the core of several urban renewal programs, posing what the critical urban scholar calls the "false choice between gentrification (a form of reinvestment) and a 'concentration of poverty' (disinvestment)."

If several considerations about gentrification-led displacements are embedded in central urban locations—as in "classical" gentrification—the cycle of disinvestments and investments has been affecting in recent years also the peripheral and even rural areas (Kallin and Slater 2014; Hochstenbach and Musterd, 2018). As a matter of fact, it is not unusual that large-scale urban regeneration programs in peripheries (implying demolitions and reconstruction) exploit territorial stigmatization together with regeneration through gentrification as "two sides of the same conceptual and policy coin." By a continuous reproduction of the urban stigma, the "blemish of place" becomes both the target and the rationale to filter up the peripheral area: a variegated set of institutional narratives and discourses which furthered the area's negative reputation to legitimate state-led huge interventions.

So, the question of the "power" to decide about a community's residential choices—their "right to the city"—should be addressed in every urban regeneration project, whatever it could be the more or less "centrality" (or "peripherality") of the related neighborhood.

Following Brenner and Schmid (2015), inherited paradigms of urban intervention, ranging from the post-war state-led modernist programs to neoliberist entrepreneurial market-led agendas of the 1980s onwards, are no longer viable to face the current extreme pressure cities have to deal with.

In this context, tactical urbanism is often seen as a theoretical and analytical framework to guide and interpret emergent urban design experiments in several contemporary cities, embedded in several local planning agenda insofar it would entail appropriation of urban space as well as social justice.

Synthetically, tactical urbanism encompasses a repertoire of bottom-up low cost and small-scale actions producing ecology-driven changes—often in a temporary manner—into urban environment, especially in city gathering. In many cases, bottom-up approach supplements top-down projects. Although traditionally referred to "guerrilla urbanism," "pop-up urbanism" "city repair" or "Do it yourself—DIY-urbanism" as to highlight the participatory and bottom-up perspective, recently this small-scale, low-cost, and temporary actions are often promoted by professional urbanists who tend to seek out flexibility of land use planning and territorial governance as well as encouraging for increasingly engaged pro-active citizens in shaping their own urban spaces. This shift from top-down long-term big-scale urban planning to small-scale participatory urban micro-actions is also due to the austerity regime underwent by several urban agendas. While "insurgent" and "spontaneous" practices of everyday urbanism stem exclusively from "guerrilla" actions of local communities, the term "tactical" also entails those micro-actions developed by local institutional actors.

Although being controversial owing to the rhetoric of "bottom-up participation" it could imply, tactical urbanism conveys a crucial idea of contemporary urban planning, particularly in peripheral areas: micro-actions at the hyper-local level, based on a *truly* participative planning methodology, can mirror local community's expectancies and even resistances to change.

This is particularly clear when spatial planning has to address the challenges that contemporary peripheries have to face. Without considering them just as deprived and marginalized areas nor just as "living" workshops for innovation to be exploited for market-led interests, peripheral areas have first of all to be reconceptualized in order to reframe their inherent territorial, socio-economic, and spatial complexity, going beyond some widely-spread narratives of "smart growth." What is more, it is even more crucial to adopt mixed quali-quantitative methods, included participatory and community-led planning strategies, in order to catch the socio-spatial practices informing everyday life of cities. These tools are also capable to incorporate conflictual uses, functions, and perceptions that are embedded in the spatial organization and representation of the territories emerging from "postsuburbanization" (Phelps et al. 2015; Savini et al. 2015). Issues such as poverty distribution, housing affordability, transport accessibility have to be reframed within national and local urban policies, by taking into account new relations among national governments, the core city, and private actors, embedded in an ever-changing geography of the wider city–region where categories such as "center" and "periphery" have been recently completing changing.

As Geneletti et al. (2017; p. 238) underline,

> The relative low number of papers focusing on urban peripheries that was found in our search suggests that peripheries remain a marginal topic in research of sustainable planning approaches. This is also reflected in the lack of a shared definition of urban periphery among the reviewed papers. The social sciences have formulated many different definitions that describe peripheries starting from the socio-economic and institutional processes that determine their generation (Sassen 2005). However, these definitions have a limited capacity to drive actions on peripheries, which can justify the fact that they are largely overlooked by the papers. No shared, practice-oriented classification of peripheries exists (. . .)
>
> However, resources and opportunities for sustainable planning of urban peripheries are seldom discussed. Very few papers highlight the presence of positive elements, and even fewer go beyond simple acknowledgement to demonstrate how it is possible to act on them.

Particularly in the aftermath of 2007–2009 crisis and the related post-recession austerity regime there has been a flourishing of policy and academic interest in the idea of resilience planning which mirrors a widespread discourse on sustainability. However, in their place-based analysis of post-recession urban development, Raco and Street (2012) highlighted how different local interests tend to establish their own selective storytelling around fuzzy concepts such as recovery and resilience in order to support a greater emphasis on economic competitiveness, "with broader social and even environmental policy agendas being refashioned to act as contributors to economic recovery." As a consequence, it becomes more and more crucial to develop community-led place-based planning strategies which, starting from micro-actions at the hyper-local scale, could deeply transform in a sustainable way the present and the future of extremely rich and complex urban areas such as the peripheral ones.

5.4 Participatory Approaches for Urban Peripheries

As already highlighted, contemporary peripheries are characterized by odd opposition and endemic problems with complex, and thus multifaceted, dynamically changing, contextual issues, difficult to capture or steer. In these areas physical, infrastructural, environmental, economic, and social issues define what planners call "wicked problems," i.e. difficult to define, with unpredictable consequences, and defying rational decision-making. This term has gained importance in urban planning and policy analysis, especially after the adoption of the concept of sustainable development since the early 1990s, which has introduced the environmental dimension to the complexity.

New flexible and adaptive approaches for urban regeneration planning are spreading in order to deal with strategic opportunities and social pressure, development requests, and protection needs. In particular, the importance of relationships and interactions between peripheries cities, landscapes, and communities emerged for the circularization of sustainable development processes through a long-term commitment with continuous improvement in the short/ medium term (Fusco Girard and Nijkamp 2004).

The search for finding urban planning approaches, which includes "wicked problems" of cities and peripheries is increasingly inspiring scholars, in order to give a contribution for the transition from models of urban spreading growth to urban regenerative cycles by which transfer a set of values in terms of civil engagement, environmental, and productive perspectives.

Over the last several decades planning theorists have proposed numerous alternatives offered by different theories closely intertwined, that shed light on the same phenomenon from different perspectives, and for many purposes work together as a unity (Sager 2001). Therefore, methods useful for regeneration of peripheries have splintered into a large number of different approaches.

Broader shifts towards post structural and postmodern thinking undoubtedly broke the rational, technical planning model in the 1950s and 1960s. The rational, technical, method for planning model of the 1950s and 1960s is rooted in the positivist tradition of modernity, and was concerned primarily with procedural planning issues. Engagement with stakeholders and communities was not part of this process and the planners' role was that of the technical expert in managing the process. The 1980s saw the shift towards "post-positivism" and "post-structuralism" in a range of new social theories, which planning theorists drew on to find new ways to explain and suggest roles for planning. Urban regeneration was called upon in the debate through the introduction of innovative approaches to overcome some critical points of contemporary cities for achieving some durable development in terms of economics and of social and environmental condition (Watson 2016).

The post-normal science approach, developed by Funtowicz and Ravetz (1993) at the beginning of the 1990s has underpinned the importance of including grassroots stakeholders as scientific peers and for integrating their diverse perspectives into the scientific analysis. They suggest that the complexity of the interactions and the differential impacts on stakeholders require to relay not only on the so-called experts, but it is recommended to involve an "extended peer community," consisting of all those affected by and willing to discuss the issue at hand. This "extended peer community" approach is reflected in urban planning and regeneration process in peripheral areas, in which the role of the complex and multi-stakeholder relationship among private subjects, communities, and public administration has evolved from a traditionally linear science-policy interface towards a more interactive governance system that involves actors beyond scientists and policymakers. Participation mechanisms emerged by the need to meet the nature of policymakers' demands and at the same time to stimulate an active transformation for a synergy between citizens and technicians. Urban regeneration processes have recognized capable of generating social and economic activation mechanisms, encouraging a sense of re-appropriation of public spaces. Nowadays, the importance of stakeholder involvement in regeneration processes is well-established in the practices and in the literature for normative reason (the benefits for a democratic society and equity are crucial) and for pragmatic reason (participation improves the quality and sustainability of decisions) (i.e., Munda 2004; Rey-Valette et al. 2017).

Urban regeneration works on planning and design processes directed to the social part and to economic stakeholders, acting through effective participation aimed at the empowerment of local actors and at supporting local development according to sustainable resources. Participatory methods represent a valuable help for communities that undertake the path of self-construction. Researchers tend to use participation for pragmatic reasons, whereas in participatory development, normative argument has been more prominent. Participation develops local trust, improves a program's efficiency, and supports the theory that complex socio-environmental problems meet diverse knowledge, values, and ideas. Multi-methodological frameworks for the implementation of urban planning in peripheral areas are often based on multi-criteria decision aiding (MCDA). It emphasizes the idea of problem construction, focusing on the modeling of the decisional context, starting from the beliefs and values of the actors involved in the decision-making process. This is used to construct the most appropriate decision-making model for a given context (Roy 1990). MCDA transcends traditional Operational Research (OR), which analyses only one criterion, by using normative mathematical models to find an optimal solution. At the end of the 1960s, new methods emerged to support the decision-making process for complex problems, the so-called soft approaches. However, there are no features inherent in classical MCDA, which capture the values of multiple decision makers or consider social uncertainty in public policy decisions such as planning activities.

Over the years, many scholars have recognized the importance of adequate problem structuring to reach favorable outcomes in analytical decision support interventions. Most of them have relied on impromptu problem structuring practices. The use of a formal methodology for identifying the key variables and interactions in a complex problem situation may enhance problem structuring and system dynamics modeling. PSMs (Problem Structuring Methods) are now widely accepted decision analytic tools and there is an emerging body of research and practice on the integration of such methods with other formal and/or quantitative methods (Tsoukias et al. 2013). PSMs deal with unstructured problems characterized by the existence of multiple actors with divergent perspectives and disparate, and/or conflicting interests (Rosenhead and Mingers 2001). The methods of PSM rely heavily on the participation of stakeholders in the decision-making process and often employ qualitative models (Montibeller and Franco 2010).

One of the most used tools is the cognitive map that creates a visual representation of how participants think about a particular issue by analyzing and arranging the problems, identifying causes and effects, explaining causal links and diagramming how concepts relate to each other (Eden and Ackermann 1998).

According to the theory, based in cognitive psychology, Kelly (1955, 1970) argues that human beings are problem finders/problems solvers, continually striving "to make sense" of their world in order to "manage and control" that world. By identifying the causal links of a problem, actions are guided by logic rather than emotion. Understanding how individuals or group members perceive a situation is fundamental, as it is this that influences actions. Checkland (1978) calls this approach of thinking of systems as mental constructs to help individuals make sense of problematic situations "soft systems thinking." The development and application of the necessary skills, methodologies, methods and technologies, needed to engage relevant stakeholders in policymaking in a meaningful and reflective way. In light of this, it is useful to incorporate other decision support systems into the multi-criteria methodology to create a single paradigm—the learning paradigm—to ensure the process is consistent and theoretically and practically cohesive (Midgley 1997).

5.5 Artificial Intelligence and Participatory Design Theory for Urban Planning

Data collection and analysis methods, such as surveys, focus groups, case studies, participatory observations, interviews have been criticized since they capture a relatively limited sample of data tightly focused, time and space specific, restricted in scope and scale, and relatively expensive to generate and analyze. New urban science has opened new windows of opportunity to deal with the enormous amount of information currently available. It generates valuable knowledge for enhanced decision-making and provide insights in urban peripheral planning. In particular, data mining employs sophisticated algorithms to automatically extract useful knowledge and insights from datasets in order to find frequent, hidden, previously unsuspected, and unknown patterns (Fayyad et al. 1996). The results can be visualized in novel ways, in an understandable format prior to their deployment for decision-making purposes. Being a buzzword, there are a wide variety of definitions and criteria for data mining. Data mining is also referred to as knowledge discovery, machine learning, and predictive analytics. However, each term has a slightly different connotation depending upon the context.

The main advantage of data mining and the underlying algorithms for urban planning can be approached as an evolving, systematic knowledge in form of explanations and predictions using data-driven inductive empiricism. It uses computational methods to discover meaningful structures in the data mainly derived from the fields of machine learning and artificial intelligence. The commonly used algorithms are based on decision rules consisting in a simple "if-then" statement where "if" is a condition (also called antecedent) and "then" a prediction. Decision rules are probably the most interpretable prediction models and their structure semantically resembles natural language.

Broadly are used two types of Machine Learning algorithms. The supervised learning, algorithms consisting of a target/outcome variable (or dependent variable) which is to be predicted from a given set of predictors (independent variables). Using these set of variables, the training process continues until the model achieves a desired level of accuracy on the training data (such as regression, decision tree, logistic regression). The unsupervised learning, algorithms used when there is not any target or outcome variable to predict/estimate and thus used for clustering in different groups, such as Apriori algorithm, K-means (Meij 2002).

Analogy, re-combination, and re-elaboration are continuously applied to the design due to the input of different stimuli (Borgo and Stufano Melone 2019). This means that urban planning activities rely on a corpus of rules, informally referred to as "the state of art," where all different layers of meanings, effects, and functionality of the designed object find a place and integrate. These layers must embrace the intention of the designer/architect, but also attain the needs and the expectations of those who will live in and use those space.

Various reasons justify the adoption of data-intensive algorithm in urban planning for dealing with wicked problems. According to Schön (1983) the reflexive architect works by continuously asking herself the question: "what if?" The view of activities as receptive actions (knowing in action and reflection in action) departs from the idealization of the practitioner as a (rational) problem solver.

To answer the "what if" question, one has to image cases alternative to the present and to the immediately foreseen, and this act of imagination is based on the distinction between what is expected (or even desired) and what is possible. The reflective architect uses the rules of its domain to extend her thinking from the class of expected cases to the larger class of possible cases. When facing a new or unique problem which falls outside known categories, this investigation becomes a process of artistic design. The structure of this procedure is like a reflexive dialogue that permeates all the design activities (Borgo and Stufano Melone 2019).

In this perspective creativity plays an important role within the design process in architecture, according to the cognitivist approach using the tools of knowledge engineering and scientific literature related to Artificial Intelligence. Creativity is often considered as an innate ability, but can also be regarded as a process able to transform and recombine existing entities, toward different, novel configurations. In cognitive environments of artificial intelligence research, creativity is seen as a normal function of the human intellect, to be analyzed according to a strict theoretical and experimental scientific investigation. The modeling and design of artificial space environments, cities and urban architectures in particular, must take into account highly heterogeneous information sources.

It is surprising to note that creativity is not a priority in the mainstream research in AI and it has been studied intensively in design research, especially with empirical approaches. Starting with early work by Eastman (Eastman 1969, 1970), Akin

(1978) and still others, a large quantity of contributions has been produced. A remarkable feature of a majority of this research is the quasi-total reliance on the problem-solving paradigm and in their interpretation of their results (Kazakci 2014). There is now a growing consensus (Dorst 2006; Hatchuel et al. 2002) claiming that problem-solving, even in a broad sense, is too restrictive as a "lens" to interpret design, which is a cause for concern in the interpretation of those results (Wagner and de Vries 2019).

However, adopting the problem-solving paradigm as their conceptual framework for analysis, those studies only recently contribute. Concept–Knowledge (C–K) theory has recently contributed to the modeling of design, especially in designing alternatives This theoretical framework provides powerful generative mechanisms to overcome cognitive obstacles, thus improving our ability to innovate (Pluchinotta et al. 2019).

There are different issues discussed under AI, which offered perspectives based on traditional paradigms of AI, such as learning and interaction (Bedau 2003). Some authors refer to a dual "imaginative constructivism," coming from design research, where creativity can occur both at the level of top-down generation of new definitions and the bottom-up generation of methods for building object (Kazakci 2013). The notion of design as imaginative constructivism has allowed to introduce an alternative worldview, namely the-world-as-it-can-be, opposed to classical and foundational models in AI and related fields, such as decision and learning models, implicitly based on that we call the-world-as-it-is paradigm. The dual constructivist perspective offers the possibility to create novelty in urban planning. Creativity is the ability to come up with ideas or artifacts that are new, surprising, and valuable. The deepest cases of creativity involve someone's thinking something, which, with respect to conceptual spaces in their minds, they could not have thought before. Innovation in action for urban regeneration depends on the discovery of new matches a context of a strong intention, the strong factor which activates the re-combination of elements.

5.6 From the Rehabilitation of Historic Centers to the Urban Regeneration of Peripheries in Italy

In the last 60 years urban planning has slowly but deeply changed its way of acting on the territory thus replacing an additive and expansive approach with a transformative approach. This period can be defined as the "3Rs period" since it can indeed be divided into three different phases respectively marked by urban Rehabilitation, Requalification, and Regeneration.

The first phase started with the eight Congrès International d'Architecture Moderne (CIAM) in 1951 in Hoddesdon titled "The Hearth of the City" and continues through the 1960s. In Italy, the founding of ANCSA Associazione Nazionale Centri storici ed. Artistici (National Association Historic and Artistic

Urban Centres) and, in particular, the subsequent adoption of the declaration called La Carta di Gubbio (The Charter of Gubbio) on the safeguarding of the historic urban centers, signed in 1960, constituted the starting point of the Italian conservation policies of historic centers. During these years the debate on the historic centers is marked by a growing awareness of their symbolic significance and role for communities as the embodiment of identity values and of the need to preserve their historic values through urban rehabilitation.

The focus of the second phase, which develops through the 80s, is on the "existing city," i.e. those urban peripheries and marginal areas with no historic value or which have lost their urban quality often because they have been turned into dormitory suburbs without any identity. In this second phase the "existing city" becomes the place where it is possible to insert or re-insert urban quality through urban requalification. It aims at restoring quality and meaning to the open space system, the urban relation system, and the built environment of our peripheries also through innovation processes. The third phase, the contemporary one, corresponds to the period between the end of the XX century and the first decades of the XXI century. The disciplinary debate on the field focuses its attention on those areas which have never had or have lost their role inside a territorial system. These are generally dismissed or abandoned areas undergoing functional change or technological obsolescence, places that show symptoms of environmental, physical, social, and economic decline. These communities, industries, and places in decline become places in which regeneration "[breathes] new life and vitality into an ailing community, industry and area [and brings] sustainable, long term improvements to local quality of life, including economic, social and environmental needs" (Evans and Shaw 2004, p. 4) through urban regeneration.

During these last 60 years urban rehabilitation, urban requalification, and urban regeneration have represented three different ways of transforming and intervening in the urban context and have also testified the evolution the way of understanding urban transformation has undergone along with the development of new normative instruments. Each of these terms reflects different disciplines with different visions, methodologies, and objectives. Nevertheless, they share some common ground: they all intervene in already urbanized areas but, most importantly, with no soil consumption. In some ways, urban regeneration embraces both urban rehabilitation and requalification but, by postulating the inextricable relation between territory, economic activities, and the community needs, it goes further.

Its pursues a triple aim which defines three capitals: the improvement of the urban infrastructural capital, of the socio-economic capital, and of the physical and environmental capital. Then, urban regeneration aims not just at the physical and spatial improvement of certain areas or at their economic development (they are important but not enough to explain the process of urban regeneration) but also at the improvement of their social and housing conditions, energy efficiency, environmental sustainability, and ecology. In other words, urban regeneration promotes social inclusion, urban welfare and equity. It represents an open and inclusive process of economic and social progress as well as of transformation of the physical space and this is a deep cultural change in urban transformations. This is precisely its innovative, holistic character. It embraces the theme of conservation typical of urban rehabilitation and that of transformation typical of urban requalification in order to intervene in the urban space in a more comprehensive and integrated way. Since urban regeneration addresses both urban physical decay and social decline, its actions must necessarily be physical, economic and must stress the social inclusion; its actions "seek to bring about a lasting improvement in the economic, physical, social and environmental condition of an area that has been subject to change" (Roberts 2002). Unfortunately, urban regeneration is often exhausted in the theme of economic improvement, is considered just as an architectural project or urban space planning. An effective urban regeneration process is based on compliance with the criteria of physical, environmental, economic, and social sustainability. It enhances social cohesion and resilience.

5.7 A Place-Based Case Study: The G124 Project

Since 2013 Renzo Piano has identified in peripheries "the great project of our country [...]: the city that will be, the city that we will leave to our children" (Piano 2014, p. 12) and in young people the best energies capable of triggering countless "sparks" in these forgotten territories.

Peripheries of Milan, Catania, Venice, Rome, Sora, Padua, Syracuse, and now Palermo and Modena are the places on which, in the various editions of the G124, the working group of Senator Piano decided to work through urban mending actions; places where "to sew and tie together different parts of the city [. . .] means to reestablish in a world relationships between subjects and conflicting objects; means [...] the problem of incongruity" (Secchi 1989, p. 31). Small groups of young architects, the "leading architects" of peripheries have experimented new forms of participation in urban regeneration under the supervision of expert architects. They worked on small projects that involved the inhabitants of the peripheries and aspire to build beauty in "discarded" places. This modus operandi aimed at the design of small intervention to regenerate the peripheries and to build on social identity, sense of belonging, and social dignity.

The G124 project was carried out in a relatively short time of 1 year, and with modest financial resources available. It was finalized at building on physical, tangible, and concrete transformations albeit limited, and social networks, to demonstrate that it is possible to change and that peripheries have a future.

The following figure briefly synthesizes the processes which have been activated, the involved actors, the participatory tools used, and the outputs achieved both in terms of community involvement and of micro-architecture interventions (Table 5.1).

A bottom-up design approach was adopted through shared design actions and co-design processes, which empowers and invites the inhabitants to be active protagonists. In other words, it stimulates the inhabitants of the suburb to work synergistically together with all the social (associations and individual citizens),

Table 5.1 Community participation, tools, and outputs

Community participation	Tools	Micro-architecture
Three young architects working on the project for a year Several academicians and experts from a variety of field (sociology, co-design methods, geography, economics, and so forth) Community stakeholders: Members of a neighborhood social cooperative and the local parish Teachers of the local school; several inhabitants of the neighborhood Institutional stakeholders: Local municipality councilor, local politician representatives	Three face-to-face meetings at the Renzo Piano Foundation (Genoa) Several fieldworks and community "listening": exchanges and confrontations with local community throughout the year Several urban promenades with local stakeholders Two meetings at the local parish One meeting at the social cooperative office One workshop of co-design with external experts and local community One event of presentation of results	One architectural equipment linking the neighborhood to the bike route and the waterfront (a wood ladder connecting to the solarium) One bus stop shelter One grandstand for the soccer field The "garrison" (*Il presidio*): An equipped space within the former office of the neighborhood district, open to the community

economic, and institutional actors promoting the interaction and collaboration between citizens, institutions, and technicians.

Some authors have criticized this approach for interventions in peripheries, considering it inadequate both in terms of economic resources and methodological approach (Manzione 2014), as well as ineffective in architectural terms (Manzione 2014). These criticisms suffer from a double ideological limit: the idea that only a strong centralization of the urban regeneration process can produce a change and that only a substantial public investment can sustain the transformation over time. The experiences of the Agence Nationale pour la Rénovation Urbaine (ANRU) in France show how crucial is to invest important economic resources in peripheries and how important it is to trigger social innovation processes in the practice of urban regeneration. Many scholars, observing how the current economic crisis is strongly reducing the margins of public action, demonstrate how urban regeneration and social innovation are two sides of the same urban and social process (Ostanel 2017).

The introduction of social innovation in regeneration is challenging due to the increasing concentration of phenomena of poverty, social exclusion, crime, cultural marginality, and foreign immigration in peripheries. Since its first experiences, the G124 project has identified social innovation as a cornerstone of the urban regeneration process of periphery. Different areas of intervention, strategies ad action have been identified in order to elaborate an agenda for further work on sustainability pathways useful for policy makers.

Several of the above methodologies have been applied in our case study, and in particular the Concept–knowledge (C–K) theory has proved to have a great potential in design alternative strategies in a process by which something unknown intentionally emerge from what is known. New knowledge has been produced constantly and has intervened in the design processes completely unknown to most of us.

The results show that urban regeneration process in the periphery of Mazzarona is grounded on its valuable environmental resources, landscape, archeological and social heritage characteristics.

Improvement of the quality of life of inhabitant has emerged as one important goal in the regeneration process of the area as well as for the whole city. Regeneration of green spaces participate to this achievement, by providing to citizens outside places, where they can rest, enjoy nature, meet each other, participating in this way to better social cohesion. Besides social considerations, green spaces and trees also have a high impact on climate mitigation. Therefore, a long-term vision was also elaborated as uniting component that all stakeholders from leading politicians to citizens and interest groups can refer to. Thematic working groups have defined main intervention areas/measures as well as strategies and connected actions. Stakeholders and citizens have been stimulated to share their points of view, and gain information on "hot topics" connected to thematic domains in order to have a broader/clearer view on the situation and preparing the ground for new citizen engagement connected to the areas of intervention (Table 5.2).

Each intervention of the G124 has triggered new processes and become a Keynesian social and architectural multiplier of the periphery. For these reasons, the importance of the G124 project lies not in the size and quality of the architecture but it builds but in the possibility that it offers to give trust, voice, and active citizenship to those who live in the suburbs, which claim the right to better quality of life declined in all its aspects.

5.8 Concluding Remarks

Over the last few decades, urban peripheral areas have been increasing in number, typology, and implications, which make it necessary to completely reframe both theoretical frameworks and methodological approaches of sustainable urban planning. Since urbanization has becoming an increasingly complex and multifaceted phenomenon at the global scale, traditional dualisms which urban and regional sciences are built on, such as center/periphery, should be entirely re-conceptualized in order to catch the inherent multiscalar complexity of ongoing processes that have been shaping contemporary urban spaces.

On the one hand, the growing rates of urban sprawl have been upsetting fragile balances between urban core, suburban rings, and peri-urban settlement areas. On the other hand, urban shrinkage has increasingly transformed the concept of peripheries to the point to make it difficult to trace in a single way its assumptions. These transformations have also increased the complexity of the challenges which contemporary urban planning has to face, owing to the unprecedented socio-economic inequalities and new forms of marginalization affecting urban peripheral areas.

Table 5.2 Main areas of intervention and strategic lines for actions

Area of intervention	Strategy	Actions
Distance between the periphery and the city center	Identification of urban attractors	Implementation of services according to their features of attraction for visitors and related to main points of interests
Distance between the periphery and the coast	Intervention on the cycle path	Promoting mobility services Greenways dedicated to walking and cycling routes following public transport corridors
Ground connections of the buildings with the streets, not defined by urban design but by a spontaneous use of the spaces	Redefining the front road	Green pathways connection between the houses and the roadway
Abandoned large open spaces	Using spaces with different services for citizens	Playground with play areas, thematic gardens, urban gardens, trees for gathering areas
Lack of relations of affection and belonging of inhabitants	Encouraging the interrelationships between citizens and urban context	Encouraging the active participation of inhabitants in self-construction projects, and in administration future choices
Huge road sections	Reduction of the width of the roadways	Implementation of cycle-pedestrian paths
Lack of services for citizens	Establishment of new services	Construction of schools, social centers, sports centers, provide areas for retail
Valorization of cultural attractions for tourists	Enhancement of the Dionigian walls within the museum system of the city	Paths and elements useful to discover the visible marks of the wall system
Sea-bathing activity	Promoting tourism and recreation	Integration of services such as shelters, boxes for the sale of drinks, benches near the service, access to the sea facilitated
Pollution caused by illegal landfills disposals	Transforming the dis-economy of illegal landfills into economics	Creation of ecological islands to facilitate recycling

As a result, it is crucial for planning research to increase awareness about the impacts of urbanization processes in peripheral contexts in order to improve sustainability of peripheries and their wider metropolitan contexts.

Although far from being devoid of controversial assumptions, as underlined along the chapter, the place-based case study has demonstrated to what extent multi-method frameworks, ranging from qualitative community-driven qualitative methods to multi-criteria decision aiding models, could provide a truly participative approach for urban regeneration of peripheries, capable to trigger hyper-local innovation processes which go beyond the mere architectural renovation. The theoretical and methodological approach embedded in the Renzo Piano's program of "mending" peripheries is rather aimed at empowering local communities, insofar as they can become active agents of changes, supporting experts of urban planning in re-designing their lived environments according to their exigencies and expectations.

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Chapter 6
Cities and Spatial Data in the *New Urban World*: A Data-Analytic Exploration

Karima Kourtit

Abstract The uncritical use of the notion of the '*urban century*' has led to a neglect of two important issues: (1) the need for an unambiguous definition of a city from a comparative global perspective; (2) the fact that in our mobile and digital age flows of people and data are not restricted to a given urban territory. This chapter seeks to address the emerging research and policy challenges in modern cities, as the result of the presence and use of extensive spatial (mainly urban) data and statistics in the digital society. Particular attention is paid to the way in which the present digital data deluge may influence our thinking about the nature of cities, the mechanisms of sustainable urban development, the spatial resilience of regions and cities, and data-oriented urban planning. Cities tend to become both producers and consumers of large data sets. Various caveats inherent in smart evidence-based planning for cities or urban areas are discussed in this study. It is concluded that the 'third revolution' in spatial data science will require different professional skills and new modi operandi in smart urban planning.

Keywords Cities · Digital technology · Data science revolution · Urban century · New urban world

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6.1 A World of Cities

The twenty-first century is characterised by a new phenomenon in world history, viz. large-scale and increasing urbanisation (Tellier 2009). More and more people are moving to cities, urban agglomerations and urban regions, with the inevitable consequence that worldwide rural areas show—at least a in relative sense—a weakening of their socio-economic position (see Nijkamp et al. 2019). Most cities all over the world tend to increase in size (people and activities), while the number of big cities is also rising.

Cities are often seen as magnets of human activity. The emerging '*New Urban World*' (Kourtit 2019a) is full of both medium-size and large cities. In addition, most of these cities are powerhouses of socio-economic potential and have also an enormous diversity of wealth-creating urban structures and functionings. Clearly, the '*urban century*' is characterised by an abundance of cities of all kinds (ranging from towns in rural areas to metropolitan areas in the industrialised world or even mega-cities).

It is noteworthy that modern cities are very different in terms of appearance and importance, not only regarding their size, history, culture, life style, architecture, or morphology, but also regarding their growth rates, political power, environmental quality, health conditions, innovativeness, (private and public) investments, and the like. The 'city' is not a uniform concept. Cities are heterogenous settlement systems. But in all cases they share a common urgent need: sustainable and resilient development.

It should be noted here that on January 1, 2016, the 17 Sustainable Development Goals (SDGs) of the 2030 Agenda for Sustainable Development came officially into force. This means that governments were committed to take ownership and to develop effective institutional frameworks for achieving these 17 Goals. Consequently, nations have a great responsibility for the management and monitoring of the progress towards these goals, which will require *high-quality, accessible, and timely data collection*. It is noteworthy that in particular Goal 11 refers to Sustainable Cities, and concludes that *Cities are hubs for ideas, commerce, culture, science, productivity, social development, and much more. At their best, cities have enabled people to advance socially and economically*. Later on in 2016, *The New Urban Agenda* was signed by all member states during The United Nations Conference on Housing and Sustainable Urban Development (Habitat III) that took place in Quito, Ecuador, in October 2016. The operationalisation of SDGs for cities may take different forms: climate-neutral cities, circular cities, zero-emission cities, liveable cities, and so forth. Apart from the measurable conceptualisation of such sustainable settlement systems, there is also the question: how to quantify urban SDG achievements?

In the contemporaneous urban world, there is an abundance of heterogeneous spatial data (ranging from statistical information to social surveys and social media data), which describe and monitor socio-economic developments in cities all over the world. This wealth of statistical data (often 'big data') on cities or urban areas exhibits a great diversity, ranging from aggregate indicators such as population, firms, or dwellings to sector-specific indicators such as amenities, sports events, or R&D investments. In particular, digital information systems are providing an avalanche of new and accessible data on modern city life. Cities can be characterised nowadays by data-rich information systems which originate from many sources. Batty (2018) speaks even of cities as 'data engines' to highlight the critical data position of cities.

The great variety in cities all over the world is also reflected in pluriform urban governance, planning, and policy systems. Thus, there is no uniform definition of cities (see Sects 6.2 and 6.3), there is no uniform urban statistical database (Sects. 6.4 and 6.5), and there is no uniform urban governance system (see Sects. 6.6 and 6.7). The '*New Urban World*' does apparently not have a uniform profile: it is a world of diversity, and this prominent characteristic is reflected in urban data or spatial statistics, in urban information systems, in social media platforms, and in urban data management systems and governance.

A satellite or macroscopic view on modern cities shows indeed a multidimensional and kaleidoscopic spatial map of our planet, including intense interactions of actors inside the urban system, but also between actors located in different urban systems (leading to complex material and virtual inter-urban connectivity networks; see Castells 1996, Neal 2013). Cities may essentially be seen as multi-layer networks within networks of cities (see also Berry 1973). Urban policy has hardly kept pace with the turbulent and often unforeseen dynamics in urban and spatial systems. Consequently, complex urban dynamics, resilient development, and the magnetic influence of a city have become a challenging governance issue, in particular since large cities (including metropolitan areas and mega-cities) have gained a significant power position in regional and national economies.

In tandem with the trend that cities have become powerful engines of economic and technological progress and of cultural-political significance ('*urban empires*'; see Glaeser et al. 2020), we observe also that cities provide new platforms for a rising tide of geographical statistical data and pluriform information. Consequently, urban economies and policies in the emerging digital information age are increasingly being driven by data and information on all aspects and dimensions of city life.

Cities are often unidentified objects: they provide habitat facilities for people and business, but are not precisely demarcated in measurable terms, so that a comparative analysis of urban performance is fraught with many severe difficulties. Do we really know what a city is? And do available statistical data really measure the essence of modern city life?

The aim of the present chapter is to first highlight the fuzzy nature of city concepts and then to critically review the strategic potential and the shortcomings of big (digital) spatial data systems for both city analysis and smart urban planning.

The chapter is organised as follows. In Sect. 6.2 we will outline various conceptual and substantive problems in delineating cities. Next, in Sect. 6.3 we will address the question of understanding the very nature of the city from an open spatial systems perspective. Section 6.4 will then be devoted to new challenges for smart urban planning as results of the large-scale introduction of digital information, while in Sect. 6.5 we will discuss several operational problems associated with modern urban statistical data in the digital era. The important question of professional urban data management and urban governance will be addressed in Sect. 6.6, while a future outlook will be offered in Sect. 6.7. Finally, a broader perspective is provided in the concluding section.

6.2 The Fuzzy Concept of Cities in the Modern Age

The phenomenon of cities and city formation has prompted an ongoing worldwide discourse spanning several centuries—and even millennia—of basic reflections on the very nature of cities, starting already in ancient Greece on the '*polis*' and in ancient Roma on the '*urbs*'. In modern times a conceptual distinction is sometimes made on the city as: (1) a statistical unit; (2) a functional unit; (3) an institutional governance unit. Examples of these conceptual angles from the extant literature can be found inter alia in successive contributions by Weber (1899) on the statistical basis of a city, by Weber (1909) on the economic basis of an agglomeration, and by Max Weber (1921) on the city as human construct governed by conventions and institutions. There is indeed an avalanche of scientific contributions on the very essence of a city centering on the question: '*what makes the city a city?*'

Cities have been in existence since the early history of mankind, but have structurally grown in importance in the course of history (see for an interesting historical overview Tellier 2009). Cities have shown a wide array of different appearances, so that a clear and undisputed definition and conceptualisation of cities is problematic. There is an abundance of definitions of cities, which, for instance, show that a city may range in size from a few thousand citizens to more than 25 million people (see, e.g., Beaverstock et al. 1999). The variety in the scale of cities is clearly enormous. In the *Dictionary of Human Geography* (edited by Gregory et al. 2009) an extensive description of several definitions and types of cities has been given.

Cities generally offer extensive spatial opportunities based on a concentration of housing, job opportunities, transportation, sanitation, utilities, culture, education, human land use, and communication. Their density facilitates efficient interaction between people, government organisations, and businesses. In this way cities are able to render services to many inhabitants of a country. It should be noted that most city definitions do not say very much about the presence or functioning of urban life, not to mention the nature of human interactions, the use of public space, or urban morphological dynamics. And thus, there is a lack of useful information on the difference between endless suburban landscapes and traditional mixed-use structures. Apparently, city size and density are relative characteristic indicators and only superficial identifiers of a city.

Size is usually the main criterion used to define a city, but there are certain morphologies that have very strong urban features regardless of size. Small hamlets in Tuscany or Calabria very often have a square with a bar and a café, and, therefore, they attract locals and visitors, creating the potential for interaction between inhabitants and strangers (see the concept of '*Urban Piazza*' presented in Kourtit et al. 2014). Places of human interaction and exchange, such as bars and cafés, are what the sociologist Oldenburg (1989) once referred to as '*Third Places*'. Such meeting places—involving the exchange of information and goods—were usually a fundamental quality in historical cities of the world. This quality is reflected in their morphology and spatial interactivity, which provides a city-wide system of streets and public spaces (squares, parks, and piazzas). Today, we have a considerable amount of data on where people live and work, but much less data on where they engage in leisure or social activities. Clearly, the question remains: What are the distinct characteristics that make a modern city a real city? Even in the digital data era cities are nowadays sometimes still unexplored fields.

In the core of the *New Urban World* is, of course, the word '*city*'. It is noteworthy that there exists in the literature no commonly accepted and unambiguous definition of what a city is, or where it starts and ends. If we do not know the demarcation line around the city, how can we measure its density (people divided by surface)? The more surface area we incorporate into the city definition, including low-density hinterlands, the lower its average density will generally be. It is, for example, an amazing fact that—in contrast to popular opinions—the metropolis of Los Angeles has a higher density than the metropolis of New York (according to the Major Urban Areas US Census, 2010). The reason is that Los Angeles suburbs are much denser than those of New York. It should also be noted that the spatial distribution of the density within the city is also an important factor to be considered. A city with all people living in a dense core area, but with a boundary that encompasses an unsettled area, will, ceteris paribus, have a higher density within its settled neighbourhood (built environment) than the one that distributes the same population evenly. We may thus conclude that, in order to meet the expectations from the UN Agenda 2030 and the New Urban Agenda, official national statistics need to be revisited, harmonised, and updated in order to serve and govern the three pillars of sustainability: sound economic, environmental, and social development. This task applies certainly also to cities.

It is only natural that worldwide, modern cities look different in terms of physical appearance. In general, however, there is one common feature: with the introduction of the car, the role of streets as public space has diminished; streets have become merely transportation corridors serving mobile people. Under the influence of modern town planning, the mixed-use streets were replaced by roads connecting single-use zones. At the same time, cities began to sprawl far beyond their traditional borders, with the consequence that as a result of spatial segmentation it has become increasingly difficult to achieve an unambiguous statistical coverage. This made it difficult to prove where a city begins and where it ends. This resulted in the need for administrative municipal statistics, while neglecting the various functionalities of these areas.

The conventional administrative solution for city boundaries is, however, becoming increasingly obsolete. The economic system that orbits cities very often goes far beyond the municipal borders. Cities are not only a network per se, but often also part of a broader regional, national, or even global network (‘*the connected city*’; see Neal 2013). As a result, some international organisations like Eurostat and the OECD have started to look at ‘*functional urban areas*’: larger structures containing several cities and settlements regardless of municipal borders (see, e.g., Dijkstra et al. 2018). These areas resemble the Standard Metropolitan Areas in the USA. It should be admitted that most analyses of functional urban areas are based on the intensity of commuting flows between geographical units. However, since in many urban areas these transport flows are usually even less than 50% of all flows, the demarcation of cities based on functional urban areas (i.e. commuting areas) is rather fuzzy and does not provide an transparent and unambiguous way out. In particular, since social and leisure flows are sometimes dominant and have different spatial patterns, statistical urban definitions tend to be flawed. In addition, interactivity and connectivity based on digital communication between often faraway people is also left aside.

Clearly, borders have to be drawn as identifiers of cities. For many purposes—such as population registers, cadaster, elections, etc.—administrative borders are needed and may suffice. But for several types of socio-economic analyses, the municipal borders offer a too narrow or otherwise flawed perspective. Furthermore, in other cases, when the topic is related to social life, health, walkability, attraction, integration, and so on, the municipality border is far too wide. The need here is not only to focus on, but also to differentiate between, different types of settlement. Historical city cores, pre-war suburbs, post-war suburbs, modern city cores of the American type, edge cites, urbanised suburbs, etc., all produce very different outcomes of urban life.

It is noteworthy that what is called the urbanisation of our world manifests itself mainly in the form of suburbanisation (Keil 2018). Nowadays, however, suburbanisation is not only a land-use conversion process of residential development that is outside—but still rather adjacent to—the central city, but has also become a modern way of living in a less hectic central city location, while still enjoying the benefits of city life (known as ‘*suburbanism*’). Consequently, the borders of a city have become rather fluid and fuzzy. It is especially the rise in commuting distance which has prompted complex urban, suburban, and metropolitan morphological developments in the ‘*New Urban World*’.

There is, therefore, a need for new urban statistics that transcend the standard municipal border definition. The answers to questions like ‘How do we define an urban area?’ and ‘What data are necessary to capture the complexity of urban areas?’ will not be unambiguous, but need to be addressed (see in particular Sects. 6.3 and 6.5). It seems likely that there will exist many different city demarcations, depending on who asks the question and for what purpose. Therefore, it is pertinent to obtain more precision and rationality with regard to city concepts in our ‘*urban century*’. In this connection, the previous background observations about the ‘*New Urban World’* prompt a series of fundamental issues on the statistical base of cities.

6.3 What is the City?

A discussion on cities (including sustainable and smart cities) is futile, if a clear perspective on the very essence and nature of cities is lacking. The aim of this publication is to explore the contemporary discussions surrounding the need for a modified or perhaps new definition of cities and urban areas and to highlight the challenges and opportunities presented, while taking into account the far-reaching impacts of modern ICT on city life (see Farrell and Reid 2019; Farrell and Nijkamp 2019). This has serious implications for urban and spatial statistics, as was explained above.

There are numerous reasons to explain why a clear definition of an urban area is important. At the city level, a clear delineation between urban and rural areas offers a planning support in the provision of amenities and basic services (Peterson 1981). For example, at the national level, it becomes necessary for cash transfers and subsidies. Furthermore, from a statistical perspective, a solid operational definition is an essential element for establishing baselines and measuring changes over time for policy monitoring purposes. Needless to say, a clear definition of urban areas is essential for both the planning and management of cities, as well as for the general political economy of a country, region, or city. Not only is clarity of definition important, but so is international agreement on city boundaries and institutional competences. In their 2018 Revision of World Urbanization Prospects data set, the United Nations utilises the definition of 'urban' used by each individual country. This means that they are effectively using 232 unique definitions of 'urban' (United Nations 2018; World Bank 2018). Lack of a uniform definition creates significant challenges when trying to make cross-country comparisons (Uchida and Nelson 2010). Clearly, many comparative urban studies may be seriously biased.

For example, according to the United Nations (2014), an urban area can be defined using a number of criteria: administrative definitions; population thresholds; population densities; proportion employed in non-agricultural sectors; availability of urban infrastructure; presence of urban amenities; and in some cases, a combination of all these. Such definitions vary significantly by country. Unfortunately, the way cities are currently defined is marked by frequent contradiction. This is encapsulated in numerous claims as to the extent of urbanisation worldwide. For example, in 2008 the United Nations announced that the world was more than 50 per cent urbanised. Since then, a number of academics and statistical agencies have set out to challenge this. Brenner and Schmid (2014), in their planetary urbanisation thesis, claimed that due to the spread of global capitalism, urbanism was in fact everywhere. For the purpose of a sound comparison of city indicators (such as the previously mentioned SDG 11), a number of organisations are currently working towards a harmonised definition of urban areas. Utilising new geospatial techniques, the OECD and the European Commission have put forward alternative definitions and methodologies for measuring the extent of the urban cover. According to the European Commission's definition more than 80% of the world is considered urban (Dijkstra et al. 2018; Farrell 2018), while the OECD definition is more modest and puts it somewhere closer to 54%. Other previous attempts to construct a definition of 'urban' that would have universal international utility include that of Uchida and Nelson (2010).

Currently, there are various serious attempts to come to grips with these issues. The OECD definition, for example, looks at functional urban areas (OECD 2012). This comprises data from global human settlement population layers (people); a population model vector database (density); and a global travel impedance grid (commuting zones). Aside from their assessment that 54% of the global population resides in functional urban areas, they also found that: 12% is located in commuting zones; suburbanisation is more prevalent in richer countries; and there is most suburbanisation in medium-sized cities. In other OECD programmes which build on this ongoing research, the data are continuously being enriched (i.e. ongoing efforts include attempting to identify the percentage of the population who have access to certain amenities). It may be added that the Internet also has far-reaching implications for the nature of cities. If an increasing number of people purchase goods on the Internet, the local orientation and the traditional role of the city centre are completely lost. Cities may become 'unidentified objects'.

One of the intriguing observations on modern city life is that the action radius of the '*homo urbanus*' has increased significantly. Residents live often in two worlds: their daily living environments (home, street, public space, infrastructure, etc.) and their virtual contact network (Internet, social, etc.). The connectivity patterns range from local to global, while both types of connectivity infrastructure (physical and virtual) influence each other (see Katz 2006; Rotondi et al. 2017; Sato and Zenou 2015).

We must also recognise that cities are not crafted in stone—neither functionally nor statistically, but evolve in various ways over time. As a result, we must be cognizant of the possibility that definitions too may need to evolve to accommodate changes in city structure, function, and morphology. Definitions may also have to evolve in response to the availability of new data sources and types, and new methods of analysis. This raises the issue as to whether a city at the end is a 'floating concept', with a high degree of volatility. If the nature of cities evolves, urban statistical data may evolve as well.

The importance of urban morphology and urban dynamics in studying urban functions and public space is indeed an important issue. There is tremendous diversity in urban form (see, e.g., Brotchie et al. 2019). While there is no perfect shape for a city, variations in urban form can be important. For example, in the context of cities in developing countries, compact and internally well-connected cities tend to exhibit higher levels of productivity than elongated cities, which have poor connections. It is clear that the urban form of many African cities inhibits their economic performance. And this holds to the same extent for cities in other parts of the emerging economic world.

Although many cities around the world may meet their current national definitions of 'urban' in terms of population, some urban functions (e.g. historical-cultural amenities) may not actually be present. This raises questions as to what elements of a city are deemed essential—density, mixed-use, public space, etc. A number of recent studies have begun to move in this direction, providing measures of activity (commercial vs. residential), road intersection density, distance between street corners, shape of city, connectivity, etc. We will illustrate this by means of citation from a recent book by Kourtit (2019b), p. 334: “In a standard textbook on urban economics by Mills and Hamilton (1984), the authors raise the question: ‘What are urban areas?’ They argue that there are many urban concepts: town, city, urban area, metropolitan area, and the like. Some of these concepts are based on legal definitions, and hence these definitions vary across nations. Others are based on population figures and reflect the fact that in urban areas the average population density is higher than elsewhere. The authors provide the following basic description: ‘Thus the fundamental and generic definition of an *urban area*, or *metropolitan area*, is a place with a much higher population density than elsewhere’ (p. 3). Hence, it is thus clear that the concept ‘urban’ is not a clearly operational term. In general, a city is an area or place with a relatively high concentration of people in a demarcated built environment. To be more precise, in the *Dictionary of Human Geography*, edited by Gregory et al. (2009), the following nomenclature is adopted:

- *urbanisation*: has often been understood as a process of human distancing from first nature.
- In cities, *nature* has often been treated as a residual or artificial category limited to parks, zoos, and urban—mostly ornamental—gardens.
- *city*: today, a more generic usage of this term refers to an urban demographic, economic, and above all political and jurisdictional unit, usually bigger than a town.
- *agglomeration*: the association of productive activities in close proximity to one another. It typically gives rise to external economies associated with the collective use of the infrastructure of transportation, communication facilities, and other services. Agglomeration also facilitates the rapid circulation of capital, commodities, and labour.
- *urban areas*: may be cities or towns and are characterised by higher population density in comparison with the areas surrounding them”.

The issue of accessibility—and of connectivity (see Neal 2013)—is also critical. Thus, while a city may have what appears to be abundant public space, important questions such as ‘What percentage of the population has access to that space?’ or ‘Do green areas meet the needs of citizens?’ still need to be answered. Moreover, and more critically, which segments of the population have access to it or use it? An important question is also: ‘What is an optimal city size?’ ‘Is there in reality an optimal city size?’ (see Alonso 1964). ‘And, if there is, what is it?’ ‘How may optimal city size vary from country to country, and what are the factors which determine optimal size?’ In thinking about optimal city size, both absolute population size and geographic surface area (and the interplay between the two) should be considered. If cities are symbiotic organisms, the notion of interaction and communication deserves far more attention in the research world.

Such new research is important, because the way we define a city will have implications for all other urban statistics as well. Too broad of a definition will increase the complexity of a city as an organism, while too narrow of a definition will limit its potential. Needless to say, striking a balance will be critical.

The discussion on the demarcation of cities (e.g. city centres, functional urban areas, standard metropolitan areas) also has a dual side, and prompts the question: ‘What is a rural area or what is a suburb?’ One might argue that, if urban and rural areas sum up to the total territory of our world, an unambiguous definition of either of the two categories (urban and rural) would automatically lead to a clear definition of the other one. But unfortunately, there is neither any clear definition of rural areas (see, e.g., Ratcliffe et al. 2016). One even speaks of rural urbanisation or ‘rurban’ (see Nijkamp et al. 2019; Walks 2013). In addition, there are semi-urban areas, semi-rural areas, and several other concepts.

A similar confusion holds for the definition of suburbs (see, e.g., Airgood-Obrycki and Rieger 2019). These authors distinguish census-convenient, suburbanisms, and typology definitions, and provide an interesting overview of the literature. The latter authors do not only discuss critically various suburban concepts, but also argue that the use of a given definition may have an impact on suburban landscapes, spatial interactions, and land-use planning. They make a plea for more standardisation in the terminology and conceptualisation of urban, suburban, and rural areas.

6.4 Challenging Questions

The previous summary and exposition of the unprecedented urban growth and global developments in the ‘*New Urban World*’ and of the related conceptual city challenges (including digital data) implications raise various intriguing questions for researchers, practitioners, and planners:

- Is our world really as urban as it is often assumed, or are we facing increasingly a fuzzy intermediate pattern of settlements that is less ‘black or white’ (i.e. urban vs. rural) and that offers more flexible modes of living (e.g. suburban or ‘rurban’ (rural–urban) developments)? For instance, African cities differ completely from American cities.
- When modern cities become a melting pot of a pluriform population, and of different socio-cultural and economic developments with high spatial mobility patterns, is then the current urban statistical database sufficient to understand and govern complex spatial dynamics in an open multicultural society?
- Is the modern business world really moving towards concentrated industrial agglomeration patterns in or near cities, or is the lower rent level in designated areas and specific urban land-use control policy a driver for diffuse industrial agglomeration patterns, taking into account differences between big enterprises, SMEs, or the creative sector? For example, the ‘*edge city*’ phenomenon is a new mixed phenomenon.

- Can the heterogeneity in city developments adequately and sufficiently be mapped out in our statistics (including also GIS or BIM models), so that we are able to make meaningful comparative studies of urban developments in our world? And are the available statistical data appropriate for really understanding the growth in urbanisation in the Western world compared with drastic changes in emerging and developing economies? Or is, at the end, the urban mode of living mainly a matter of subjective feeling, or perception (e.g. the 'rural citizen')?
- What are the opportunities for, and barriers to, multiple-source statistical information, with different levels of reliability, spatial scale and aggregation, that still ensure solidity and accountability of current statistical data for urban planning purposes. Could machine-generated data for smart statistics in key policy domains (especially, geospatial data) be a useful instrumental approach?
- Are we able to utilise user-oriented data in relation to cities (e.g. visitors' information, social media data, commuting flows, shopping, or visiting friends and relatives (VFR) data) for a reliable mapping of the open urban territory, while ensuring space–time comparability among such data? Are accessibility and connectivity data helpful in this respect, especially in a social media context?
- Do we need a special category of urban statistics for rapidly growing cities in emerging or developing economies (e.g. Lagos, Nairobi, Sao Paulo), given the fact that land-use control is often flawed in these cities? Is it possible to define adequate operational principles for urban data management in these conditions? And are such data management practices a critical support for smart cities?
- Is there a threat that the high-tech orientation of modern data and the broad social sources of data are leading to cumbersome dichotomies in urban data management ('*data verse*'), especially given the level of sophistication in big data handling (machine learning, algorithmic decision-making, sensor technology, serious gaming simulation, and visualisation)?
- Is the current popular '*smart city*' hype really driven by an intelligent handling of an avalanche of operational and strategic information on the city, or is it mainly driven by a digital technology fix from the commercial sector? And are the tonnes of data created and collected nowadays in cities appropriate to serve the needs of people and enhance citizen engagement? Are the masses of, often informal, data helpful in redefining and reshaping the boundaries of the urban space-economy?
- Is the broad penetration of digital information—not only in the form of formal, numerical data, or qualitative information systems, but also as an ever-increasing avalanche of informal data with different degrees of access, use, and reliability—a new opportunity for improving the rational and balanced underpinning of urban planning decisions in both the private and public sectors, or is the uncontrolled and unsolicited supply of '*big data*' a real threat for sustainable, resilient, or inclusive cities in the framework of the SDG goals? And are civil servants sufficiently trained for managing complex data systems?

Hence, city research and governance are indeed fraught with many data difficulties in terms of city size, density, and form.

It should be added that the above-mentioned UN New Urban Agenda takes the urban challenge very serious and addresses many aspects of urban life. It also puts forward a strong argument on the underresearched issue of urban form. In particular, in Paragraph 44, it concludes that: 'We recognize that urban form, infrastructure and building design are among the greatest drivers of cost and resource efficiencies, through the benefits of economy of scale and agglomeration and by fostering energy efficiency, renewable energy, resilience, productivity, environmental protection and sustainable growth in the urban economy'. It is disappointing that, although several academic and private research institutions are trying to invent new methods to measure and monitor cities, the official urban statistics in many countries are still lagging behind. Governmental statistics on cities are—as mentioned before—in many countries mainly based on administrative borders, and the main categorisation is whether they are urban or rural. Other categorisations (e.g. functional subdivisions, user-oriented categories) that are used for specific purposes are often based on vaguely defined and interrelated concepts, while the totality of all of them tends to blur our understanding of what a city is. Concepts like 'urban', 'rural', 'city', 'urban areas', 'density', 'region', 'mixed use', 'public space', 'public life', etc., are used in many different ways. Urban concepts appear to be situated in a heterogenous and often ambiguous statistical context. Therefore, Sect. 6.5 will be devoted to the question of the urban response to the new challenges and opportunities offered by digital technology.

6.5 Concerns about Urban Statistics

In the present section, we briefly pay attention to the ongoing discussions surrounding the advancement of urban statistics (big data and smart statistics) and take a deeper look into the implications of a new view on urban statistics, against the background of our modern data-rich society (see also Kourtit 2019b). The current concerns on urban statistics have generally been induced by recent mega-trends in our digital world. Examples are:

- the rise in a broad collection of social media platforms addressing many human activities in cities, relating to both physical and virtual interaction and often using also geovisualisation techniques;
- the introduction and use of micro-based data and behavioural or experimental social science research methods for quantitative scientific and policy purposes, including open data and using sometimes also data warehousing;
- the awareness that modern urban statistical data (e.g. density patterns, perception of liveability, size of urban areas, significance of districts, local communities, or open-access space, and streets for real city life) do not present the prominent features of a city (as is clear from comparing the morphology and socio-geographic features of different cities in the world); for example, OpenStreetMap is increasingly becoming a rich source of urban information;

- the increased use of advanced digital spatial information sources, e.g. satellite data, sensors, cameras, and many other electronic devices that deliver a permanent online data map on people's behaviour ('*big data*'), also regarding their mobility patterns ('*territorial intelligence*');
- the popularity of individual digital information from original information sources, used in both the public and private domain, as well as the rising popularity of interesting information through info-graphics, visual analytics, geo-design, and social media metrics (e.g. volunteered geographical information);
- the rising potential to support several smart city initiatives in different governance areas with online daily practical information and permanent data access, such as urban dashboard options and city disaster management systems;
- the growing presence of business opportunities and initiatives for storing and employing digital data for several public and private purposes ('*democratisation of big data*').

It is thus clear that the field of urban data management is in full motion and has to explore and follow different paths compared to the past. Historically, most of the data in cities and urban regions stem from official statistics, which were established to measure societal phenomenon such as population dynamics, economics, health, and so on. These were primarily accounting exercises, providing a more detailed account of the composition of urban areas. The primary purposes of official statistics were for monitoring and comparison, across both space and time. However, in recent years there has been a shift towards more evidenced-based long-range policymaking and a desire to utilise official statistics and informal data to add further value, including '*big data*' (see, e.g., Kourtit 2019b).

'Big data' does not only refer to the volume of available data, but also—and in particular—to the variety of sources of data, their reliability or accuracy, their measurement scales (from textual to numerical information), their different specifications, their aggregation levels (from individual to collective data), and their variability in space and time. In this context, the concept of '*smart cities*' finds its place, as such cities are knowledge-based and data-oriented. As will be argued later on, smart city policy is, therefore, first a challenge of data management, information coordination, and citizen involvement.

One area of particular interest is the role of big data for better understanding the complexity of cities, and whether or not it could be validated in such a way that it could supplement official statistics. Many experiments are currently underway, involving, for instance: the role of big data for measuring GDP (e.g. through night-light data); the movement of people (using road sensors and telecom data); and consumer confidence (e.g. with twitter data) to name but a few. More recently, studies have ventured into the territory of behavioural patterns and predictive analytics. A recent example illustrates how *Trip Advisor* data can be utilised to illustrate the behavioural patterns of tourists in a city (see Kourtit 2019b).

Multiple benefits can arise from more innovative sources of statistics. These include: a better understanding of the complexity of cities; new opportunities for comparability across time and space; an ability to measure impact (progress towards

SDGs); greater levels of detail; real-time access; zero eco-footprint; circular city models; fast production and processing; climate adaptation, and, ultimately, more informed (evidenced-based) policymaking. In the future, such sources of data could confirm or dispute official statistics as a tool for accountable policymaking.

However, one should be aware of the potential challenges that accompany such new approaches. This is because new sources of data are often messy and unverified. A number of key challenges for urban statistics will be mentioned here; these will require further consideration before we may be able to harness the benefits that accompany the urban data deluge. These key challenges for urban statistics are in particular the following:

- There are a number of potential barriers to entry: organisational, regulatory, budgetary, legal, governance, ethical, and cooperative. In terms of the latter, this has to do with the incentives and motivations behind data sharing.
- It is necessary to establish a balance between the application of novel approaches and the ability to ensure consistency and comparability over time (longitudinal). If we utilise new data and adopt new methods and approaches, what are the implications in terms of measuring change over time?
- New sources of data mean new ways of interpretation and misinterpretation. Further exploratory work will be required to see what sort of opportunities and challenges arise.
- The availability of new data sources may create issues of ownership. Who owns what data? How are data ownership and access issues regulated? How do we settle data ownership and access disputes? Through which platforms should data be made available? Data transparency is also an important concept.
- Data asymmetries are beginning to arise: both in terms of those who have access to data within urban areas and also between those countries having the resources and capabilities to harness new approaches to data management and those who do not.
- It is essential to provide the necessary data analytics expertise. Currently, the quality of expertise within municipal agencies is not sufficiently equipped to handle the statistical understanding needed to operate in these emergent new areas. Training programmes for professionals will be critical to ensure that users of new data from new sources are appropriately equipped. In this context, universities and technical schools have an important role to play.
- With the vast amounts of data being produced, it will be important to filter out the noise. There is thus a need for smarter data to reduce the risk of a data deluge and increase the potential for actionable intelligence. Smarter statistics can also help to protect against privacy concerns (i.e. comparing indicators to see the difference, as opposed to focusing on the details of each indicator which may remove anonymity).
- We should recognise that it is unlikely that a universal agreement on every relevant issue concerning city concepts and statistical data will be achieved. It, therefore, becomes important to prioritise issues and work hard to find as much as agreement on commonalities as we can.

- Data gaps are a significant issue in many developing countries. This negatively affects our ability to make international comparisons. In the case of developing countries, remote sensing and satellite imagery can be useful tools. For example, remote sensing can be used to indicate land use and land-use change, while satellite imagery of night-lights may be useful in delimiting city boundaries, e.g. as a proxy for spatial productivity.

It is evident that the emergence of new sources of data has begun to disrupt conventional standards and protocols. In many ways, this is presenting new opportunities for understanding complex urban phenomena. However, it will also be important to recognise that some initiatives and decisions cannot be made using modern (big) digital data alone, and that there is still a need for more traditional techniques. While they are costly and time-consuming, self-reported surveys and questionnaires are still necessary means of understanding personal perceptions and quality of life in cities. Needless to say, combining data sets and promoting a shift from single indicators to multiple indicators will be an important area of future exploration. The '*public space*' indicator of SDG 11 is a good example of this (with a division in statistical scope: big data measuring the quantity of open space, and surveys measuring quality of public space).

The supply and use of digital technology and the availability of a broad variety of data (statistical information, residents' surveys, online information systems, digital social media platforms) have meant an important turn in the way a city is managed and governed (see for an informative study, Komninos and Kakderi 2019). The concept of a *smart city* has in recent years become very fashionable and indicates the strategy of a city to improve its multidimensional performance—both over time and in comparison to peers—through a knowledge-based orientation that is supported by the use of a variety of up-to-date information sources, in particular, data emerging from digital information technology (see, e.g., Kitchin et al. 2015; Graham 2013; Giffinger et al. 2007; Caragliu et al. 2011; Kourtit and Nijkamp 2018; Kourtit 2019b). We speak nowadays even of the 'datafication' of urban planning (see Mayer-Schönberger and Cukier 2013). A cognitive and evidence-based underpinning of urban policy through advanced and accessible data—including 'big data'—may offer great opportunities for the enhancement of a broad portfolio of urban development and planning goals ('the informational city'; see Castells 1996).

6.6 Data Management and Urban Governance

Data management is another important element that needs to be considered. In the private sector, companies have a long history of managing their data within bookkeeping systems and ledgers. In many ways, this becomes the DNA of a company. Cities might adopt similar principles for their operation (e.g. in urban blockchain systems). Successful cities have already begun to do the same.

A possible strategy sometimes advocated is the creation of data lakes (sometimes instead of data warehouses). This would promote the pooling of sources of data in order to break down organisational silos, thus providing an opportunity to make such data open access. It also creates the potential to establish a safehouse, which can eliminate privacy concerns. The first steps towards promoting citizen participation and entrepreneurship will be the creation of an enabling environment. This will involve collaborations between multiple entities—university, business, and public organisations. Interconnected data systems can lead to the better overall management of a city.

The above-mentioned data issues are of crucial importance to policymakers. A critical issue is the need for professional evidence-based policymaking and decision-making. There is a clear need to strive for excellence in both of these areas. Poorly crafted policies and bad decision-making can be expensive. Their negative effects can resonate for years, and can be very costly to fix. One of the challenges will be to figure out how to integrate new sources of data, including real-time data, into policymaking and decision-making processes.

We must also recognise that there is no absolute truth in data and that data are not value-neutral. This has important implications for spatial policymaking and decision-making oriented towards sustainability, inclusion, and resilience. Moral standards, when it comes to both of these, are not clear. The ethics of policy and decision-making are important. Social scientists, working in an advisory capacity, can assist policy- and decision-makers in this area. It is important that statistical agencies have statutory independence and that they are beyond the punitive reach of lawmakers. It should be noted that data are a means to an end. The question is: 'What is the end'? 'What needs to be achieved?' And: 'Which action lines are needed?' We will conclude this section with the formulation of some guidelines:

- *A systematic contextualisation and conceptualisation* of the 'city' concept (and a series of related concepts, like towns, villages, urban areas), with due attention for administrative relevance, planning-oriented strategies, cluster-based perspectives in terms of in- and outflows, functionality and hierarchy principles, morphology, scale and density, population size.
- *The city as a provider of public space* (including streets, green space, squares, playing grounds, pedestrian zones, etc.), in which public urban life (and free access) is a key force of urban vitality and magnetism.
- *The city as a vehicle for a sustainable future* (including its key roles as an economic magnet, a source of human, social, and cultural well-being, as well as a supplier of infrastructural and technological capital, e.g. robotics).
- *The recognition of the importance of digital technology*; information will most likely be the key determinant of sustainable, prosperous, and inclusive cities.
- *The awareness of clear limitations* of the promises of smart city policy, in particular in regard to privacy issues, unequal access to digital technology (digital divide), securization issues, fake news, and data manipulation.

Finally, it should be recognised that there are individuals, agencies, and even cities as a whole that are not data-driven, and do not sufficiently integrate data and data analytics into their policy and decision-making. This backlog would have to change and may require a removal of the barriers which prevent the adoption of data-driven approaches by statistical agencies and cities, as well as their citizens.

6.7 Pathways for Urban Data Management

In this section, we will present a number of key highlights as well as core areas that require further research. Evidence-based and solid statistical support for a scientific approach to pressing urban issues needs the following actions to be pursued for useful and professional urban data management:

- make an inventory of the worldwide variety of statistical definitions of a city, and choice of appropriate city indicator(s);
- collect operational and widely used types of data on cities (survey data, administrative data, digital information, satellite information, etc.);
- design new operational methods for handling urban data (at both city and sub-city level), based on both conventional analysis techniques and modern 'big data' approaches (e.g. neurocomputing, machine learning, visual analytics, data mining).
- balance the need to come up with more accurate and universally acceptable definitions, while at the same time being able to compare data over time. This may involve having individual definitions by country, as well as standardised definitions for the purpose of comparison. To this end, a useful next step might be to make an inventory of the definitions of city/urban concepts currently used by the major international entities such as the World Bank, OECD, and the United Nations. This would enable commonalities and discrepancies to be identified. Ultimately however, a universally accepted definition will require agreement between key global agencies, while respecting specific city needs;
- move from a single indicator to multiple indicators in order to have a more accurate understanding of complex urban phenomena;
- favour cooperative endeavours among national and subnational governments to allow for easy aggregation and disaggregation of data, including data sharing and eliminating barriers for cooperative work;
- address the ethical side of big data and smart statistics in a digital world;
- ensure that measurement techniques are adaptable and non-exclusionary, so that in principle all countries have access to the same sources of data;
- attract advanced knowledge and talent into the smart city sector (primarily from the public sector side).

6.8 The Broader Outlook

Balanced urban policy in the future will increasingly be influenced by professional data management. Urban planners will to a large extent become data analysts and managers. The match between urban policy (with a great variety of public–private components, with place-based and specific people-based orientations, and with a broad social and economic portfolio) and evidence-based data management in cities will become a great challenge (see Holland 2015).

Statistical data and reliable information systems are essential for the effective and efficient governance of urban systems (see for more details Kourtit et al. 2019). Data and information also shape the contours within which urban research and planning take place. When the *first* quantitative revolution in geography and regional science took place (see, e.g., Haggett 1965; Isard 1956), the expectations concerning the benefits of statistical and modelling possibilities were very high; they were only tempered by data availability. Examples are economic base models, retail models, etc. Consequently, the available spatial data were a serious constraint for an open and flexible scientific analysis of urban and spatial phenomena; their frame of reference was limited to a domain determined by data. The *second* quantitative revolution in spatial data metrics took place at the end of the last century, when the scope of conventional (linear and static) modelling was greatly extended by addressing the unforeseeable dynamics of spatial systems. Examples can be found in spatial synergetics, catastrophe and chaos models, computational neural network models, and the theory of complex (network) systems (see Reggiani and Nijkamp 2009, 2014). This approach was able to open up the restrictive borders of traditional spatial-economic analysis (see also Nijkamp 2007). In recent times we have witnessed the rise of a *third* revolution in spatial data science, in which we observe the emergence of a great diversity of formal and informal, verified and unverified data, which enter the public domain in both organised and unorganised ways, and which have often no explicit reference to spatial boundaries. For example, cell-phone data are used for systematically analysing spatial mobility patterns, but also ad-hoc emerging social media data on a wide diversity of locational phenomena are becoming increasingly important. Official systems boundaries (e.g. city or district) are no longer playing a prominent role in the digital stage, so that the systematics of spatial data analysis is at stake here.

The current avalanche of big data poses enormous challenges for the future of spatial data analysts. It is thus clear that digital technology will have far-reaching implications for urban and spatial informatics and planning as a critical mechanism for achieving sustainable, inclusive, and resilient development of cities and urban regions. Urban data management should not take place in the dark corners of townhalls, but ought to have a strategic place in any city.

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Part II
Society and Culture

Chapter 7
Group-Size Bias in the Measurement of Residential Sorting

Mohana Mondal, Michael P. Cameron, and Jacques Poot

Abstract We revisit in this chapter a common issue with popular indices used for measuring residential sorting, i.e. the extent to which a subgroup of the population is spatially distributed (sorted or segregated) differently from the remainder of the population. Specifically, we show that three common measures of residential sorting (viz. the *Index of Segregation*, the *Index of Isolation* and the *Entropy Index of Segregation*) are affected by group size, i.e. the expected values of the indices are positive rather than zero under random sorting, and the size of this positive bias is related to group size. This is an important issue because it is common to compare sorting indices across groups of rather different sizes, both cross-sectionally and over time. Using New Zealand data, we demonstrate group-size impact on bias in measures of residential sorting by means of scatter plots and regression in four different ways: (1) investigating the relationship between group size and each residential sorting measure calculated with actual data; (2) randomly allocating individuals across area units, calculating the resulting residential sorting measures, and again investigating the relationship between index values and group size; (3) showing that normalised/systematic indices of sorting are also related to group

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size; and (4) calculating the bias for each sorting index and investigating the relationship with group size. Our empirical illustration uses microdata on the self-reported ethnicity of individuals (with multiple responses possible) from five New Zealand Censuses of Population and Dwellings (1991–2013) for the Auckland region, selected due to its high ethnic diversity. Our results demonstrate that the *Entropy Index of Systematic Segregation* measure of residential sorting is the measure that is least affected by group size variation. As a result, we strongly recommend using this index of sorting as a preferred measure.

Keywords Residential sorting · Segregation · Group-size bias · Entropy index

JEL Codes C18 · J19 · Z13 · R23

7.1 Introduction

Residential segregation or sorting[1] among ethnic groups has been a popular area of study since Duncan and Duncan's (1955) seminal contribution. By 2019, Google Scholar identified more than 2500 articles with 'residential segregation' in the title (and many more that cover residential segregation or sorting but where it is not explicit in the title). There has been a lot of debate about the correct index to use in measuring residential sorting (White 1983; Massey and Denton 1988; Carrington and Troske 1997; Reardon and Firebaugh 2002; Fossett 2017), and extant studies mostly use the *Index of Dissimilarity* and/or the *Index of Isolation*. In this chapter, we contribute to the methodological debate on the choice of a preferred index.

Specifically, we investigate a particular source of bias in many common measures and indices, arising from their sensitivity to the size of the groups for which the measures or indices are being calculated. Such bias arises when the expected value of the index is not zero but is strictly positive, even in the case in which the group of interest is randomly allocated across areas such that the expected value of its population share in every area is equal to its share of the total population.[2] Hence the primary aim of this chapter is to show the sensitivity of popular measures of residential sorting to group size. An unbiased index of sorting would return an average value of approximately zero in the case where people are randomly distributed across areas. Thus, following Carrington and Troske (1997) we calculate modified versions of each of the selected sorting measures, which we refer to as

[1]We use 'residential sorting' as a term that encompasses a range of measures of residential segregation that include dissimilarity, isolation, and concentration (e.g. Massey and Denton 1988). Our preferred term is not only broader, but carries none of the negative connotations associated with use of the word 'segregation'.

[2]A randomised allocation is obtained when the number of persons of the group allocated to an area is given by a draw from a binomial distribution B (n, p) with n equal to the area's population and p the fraction of the group in the total population.

the indices of systematic segregation. Each index of systematic segregation has an expected value of zero under random sorting. We find that the *Entropy Index of Systematic Segregation* measure is least affected by group-size bias and hence we recommend it as a preferred measure of sorting, even though this index has to date been far less commonly used than other sorting measures we consider.

The bias is also a function of the granularity of the data. The smaller the spatial units, and therefore their expected population size, the greater the bias under random sorting. However, granularity is not addressed in this chapter.

We illustrate our results on group-size related bias by means of microdata on self-reported ethnicity of individuals (with multiple responses possible) from the New Zealand Census of Population and Dwellings (1991–2013) for the Auckland region, selected due to its high ethnic diversity. Although there is a relationship between income and the patterns and decision-making processes of residential mobility (Rosenblatt and DeLuca 2012; Karina et al. 2014), Mondal et al. (2020) show that in Auckland residential sorting by ethnicity is much more prominent than sorting by income. Thus, we base our analysis on residential sorting by ethnicity. Throughout this chapter, by 'region' we mean the Auckland region, as defined by Statistics New Zealand. The Auckland region is made up of about 409 area units that roughly represent suburbs or wards. Hence, the term 'area' refers to area units in the Auckland region. We refer to an individual's ethnic group as 'group'. The number of individuals belonging to a specific ethnic group is referred to as the 'group size'. The New Zealand census allows for multiple responses to the ethnicity question and, hence, individuals can belong to more than one group. The counts used in the chapter refer to total responses, not total individuals. An ethnic group proportion in an area unit is the number of people residing in that area unit who are reporting that ethnicity divided by the aggregate count of all reported ethnicities in that area unit.

The remainder of the chapter proceeds as follows: In Sect. 7.2, we briefly discuss some relevant studies on popular measures of residential sorting. Section 7.3 describes the data and Sect. 7.4 details the methods. Section 7.5 presents and discusses the results, and Sect. 7.6 concludes.

7.2 Literature Review

Residential sorting is defined as the degree to which groups live away from each other (Denton and Massey 1988; Johnston et al. 2007). There have been thousands of studies of residential sorting, including several in the New Zealand context (e.g. Johnston et al. 2002, 2005, 2011; Maré et al. 2012). These studies mostly resort to one of the several 'traditional' measures of residential sorting, of which the most common are the *Index of Dissimilarity*, the *Index of Segregation*, and the *Index of Isolation*.

Denton and Massey (1988) summarise the literature on residential sorting to that point in time and conclude that residential sorting is a multidimensional concept that captures five distinct dimensions of spatial variation: (1) evenness; (2) exposure;

(3) concentration; (4) centralisation; and (5) clustering. Each dimension brings out different features of the spatial distribution of social groups. While measures of evenness calculate the differential distribution of the subject population, measures of exposure reveal the extent of potential contact with other groups. Concentration refers to the relative physical space occupied by a group, whereas centralisation indicates the extent to which a group is located near the centre of an urban area. Finally, the degree to which minority group members live disproportionately in adjacent areas is defined as clustering. Massey and Denton (1988) point out that these five dimensions overlap empirically (a group that is residentially sorted on one dimension will often also show some evidence of sorting on one or more of the other dimensions). However, the dimensions are conceptually distinct and have led to a considerable number of measures that each aim to quantify a specific dimension. For example, formulae for 17 segregation indices defined in Massey and Denton (1988) can be found in Iceland et al. (2002).

James and Taeuber (1985) presented a set of criteria for evaluating measures of sorting, viz. the principles of organisational equivalence, size invariance, transfers, and exchanges. By organisational equivalence, they mean that when an area unit is subdivided, with the same group proportions as in the original unit, then the sorting measure should remain unchanged. A measure is size invariant if its value is unchanged when the number of persons in each group in each area is multiplied by a constant factor. According to the principle of transfers, if an individual is relocated from one unit to another unit, where the proportion of persons in the group is greater in the former unit, then sorting will decrease. The principle of exchanges states that if an individual in group g in area a is exchanged with an individual in a different group in a different area, with the proportion of persons in the respective groups being greater in their original areas units, then sorting will decrease.

The most important and well-known dimension of residential sorting is evenness (Johnston et al. 2002). The *Index of Dissimilarity* (Duncan and Duncan 1955) is a measure of evenness that reflects the proportion of people in a population subgroup that would have to relocate in order to make their distribution identical to that of the reference group. When the same index is computed between one group and all other groups combined, the index is sometimes referred to as the *Index of Segregation* (Maré et al. 2011), although the term ‘segregation index’ in the literature can also be the generic term that refers to any of the sorting measures. The *Index of Dissimilarity* and the *Index of Segregation* range between 0 (the two groups are identically distributed spatially) and 1 (in any area only one group or the other is represented but never both). A high value represents a high level of residential sorting—most of the group members live in an area where other groups are relatively absent (Duncan and Duncan 1955). In contrast, the *Index of Isolation* is a measure of exposure and is used to measure the degree to which individuals locate with other members of their own group (Duncan and Duncan 1955).

Many studies have noted the weaknesses of using such measures of residential sorting, as they are sensitive to many factors (Duncan and Duncan 1955; White 1983; Carrington and Troske 1997; Fossett 2017). For example, the traditional measures of residential sorting described above are only global measures because they summarise residential sorting for the entire region under study (Wong 2002). Hence they do not capture differences in sorting between parts of the overall region.

White (1983) identified faults in using the *Index of Dissimilarity* to measure residential sorting. He stated that the values of this measure are sensitive to the group sizes, as well as to the size and number of the areal units. He added that all measures of residential sorting that are related to the *Index of Dissimilarity* have the same disadvantages. Moreover, the *Index of Dissimilarity* does not obey the principles of transfers and exchanges (White 1986; Reardon and Firebaugh 2002). Voas and Williamson (2000) note that even when there is random distribution, the *Index of Dissimilarity* can give highly misleading results when the area population is small or the group proportion is low. They add that the value of the index is also difficult to interpret when there are more area units under consideration than minority individuals (the minimum value of the *Index of Dissimilarity* then rises very rapidly with the number of area units). Moreover, the *Index of Dissimilarity* does not capture changes in the level of residential sorting when population groups in different area units are swapped (Wong 2002), demonstrating that it fails to obey the exchange principle.

Carrington and Troske (1997) note that the *Index of Segregation* and the *Index of Isolation* can suggest the presence of substantial residential sorting, even when there is an absence of residential sorting behaviour, in the case of there being many small spatial units and for groups that form a small proportion of the overall population. This can be easily demonstrated by simulating random sorting, as Maré et al. (2012) show in the appendix to their paper. The *Index of Isolation* is sensitive to group size as well as group settlement patterns, being generally low for small groups and rising with increases in group size, even though the group's level of sorting may actually remain the same.

In the New Zealand context, Johnston et al. (2011) also note that the *Index of Dissimilarity*, and hence the *Index of Segregation* as well, can give misleading results when there are small groups. They argue that the best approach to measuring residential sorting is therefore to report multiple indices. In their study, they calculate the *Index of Segregation* and the *Index of Isolation* for 25 ethnic groups in Auckland, using 1996 New Zealand Census data. They show that the smallest groups are the most segregated according to the *Index of Segregation* values, and that there is also a close relationship between a group's size and the *Index of Isolation* values. Maré et al. (2012) show that, when they randomly allocate group members across spatial units, the *Index of Segregation*, *Gini coefficient,* and the *Maurel and Sédillot Index of Concentration* all suggest the presence of substantial residential sorting even when there is none. However, despite the inappropriateness of the traditional measures, they continue to be used because of the simplicity of their calculation, their ease of interpretation, and their comparability with past studies.

The *Entropy Index of Segregation* (also called the *Information Theory Index*) was originally proposed by Theil (1972) as another measure of evenness, i.e. this measure also suggests the degree to which groups are unevenly distributed among area units (Denton and Massey 1988). The *Entropy Index of Segregation* measures the area unit population-weighted average difference between an area unit's group proportion and the group proportion in the city or region as a whole (Theil 1972).

Reardon and Firebaugh (2002) evaluated a set of six multi-group segregation indices following the principles introduced by James and Taeuber (1985) that we outlined earlier. They found that the *Entropy Index of Segregation* is the only multi-group measure of residential sorting that obeys the principles of organisational equivalence, size invariance, transfers, and exchanges. Moreover, this measure has the added advantage that it can be decomposed into a sum of between-group and within-group components (Theil 1972; Nijkamp and Poot 2015). Despite having many favourable properties, until now relatively few studies have used the *Entropy Index of Segregation* as a measure of residential sorting. Most of those studies are based on U.S. data (Wright et al. 2014; Parry and van Eeden 2015; Fowler et al. 2016; Lichter et al. 2017).

Though previous studies have identified the presence of group-size bias in the traditional measures of residential sorting, there has been to date relatively little systematic analysis of this. Group-size bias is an important issue because the interpretation and comparison of groups and areas in terms of residential sorting is affected by the choice of the number (and hence size) of groups included within the calculation of the indices. Thus, in this chapter we compare the two traditional measures of residential sorting and the *Entropy Index of Segregation*, in terms of their sensitivity to group size. Specifically, we demonstrate in four different ways the group-size bias of each measure and show that the *Entropy Index of Systematic Segregation* (which has expected value zero under random sorting) is the least affected by this bias.

7.3 Data

Auckland is the most ethnically diverse region in New Zealand. According to the 2013 Census,[3] the ethnic composition of its population at the time was: European (59.3%); Asian (23.1%); Pacific Islander (14.6%); Māori (10.7%); Middle Eastern, Latin American and African (MELAA, 1.9%); and Other Ethnicity (1.2%) (Statistics New Zealand 2013a).[4] Auckland is also the most populous of the 16 regions in New Zealand. It alone accounts for about one-third of the New Zealand population of close to five million. Auckland can be considered a very good example of a

[3]The most recent population census was held on March 6, 2018. At the time of collecting the data for this chapter, the results of that census were not yet available. In any case, due to non-response issues, 2018 Census data are of somewhat lesser quality than previous censuses with respect to variables such as ethnicity. Additionally, caution is needed in comparing results of the 2018 Census with those of previous censuses. See 2018 Census External Data Quality Panel (2020) *Final report of the 2018 Census External Data Quality Panel*. Retrieved from www.stats.govt.nz.

[4]The sum of these percentages exceeds 100 percent, as people can report more than one ethnicity.

modern EthniCity (Johnston et al. 2002) or superdiverse city (Spoonley 2014; Vertovec 2019). It is therefore a suitable focus for our empirical analysis.

We obtained population data from the 1991, 1996, 2001, 2006, and 2013 New Zealand Census of Population and Dwellings for the Auckland region of New Zealand. The New Zealand Census of Population and Dwellings collects information on each person present in New Zealand on census night. For usually resident individuals the census provides a range of information about each person, including location, age, sex, ethnicity, income level, occupation, education, marital status, etc., which can be aggregated to population statistics at the meshblock level.[5] The Auckland region is made up of 413 land-based area units,[6] of which 409 had a non-zero usually resident population in 2013. Area units with no usually resident population were excluded from the analysis. Unit record data were accessed within Statistics New Zealand's secure data laboratory to meet the confidentiality and security rules according to the Statistics Act 1975. In accordance with the strict confidentiality rules laid down by Statistics New Zealand, the summary statistics, counts, and calculations are based on data that have been suppressed for raw counts less than six and otherwise randomly rounded to base three.[7]

Self-reported ethnic identification is collected in the census, and each person can choose a single or multiple ethnic response. An individual reporting more than one ethnicity is included in each ethnic group that they report (this is referred to as 'total count' ethnicity) (Statistics New Zealand 2015). According to the New Zealand Standard Classification of Ethnicity, ethnicity is classified in a hierarchy of four levels (Statistics New Zealand 2013b). The main (Level 1) ethnic groups defined in the 2006 and 2013 Census by Statistics New Zealand are: New Zealand European; Māori; Pacific peoples; Asian; Middle Eastern, Latin American and African (MELAA); and Others (Statistics New Zealand 2013b). Previous research on ethnicities in New Zealand, such as Maré et al. (2012), have only investigated ethnic residential sorting using Level 1 ethnic groups. As there is considerable diversity in the characteristics and choices within most of these broad ethnic groups, we use data on Level 2 ethnic groups (total responses) instead. Level 1 and Level 2 classifications

[5] A meshblock is the smallest geographic unit for which Statistics New Zealand collects statistical data. Meshblocks vary in size from part of a city block to large areas of rural land. The country is divided into about 50,000 meshblocks that are aggregated to about 2000 area units. Our analysis is based on data aggregated to the area unit level. Area units are non-administrative areas that are in between meshblocks and territorial authorities in size (Statistics New Zealand 2013b). In urban areas, area units are approximately the size of individual suburbs, and in our dataset they have an average population of 1530.

[6] In this chapter, we use 2013 area unit boundaries.

[7] Counts that are already a multiple of three are left unchanged. Those not a multiple of three are rounded to one of the two nearest multiples. For example, a one will be rounded to either a zero or a three. Each value in a table is rounded independently.

Table 7.1 Level 1 and Level 2 classification and counts of ethnic groups in New Zealand, 2013

Ethnic group code (Level 1)	Ethnic group code description (Level 1)	Total responses	Ethnic group code (Level 2)	Ethnic group code description (Level 2)	Total responses
1	European	2,969,391	10	European not further defined	26,472
			11	NZ European	2,727,009
			12	Other European	268,044
2	Māori	598,605	21	NZ Māori	598,605
3	Pacific peoples	295,941	30	Pacific Island not further defined	1026
			31	Samoan	144,138
			32	Cook Island Māori	61,077
			33	Tongan	60,333
			34	Niuean	23,883
			35	Tokelauan	7173
			36	Fijian	14,445
			37	Other Pacific Island	11,925
4	Asian	471,708	40	Asian not further defined	4623
			41	Southeast Asian	77,430
			42	Chinese	164,949
			43	Indian	154,449
			44	Other Asian	82,242
5	MELAA	46,953	51	Middle Eastern	20,406
			52	Latin American/Hispanic	13,182
			53	African	13,464
6	Other	67,752	61	Other ethnicity	67,752
Total responses all ethnic groups		4,450,350			4,542,633

Source: Statistics New Zealand (2013c)

along with the number of total responses for each ethnic group in New Zealand are shown in Table 7.1.[8]

The format of the question about ethnicity in the Census of Population and Dwellings was inconsistent between the Censuses from 1991 to 2001. The format in 2001 was similar to that of 1991, but both differed to that of 1996.[9] Thus,

[8]The sum of Level 2 total responses in Table 1 is greater than the sum of Level 1 total responses because some individuals reported multiple ethnicities at Level 2 for which some or all belonged to the same ethnic group at level 1.

[9]The ethnicity question in the 1996 Census had a different format from that used in 1991 and 2001. In 1996, there was an answer box for 'Other European' with additional drop down answer boxes for 'English', 'Dutch', 'Australian', 'Scottish', 'Irish', and 'other'. These were not used in 1991 or

comparability across censuses is likely to be affected. Consequently, there were some significant changes in the responses in 1996 compared to 1991 or 2001 that were likely to have been caused by the change in the wording of the question. These included increased multiple response in 1996, a consequent reduction in single responses, and a tendency for respondents to answer the 1996 question on the basis of ancestry (or descent) rather than ethnicity (or cultural affiliation). For example, van der Pas and Poot (2011) noted that almost 48,000 people identified themselves as Dutch in the 1996 Census but at the time of the 2001 and 2006 census there were only close to 29,000 people in New Zealand who identified themselves as Dutch. According to van der Pas and Poot (2011), this huge difference between the 1996 and the subsequent two censuses was the result of the 1996 Census question on ethnicity including Dutch as a specific option. The resulting inconsistencies mainly appear for the 'European' ethnic groups (including 'New Zealand European') and the 'Māori' ethnic group. In the 1996 data, the counts for 'Other European' were much higher and the counts for the 'New Zealand European' category were much lower than in the 1991 or 2001 data. This can be attributed to the fact that, in 1996, people saw the additional 'Other European' category as being more suitable to describe their ethnicity than the 'New Zealand European' category (Statistics New Zealand 2017).

In addition, many people choose 'New Zealander' as their ethnicity in the Census. This term was introduced in the 2001 census. Its assignment in the classification has changed over time. In 2001, 'New Zealander' was counted in the New Zealand European category. But from 2006 onwards, New Zealander has instead been included as a new category, as part of the 'Other' ethnicities. The increase in counts for the New Zealand European category from 2006 to 2013 is attributed partly due to fewer people identifying themselves as 'New Zealander' in 2013.

The changing ethnic classifications can have an impact on the comparison of sorting measures across groups and over time. However, they should have little effect on our analysis of group-size effects. In any case, we will control for differences between censuses by means of time-fixed effects in our regression models.

2001. Furthermore, the first two answer boxes for the question were in a different order in 1996 from 1991 and 2001. 'NZ Māori' was listed first and 'NZ European or Pakeha' was listed second in 1996. The 1991 and 2001 questions also only used the words 'New Zealand European' rather than 'NZ European or Pākehā' (Pākehā is the Māori word referring to a person of European descent). The 2001 question used the word 'Māori' rather than 'NZ Māori'. The format of the 2006 and 2013 questionnaire was the same as that of 2001 (Statistics New Zealand 2017).

Table 7.2 Summary measures of residential sorting

Index of segregation	$\mathrm{ISeg}_g = \frac{1}{2}\sum_{a=1}^{A}\left\lvert \frac{P_{ga}}{P_{g.}} - \frac{(P_{.a}-P_{ga})}{(P_{..}-P_{g.})}\right\rvert$
Index of isolation	$\mathrm{IIsol}_g = \frac{\left(\left[\sum_{a=1}^{A}\pi_{ga}\frac{P_{ga}}{P_{.a}}\right]-\frac{P_{g.}}{P_{..}}\right)}{\left(1-P_{g.}/P_{..}\right)}$
Entropy index of segregation	$\mathrm{EIS}_g = \sum_{a=1}^{A}\frac{P_{.a}}{P_{..}}\left(1-\frac{E_a}{\overline{E}}\right)$ where $E_a = -\frac{P_{ga}}{P_{.a}}\ln\left(\frac{P_{ga}}{P_{.a}}\right)-\left(1-\frac{P_{ga}}{P_{.a}}\right)ln\left(1-\frac{P_{ga}}{P_{.a}}\right)$ $\overline{E} = -\frac{P_{g.}}{P_{..}}\,ln\left(\frac{P_{g.}}{P_{..}}\right)-\left(1-\frac{P_{g.}}{P_{..}}\right)ln\left(1-\frac{P_{g.}}{P_{..}}\right)$

P_{ga} refers to the population of group g (=1, 2,. . .G) in area a (= 1,2,. . .A). A subscript dot refers to the sum over that specific subscript. $\pi_{ga} = \frac{P_{ga}}{P_{g.}}$, hence $\sum_{a=1}^{A}\pi_{ga} = 1$. The calculation of *EIS* requires that we define 0*ln(1/0)= $\lim_{q\to 0}\left[q\left(\ln\left(1/q\right)\right)\right] = 0$ to account for any cases in which group g is not represented in an area a. These summary measures of residential sorting are defined in Iceland et al. (2002)

7.4 Methodology

As stated in the introduction, the aim of this chapter is to show the sensitivity of popular measures of residential sorting to group size. We achieve this aim using four steps.

First, we calculate the values of the *Index of Segregation*, *Index of Isolation,* and the *Entropy Index of Segregation* using the formulas outlined in Table 7.2, applied to census data for the Auckland region of New Zealand. High values of these indices represent more residential sorting by ethnicity. The values of these indices vary between 0 (when all areas have the same ethnic composition) and 1 (complete sorting). Each measure of residential sorting is calculated based on data aggregated to the area unit level. We calculate the values for all Level 2 ethnic groups in Auckland for all census years from 1991 to 2013. We proportionally distributed the population counts of the 'not further defined' category for each Level 2 ethnic group into the rest of Level 2 groups sharing the same Level 1 ethnic group.[10] We then use scatter plots to display the relationship between group size and the value of each index.

Second, following Maré et al. (2012) we simulate 100 random allocations of the population using a binomial distribution for each ethnic group. The simulated number of group members in an area unit is based on the total number of draws being equal to the actual area unit population and the probability of a person being a member of an ethnic group equal to the group's share of the total Auckland population. We then calculate the values of the indices in each of these

[10]We also ran the analysis with not further defined as a separate category, as well as dropping them completely. The ranking of groups, the trends over time, and our key conclusions are not affected.

100 independently simulated random allocations. We take the average of these index values as our estimate of the sorting that would be observed had the allocation across area units been random.

In the absence of bias, the expected value of a measure of sorting should be equal to zero when we calculate the indices based on the randomised data. In other words, in the case of randomly allocating people across areas (but taking into account area populations), there should be ideally no relationship between group size and measures of residential sorting. We use scatter plots and simple linear regression to show that this is not the case for the conventional measures of residential sorting. To check the statistical significance of the effect of group size in relation to the different index values, we ran simple ordinary least squares (OLS) regression of each index value on group size (logarithmic scale), with census fixed effects added to the regression (accounting for growth in the Auckland population). However, the effect of group size identified using OLS could be spurious because of unobserved heterogeneity by ethnicity. To account for this and to again account for the change in average group size across censuses, we also ran regressions with group fixed effects and time-fixed effects, using the fixed effect (FE) panel data estimator.

In the third part of our analysis we calculate a modified version of each of the standard segregation measures, following Carrington and Troske (1997). These authors refer to such a modified sorting measure as an index of systematic segregation, which has an expected value of zero under random sorting. When such an index yields a positive value, it measures the amount of excess sorting that would occur if allocation across area units is not random.[11] We calculate the systematic index values IS for the sorting index I, where I is the *Entropy Index of Segregation* or the *Index of Segregation* by means of the formula: $\mathrm{IS} = \frac{(I - I_R)}{(1 - I_R)}$, where I is the index value based on actual data and I_R is the average of the index values based on randomised data.

Following Maré et al. (2012), we calculate the *Index of Systematic Isolation* using the formula: ISIsol: $= \left(\left[\sum_{a=1}^{A} \boldsymbol{\pi}_{ga} \frac{P_{ga}}{P_{.a}} \right] - \left(\sum_{a=1}^{A} \boldsymbol{\pi}_{ga} \frac{P_{ga}}{P_{.a}} \right)_R \right) / \left(\mathbf{1} - \left(\sum_{a=1}^{A} \boldsymbol{\pi}_{ga} \frac{P_{ga}}{P_{.a}} \right)_R \right)$. The subscript R refers to the average of values based on randomised allocations. We run again OLS and FE linear regression to identify the relationship between group size and the different measures of systematic residential sorting.

Finally, we define the bias for each index as $I - \mathrm{IS}$, where I is an index value based on actual data and IS the value of the corresponding index of systematic sorting. We calculate the bias for each index and plot these against group size (on a logarithmic scale).

[11] Fossett (2017) has introduced an alternative way of generating sorting measures that will have an expected value of zero under random sorting.

7.5 Results and Discussion

As stated in the introduction, the aim of this chapter is to show that the selected measures of residential sorting are sensitive to (and hence, biased by) group size and propose the best index among these to measure residential sorting. We calculate the values of the measures of residential sorting, for each ethnic group in Auckland, using 1991–2013 census data (Appendix Table 7.7). We have multiplied the index values by 100 for easy interpretability.

Next, for each population subgroup, we simulate 100 random allocations using a binomial distribution.[12] As expected, we see that under random spatial allocation the values of the sorting indices are always less than the values based on actual data.

We now plot these index values based on actual data as well as the average values of sorting indices under random allocation, pooled across all five censuses, against group size, in Fig. 7.1. We use a logarithmic scale for group size. The panels in Fig. 7.1 show that in the case of residential sorting indices based on both actual data and randomised allocation, there is a relationship between each residential sorting measure and group size. Panel (a) shows the relationship between the *Index of Segregation* values and group size. The scatter plot clearly shows that larger groups have lower *Index of Segregation* values, i.e. large groups are less residentially sorted than small groups in Auckland.

Similarly, Panel (b) shows the relationship between the *Index of Isolation* and group size. The scatter plot shows that in the case where the index value is based on actual data, for larger groups, values of this measure are larger.[13] We observe that, under random sorting, the *Index of Isolation* values appear to be almost zero irrespective of group size. When using a different scale on the vertical axis (see Appendix Fig. 7.3), it can be shown that there is very little effect of group size on the *Index of Isolation* for small and medium group sizes under random spatial allocation. In contrast, the index is somewhat less for the largest group sizes.

The relationship between the *Entropy Index of Segregation* and group size is shown in Panel (c). As in the case of the *Index of Segregation*, the *Entropy Index of Segregation* values also decrease with increases in group size. This is not surprising, because the *Index of Segregation* and the *Entropy Index of Segregation* values are in applications often highly positively correlated. This can be seen in Table 7.3 for our Auckland data. With sorting observed for 18 groups in 5 census years, $N = 90$. The

[12]Appendix Table 7.8 reports the average of index values obtained from the 100 simulations. We have multiplied the index values by 100 for easy interpretability.

[13]It can be easily shown by calculus that for a given spatial distribution of the group across areas, the *Index of Isolation* is non-decreasing in total group size. It should also be noted that the *Index of Segregation* is scale free in the total size in the group of interest for a given spatial distribution of this group. No simple mathematical result can be established in the case of the *Entropy index of Segregation*. This is because, even if E_a is scale-invariant for a given distribution of group g across areas, $\overline{E}$ and $\frac{P_{.a}}{P_{..}}$ depend on how relatively important the group g is in the population and in each area unit 'a', respectively. This group size effect has been investigated previously by Fossett (2017) in empirical terms with US data.

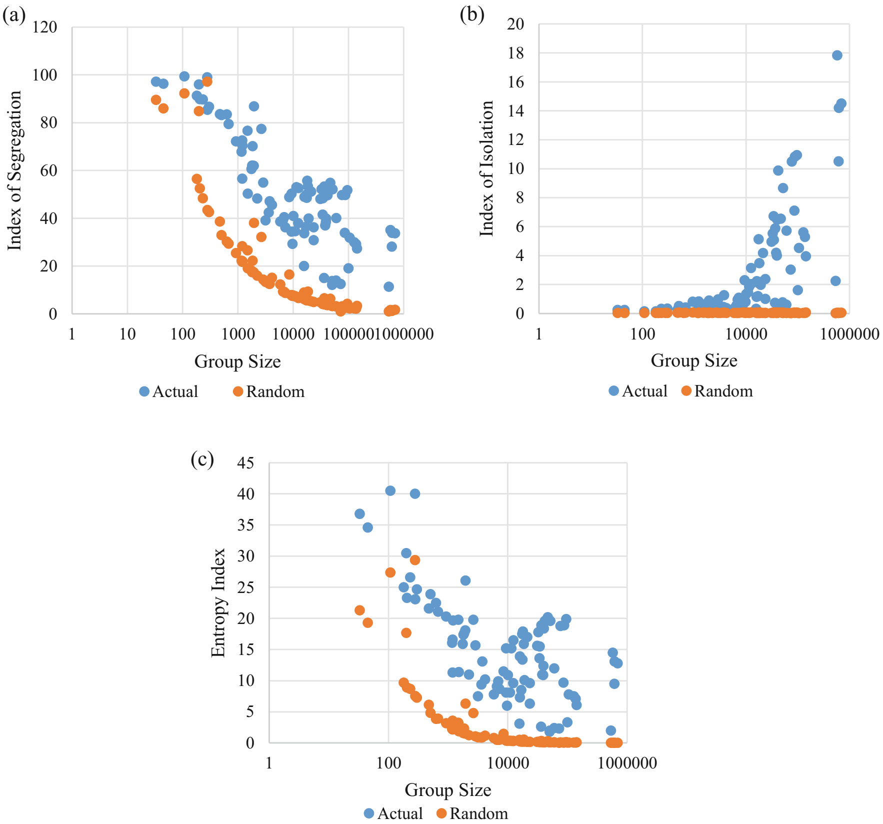

Fig. 7.1 Scatter plots of index values and group sizes, based on randomised and actual data: Auckland region, 1991–2013

Table 7.3 Correlation between the three sorting measures

	Index of segregation	Index of isolation	Entropy index of segregation
Index of segregation	1.000		
Index of isolation	−0.3027*** (0.0037)	1.000	
Entropy index of segregation	0.9306*** (0.000)	−0.0627 (0.5574)	1.000

$N = 90$ (18 ethnic groups × 5 census years)
p-values in parentheses,* $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$

Table 7.4 Effect of group size on sorting indices

(a) Regression results from actual data						
	OLS			FE		
	ISeg (1)	IIsol (2)	EIS (3)	ISeg (4)	IIsol (5)	EIS (6)
Log group size	−8.466*** (0.634)	1.252*** (0.13)	−2.366*** (0.304)	−13.063*** (1.010)	0.245 (0.248)	−5.534*** (0.458)
R^2 within				0.78	0.17	0.75
R^2 between				0.70	0.67	0.34
R^2 overall	0.70	0.54	0.47	0.75	0.41	0.44
(b) Regression results from randomised data						
Log group size	−8.000*** (0.611)	0.00049 (0.00043)	−1.676*** (0.201)	−15.399*** (0.867)	0.005*** (0.001)	−4.141*** (0.314)
R^2 within				0.87	0.78	0.78
R^2 between				0.70	0.00	0.47
R^2 overall	0.71	0.68	0.51	0.68	0.45	0.47

Notes: $N = 90$ (18 ethnic groups × 5 census years)
Standard errors in parentheses,* $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$
OLS = Ordinary least square regression with census fixed effects
FE = Fixed effect regression with group and census fixed effects
ISeg = *Index of Segregation*
IIsol = *Index of Isolation*
EIS = *Entropy Index of Segregation*

Pearson correlation coefficient between the *Index of Segregation* and the *Entropy Index of Segregation* is about 0.93. However, the *Index of Segregation* is weakly inversely correlated with the *Index of Isolation* (with a correlation coefficient of about −0.3), while there is no statistically significant correlation between the *Entropy Index of Segregation* and the *Index of Isolation*.

As noted in Sect. 7.4, to check the statistical significance and size of the effect of group size in relation to the different index values, we ran a simple linear regression of each index value on group size (logarithmic scale), with census fixed effects added to the regression, using the ordinary least square (OLS) estimation method and also with census and groups fixed effects, using the panel fixed effect estimation (FE) method. The results are shown in Table 7.4.

Columns (1)–(3) of Table 7.4 report the estimators from the OLS regressions, whereas columns (4)–(6) report the same for the FE regressions. Part (a) of the table reports the statistical significance of group size (logarithmic scale) in relation to the different index values based on the actual data. From columns (1) to (3) of part (a) of

Table 7.4, we observe that group size is statistically significantly correlated with all the measures, at the 1% level of significance. However, in the case of the *Entropy Index of Segregation*, we see that the coefficient for group size (−2.37) is much smaller in absolute value than for the *Index of Segregation* (−8.47), even though they are similar measures. From columns (4) to (6), we see that group size is statistically significantly correlated with the *Index of Segregation* and the *Entropy Index of Segregation,* at the 1% level of significance. Again, we see that the coefficient for group size (−5.53) is much smaller in absolute value for the *Entropy Index of Segregation* than for the *Index of Segregation* (−13.06). We observe that the coefficient for group size for the *Index of Isolation* from both the OLS regression (1.25) and the FE regression (0.25) is smaller in absolute value than for the other two measures. However, we note that the *Index of Isolation* is not directly comparable to the *Entropy Index of Segregation*, as it measures a different aspect of the population distribution. The *Index of Isolation* for any group *g* measures the degree to which individuals of group *g* co-locate with other members of their own group, whereas the other index measures the extent to which group *g* is concentrated in particular areas.

When we check the statistical significance of group size (logarithmic scale) in relation to the different index values based on randomised data, by running simple linear regression with census fixed effects, we observe that group size is statistically significantly correlated with both *Entropy Index of Segregation* and *Index of Segregation* (Table 7.4, part (b), columns (1) and (3)). However, we observe that the absolute value of the coefficient for group size is again much smaller for the *Entropy Index of Segregation* (−1.68) than for the *Index of Segregation* (−8.00) and thus the *Entropy Index of Segregation* is less affected by group size in the case of random sorting. We saw in Fig. 7.1 that the *Index of Isolation* values after randomisation are almost zero and column (2) in part (b) of Table 7.4 shows that there is no statistically significant relationship between the isolation measure and group size with randomised sorting. Results from the FE regression show that group size is statistically significantly correlated with all the measures, at the 1% level of significance (Table 7.4, part (b), columns (4), (5), and (6)). Again, we find that the coefficient for group size for the *Entropy Index of Segregation* (−4.14) is much smaller in absolute value than that of the *Index of Segregation* (−15.4).

Following Carrington and Troske (1997), we next calculate the *Index of Systematic Segregation* for each index (Appendix Table 7.9)[14] and then check the statistical significance of the relationship with group size (logarithmic scale) using simple linear regression with census fixed effects (Table 7.5, columns (1), (2), and (3)) and fixed effect regression with group and census fixed effects (Table 7.5, columns (4), (5), and (6)). From columns (1) to (3), we see that all three of the indices of systematic segregation are sensitive to group size, with the effect being statistically significant at the 1% level in all three cases. However, the coefficient of log group size in the regression for the *Index of Systematic Segregation* (−6.43) is much more negative than is the case for the *Entropy Index of Systematic Segregation* (−0.98).

[14]We have multiplied the index values by 100 for easy interpretability.

Table 7.5 Effect of group size on indices of systematic segregation

	OLS			FE		
	ISSeg (1)	ISIsol (2)	EISS (3)	ISSeg (4)	ISIsol (5)	EISS (6)
Log group size	−6.432*** (0.648)	1.254*** (0.130)	−0.980*** (0.243)	−10.015*** (1.107)	0.244 (0.249)	−2.112*** (0.329)
R^2 within				0.64	0.17	0.50
R^2 between				0.56	0.67	0.13
R^2 overall	0.57	0.54	0.20	0.64	0.34	0.19

Notes: $N = 90$ (18 ethnic groups x 5 census years)
Standard errors in parentheses,* $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$
OLS = Ordinary least square regression with census fixed effects
FE = Fixed effect regression with group and census fixed effects
ISSeg = *Index of Systematic Segregation*
ISIsol = *Index of Systematic Isolation*
EISS = *Entropy Index of Systematic Segregation*

The *Index of Systematic Isolation* is positively related to log group size. From columns (4), (5), and (6) we observe that the *Index of Systematic Segregation* and the *Entropy Index of Systematic Segregation* are sensitive to group size, at 1% level of significance. Again, the coefficient of log group size for the *Index of Systematic Segregation* (−10.01) is much more negative than that of the *Entropy Index of Systematic Segregation* (−2.11).

Comparing the values from Table 7.4, part (a), columns (1)–(6), with those of Table 7.5, we conclude that the *Entropy Index of Systematic Segregation* is the best measure, as the coefficient of group size for this measure both in the case of OLS (−0.98) and FE (−2.11) is much smaller in absolute terms than in the case of the *Index of Systematic Segregation* based on actual data.

Finally, we calculate the bias values for each of the three original indices and plot them against group sizes (on a logarithmic scale) in Fig. 7.2. The bias decreases with increases in group size in the case of the *Index of Segregation* and the *Entropy Index of Segregation*. However, we note that group size has a far less notable effect on the bias defined as the difference between the *Index of Isolation* and the Maré et al. (2012) modification of this original index. Recall that under random sorting the values of the *Index of Isolation* itself appear to be almost zero irrespective of group size (see Fig. 7.1, panel (b)).

We run a simple OLS regression, with census fixed effects (Table 7.6, columns (1), (2), and (3)), and also FE regression with group and census fixed effects (Table 7.6, columns (4), (5), and (6)) to see the relationship between the index bias and the group size (on a logarithmic scale). From the OLS estimation results, we find that group size is negatively related to the index bias values, with statistical significance at the 1% level in all three cases. Moreover, we observe that the coefficient for the *Entropy Index of Segregation* (−1.39) is somewhat smaller in absolute terms than the coefficient for the *Index of Segregation* (−2.03), while the

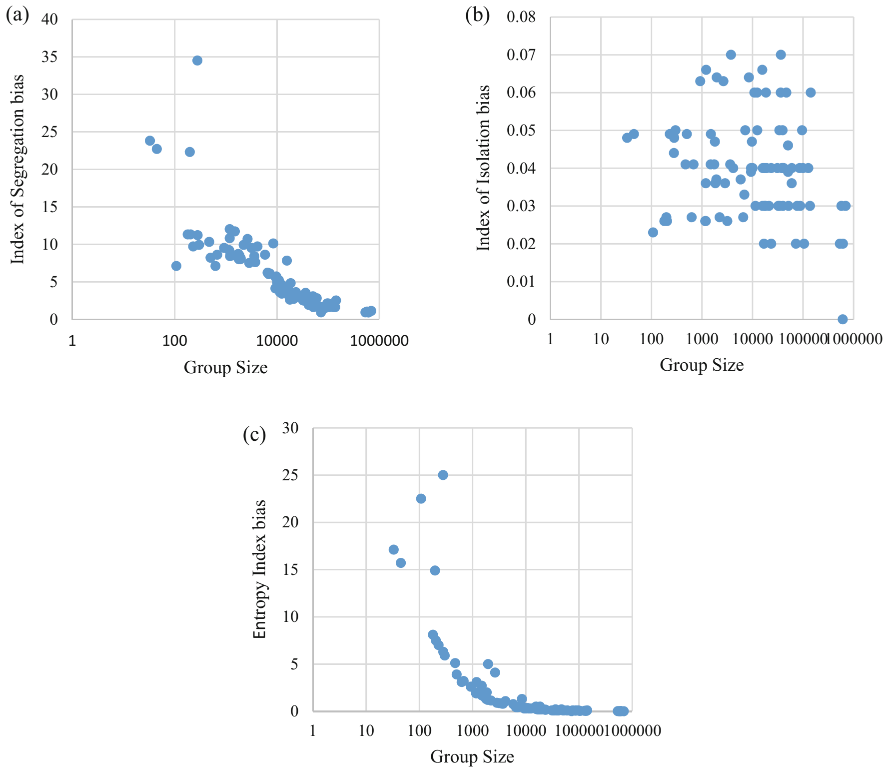

Fig. 7.2 Scatter plot of index bias and group size

effect of group size on bias is very little indeed for the Index of Isolation.[15] While the decline in the bias with group size is somewhat greater with the *Index of Segregation* than with the *Entropy Index of Segregation*, the bias of the latter is generally smaller. We observe this from our results from the FE regression. From columns (4) and (6) we see that the decline in bias for *Entropy Index of Segregation* (−3.42) with increase in group size (for a given group) is greater than that for the *Index of Segregation* (−3.05).

Overall, our results show that all sorting measures considered are sensitive to group size. However, we find that the *Entropy Index of Systematic Segregation* is much less affected by group size than the *Index of Systematic Segregation*. Moreover, the *Entropy Index of Systematic Segregation* is an unbiased index because it has an expected value zero with randomisation (Carrington and Troske (1997).

[15]Because regression coefficients are linearly related to the dependent variable, the coefficients in Table 6 can of course also be obtained by subtracting the coefficients in Table 5 from the corresponding columns in Table 4. However, Table 6 also reports the R^2 (within, between, and overall) and the correct standard errors of the regressions of bias on group size.

Table 7.6 Effect of group size on sorting index bias (difference between original measures and systematic indices)

	OLS			FE		
	ISeg-ISSeg (1)	IIsol-ISIsol (2)	EIS-EISS (3)	ISeg-ISSeg (4)	IIsol-ISIsol (5)	EIS-EISS (6)
Log group size	−2.034*** (0.163)	−0.002*** (0.00033)	−1.387*** (0.167)	−3.048*** (0.427)	0.001* (0.001)	−3.422*** (0.259)
R^2 within				0.50	0.85	0.78
R^2 between				0.82	0.55	0.46
R^2 overall	0.67	0.78	0.50	0.66	0.57	0.47

Notes: $N = 90$ (18 ethnic groups × 5 census years)
Standard errors in parentheses,* $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$
OLS = Ordinary least square regression with census fixed effects
FE = Fixed effect regression with group and census fixed effects
ISeg = *Index of Segregation*; ISSeg = *Index of Systematic Segregation*
IIsol = *Index of Isolation*; ISIsol = *Index of Systematic Isolation*
EIS = *Entropy Index of Segregation*; EISS = *Entropy Index of Systematic Segregation*

7.6 Conclusion

The aim of this chapter is to demonstrate the sensitivity of alternative measures of residential sorting to group size. The traditional measures included in our study are the *Index of Segregation* and the *Index of Isolation*. Both of these measures have a positive bias in that their expected value under a random spatial distribution is positive rather than zero. We show empirically that this bias is affected by group size. As residential sorting is affected by not only the distribution of population but also the relative size of population groups, the interpretation and comparison of groups and areas in terms of residential sorting using these measures is problematic because of their sensitivity to group size. In contrast, while the *Entropy Index of Segregation* measure of residential sorting is also biased and the bias is also affected by group size, our empirical data demonstrate that the effect of group size on the index value is the least with the *Entropy Index of Systematic Segregation*.

We interpret the observed empirical relationship between the *Entropy Index of Systematic Segregation* values and group size as reflecting an underlying behavioural relationship observed in Auckland, in which larger groups are more evenly dispersed spatially, rather than just evidence of statistical bias. Moreover, the *Entropy Index of Segregation* also is the only multi-group measure of residential sorting that obeys the principles of organisational equivalence, size invariance, transfers, and exchanges (James and Taeuber 1985) and thus the same is true for the *Entropy Index of Systematic Segregation*.[16]

Our chapter provides evidence that the *Entropy Index of Systematic Segregation* measure of residential sorting is the measure of residential sorting (among those we tested) that is the least biased by group size. However, our empirical results are based on an analysis within a single region of New Zealand. Therefore, these results should be corroborated by further analysis in other geographical contexts and with different numbers of groups and areas. In the meantime though, given the relationship we have identified between group size and measures of residential sorting, along with the desirable properties of entropy measures identified in the literature (James and Taeuber 1985), we strongly recommend using the *Entropy Index of Systematic Segregation* for analysing residential sorting. We also recommend that some conclusions of past studies of residential sorting should be re-interpreted in light of the potential for significant group-size bias in the results of these studies.

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Disclaimer The results in this chapter are not official statistics. They have been created for research purposes from census unit record data in the Statistics New Zealand Datalab. The opinions, findings, recommendations, and conclusions expressed in this chapter are those of the authors, not Statistics New Zealand. Access to the anonymised data used in this study was provided by Statistics New Zealand under the security and confidentiality provisions of the Statistics Act 1975. Only people authorised by the Statistics Act 1975 are allowed to see data about a particular person, household, business, or organisation and the results in this chapter have been confidentialised to protect these groups from identification and to keep their data safe. Careful consideration has been given to the privacy, security, and confidentiality issues associated with using unit record census data.

Appendix

Table 7.7

Table 7.8

Table 7.9

Fig. 7.3

[16]This is the case because the *Entropy Index of Systematic Segregation* is defined as $(E - E_R)/(1 - E_R)$ and the expected value of E_R is constant across different realisations of the actual spatial distribution of the group. Hence the *Entropy Index of Systematic Segregation* is a simple linear transformation of the *Entropy Index of Segregation.* Since the latter index satisfies the James and Taeuber (1985) criteria, the former does also.

Table 7.7 Measures of residential sorting based on actual data: Auckland region, 1991–2013

Year	1991				1996				2001				2006				2013			
Ethnicity	Group Size	*ISeg*	*IIsol*	*EIS*	Group Size	*ISeg*	*IIsol*	*EIS*	Group Size	*ISeg*	*IIsol*	*EIS*	Group Size	*ISeg*	*IIsol*	*EIS*	Group Size	*ISeg*	*IIsol*	*EIS*
New Zealand European	574,932	35.1	17.83	14.5	536,606	11.3	2.25	2	616,859	33.9	14.2	13.1	611,901	28.1	10.51	9.5	696,966	33.7	14.49	12.8
Other European	50,532	13.7	0.769	1.8	72,576	12.5	3.03	2.3	50,668	12.1	0.393	2	59,959	13.9	0.601	2.4	36,362	15	0.731	2.6
NZ Maori	85,926	33.9	7.09	9.7	105,213	31.9	4.52	7.8	127,704	29.9	5.61	7.5	137,304	29.2	5.29	7.1	142,767	27.3	3.94	6.1
Samoan	41,784	49.6	9.86	19.6	51,639	52.1	8.66	19.6	76,584	49.7	10.48	18.8	87,840	49.7	10.82	18.9	95,916	51.7	10.93	19.9
Cook Island Maori	17,466	49.9	5.13	17.5	21,234	51.2	4.17	17	31,077	48.1	4.95	15.6	34,371	48.4	5.08	15.5	36,546	53.3	5.88	18.9
Tongan	12,456	52.6	3.14	16.5	17,958	55.7	3.47	17.9	32,535	52.1	5.53	17.8	40,140	52	6.47	18.4	46,971	54.8	6.54	20.2
Niuean	9354	50.3	2.29	15.2	11,466	53	1.84	15.2	16,038	48.9	2.23	13.9	17,667	48.6	2.08	13.4	18,555	53.4	2.17	15.9
Tokelauan	504	83.2	0.512	23.9	627	83.5	0.316	22.5	1488	76.6	0.405	19.8	1848	70.2	0.399	17.6	1959	86.8	0.616	26.1
Fijian	1506	50.3	0.299	11.4	3174	39.1	0.212	7.5	4155	45.6	0.359	10.2	5847	38.6	0.335	7.8	8493	48.8	0.51	11.5
Other Pacific Island	300	86.6	0.334	24.7	1164	67.8	0.272	16.1	1755	60.6	0.564	15.9	2868	54.9	0.973	15.7	1212	70.4	0.834	19.7
Southeast Asian	1806	62.1	0.752	17.4	6561	39.3	0.556	9.1	9363	34.4	0.879	8.1	15,909	33.7	1.14	7.3	10,911	34.6	1.47	8.1
Chinese	9738	29.3	0.794	6	23,505	30.8	1.01	6.3	38,025	37	4.19	11	60,186	40.1	5.72	12	39,456	39.9	6.53	12.4
Indian	7209	36.2	1.09	8.7	16,905	36.4	1.19	8.5	23,484	36.2	2.37	9.6	39,262	38.4	3.99	10.9	34,064	41.5	6.72	13.6
Other Asian	231	89.7	0.313	26.6	2240	48.3	0.271	11	10,086	40.9	1.33	10.9	19,105	39.9	1.97	10.1	12,335	37.9	2.02	9.6
Middle Eastern	282	85.4	0.255	23.1	1194	56.6	0.138	11.3	3624	42.4	0.452	9.4	6897	40.5	0.963	9.9	3759	47.1	1.26	13.1
Latin American/ Hispanic	33	97.2	0.243	36.8	204	89.8	0.126	23.3	474	83.6	0.261	21.6	1194	72.6	0.222	16.6	2658	77.4	0.404	19.8
African	45	96.3	0.241	34.6	180	91.3	0.147	25	681	79.4	0.414	21.1	1932	62	0.889	18.1	927	72.2	0.805	20.3
Others	108	99.4	0.143	40.5	198	96	0.109	30.5	279	99	0.139	40	100,110	19	1.61	3.3	15,639	20	0.321	3.1

Note: *ISeg* Index of Segregation, *IISol* Index of Isolation, *EIS* Entropy Index of Segregation. We have multiplied the index values by 100 for easy interpretability

Table 7.8 Measures of residential sorting based on randomised data: Auckland region, 1991–2013

Year	1991				1996				2001				2006				2013			
Ethnicity	Group Size	*ISeg*	*IIsol*	*EIS*	Group Size	*ISeg*	*IIsol*	*EIS*	Group Size	*ISeg*	*IIsol*	*EIS*	Group Size	*ISeg*	*IIsol*	*EIS*	Group Size	*ISeg*	*IIsol*	*EIS*
New Zealand European	574,932	1.55	0.048	0.029	536,606	1.03	0.017	0.013	616,859	1.36	0.03	0.023	611,901	1.23	0.026	0.019	696,966	1.67	0.047	0.034
Other European	50,532	3.25	0.061	0.094	72,576	0.976	0.017	0.012	50,668	3.34	0.038	0.093	59,959	3.11	0.034	0.081	36,362	4	0.06	0.137
NZ Maori	85,926	2.47	0.057	0.061	105,213	2.31	0.024	0.048	127,704	2.26	0.035	0.05	137,304	2.2	0.032	0.047	142,767	3.28	0.058	0.099
Samoan	41,784	3.57	0.062	0.111	51,639	3.29	0.025	0.085	76,584	3.12	0.038	0.084	87,840	2.89	0.034	0.073	95,916	4.17	0.061	0.146
Cook Island Maori	17,466	5.61	0.064	0.23	21,234	5.21	0.026	0.181	31,077	4.89	0.039	0.174	34,371	4.56	0.036	0.152	36,546	6.53	0.063	0.303
Tongan	12,456	6.65	0.063	0.307	17,958	5.6	0.026	0.204	32,535	5.01	0.04	0.18	40,140	4.39	0.035	0.141	46,971	6.27	0.062	0.282
Niuean	9354	7.64	0.066	0.388	11,466	7.06	0.026	0.3	16,038	6.75	0.04	0.296	17,667	6.4	0.036	0.265	18,555	9.27	0.064	0.54
Tokelauan	504	32.9	0.062	4.83	627	30.2	0.026	3.87	1488	26.6	0.041	3.23	1848	22.2	0.037	2.31	1959	38	0.064	6.32
Fijian	1506	19	0.064	1.86	3174	13.4	0.026	0.918	4155	15.1	0.04	1.18	5847	12.3	0.036	0.802	8493	16.4	0.063	1.45
Other Pacific Island	300	42.6	0.027	7.29	1164	22.2	0.026	2.24	1755	18.1	0.041	1.64	2868	14.3	0.036	1.05	1212	22	0.064	2.47
Southeast Asian	1806	17.4	0.026	1.59	6561	9.32	0.026	0.485	9363	7.84	0.041	0.381	15,909	6.11	0.036	0.243	10,911	7.37	0.063	0.369
Chinese	9738	7.46	0.026	0.369	23,505	4.92	0.026	0.165	38,025	3.9	0.039	0.121	60,186	3.11	0.034	0.082	39,456	3.8	0.06	0.126
Indian	7209	8.73	0.026	0.483	16,905	5.79	0.026	0.215	23,484	4.98	0.04	0.18	39,262	3.87	0.035	0.116	34,064	4.13	0.06	0.143
Other Asian	231	48.4	0.026	8.68	2240	16	0.026	1.25	10,086	7.63	0.041	0.364	19,105	5.54	0.035	0.207	12,335	6.87	0.062	0.326
Middle Eastern	282	43.4	0.025	7.53	1194	21.7	0.026	2.15	3624	12.7	0.041	0.875	6897	9.17	0.037	0.484	3759	12.5	0.063	0.896
Latin American/Hispanic	33	89.5	0.027	21.3	204	52.5	0.026	8.91	474	38.6	0.042	6.13	1194	28.3	0.036	3.59	2658	32.2	0.065	4.81
African	45	86	0.027	19.3	180	56.5	0.026	9.7	681	29.4	0.041	3.9	1932	17.4	0.036	1.49	927	25.4	0.064	3.18
Others	108	92.2	0.028	27.4	198	84.8	0.027	17.7	279	97.2	0.042	29.4	100,110	2.52	0.033	0.058	15,639	8.9	0.063	0.502

Note: *ISeg* Index of Segregation, *IISol* Index of Isolation, *EIS* Entropy Index of Segregation. We have multiplied the index values by 100 for easy interpretability

Table 7.9 Systematic measures of residential sorting: Auckland region, 1991–2013

Year	1991				1996				2001				2006				2013			
Ethnicity	Group size	*IISeg*	*ISIsol*	*EISS*	Group size	*IISeg*	*ISIsol*	*EISS*	Group size	*IISeg*	*ISIsol*	*EISS*	Group size	*IISeg*	*ISIsol*	*EISS*	Group size	*IISeg*	*ISIsol*	*EISS*
New Zealand European	574,932	34.1	17.8	14.5	536,606	10.4	2.23	1.99	616,859	33	14.18	13.1	611,901	27.2	10.51	9.48	696,966	32.6	14.46	12.8
Other European	50,532	10.8	0.723	1.71	72,576	11.6	3.01	2.29	50,668	9.06	0.354	1.91	59,959	11.1	0.565	2.32	36,362	11.5	0.671	2.47
NZ Maori	85,926	32.2	7.05	9.64	105,213	30.3	4.5	7.76	127,704	28.3	5.57	7.45	137,304	27.6	5.26	7.06	142,767	24.8	3.88	6.01
Samoan	41,784	47.7	9.82	19.5	51,639	50.5	8.63	19.5	76,584	48.1	10.45	18.7	87,840	48.2	10.79	18.8	95,916	49.6	10.88	19.8
Cook Island Maori	17,466	46.9	5.09	17.3	21,234	48.5	4.14	16.8	31,077	45.4	4.91	15.5	34,371	45.9	5.05	15.4	36,546	50	5.81	18.7
Tongan	12,456	49.2	3.09	16.2	17,958	53.1	3.44	17.7	32,535	49.6	5.5	17.7	40,140	49.8	6.44	18.3	46,971	51.8	6.48	20
Niuean	9354	46.2	2.25	14.9	11,466	49.4	1.81	14.9	16,038	45.2	2.19	13.6	17,667	45.1	2.05	13.2	18,555	48.6	2.11	15.4
Tokelauan	504	75	0.463	20	627	76.4	0.289	19.4	1488	68.1	0.364	17.1	1848	61.7	0.363	15.6	1959	78.7	0.552	21.1
Fijian	1506	38.6	0.25	9.72	3174	29.6	0.186	6.64	4155	35.9	0.319	9.13	5847	30	0.298	7.05	8493	38.7	0.446	10.2
Other Pacific Island	300	76.7	0.284	18.8	1164	58.6	0.246	14.2	1755	51.9	0.523	14.5	2868	47.4	0.937	14.8	1212	62	0.768	17.7
Southeast Asian	1806	54.1	0.705	16.1	6561	33.1	0.529	8.66	9363	28.8	0.84	7.75	15,909	29.4	1.11	7.07	10,911	29.4	1.41	7.76
Chinese	9738	23.6	0.747	5.65	23,505	27.2	0.99	6.15	38,025	34.4	4.15	10.9	60,186	38.2	5.68	11.9	39,456	37.5	6.48	12.3
Indian	7209	30.1	1.04	8.26	16,905	32.5	1.17	8.3	23,484	32.9	2.33	9.44	39,262	35.9	3.95	10.8	34,064	39	6.67	13.5
Other Asian	231	80	0.264	19.6	2240	38.4	0.244	9.87	10,086	36	1.29	10.6	19,105	36.4	1.93	9.91	12,335	33.3	1.96	9.3
Middle Eastern	282	74.2	0.207	16.8	1194	44.6	0.112	9.4	3624	34	0.411	8.6	6897	34.5	0.93	9.46	3759	39.5	1.19	12.3
Latin American/Hispanic	33	73.4	0.195	19.7	204	78.5	0.1	15.8	474	73.3	0.22	16.5	1194	61.8	0.186	13.5	2658	66.7	0.341	15.7
African	45	73.6	0.192	18.9	180	80	0.121	16.9	681	70.8	0.373	17.9	1932	54	0.852	16.9	927	62.7	0.742	17.7
Others	108	92.3	0.12	18	198	73.7	0.082	15.6	279	64.5	0.095	15	100,110	16.9	1.57	3.24	15,639	12.2	0.255	2.61

Note: *ISSeg* Index of Systematic Segregation, *ISIsol* Index of Systematic Isolation, *EISS* Entropy Index of Systematic Segregation. We have multiplied the index values by 100 for easy interpretability

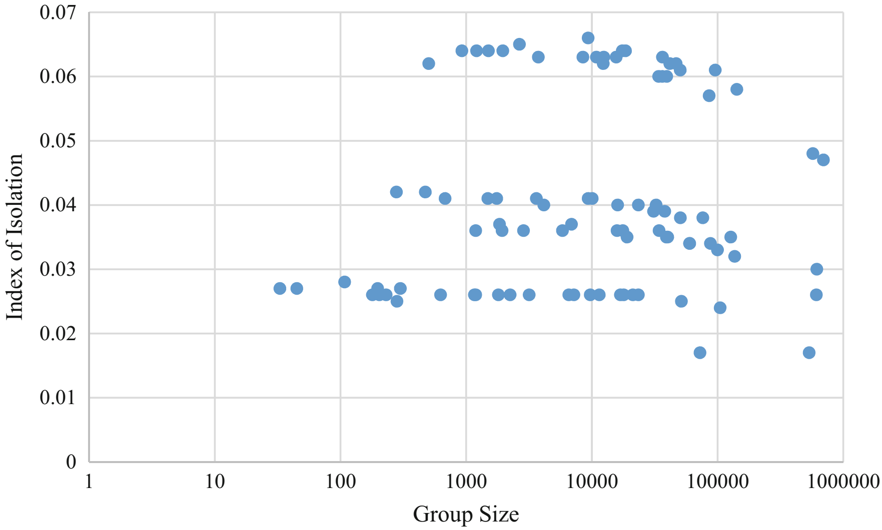

Fig. 7.3 Scatter plot of *Index of Isolation* values and group sizes, based on randomised data: Auckland region, 1991–2013

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Chapter 8
Entrepreneurial Interest of University Students in a Multicultural Society

Tüzin Baycan

Abstract This chapter aims to investigate the diverse attitudes, career motivations and perceived leadership skills of university students in the Netherlands and to analyse, compare and evaluate their entrepreneurial interest, inter alia on the basis of gender and ethnic differences. Since influences that affect career choice begin early in life, this chapter focuses on the *next generation of entrepreneurs* and on their career motivations, attitudes and self-perceptions. The data and information used for our comparative analysis are based on a survey conducted among students in the metropolitan area in the Netherlands including Amsterdam, Rotterdam, The Hague and Utrecht. The descriptive results of our comparative evaluation show that there are gender- and ethnic-based differences in entrepreneurial interest of university students. While interest in entrepreneurship as a career is higher among immigrant boys than natives and girls and boys are more motivated by 'external factors' such as family and friends, prestige and also financial gain, interest in entrepreneurship as a career is lower among girls than boys and girls are more motivated by 'internal factors' such as using own skills and abilities. The results of our comparative evaluation show also that factors such as being own boss, flexible, independent, etc. are equally important for both boys and girls.

Keywords Entrepreneurial interest · Entrepreneurial intention · Entrepreneurship as a career · Next generation of entrepreneurs · University students · Ethnic differences · Gender differences · Multicultural society · Netherlands

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8.1 Introduction

Today's students represent tomorrow's entrepreneurs and leaders, yet little is known about this generation's attitudes towards careers in business and entrepreneurship. While extensive research has been undertaken to better understand the motivations of adults in starting their own ventures, there is little insight into the motivations and needs of today's adolescents. Similarly, there is little understanding of the differences that exist between different ethnic groups and between the genders. Only a few empirical studies have examined the entrepreneurial propensity of university students as a source of future entrepreneurs.

Therefore, this chapter aims to examine the potential interest of both native and immigrant young people in entrepreneurship and the key factors affecting their interest. The objectives of the chapter are:

- to measure and compare the entrepreneurial interest of native and immigrant youth;
- to understand native and immigrant youth's attitudes and motivations towards careers in entrepreneurship;
- to evaluate gender- and ethnic-based differences in attitudes, self-perceptions and motivations towards entrepreneurship;
- to identify the possible features and composition of the future labour market in the Netherlands.

On the basis of these objectives, our chapter also aims to test three groups of hypotheses which cover ethnic- and gender-based entrepreneurial interest, motivations and risk-averse attitudes. These three groups of hypotheses are the following:

8.1.1 Hypotheses on Ethnic- and Gender-Based Entrepreneurial Interest

- The level of interest in entrepreneurship is related to ethnicity: immigrants' interest is higher. Therefore, interest in entrepreneurship as a career is lower among Dutch youth than among immigrant youth.
- The level of interest in entrepreneurship is related to gender: the males' interest is higher. Therefore, interest in entrepreneurship as a career is lower among female than among male students.

8.1.2 Hypotheses on Motivation

- Females interested in entrepreneurship are more likely to be motivated in their career choices by social and relational factors: Females are more motivated than

males by factors such as working with others, having good social relationships and earning respect.
- Male students interested in entrepreneurship are more likely to be motivated in their career choices by autonomy. Financial gain is a strong motivator for males in general.

8.1.3 Hypotheses on Risk-Averse Attitude

- Respondents with a low interest in entrepreneurship are more risk-averse than are those with high interest.
- Females are more likely to have a lower propensity for risk-taking in the current socio-economic context.

An overall objective of the chapter is to highlight the critical factors for an entrepreneurial future in a multicultural society. Therefore, the chapter focuses, in particular, on the multicultural environment in higher education in the Netherlands. Section 8.2 examines the entrepreneurial interest of university students as a source of future entrepreneurs while also addressing the limited number of empirical studies undertaken them for. Next, Sect. 8.3 evaluates higher education in a multicultural environment in Europe and specifically in the Netherlands. Section 8.4 describes the survey conducted in the Netherlands and summarises the empirical results. This section compares and evaluates, in particular, the ethnic- and gender-based entrepreneurial interest and motivation among university students. Finally, Sect. 8.5 discusses the results of the chapter and highlights the potential impacts of the current dreams and plans of university students on the future labour market in the Netherlands.

8.2 Entrepreneurial Interest of University Students as a Source of Future Entrepreneurs

The success of the young entrepreneurs behind YouTube, Facebook and Skype has inspired a growing number of young, energetic and self-reliant people to start their own business in recent years. The idea that entrepreneurship is a viable career path has been ingrained in the minds of young people—especially students—and their parents. Young people have been attracted as never before to the idea of starting their own business, while interest in entrepreneurship has developed earlier and earlier among young people in the last decade. For example, a national sample survey of US high school students reported that 67% wanted to start a business on their own (Kourilsky and Walstad 1998). Conversely, more and more students have joined business schools with the intention of becoming entrepreneurs. According to Timmons (1994), one-third of Harvard Business School (HBS) graduates ended up working for themselves, while 90% of HBS students have the dream of being self-employed. Colleges and universities have started to offer courses in business, including encouraging students to set up small businesses. Governments and higher education institutes have also woken up to the job-creating capacity of start-up businesses and have established new entrepreneurship education programmes. More educational programmes have led to more business plan contests, more resources and more funding. There has been a major change since the early 1990s in the education programmes of high schools, universities for professional education and universities.

In parallel with these developments, entrepreneurship education has become an important topic in entrepreneurship studies (for a comprehensive overview, see Gorman et al. 1997; Katz 2003; Meyer 2001). The research has addressed the question of how entrepreneurship education can become more effective. However, this research has been rather limited in investigating the level and determinants of interest in entrepreneurship among students. The few empirical studies show that there are two streams in the research on students' entrepreneurial interest. One stream has focused on the key background factors, such as gender, ethnicity, family experience and educational level, which affect entrepreneurial interest (Wilson et al. 2004; Wang and Wong 2004). The other stream has developed a modelling approach from a social psychology perspective and addressed the entrepreneurial intentions and new venture formation (Audet 2004; Krueger et al. 2000; Li 2006; Veciana et al. 2005). In this stream, two main theory-driven models have been used by researchers: the Theory of Planned Behaviour by Ajzen (1991) and the Entrepreneurial Event Model by Shapero and Sokol (1982).

According to Ajzen's Theory of Planned Behaviour (TPB) there are three conceptually independent determinants of intention: *attitude towards the behaviour, subjective norms* and *perceived behavioural control.* Attitude towards behaviour '*refers to the degree to which a person has a favourable or unfavourable evaluation or appraisal of the behaviour in question*'. The second determinant, subjective norms, '*refers to the perceived social pressure to perform or not to perform the behaviour*'. And, the third determinant, perceived behavioural control '*refers to the perceived ease or difficulty of performing the behaviour and it is assumed to reflect past experience as well as anticipated impediments and obstacles*'. According to Ajzen: '*As a general rule, the more favourable the attitude and subjective norms with respect to a behaviour, and the greater the perceived behavioural control, the stronger should be an individual's intention to perform the behaviour under consideration*' (Ajzen 1991, p. 188). In other words, intentions in the TPB depend on perceptions of personal orientation to entrepreneurship, social norms and feasibility.

The intention model by Shapero and Sokol (1982) was developed specifically for the field of entrepreneurship and is called the entrepreneurial event model (EEM). According to Shapero and Sokol, decisions change direction significantly in life as a result of an event or break in the established routine. In the EEM, the entrepreneurial intentions depend on three elements: *perception of personal desire to be an entrepreneur, feasibility* and *propensity to act.* Perception of desirability in the EEM considers a combination of the first two variables in the TPB, attitude and social norms, while perception of the feasibility in EEM is similar to the third variable, perceived behavioural control in the TPB. In EEM, the intent to start a business derives from perceptions of both desirability and feasibility.

A combination of these two intention-based models, the TPB and the EEM, has also been used by researchers (Krueger and Brazeal 1994; Krueger et al. 2000). In addition, Krueger et al. (2000) tested and compared both models. They found strong statistical support for both models, but the model of Shapero and Sokol was found to be slightly superior to that of Ajzen. On the basis of their comparative analysis Krueger et al. (2000) suggested that intentions are the best predictor of any planned behaviour including entrepreneurship, while intentions predict behaviour. In turn, certain attitudes predict intention, and intention models predict, rather than explain, any planned behaviour better than either individual or situational variables. They argued that personal and situational variables have an indirect influence on entrepreneurship through influencing key attitudes and general motivation to act, whereas intention-based models describe how exogenous influences change intentions and venture creation. They have also argued that the versatility and robustness of intention models support the broader use of comprehensive, theory-driven, testable process models in entrepreneurship research. In short, intention models offer a significant opportunity to better understand and predict entrepreneurial activity.

The empirical results of the studies in the above-mentioned first stream that aim to investigate the level and determinants of interest in entrepreneurship among students (Wilson et al. 2004; Wang and Wong 2004) show some interesting and significant variations across gender, ethnicity and family background. The results of two studies—two large surveys—one including over 5000 middle and high school students in four geographic states in the USA. Wilson et al. (2004), and the other one including 5326 undergraduate students in Singapore (Wang and Wong 2004)—show that there is a high level of interest in becoming entrepreneurs among students. The results of the study in the USA show that there is a significant gender disparity in entrepreneurial interest: entrepreneurship as a career was found lower among girls than among boys. However, African-American and Hispanic girls were found more likely to be interested in entrepreneurship than White/Caucasian girls. The results of the study also show that there are significant differences in social and relational motivations across both gender and ethnicity: girls interested in entrepreneurship were found more likely to be motivated in their career choices by social and relational factors, whereas boys interested in entrepreneurship were more motivated by autonomy. Financial gain was also found as a strong motivator for boys in general. Interestingly, when self-perceptions of leadership skills were asked, girls rated themselves higher than did boys, with the exception of perceived ability to manage money. The overall result of the study indicates that goals and motivations differ among boys and girls interested in entrepreneurship and also across ethnicity (Wilson et al. 2004). The results of the study in Singapore show that three background factors: gender, family experience with business and educational level affect entrepreneurial interests. The gender factor was found as the most significant factor among the (seven) background factors and girls were found less interested in entrepreneurship. Family business experience was found the second most significant factor after gender. Interestingly, other factors including ethnicity, citizenship and family income status were found little independent effect on entrepreneurial interest. An overall result of the study indicates that although many students desire to run their own businesses, their business knowledge is insufficient and they are not prepared to take risk in order to realise their dreams (Wang and Wong 2004).

The empirical results of the studies in the second stream in the literature that aim to investigate the entrepreneurial intention of students show, first of all, that intention-based models are very useful in understanding the role of personal orientation, social norms and perceived feasibility in entrepreneurial intention (Audet 2004; Li 2006; Veciana et al. 2005). In order to evaluate the level of entrepreneurial intention among international students—Chinese and Indians—in the Midwest United States, Li (2006) used the TPB as an analytical model. The results of Li's study show that the entrepreneurial intention of international students was predicted significantly by personal orientation to entrepreneurship and perceived feasibility. Interestingly, social norms were found to be non-significant in this study. The results of Li's study also show that perceived feasibility was a stronger predictor of entrepreneurial intention than a person's desire to be an entrepreneur. Another study by Veciana et al. (2005) that aimed to assess and compare the attitudes of university students towards entrepreneurship in Catalonia and Puerto Rico used Krueger and Brazeal's (1994) entrepreneurial potential model that is based on Ajzen's TPB and Shapero and Sokol's EEM. The results of this study show that university students both in Catalonia and Puerto Rico have a positive perception of the desirability to set up new businesses. Comparative evaluation of the results of this study and the results of another survey made in Spain by the researchers show that this desirability has increased considerably in the past decades. However, regarding the perceptions of feasibility, the students found it more difficult to create a firm at present than in the past decades. The results also show that there are some differences between the students in Catalonia and Puerto Rico. In Catalonia a relationship seems to exist between the student's gender and the desire to be an entrepreneur, as well as intention, and the males have a higher desire and intention to create new firms, while in Puerto Rico a relationship between gender and the desire to be an entrepreneur and intention was not found. Similarly, while a relationship was found between the entrepreneurs working with relatives and intention in Catalonia, entrepreneurs working with relatives was not found to be an important factor in desire, feasibility and intention to create a new firm in Puerto Rico. The third study to which we refer here is a longitudinal study of the entrepreneurial intentions of university students in a business administration programme conducted by Audet (2004). The results of Audet's study confirmed the results from previous studies: perceptions of the desirability and feasibility of starting a business significantly explain entrepreneurial intentions. In addition, the results of Audet's study show that entrepreneurial intentions vary over time. As an overall evaluation, Audet has stated that, as the temporal stability of intentions is a condition for an intention-based model to accurately predict behaviour, the link between entrepreneurial intentions and actual venture creation may prove difficult to establish.

Although the number of empirical studies is very limited, the studies that we have reviewed in this section show that intention-based models are well suited for entrepreneurship studies. Nevertheless, these studies were aimed at explaining the formation of intention and were not concerned with the connection between intention and action. The question concerns what factors influence the shift from intention to action is a challenge for future research. To introduce our exploratory research, we will now first pay some attention to the higher educational system in the Netherlands.

8.3 Higher Education in a Multicultural Environment: The Case of the Netherlands

Over the last few decades—with an increasing influx of foreign migrants—institutions of higher education are increasingly operating in a multicultural environment in many European countries (Bie and Weert 1998; Wolff 2003). The number of students of foreign origin (especially from non-Western countries) in the European higher education system is increasing, and student populations are becoming more and more diverse. However, students of foreign origin are still underrepresented in higher education, and they encounter more problems in entering higher education and during their study period than native students (Wolff 2003). Conversely, given the ageing population in Europe, the main source of demographic growth and the driver of future educational expansion are immigration (Marginson et al. 2007). Therefore, the recruitment and the retention of students of foreign origin are attracting ever-increasing attention in European higher education. In addition, European higher education itself is becoming more multicultural in several respects.

Like most of the other European countries, the Netherlands is increasingly becoming a multicultural society. The population of ethnic minority groups has grown since the late 1960s and the projections by Statistics Netherlands (CBS) suggest that the rate of migrants will grow from one in five in 2006 to almost one in three (29%) in 2050. Today, especially in larger urban areas, more than 50% of the under-25 age group belong to one or more ethnic minority groups and they represent a growing population of young people at all levels of education. However, as also observed in other European countries, despite the progress made, students of foreign origin in the Netherlands still remain disadvantaged, perform lower than the native Dutch and the level of school dropout among students of foreign origin is higher than among native Dutch young people (Choenni 2007; Muskens 2006).

Similar problems are observed in higher education as well. In the Netherlands, there is a dual system of higher education: universities and universities for professional education (HBO, the highest level of vocational education). There is only one level of secondary education (the highest) that grants access to universities (VWO), and therefore access to university institutions is most difficult. For HBO there are three access levels (vocational secondary education, HAVO and VWO), and hence access to HBOs is easier. About two-thirds of all students are enrolled in the HBOs rather than in the research-intensive universities (Marginson et al. 2007). The largest number of students of foreign origin can be found in HBOs (Choenni 2007; Marginson et al. 2007).

Although the proportion of students of foreign origin has increased over the years, they are still underrepresented in higher education. Moreover, students of foreign origin have a higher dropout rate than that of native Dutch students (Bie and Weert 1998; Choenni 2007; Marginson et al. 2007; Wolff 2003). According to the study *Facts and Figures on the Integration of Ethnic Minorities in the Netherlands* in 2006 (Choenni 2007), the main reason for this is that students of foreign origin tend to move less into those forms of secondary education that qualify students for higher education.

The above-mentioned report (Choenni 2007) states also that, albeit slowly, more and more non-Western students of foreign origin are graduating with a diploma. The percentage of non-Western students who graduated with a diploma was around 50% in 2004. However, there is still a remarkable difference between non-Western and Dutch students. In 2004, the percentage of Dutch students graduating with a diploma was 17% higher than non-Western students. It can be said that, on average, non-Western students round off their studies successfully in more time than native Dutch students.

Participation by non-Western minorities is a significant issue in the Netherlands and several activities have been initiated in order to serve ethnic minority students. The Ministry of Education, in collaboration with universities and HBOs, founded the National Expert Centre for Ethnic Minorities in Higher Education (ECHO) in 1995. The main objective of ECHO is '*to improve the access, retention, and graduation of ethnic minority students and to support universities and HBOs in developing policies for achieving equal opportunities and multiculturalism*' (Bie and Weert 1998, p. 6). ECHO can be seen as a policy tool of the national government for policy implementation. Several efforts are underway on both the government and institutional level to increase the participation of non-Western minorities. The government has encouraged higher education institutions to develop plans to increase the enrolments of ethnic populations and to improve completion rates. However, the relative participation and completion of non-western students remains an issue. Although non-Western students are enrolling in greater numbers, their success rates in graduating are markedly lower than those of the native Dutch. For the cohort who started education in 2000, the gap after 5 years was 20% points at the HBOs and 10% points at the universities. However, the proportion of non-Western students who leave after 5 years without degrees has fallen from 20% to 15% over the past six cohorts at the universities (Marginson et al. 2007). These structural trends are encouraging for the participation in higher education of foreign students.

With regard to our study, another important initiative that has been developed is the newly developed Education and Entrepreneurship Programme. In order to imbue students with a more entrepreneurial spirit and a more positive attitude towards entrepreneurship, two ministries in the Netherlands, the Ministry of Economic Affairs and the Ministry of Education, Culture and Science, have recently started an Education and Entrepreneurship Programme (Bakkenes et al. 2009). As a part of this programme, six Centres of Entrepreneurship at universities and other institutes of higher education were set up. The main goal of these centres is to instil a more entrepreneurial attitude in students and to encourage them to pursue a more entrepreneurial career path. As this programme has recently started, it is too early to evaluate the results. However, the programme can be expected to have a positive impact especially on non-Western students and increase their labour market participation as entrepreneurs.

8.4 Entrepreneurial Interest and Future Job Orientation of University Students in the Netherlands

8.4.1 Prefatory Remarks

The applied part of our chapter is based on a survey conducted among university students in the Netherlands between September and December 2009. The survey was carefully designed on the basis of a preliminary study, the respondent selection criteria were precisely defined and a research questionnaire was prepared before starting the survey. These respondent selection criteria were divided into six groups: (1) cities; (2) universities and universities for professional education (HBOs); (3) faculties; (4) target groups; (5) gender and (6) sample. The Randstad metropolitan area, which includes the four big cities Amsterdam, Rotterdam, The Hague and Utrecht, was selected in order to conduct the survey. There are four universities: (1) VU University Amsterdam (VU), (2) University of Amsterdam (UVA), (3) Erasmus University, and (4) Utrecht University. The last one: INHOLLAND, the largest university for professional education (HBO) in the Netherlands (INHOLLAND-Amsterdam Diemen, INHOLLAND-Rotterdam, and INHOLLAND-Den Haag). This is a different category as professional education (HBO) (the highest level vocational education) and it was explained in the previous sentences in the text. However, during the survey—in order to complete the described sample—four more universities for professional education, including the Hogeschool van Amsterdam, the HES Rotterdam, the Haagse Hogeschool and the Hogeschool Utrecht, were added to the survey. As students with ethnic backgrounds are overrepresented in HBOs in the Netherlands, it was decided, as a research criterion, to distribute 50% of the research questionnaires in selected universities and the other 50% in selected HBOs. Another respondent selection research criterion was the selection of faculties. As students with ethnic background are overrepresented in two particular faculties: the Faculty of Economics and Business Administration and the Faculty of Law, it was decided to deliver 50% of the questionnaires to these two faculties, and the other 50% to the other faculties. As target groups, six dominant socio-cultural and ethnic groups in the Netherlands, viz. Dutch, Antilleans, Moroccan, Surinamese, Turkish and Others, were selected. Besides the ethnicity, gender was chosen as another criterion, and it was decided to give 50% of the research questionnaires to female students. Finally, on the basis of these research criteria the sample was described. It

Table 8.1 The survey and the sample

Cities	Universities	Female students	Total students	General total
AMSTERDAM	VU University Amsterdam (VU)	*77*	150	
	University of Amsterdam (UVA)	*74*	150	449
	INHOLLAND Diemen and Hogeschool van Amsterdam	*73*	149	
ROTTERDAM	Erasmus University	*76*	150	303
	INHOLLAND Rotterdam and HES Rotterdam	*77*	153	
THE HAGUE	INHOLLAND Den Haag and Haagse Hogeschool	*79*	157	157
UTRECHT	University of Utrecht	*76*	150	303
	Hogeschool Utrecht	*79*	153	
Total				1212

was aimed to conduct 200 interviews per group, resulting in a total sample of 1200 university students. Table 8.1 shows the selected cities, universities and the sample by universities.

The survey was conducted on the basis of systematic research questionnaires. The questionnaire was designed in order to collect information especially in five areas including the students: (1) motivation for education and selected discipline; (2) entrepreneurial interest; (3) risk-averse attitude; (4) perceived leadership skills and (5) entrepreneurial motivation. The questionnaires were applied in two ways: the questionnaires were delivered to students at the campuses of the selected universities and HBOs in order to be filled out and were sent electronically to students via Student Associations. The Student Associations, in particular, Migrant Student Associations were used to reach the specific ethnic groups.

The survey was successfully carried out and encountered no major difficulty. However, the criteria used to select the sample made it especially difficult to complete the sample in the final stage of the survey. To complete the sample in accordance with the described criteria made the survey process longer than that the expected time frame and caused a delay. Nevertheless, the survey was successfully completed without any change in the criteria.

In Sect. 8.4.2, we discuss the empirical results of our survey, and then, in Sect. 8.4.3 we evaluate the results in a comparative way.

8.4.2 *Empirical Results*

We will now first present and discuss the empirical results of our survey in three sub-sections. In Sect. 8.4.2.1 we evaluate ethnic- and gender-based entrepreneurial interest among university students. Then, in Sect. 8.4.2.2, we compare ethnic- and gender-based risk-averse attitudes among university students. In Sect. 8.4.2.3 we discuss ethnic- and gender-based entrepreneurial motivation among university students.

8.4.2.1 Ethnic- and Gender-Based Entrepreneurial Interest Among University Students

In order to measure ethnic- and gender-based entrepreneurial interest among university students, the students were asked three main questions:

1. Why did you choose to have an education at university/HBO level?
2. What kind of job position do you dream of or plan?
3. How much are you interested in starting/owning your own business?

The results of our survey show that the motivation for university education differs among socio-cultural and ethnic groups (Table 8.2). While Dutch students are more interested in having more job alternatives, Turkish and Moroccan students are more interested in having a higher position in the labour market, and Surinamese, Antillean and Moroccan students have a higher interest in becoming an entrepreneur. The results also show that Surinamese and Antillean students are more money-oriented.

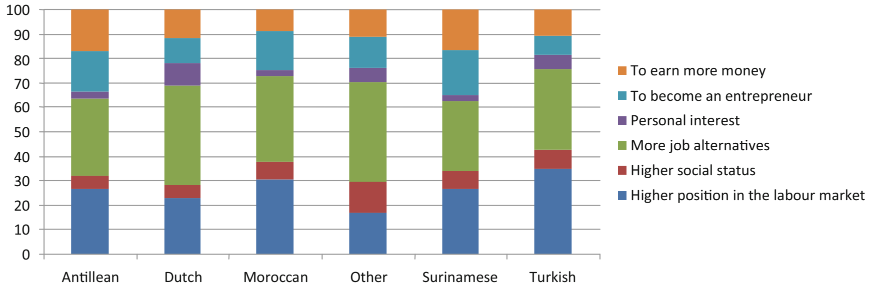


Table 8.2 ‘Ethnic’ motivation for university education (percentages)

	Higher position in the labour market	Higher social status	More job alternatives	Personal interest	To become entrepreneur or self-employed	To earn more money
Antillean	27	5	32	3	16	17
Dutch	23	5	41	9	10	12
Moroccan	31	7	35	2	16	9
Other	17	13	41	6	12	11
Surinamese	27	7	29	2	18	16
Turkish	35	8	33	6	8	11
Total	26	8	35	5	14	13

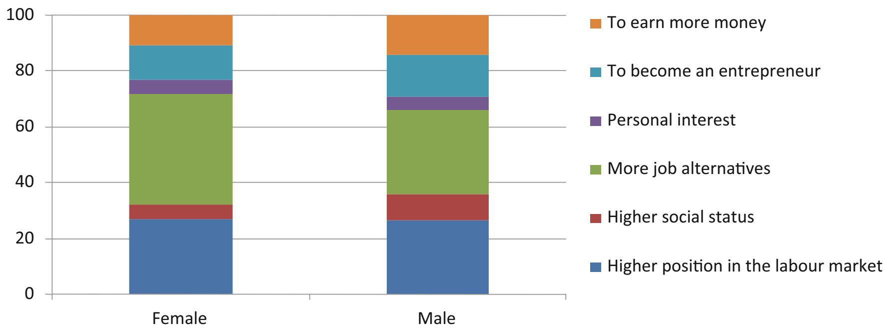
Table 8.3 ‘Gender’ motivation for university education (percentages)

	Higher position in the labour market	Higher social status	More job alternatives	Personal interest	To become an entrepreneur or self-employed	To earn more money
Female	27	6	40	5	12	11
Male	26	9	30	5	15	14
Total	26	8	35	5	14	13

Table 8.4 ‘Ethnic’ dreams about future job position (percentages)

	Paid job in private sector	Paid job in public sector	Self-employed
Antillean	27	32	41
Dutch	39	33	29
Moroccan	27	37	37
Other	23	39	39
Surinamese	32	27	40
Turkish	32	32	36
Total	30	33	37

The results also show that there are some gender-based differences in motivation for university education. While female students are more interested in more job alternatives and a higher position in the labour market, males have a greater interest in higher social status and in becoming an entrepreneur. Male students are also more money-oriented (Table 8.3).

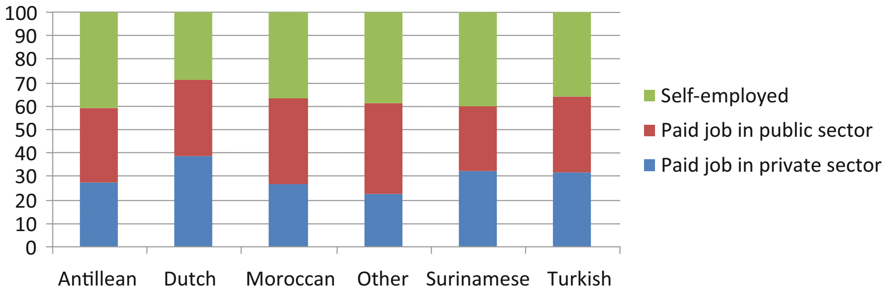


The differences are also observed among the students from different socio-cultural and ethnic background in terms of the future job position that they dream of or plan for (Table 8.4). The results of our survey show that Dutch students are more interested in a paid job in the private sector and less interested in self-employment. In contrast, Antillean and Surinamese students have the greatest interest in self-employment. While Moroccan students are more interested in a

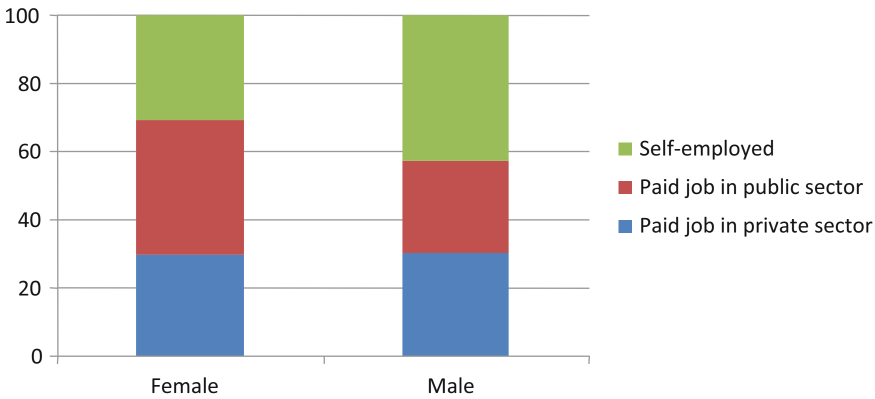
Table 8.5 'Gender' dreams about future job position (percentages)

	Paid job in private sector	Paid job in public sector	Self-employed
Female	30	39	31
Male	30	27	43
Total	30	33	37

paid job in the public sector, Turkish students have a greater interest in self-employment.



Gender-based differences are also observed with respect to the future job positions that students dream of or plan. While females are more interested in a paid job in the public sector, males have the greatest interest in self-employment (Table 8.5).



The results of our survey show that entrepreneurial interest is quite high mainly among students from a different socio-cultural and ethnic background to the native population. According to our survey results, around 70% of all ethnic groups have an

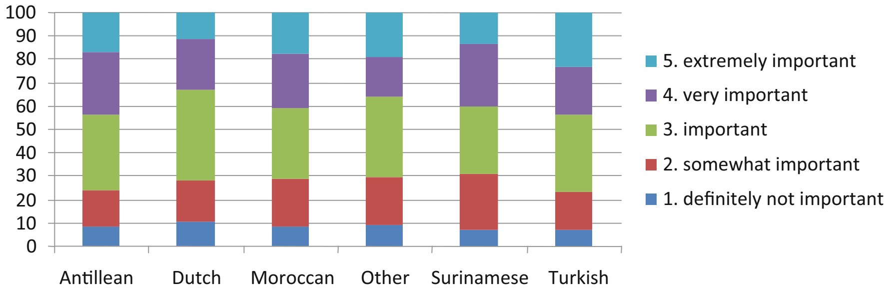
Table 8.6 ‘Ethnic’ entrepreneurial interest (percentages)

	Definitely not important	Somewhat important	Important	Very important	Extremely important
Antillean	8	15	32	27	17
Dutch	11	17	39	22	11
Moroccan	9	20	30	23	18
Other	9	20	34	17	19
Surinamese	7	24	29	27	13
Turkish	7	17	33	21	23
Total	9	19	33	23	17

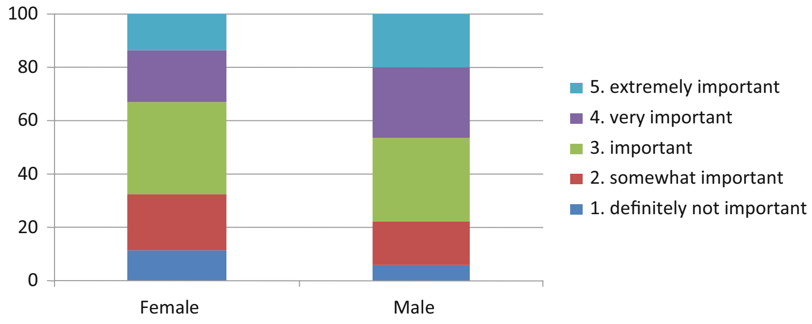
Table 8.7 ‘Gender’ entrepreneurial interest (percentages)

	Definitely not important	Somewhat important	Important	Very important	Extremely important
Female	11	21	35	19	14
Male	6	16	31	27	20
Total	9	19	33	23	17

entrepreneurial interest (Table 8.6). Antillean, Surinamese and Turkish students are more entrepreneurially oriented than other groups. While Turkish students have the highest rate among students who find starting their own business extremely important, Antillean and Surinamese students follow Turkish students with the highest rate among students who find starting their own business very important.



As observed in our interpretation of the motivation to have an education at university/HBO level and of dreams of future job positions, once again we observe gender-based differences in entrepreneurial interest. The results of our survey show that males have a higher entrepreneurial interest than females (Table 8.7).



8.4.2.2 Ethnic- and Gender-Based Risk-Averse Attitude Among University Students

Entrepreneurship is strongly related to a risk-averse attitude. Therefore, an entrepreneurial interest among university students would be expected to depend on how students rate themselves in taking risks. The results of our survey show that Antillean and Other migrant students exhibit much higher risk-taking behaviour. Turkish students also exhibit high risk-taking behaviour (Table 8.8). As can be expected, there are gender-based differences in taking risk: male students have a higher risk-taking behaviour than female students (Table 8.9).

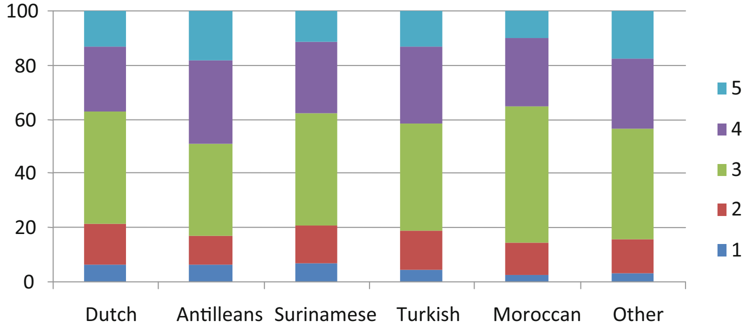
Table 8.8 'Ethnic' risk-taking behaviour (percentage shares)

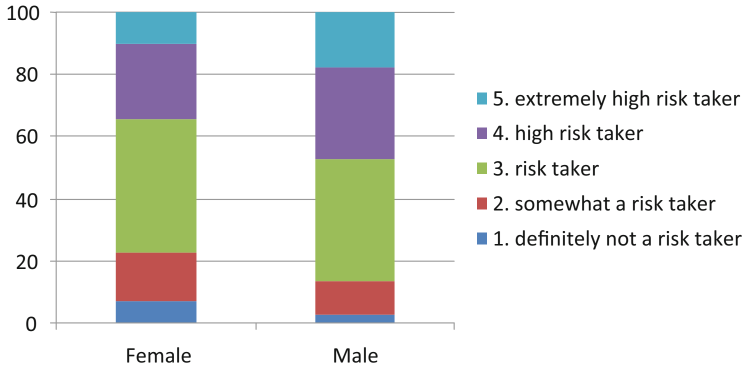
	1	2	3	4	5
Dutch	6	15	42	24	13
Antilleans	7	11	34	31	19
Surinamese	7	14	41	26	11
Turkish	4	14	39	28	13
Moroccan	2	12	50	25	10
Other	3	12	41	25	18
Total	5	13	41	27	14

Notes: 1 = not risk taker, 5 = extremely risk taker

Table 8.9 'Gender' risk-taking behaviour (percentage shares)

	1	2	3	4	5
Female	7	16	43	24	10
Male	3	10	39	30	18
Total	5	13	41	27	14





8.4.2.3 Ethnic- and Gender-Based Entrepreneurial Motivation Among University Students

In order to highlight the most important factors that may motivate students to become entrepreneurs in the future, around 20 potentially important factors were presented to the respondent, and the students were asked to rate these factors. Among 20 factors, the following six factors were rated by students as the most motivating factors. These factors are: (1) being respected by family and friends; (2) being one's own boss; (3) making lots of money; (4) having/earning prestige; (5) using one's own skills and ability and (6) building something for the family. However, as int indicated in our analysis of the entrepreneurial interest, some ethnic- and gender-based differences are observed once more in entrepreneurial motivation.

Being respected by family and friends has emerged as one of the most motivating factors to become an entrepreneur, especially for some ethnic groups. The results of our survey show that family and friends are important and a motivating factor to become an entrepreneur for Moroccan and Turkish students, whereas Dutch students

Table 8.10 'Ethnic' motivation for entrepreneurship: being respected by family and friends (percentages)

	Definitely not important	Somewhat important	Important	Very important	Extremely important
Antillean	14	19	33	21	13
Dutch	25	25	21	15	14
Moroccan	16	18	21	20	25
Other	13	25	29	20	13
Surinamese	18	21	28	15	18
Turkish	14	23	22	20	21
Total	16	22	26	19	17

Table 8.11 'Gender' motivation for entrepreneurship: being respected by family and friends (percentages)

	Definitely not important	Somewhat important	Important	Very important	Extremely important
Female	20	23	25	17	15
Male	13	21	27	19	20
Total	16	22	26	18	17

Table 8.12 'Ethnic' motivation for entrepreneurship: being own boss (percentages)

	Definitely not important	Somewhat important	Important	Very important	Extremely important
Antillean	4	9	33	29	24
Dutch	6	20	31	23	20
Moroccan	6	13	27	32	22
Other	9	15	26	26	25
Surinamese	6	12	33	20	29
Turkish	6	12	26	28	29
Total	6	14	29	26	25

do not care very much about being respected by family and friends, and it is not a motivating factor for them to become an entrepreneur (Table 8.10).

The results of our survey also show that being respected by family and friends is more important for males than for females (Table 8.11). Being respected by family and friends is not an important motivating factor for females to become an entrepreneur. It would seem that entrepreneurial motivation is affected by 'external factors' for males and 'internal factors' for females.

Another important factor that motivates students to become an entrepreneur is to be their one own boss. The results of our survey show that Surinamese, Turkish and Moroccan students have the highest motivation for being their own boss (Table 8.12). Dutch students, on the contrary, have the lowest motivation for being their own boss.

Table 8.13 ‘Gender’ motivation for entrepreneurship: being their own boss (percentages)

	Definitely not important	Somewhat important	Important	Very important	Extremely important
Female	5	9	25	28	33
Male	5	7	26	26	36
Total	5	8	26	27	34

Table 8.14 ‘Ethnic’ motivation for entrepreneurship: making lots of money (percentages)

	Definitely not important	Somewhat important	Important	Very important	Extremely important
Antillean	7	8	33	38	15
Dutch	5	12	32	31	20
Moroccan	11	12	31	26	20
Other	9	9	27	24	32
Surinamese	2	8	37	37	16
Turkish	4	8	26	34	28
Total	6	9	31	31	22

Table 8.15 ‘Gender’ motivation for entrepreneurship: making lots of money (percentages)

	Definitely not important	Somewhat important	Important	Very important	Extremely important
Female	7	11	32	30	20
Male	6	8	30	33	24
Total	6	9	31	31	22

In general, the results of our survey show that there are some gender-based differences in entrepreneurial interest and entrepreneurial motivation of university students. However, in some motivating factors including also to be one’s own boss, we cannot find any gender-based difference. Being their own boss is equally important for males and females (Table 8.13).

Obviously, one of the most important motivating factors for entrepreneurship is making lots of money. University students also rated this as an important factor to become an entrepreneur. According to our survey results, Surinamese, Turkish and Antillean students have the highest motivation for making lots of money, whereas Moroccan students have the lowest motivation for making lots of money (Table 8.14).

The results of our survey show also that entrepreneurial motivation of making lots of money is higher for male students than for female students (Table 8.15). Making lots of money seem to be less important for females.

Having/earning prestige was also rated as an important motivating factor by university students. The results of our survey show that Surinamese, Turkish and Antillean students have the highest motivation for having/earning prestige (Table 8.16). Although their entrepreneurial motivation is lower than for migrant

Table 8.16 ‘Ethnic’ motivation for entrepreneurship: having/earning prestige (percentages)

	Definitely not important	Somewhat important	Important	Very important	Extremely important
Antillean	4	17	30	33	17
Dutch	5	11	35	31	18
Moroccan	10	13	28	29	20
Other	6	14	32	25	22
Surinamese	4	14	31	35	16
Turkish	2	9	37	24	28
Total	5	13	32	30	20

Table 8.17 ‘Gender’ motivation for entrepreneurship: having/earning prestige (percentages)

	Definitely not important	Somewhat important	Important	Very important	Extremely important
Female	6	17	32	27	18
Male	4	9	32	32	22
Total	5	13	32	30	20

Table 8.18 ‘Ethnic’ motivation for entrepreneurship: to use their own skills and abilities (percentages)

	Definitely not important	Somewhat important	Important	Very important	Extremely important
Antillean	6	11	25	27	31
Dutch	3	9	27	38	22
Moroccan	9	8	32	27	23
Other	4	10	27	31	29
Surinamese	3	9	36	28	24
Turkish	1	17	28	31	23
Total	4	11	29	31	25

students, Dutch students have also a high motivation for having/earning prestige. Interestingly, Moroccan students have the lowest motivation for having/earning prestige.

The results of our survey show that there are important gender-based differences in entrepreneurial motivation for having/earning prestige. The entrepreneurial motivation of having/earning prestige is higher for male students than for female students (Table 8.17). It seems that having/earning prestige is less important as a motivating factor for females.

Another important factor that motivates university students to become an entrepreneur is to use their own skills and abilities. The results of our survey show that Antillean, Dutch, Turkish and other students have the highest motivation for using own skills and abilities (Table 8.18). An interesting result from our survey is that the use of their own skills and abilities is more important for females than for males (Table 8.19).

Table 8.19 'Gender' motivation for entrepreneurship: to use their own skills and abilities (percentages)

	Definitely not important	Somewhat important	Important	Very important	Extremely important
Female	3	13	25	35	24
Male	5	9	33	27	26
Total	4	11	29	31	25

Table 8.20 'Ethnic' motivation for entrepreneurship: to build something for the family (percentages)

	Definitely not important	Somewhat important	Important	Very important	Extremely important
Antillean	5	22	31	21	20
Dutch	11	25	26	25	14
Moroccan	13	9	23	36	19
Other	14	23	32	15	16
Surinamese	16	23	27	22	12
Turkish	3	21	28	24	24
Total	10	21	28	24	17

Table 8.21 'Gender' motivation for entrepreneurship: to build something for the family (percentages)

	Definitely not important	Somewhat important	Important	Very important	Extremely important
Female	10	17	32	25	16
Male	10	24	24	23	19
Total	10	21	28	24	17

The final important motivating factor for entrepreneurship rated high by university students is to build something for the family. The results of our survey show that Turkish and Moroccan students have a higher motivation to build something for the family, whereas Dutch, Surinamese and other students are less family-oriented (Table 8.20).

The results also show that males have a slightly higher motivation to build something for the family than females. However, there is no clear gender-based difference in motivation to build something for the family (Table 8.21).

8.4.3 A Comparative Evaluation of the Empirical Results

The empirical results of our survey highlight the diverse attitudes and career motivations of university students. The results underline, on the one hand, how different socio-cultural and ethnic backgrounds can determine the diverse attitudes and career motivations, and, on the other, independently from the socio-cultural and ethnic backgrounds, the impact of gender differences on career choice. An overall comparative evaluation of empirical results highlights the following ethnic- and gender-based differences in the entrepreneurial interest and motivation of university students:

- Migrant male students are more entrepreneurial than both natives and female students.
- Interest in entrepreneurship as a career is lower among Dutch youth than among migrant youth.
- Interest in entrepreneurship as a career is lower among females than among males.
- Migrants are more risk-taking than natives.
- Females are less risk-taking than males.
- Males are more motivated by ‘external factors’ such as family and friends, prestige and also financial gain.
- Females are more motivated by ‘internal factors’ such as using their own skills and abilities.
- Factors such as being their own boss, being flexible, being independent, etc. are equally important for both males and females.

These empirical results fully support our hypotheses. Our findings show that: (1) the level of interest in entrepreneurship is related to ethnicity and migrants’ interest is greater; (2) the level of interest in entrepreneurship is related to gender and males’ interest is greater; (3) the motivation factors are different for males and females, males are more motivated by ‘external factors’, and females by ‘internal factors’ and (4) females have a lower propensity for risk-taking.

Our results show that migrants are more entrepreneurial than natives. However, as explained in the previous sections, migrants do not make up a homogeneous group, and there are also many differences between migrant groups. Some migrant groups exhibit a higher entrepreneurial interest and motivation than other migrant groups. In addition, some migrant groups are more risk-taking than the other migrant groups. From these results, it seems that cultural differences play an important role in determining diverse attitudes and career motivations.

8.5 Image of the Future Labour Market in the Netherlands

Like other European countries, the Netherlands is increasingly becoming a multicultural society. In a multicultural society, undoubtedly the main task of higher education institutions is to educate and train students for future employment in a multicultural society. For a multicultural society it is of vital importance to use the potential of young people from various backgrounds as much as possible. In order to train all students to operate in a multicultural society, it may also be necessary to match the composition of the academic staff to the diversity of society and include more staff from different ethnic backgrounds.

The results of our chapter highlight the great potential of young people for the future labour market in the Netherlands. The overall finding is that there is a very high entrepreneurial interest especially among the migrant students. The results of our chapter demonstrate only the entrepreneurial interest of students on the basis of their personal and situational factors. However, the results highlight also the determinant role of a multicultural environment, especially on motivational factors towards an entrepreneurial career. A further analysis of our survey, especially the application of intention-based models, may enable us to predict the entrepreneurial intention of students and to measure the effects of desirability, social norms and feasibility towards entrepreneurial intention. In a multicultural environment, especially social norms can be expected to play an important role in the formation of entrepreneurial intention. How to transform the intention into action is an important issue and it is not very easy to predict the probability of realisation. However, in case of the realisation of today's tendencies of university students, the future labour market in the Netherlands will exhibit interesting features. On the basis of our research results it seems that the following stylised future image is plausible:

- Paid jobs in the private sector will be held by the native Dutch.
- Paid jobs in the public sector will be held by females.
- The public sector may become more 'feminine' or, in other words, the 'feminisation' of the public sector can be expected in the near future in the Netherlands.
- Jobs in the public sector may also be held more by Moroccans.
- New jobs will be created by immigrants, in particular by Antilleans, Surinamese and Turks.
- Gender differences will decrease, and male and female involvement will become closer in business.
- Cultural differences will remain in the near future. In particular, Turks and Moroccans will have a more traditional family-oriented approach.
- And, therefore, ethnic networks will continue to shape labour market developments in the near future.

The results of our chapter have obviously important implications for strategic thinking on future policy and educational initiatives.

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Chapter 9
How Can Small-Scale Measures of Human Development Index (HDI) be Used to Study the Local Potential for Sustainable Economic Growth?

Umut Türk, Marina Toger, and John Östh

Abstract For many years the HDI or human development index has been a global de-facto standard to describe the potential for well-being and development of individuals in countries around the world. The index is built around three central elements: health, knowledge and standard of living and serves the purpose of moving the attention from national economics to the potential of the individual in each country. Despite its individual-centred orientation, the index is almost always constructed and compared on national levels. In this study, the index is disaggregated to municipality levels to study the local patterns. Using small scale data for all residents in Sweden, we can construct individual-centred HDI-calculations that are used to depict variations on local, to regional levels. Here the HDI aggregated to municipality level and the engineering resilience index (RCI) are compared. Observed patterns are strongly correlated with commonly used resilience indexes and the newly constructed HDI index has the benefit of being transferable and comparable on any level from nation to neighbourhood.

Keywords Local HDI · RCI · Sweden · *k*nn

9.1 Introduction

The relationship between economic growth and sustainable development has been a hot topic in academic debate for many years, perhaps even more after the introduction of the environmental Kuznets curve (EKC) stating that environmental

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degradation would reach a tipping point and gradually having less negative impact as the economy grew (Grossman and Krueger 1991), while others showed that the relationship was difficult to validate especially when comparing economies at different stages of economic development and the effects on environmental degradation (Stern et al. 1996; Stern 2004). There has also been a discussion about how to measure economic development and sustainability (Nordhaus and Tobin 1973). In a famous quote from the speech at the University of Kansas, Bobby Kennedy discussed economic growth using the concept of gross national product using the following words:

> "*Yet the gross national product does not allow for the health of our children, the quality of their education or the joy of their play. It does not include the beauty of our poetry or the strength of our marriages, the intelligence of our public debate or the integrity of our public officials. It measures neither our wit nor our courage, neither our wisdom nor our learning, neither our compassion nor our devotion to our country. It measures everything in short, except that which makes life worthwhile*". Bobby Kennedy (1968)

Over time, measures of economic development and progress have become more complex and less dependent on single economic-performance metrics. The (UN) 1990 Human Development Report (HDR) is a testimony to the change of focus, not least through the opening words "People are the real wealth of a nation". The first HDR was published in 1990 both as a review of various previously established concepts of development and also as the first of several reports, which greatly contributed to the definition, measurement and policy analysis of human development (HDR 1990). The HDI (human development index) was proposed as a framework to measure attainment on several dimensions of human development. An academic debate followed on how to improve and interpret the HDI and the UNDP introduced several modifications to the index in the following annual reports.

For international comparison, the HDI was developed to focus on measuring the economic opportunities of individuals rather than gross economic indexes. The idea behind HDI was inspired by the conceptual framework proposed by Sen (1970, 1984), where he contended the role of income, commodity and wealth as instruments but not direct measures of living standards. For those who have a better living standard, say present health, the instrumental value of the material possessions will be greater and their ability to convert income into well-being will be larger. Therefore, the HDI was developed with the argument that development was not a function of only output and income, but that non-commodity factors like education, life expectancy and health can have great impact on their own. For the understanding of development, this meant a change of attention from the accumulation of physical capital to, now widely acknowledged, emphasis on the accumulation of human capital (Anand and Sen 2000). The focus on individuals and their life opportunities during social and economic development calls for a multidimensional approach to poverty and inequality. As Grusky et al. (2006) point out, multidimensional poverty and inequality are issues that require great attention among academics and policymakers and now taken beyond the single framework of maximising total economic outputs. One of the contributions of the Human Development Reports (HDRs) was the empirical illustration of how ranking countries differed when HDI was used instead of what it would yield, for instance, by using gross national product (GNP). Thus, different policies tackling poverty and inequality would be needed when HDI is employed instead of measures of wealth accumulation and growth. The latest HDR (2019) focuses on inequalities and not only restates the importance of individual-centred human development but also calls attention to the types of inequalities that are specific to the twenty-first century. One of the objectives of the report is to promote "new generation" measurements, tackling inequalities at early stages of lifecycle, before they accumulate.

In the current version of HDI (definitions have been altered slightly over time), the index is constructed to be measurable globally while keeping the people-centred orientation by combining an economic performance measure with indices of education and life expectancy (UNDP 2010). The effort to align concepts of sustainability and growth into a common wider modelling framework is clear in the 2030 agenda for sustainable development and the sustainable development goals (UN 2015), where the 17 Sustainable Development Goals (SDGs) clearly indicate that sustainability primarily is an integrative effort where goals as well as actions need to be harmonised to benefit all.

Despite the individual-centred orientation of earlier and recent versions of the HDI, the index is often constructed and compared at the national level. The present paper uses a novel approach to disaggregate the index to residential levels with the aim of studying local patterns in (human) development in Sweden. In this framework, the paper seeks to investigate the usefulness of the HDI as an indicator of local development level. To this end, residential disaggregation of the index allows to examine its performance in particular at the regional level. At the regional level we conduct correlation analysis between HDI and resilience index, where resilience is defined as a measure of how well a region can withstand an external shock.

In the present paper, we use the bespoke neighbourhood (k-nearest neighbour) approach to construct the HDI at the local level. The main question is how bespoke neighbourhood constructed index relates to other regional measures such as resilience. The design of an individual-centred index aligns with the primary aim of HDRs and opens various ways of addressing policy issues comprehensively.

9.2 Previous Work on Regional Human Development Index and Resilience

Since its conception in 1990, the HDI has received several criticisms, which are concerned with the choice of variables, arguing that the index lacks important dimensions of human development such as environmental issues, political freedom and safety. The index has also been challenged for its functional form, and for the way its dimensions are aggregated and weighted (Ray 2008). The annual HDRs have continuously instigated debates over the index and the UNDP itself responded to the critique. In 2010 the index was considerably altered and the new report addressed some of the shortcomings (Zambrano 2014). The 2010 index assigns equal weights to all dimensions, and the method of aggregation is shifted from arithmetic to geometric mean. As for the critique related to the choice of variables, several empirical applications have introduced new variables to the index, or altered the existing variables, for instance, for advanced countries. Many of these studies have been communicated by the UNDP (http://www.hdr.undp.org/); however, the original three-dimensional structure was kept in the new version of the index. The criticisms that are directed towards the HDI and the updated index with its advantages are discussed by Klugman et al. (2011). Moreover, UN (2016) reviewed 19 new composite indexes comprising either newly constructed or modified HDI to match to the local context.

Besides the efforts to refine and improve the indexes of human development, several applications provide disaggregation of the HDI into subgroups and subnational levels. Those include gender, ethnicity or rurality-based measures but also geographical subgroups such as administrative regions, where each group is treated like a separate country (Akder 1994). A number of studies have focused on HDI at the regional level, with various applications in a wide set of countries. The earlier exercises of disaggregation covered various countries, including Poland, South Africa and Turkey (see Gaye and Jha 2010, for a detailed review). These studies employ the old version of the index, before the modifications were introduced in 2010. Studies after 2010 either employ the original index or introduce modifications aiming to address the preceding criticisms. For example, Schrott et al. (2015) modified the HDI index by introducing life expectancy at birth, level of education and the logarithm of net income and by normalising the included variables. Their findings indicate a high heterogeneity among provinces and substantial differences between rural and urban areas in Austria.

The criticism that the three-dimensional HDI is too narrow to analyse human development has also been addressed in a number of papers. For example, in addition to the original three variables, Silva and Ferreira-Lopes (2014) add regional voter participation rates as the predictor of governance and the percentage of population served by wastewater treatment stations as the environmental dimension to the index, computed for NUTS 3 regions in Portugal. In their results, regions are ranked similar to a previously introduced index of regional development (synthetic index of regional development). Another study by Permanyer et al. (2015) uses census data at small aggregation levels and proposes a modification to the HDI so that it matches the distinctive characteristics of African countries. They construct a modified human development index (MHDI) with life expectancy at birth, literacy and primary education completion and access to amenities, such as potable water, waste disposal and electricity, as three dimensions of human development in 13 African countries. The study identifies inequality in human development and underlines the importance of understanding the subcomponents of the analysis of human development at disaggregated geographical scale. In a recent paper, Smits and Permanyer (2019) introduce the Subnational Human Development Database covering 1625 regions within 161 countries, and a corresponding index, wherein techniques to replace missing information in years are discussed.

Recent contributions indicate a growing interest in understanding and tackling within-country disparities in human development and growing recognition that subnational investigation of the potential to facilitate policy-making has to be directly linked to the analysis of human development (Pagliani 2010). Intuitively, the disaggregation of the HDI has a limit, which is reached when calculated for each individual (Akder 1994). The present paper employs the altered version of HDI (updated in June 2010) while addressing the critical open questions: whether the local HDI defined at the individual level can explain socio-economic outcomes such as economic resilience indicators when aggregated to a higher geographical level.

The origin of the concept of resilience is derived from ecology and deals with responses to shocks to an ecological system. The shock response mechanisms are valid in other systems as well, making resilience a well-used concept in economics (Modica and Reggiani 2015). Traditionally, the concept is split into engineering resilience (Pimms 1984; Holling 1996) and ecological resilience (Holling 1996). Ecological resilience focuses on the effects of the shock and how the system responds to the shock, while engineering resilience focuses on how well a system is designed to resist a shock in the first place. In this study we analyse how well a disaggregate measure of HDI can function as an indicator of economic resilience. For this reason, we put our attention towards the engineering understanding of resilience in Swedish municipalities. There are several studies of regional economic resilience in Sweden (see, for instance, Östh et al. 2015, 2018) where municipality-based variables are used for the calculation of economic resilience index (RCI). To facilitate comparison, we implement regional economic resilience as specified in Östh et al. (2015). In the following section, we present the data and methods used to construct the local HDI.

9.3 Data and Methods

In the following analyses, the local HDI is used as the dependent variable to examine its correlation with regional economic measures. All of the data, employed to develop the local HDI estimate, were derived from the PLACE database located at Uppsala University, Sweden. PLACE was compiled by Statistics Sweden and consists of a longitudinal, anonymised register of all residents in Sweden (circa ten million observations). PLACE contains yearly variables describing socio-demographic and economic status of individuals and geographical locations of their residence and work. The Swedish population PLACE data are available at a 100 m grid resolution comprising almost 800,000 locations.

We used residential coordinates for 2013 and the socio-demographic variables for 2014 for the whole population. The usage of 2013 is needed to record the last known residential location of individuals dying in 2014. For constructing the HDI, we use residential coordinates, municipality of residence, age, mortality rates in a given location, gender and country of birth.

9.3.1 Variables

9.3.2 HDI

Since the alteration of HDI in 2010 (UNDP 2010), the HDI has been calculated using three variables, designed to function as proxies for health, knowledge and the standard of living of populations. Health is expressed by life expectancy at birth (LE). Knowledge is expressed through a measure of observed and estimated time in education. Finally, the standard of living is expressed using a standardised Gross National Income per capita (GNIpc) measure.

For computations on the local level, it is necessary to know the age-specific mortality rate, years of schooling and disposable income on individual level. All three indicators are available in the PLACE database and included in the model as explained below.

9.3.3 Independent Variables

As independent variables, we employ a set of regional economic measures that capture engineering resilience from a regional economic perspective or the ability to withstand economic shocks. Regional variables are formulated at the municipality level (290 Swedish municipalities) and consist of economic capacity, community connectivity capacity (CCC) and socio-economic capacity indicators. Economic indicators provide insights into the health of regional economies, wherein income equality is the measure of equality in income distribution, economic diversification is measured as the deviation from national industry mix, regional affordability is housing market prices and business environment is the ranking of local businesses. The CCC variables are proxies of the resilience capacity index (Pendall et al. 2010; Östh et al. 2015), which incorporate civic infrastructure, indicating the share of individuals employed in NGOs, metropolitan stability as measured by the share of population with 5 or more years of residence in each municipality, the share of individuals who own their homes and finally turnout rates of eligible voters per municipality. The socio-economic capacity indicators comprise the following: educational attainment, the share of population without disability, the share of population that lifted themselves out of poverty and health-insured population.

9.3.4 Assembly of the HDI Variables on the Local Level

Traditionally, data used for calculation of HDI are aggregated on national or regional levels, thus the reference population is equal to geographical unit of output—i.e. country or region. For disaggregating the spatial resolution this geographical approach will not be viable at smaller scales simply because the population size becomes too small for the construction of statistically sound variables. Thus, alternative geographical strategies have been used to make spatial disaggregation possible (see, for instance, Musterd et al. 2003; Clark et al. 2015; Türk and Östh 2019). Key to these disaggregate studies is the creation of the so-called bespoke neighbourhoods, where data collection usually departs from residential location of individuals, and where the neighbourhood is made synonymous with the characteristic radius/radii or the count/s or ratio/s out of the k-nearest neighbours. The observed population that falls within the radii or counts of neighbours from any location is treated as the data pool from which the individual contextual statistics are generated. The choice between radius and count is determined by the question, but in areas with variation in population density, counts (usually referred to as k-values) will do a better job than radii. Moreover, since the population denominator can be set to the specific k-values in the calculation of, for instance, life expectancy, calculations are made easier using k-values rather than radii (Östh et al. 2016). Consequently, counts were chosen for our HDI variables with $k = 500$ nearest neighbours in each age cohort. The HDI variable is thereafter aggregated (averaged) on municipality level. The treatment also allows for estimation of values in municipalities having too few individuals for aggregation.

9.3.5 Life Expectancy Index (LEI)

The number of deaths among the k-nearest neighbours in each specific age cohort is recorded from each populated location in the Swedish dataset. For the age cohorts, 5-year intervals were used, starting from 0 years and 90 plus years. For each location, the number of deaths in each cohort is divided by k—the number of individuals in the same cohort. This procedure renders the mortality probability ratio in the LE model.

$$e_{xi} = \sum_{k=1}^{\infty} k_i \; {}_{kPx_i} \; {}_{Qx_i+s} \tag{9.1}$$

where e_{xi} represents the life expectancy at age x in location i, k is the probability of surviving from one age cohort to the next in location i and Qx_i is the probability of dying at age x in location i. Finally, S represents the average number of years lived by the deceased individuals within the specific time frame. S is set to ½ of the duration of the age cohort (i.e. 2.5 years in a 5-year cohort) in most of the age cohorts. For newborns, S is set to 1/10 (due to higher risk of neonatal mortality). For inclusion of LE in an HDI measurement, LE is normalised using the following formulation:

$$\mathrm{LEI}_i = \frac{\mathrm{LE}_i - 20}{85 - 20} \tag{9.2}$$

The formula renders values between 0 and 1. The result is 0 when life expectancy is 20 years, and 1 when life expectancy is 85 years. It should be noted that local LE in Sweden could be greater than 85 years of age at birth, rendering local values greater than one. However, since we are using the average LE value for each municipality, the values used in the subsequent regressions are well within the limits.

9.3.6 Education Index (EI)

EI is calculated using the population aged 25 or older as follows:

$$\mathrm{EI}_i = \frac{(\mathrm{MYS}_i/15) + (\mathrm{EIS}/15.8)}{2} \tag{9.3}$$

where MYS_i represents mean years of schooling among the k-nearest neighbours from each residential location, and EIS represents expected years of schooling (in Sweden 15 is the global max value anticipated during the study period). EIS is based on the national expected value (15.8 in Sweden). The $\mathrm{E_i}$ formula renders a value between 0 and 1.

Income Index (II). The variable makes use of gross national income (GNI) in the original design. For a local GNI value, individual disposable income is normalised, so that the national sum of disposable income equals the sum of GNI. Thereafter the average disposable income (expressed in $ for consistency with the original formulation) among the k-nearest neighbours is recorded and used as replacement for GNI locally. The local income index is expressed as follows:

$$II_i = \frac{\ln(k\_\mathrm{mean\_disposableIncome}_i) - \ln(100)}{\ln(75{,}000) - \ln(100)} \tag{9.4}$$

where the k_mean_disposable Income represents the k-nearest neighbour average disposable income, and where disposable incomes at 100$ (estimated as the lowest income) will render an index value of 0, and a value of 75,000$ will render a value of 1.

The local HDI is calculated for each coordinate by taking the geometric mean of the three variables using the following formula:

$$\mathrm{HDI}_i = \sqrt[3]{\mathrm{LEI}_i \mathrm{EI}_i \mathrm{II}_i} \tag{9.5}$$

The following section presents our findings at the municipality level. In the results section we discuss the spatial variation in local HDI and regress the HDI aggregated to the municipality scale against various regional indicators.

9.4 Results

To test the functionality of local HDI, we aggregate local HDI to the municipality scale and undertake correlation analysis. Table 9.1 presents Pearson's r values for the correlation between HDI ($k = 500$), its three individual components: income, education and life expectancy index, and the engineering resilience index, RCI. We observe a high correlation between RCI and HDI, and the education component of the index has the highest correlation with resilience. This finding is in line with theoretical contributions to the growth literature (Lucas 1988; Romer 1990) and recent empirical literature, which emphasises the importance of human capital in the process of economic growth (Temple 1999). Resilience is associated with sustainable growth and even countries which are highly exposed to external shocks might attain high growth rates by their ability to build economic resilience (Briguglio 2014). The RCI employed in this paper consists of economic capacity, community connectivity capacity (CCC) and socio-economic capacity indicators and their high correlation with the education component of HDI corresponds with the endogenous growth theories and in particular the idea that the ability to adapt to changes might be rooted in part in educational attainment (Nelson and Phelps 1966) and hence the growth depends on the stock of human capital (Romer 1990). Moreover, the significant relationship between educational attainment and resilience supports the theories that education is associated with lower risks of unemployment (Mincer 1991) especially in the face of external shocks and during business cycles (Rubinstein and Tsiddon 1999), and that education increases re-employment rates among unemployed individuals (Riddell and Song 2011).

Finally, the significant and strong correlation between the local HDI and RCI (Table 9.1) implies that local HDI can be used as a measure of the ability of regions to absorb and respond to an external shock. In recent years, the concept of resilience has received enormous research interest, especially in the regional studies literature. Several papers use engineering resilience index as the benchmark measure of capability of complex social systems to recover after a shock (Östh et al. 2018). Our findings suggest that HDI, such as defined in this paper, might be useful to understand the resilience profile of regions, and as the following analyses suggest, also other regional indicators.

In addition, we examine the relationships between a set of regional indicators and our computation of the HDI. We run linear regressions using HDI as the dependent variable. The model output (Table 9.2) allows us to test to what extent RCI and RCI

Table 9.1 $N = 290$, all correlations are significant on 95% (2-tailed)

	RCI	HDIk500	IncomeIndexK500	EduIndexK500	LEIK500
RCI	1	0.59	0.53	0.619	0.253
HDIk500		1	0.868	0.921	0.687
IncomeIndexK500			1	0.725	0.444
EduIndexK500				1	0.443
LEIK500					1

Table 9.2 Regression results from two models indicating the effect on the HDIk500 variable. In model 1 RCI, in model 2 the three subgroups of RCI

	Model 1		Model 2	
	B	Std.Error	*B*	Std.Error
Constant	0.88971***	0.00069	0.88971***	0.00048
RCI	0.02905***	0.00234		
Economic capacity			−0.00051	0.00035
Connectivity capacity			0.00391***	0.00016
Socio-economic capacity			−0.00021	0.00026
Adj. R2	0.345		0.692	
$n = 290$			$n = 290$	

Table 9.3 Regression results from two models indicating the effect on the HDIk500 variable. In model 3 all RCI components except the educational attainment are included

		Model 3	
		B	Std. error
	(constant)	0.88971***	0.00032
Economic capacity			
	Income_equality	0.00302***	0.00044
	Economic diversification	0.00108*	0.00046
	Regional affordability	−0.00077	0.00059
	Business environment	0.00057	0.00043
Community connectivity capacity			
	Without disability	0.00017	0.00048
	Out of poverty	0.01089***	0.00069
	Health insured	0.00054	0.00044
Socio-economic capacity			
	Civic infrastructure	0.0019***	0.00037
	Metropolitan stability	−0.00001	0.00052
	Homeownership	−0.00084*	0.00033
	Voter participation	0.00336***	0.00049
	Observations	290	
	Adjusted R^2	0,857	

subgroups (capacities) affect HDI. In model 1, we introduce the RCI which in this case represents the standardised sum of 12 variables categorised into three subgroups, indicating the resilience capacity in terms of local economy, local connectivity and socio-economics. The results indicate that increasing values representing engineering resilience (RCI) affects HDI significantly and positively. By collapsing the RCI index to the three subgroups and regressing against HDI reveals that though R2 almost doubles only the community connectivity capacity subgroup is significantly affecting HDI.

By collapsing all categories and instead regressing each of the 12 resilience components against HDI increases R2 strongly (0.85). The results (model 3 in Table 9.3) show that HDI is positively and significantly correlated with variables indicating the share of out-of-poverty population and voter participation. The last is a widely used measure of social capital accumulation. Conversely, HDI is negatively and significantly correlated with the indicators of homeownership, which indicates that house-prices are considerably higher in high-HDI, metropolitan areas. Income equality and economic diversification (industrial mix) are significantly and positively contributing to explain HDI, while regional affordability is insignificant. In addition, civic infrastructure is significant. That the local HDI has a positive and significant association with income equality, civic infrastructure and voter participation implies that regions with relatively homogenous groups (in terms of income) with higher civic engagement and social capital exhibit higher human development. This might also point to sorting behaviour of individuals into localities with their preferred local public goods and fiscal policies. From Tiebout (1956)'s "Voting with one's feet" perspective this implies that human capital accumulation is also a function of the activities of local governments that are designed according to the priorities of local communities with similar needs. This is especially relevant to the Swedish context, where local governments are strong in a highly decentralised system, and despite that positive externalities are preserved through fiscal equalisation grants among regions. The evidence for the latter is captured by the relationship between our inequality measures and development.

In sum, the results suggest that there are substantial similarities between HDI as used on a regional level and engineering resilience. In particular if regressing HDI against the different RCI (engineering resilience) components.

9.5 Conclusions

Since the first discussions, arguing that human development is a notion that is beyond wealth and simple metrics, there has been a general agreement on the conceptualisation of human development that the index should focus on individuals and their life opportunities. However, almost all previous applications have been limited to country or regional scales. Such considerations necessarily lacked solid reference to individuals and their immediate environments. In this paper, we propose a local version of HDI, wherein each component of the index is calculated by the k-nearest neighbour approach and aggregated first as the geometric mean and thereafter to municipalities allowing comparison to measures of regional economic resilience. The index allows identifying human development patterns surrounding each individual and local heterogeneity in access to human development, as shown by an empirical application in Sweden. The regressions and correlation analyses allow us to study regional relationships that cannot be conducted using macro-level statistics. Our results support the theories that underline the importance of human capital in the process of growth and resilience and reveal Tiebout (1956)'s "Voting with one's feet" type of influences at the regional scale. Importantly, the results help us to confirm that HDI can be used as an indicator of regional economic engineering resilience and can as such be used as a proxy for engineering resilience in countries or regions where data is difficult to generate or obtain.

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Chapter 10
Ceteris Paribus and Fixed Effects in Regional and Cultural Economics

Annie Tubadji

Abstract This chapter is inspired by Peter Nijkamp's contribution "Ceteris Paribus, Spatial Complexity and Spatial Equilibrium" and his original take on the deficiencies of using the ceteris paribus assumption in regional economic modelling. After summarizing Nijkamp's interpretative perspective of the ceteris paribus assumption within theoretical modelling, I suggest an analytical analogy between the ceteris paribus assumption in theoretical modelling and the use of fixed effects in empirical modelling. I argue that fixed effects have the economic meaning of the ceteris paribus assumption in empirical work and could lead to erroneous implications in empirical results, especially with regard to understanding cultural relativity across space. The chapter illustrates this point through an example focused on *religion* as one of the most important proxies for culture in the economic literature. The operationalization of the example draws on data from the World Value Survey (WVS) and employs detailed data decomposition and logistic regression analyses. The use of fixed effects is contrasted to precise quantification of cultural interactions, cultural relativity and cultural hysteresis. The chapter shows how significant effects from cultural complexity can be lost or overseen in the interpretative analysis of empirical findings when fixed effects are used in the spirit of the ceteris paribus assumption.

Keywords Ceteris paribus · Fixed effects · Religion · Culture · Decomposition · Logistic regression · Cultural interactions · Cultural complexity · Nonlinearity

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To Peter, with gratitude

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10.1 Introduction

Professor Peter Nijkamp is a global scholar and philanthropist, whose outstanding intellectual contribution spans widely from generous and most candid comments to every junior or not so junior scholar at their conference presentations, to a wealth of publications on a plethora of multidisciplinary topics, rendered in regional economic analysis. Always on the crest of the wave of lateral thinking about the socio-economic reality and the phenomena behind it, Nijkamp's work is founded on his precise and elaborate knowledge of regional economics as a science, backed by his vast imagination about the links between neoclassical economics fundamentals and other disciplines (sociology, history, geography, topology, neuroscience, to name a few). His work has generated novel conceptual and methodological insights of various nature.

The current chapter focuses on one particular original contribution by Peter Nijkamp, eloquently laid out in a paper published in 2007 in the *Journal of Regional Science and Urban Economics*. This particular Nijkamp's contribution explains in detail the defectiveness of the ceteris paribus classical economic assumption. The chapter starts by presenting Nijkamp's standpoint regarding the ceteris paribus assumption in regional economics. This standpoint is next reinterpreted with regard to the empirical practice of using fixed effects from a regional and cultural economics perspective. Thus, a Culture-Based Development (CBD) (Tubadji 2012, 2013) interpretation of the ceteris paribus deficiencies is analytically presented and illustrated with empirical examples, highlighting the statistical and practical policy implications of applying fixed effects as an empirical equivalent of ceteris paribus in econometric analysis.

The main take from this meditation on Peter Nijkamp's (2007) idea is that Peter's insight that we cannot harmlessly over-impose a ceteris paribus condition resonates with most novel regional and cultural economics considerations in empirical work. Peter's far-reaching mind and the seeds of novel out-of-the-box ideas that he has left for all of us throughout his work will always shed light on the way ahead in regional science. His constructive criticisms and novel insights will reveal their depth to us as we grow to understand how his ideas help us grasp better the subject matter and develop further the approaches in our research field. Thank you, Peter, for the inspiration! And happy 75th Birthday! To many more years ahead!

The structure of this chapter is as follows. Section 10.1 overviews the essence of the ceteris paribus notion and traces its roots in the history of economic thought. Section 10.2 summarizes Nijkamp (2007) take on the ceteris paribus condition. Section 10.3 explains the CBD take on fixed effects as an empirical equivalent of the ceteris paribus condition in econometric economic analysis. It outlines the regional and cultural economics implications of the use of fixed effects as a ceteris paribus empirical implementation. Section 10.4 offers an empirical illustration of the stated CBD implications of using fixed effects as ceteris paribus in empirical work. Section 10.5 concludes.

10.2 Ceteris Paribus in Economic Theoretical Literature

The ceteris paribus condition was potentially existent since 1311, as claimed by Persky (1990), yet in economics it was introduced to a large extent due to the work of Marshall (1898). In its essence, ceteris paribus implies focusing on a particular set of factors and outcomes, assuming the rest of the world remains constant. The application of ceteris paribus is noted by Arrow and Debreu (1954) as problematic with regard to ignoring certain contextual influences. The father of behavioural economics, Herbert Simon (1969) also clearly states that the complexity of the decision tree and the numerous possible solutions in the same moment of time makes ceteris paribus a problematic assumption that allows us to study only a fraction of the real space of possible decisions.

Adding to this discourse, Nijkamp (2007) notes that the use of ceteris paribus as a condition in economic modelling leads to avoiding to pay due attention to the interactions in the economic system. In this context, and supported by a plethora of preceding work in Nijkamp (2005), Nijkamp and Reggiani (1993, 1998, 2006), according to Nijkamp (2007) the use of ceteris paribus leads to avoiding the main question how complex network structures affect the spatial-economic equilibrium.

10.3 Ceteris Paribus and Peter Nijkamp's Approach

Nijkamp's approach to the ceteris paribus notion was inspired by Tobler (1970) who stipulated the first law of geography, stating that: 'everything in space is related to everything else, but near things are more related than distant things' (Tobler 1970, p. 236). The argument in Nijkamp (2007) is based on elucidating the characteristics of the space economy as an open system and the nature of the interactions within this system, which jointly create a complexity that generates an important effect on the spatial-economic equilibrium. According to Nijkamp (2007), imposing a ceteris paribus condition on the economic modelling leads to an amputation of this complexity as a main source of influence on the spatial-economic equilibrium, and thus makes the analysis void of explanation for the outcomes observed in reality.

In his expose on the matter, Nijkamp (2007) offers two especially important insights. Firstly, in line with Robbins (1932) comments on the time-relevance of empirical findings such as the '*fallacy of misplaced concreteness*' (pp. 48–54) and the limits of economic laws, again there, Nijkamp (2007) highlights that evolutionary processes in the external world may render certain model parameters time-dependent in their behaviour, which causes a conflict with the ceteris paribus condition. In a certain moment in time, some factors may be significant, but in the next moment, they may lose their significance as a factor for the output of interest. Secondly, the use of ceteris paribus and the entire general equilibrium analysis is highlighted as potentially problematic in light of the existing slow and fast dynamics in a complex economic system. Underlying slow and fast dynamics in the economic system (such as path dependency and lock-in behaviour) may determine different equilibria in the presence of identical inputs.

In his original contribution, Nijkamp (2007) clearly specifies that culture, among other endogenous entities, such as education, is an important source of impact on the economic system. As stated by Nijkamp, again there, culture can create qualitatively different organizational and topological structures that ultimately determine the development of the space economy. The current chapter starts from this pivotal insight and employs cultural and regional economic arguments and analysis in order to clarify the importance of culture as a complex system itself and its impact on the space economy. This is done in order to ultimately clarify that the use of fixed effects has the same aftermaths in empirical work as the imposition of ceteris paribus in theoretical modelling, and is equally erroneous for the same or similar and connected reasons as ceteris paribus is in theoretical modelling, as explained by Nijkamp (2007).

10.4 Ceteris Paribus and Culture-Based Development in Empirical Work

It is worth noting here that in his work ‘Theory of Moral Sentiments’, Adam Smith (1759) states a view on cultural relativity of valuation that is very similar to Tobler (1970) take on geographical proximity. Namely, Smith (1759) suggests that every human decision is personally weighted through our value system, but this cultural weighting is applied more rigorously to decisions concerning near things and people than to decisions concerning distant ones. One of Smith’s examples is the moral valuation of awarding one’s sympathy for suffering people. A loss of many lives due to a natural disaster in China seems more negligible to an individual in Europe, than the immediate suffering of people in front of our own eyes, and even more negligible in comparison to a mere minor but personal physical misfortune (such as a loss of one’s finger). The current chapter argues that the complexity of the cultural and moral valuation as part of the economic decision-making process is lost in the empirical economic analysis when fixed effects are used under the premise that they account for the entire cultural effect. This loss has reasons much similar to the reasons specified by Nijkamp (2007) with regard to the loss of accounting for complexity when imposing a ceteris paribus condition in theoretical economic work.

With regard to Nijkamp (2007) and his two main insights, outlined in the previous paragraph, CBD offers cultural economic support in the form of empirical evidence. Firstly, CBD has provided evidence that due to the cultural construction of reality and its culturally-based rules of the game, different places experience different impact from one unit of input. For example, CBD has demonstrated that there is cultural relativity from the impact of immigrants from one and the same ethnic background in different localities across pace (see Tubadji and Nijkamp 2015). There is also different innovation success in terms of percolations of new ideas, depending on the cultural connectedness in the social network in different localities (see Tubadji and Nijkamp 2016). In other words, the marginal product is culturally relative across space. What is notable here is that CBD adds to Nijkamp (2007) the claim that one and the same input may vary in significance as input not only across time but across space as well. Secondly, CBD has demonstrated that culture is a source of cultural persistence, cultural path-dependence and cultural hysteresis. Both individual entrepreneurs and entire regional economies seem to react differently to the same global shocks due to cultural relativity of valuation of this shock (see Tubadji et al. 2016, 2019). Put differently, CBD adds to Nijkamp (2007) argument that slow and fast dynamics exist in the complex open systems, by identifying culture as a major source of this slow and fast dynamics.

Moreover, the current chapter highlights, above all, that culture itself is a complex system on its own right and generates a nonlinear impact on the socio-economic reality. This puts in question the adequacy of the practice of using fixed effects to account for cultural differences, which has become an unwarranted heuristic in empirical work (see, for example, Kunce and Anderson 2002). It is argued here that the usual rendering of culture in an empirical setting where cultural-identity fixed effects are employed to impose an empirical ceteris paribus equivalent to the economic analysis can lead to entirely uninformative or even erroneous conclusions. There are some pioneering analyses pointing in their own way in this direction (Neumayer 2003a, b; Greene 2004; Tabellini 2010). The current chapter synthesizes the meaning and message of these pioneering studies on fixed effects from the point of view of Nijkamp's (2007) take on the ceteris paribus condition by identifying clearly the common reasons behind the bias created through ceteris paribus in theoretical work and through fixed effects in empirical work.

Namely, the current chapter aims to postulate that culture is a complex in nature form of capital, and specifically:

1. Culture is a composite proto-institution[1] that serves for the construction and deconstruction of the social perceptions of reality, thus setting all rules of all games throughout the system, rendering the same model parameter significant in one spatial open system and insignificant in another.
2. Some cultural elements evolve faster than others, so different culture-based rules experience their state of evolutionary revision and evolutionary stability in different moments in time, and this creates slow and fast dynamics in the economic system.

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[1]Tubadji (2012, 2013) defines culture and cultural capital, explaining how the latter is the potential of the former to influence the reality and defines the composition of culture into four main subdomains: living culture and cultural heritage, respectively, each being in tangible or intangible form. Besides this complexity, each of these subdomains is built of a wealth of attitudes and their related beliefs and norms, which sometimes have different direction of impact, see Tubadji and Pattitoni (2020). That is why culture is firstly a complex system itself. Second, due to defining attitudes as the core of this complex system, CBD can be considered a Neo-Weberian paradigm, as Weber (1905) approach to culture defines culture as an attitude to religion. Regarding the role of culture as a proto-institution in the hierarchy of institutions, see Tubadji et al. (2015).

Put differently, the current chapter reiterates the claim of Tubadji (2014) that the omission of culture as an input factor in the model causes under-specification of the model. This statement is further developed here from the point of view of empirical analysis. Accounting for the statistical presence of cultural grouping cannot easily be achieved via fixed effects, because their use cannot account for the complexity of culture as a factor and omits to account for the network and dynamics of evolution of the cultural interactions in the socio-economic system. The next section provides an empirical example for the above two points. A comparison is offered between the economic analysis based on the same data, yet implemented alternatively through the use of fixed effects and the use of other quantitative methods accounting for the cultural factor.

10.5 Illustration of the Ceteris Paribus and Fixed Effects Problem in Regional and Cultural Economics

10.5.1 Data

For the purpose of the illustration in this chapter, we shall use mainly the World Value Survey, in its six waves, covering a period from 1981 until 2014 and in total containing 100 countries and nearly 171,000 individual observations. A statistical summary of each variable in our analysis is available in Appendix 10.1.

The example in this chapter will be based on the context variable culture, which as noted in Nijkamp (2007) is in interaction with the economic system. Also, as said above, culture itself is a complex system on its own right. Therefore, it has been operationalized in the literature through various proxy variables: trust, ethnicity, cultural heritage, etc. (see Guiso et al. (2006) for a comprehensive literature review on the operationalization of culture in the empirical economic literature). However, one of the most prominent operationalizations of culture since Max Weber, until nowadays (see Bénabou and Tirole 2006, 2011; Bénabou et al. 2013, 2015) is culture as religion (see Knack and Keefer 1997). In a fully neo-Weberian manner, CBD defines culture from the point of view of it being a complex system of attitudes, as Weber (1905) underlines the significance of attitudes as culture (which affects economic outcomes). Thus, in the current chapter, we shall operationalize culture in specific through the cultural attitude to religion. In specific, this is the expressed self-reported valuation of religion as being an important element of one's life. This variable is labelled *religion_important* and is equal to 1 if the person has selected religion among the items they consider important—selecting it from a list of various aspects of life listed in the WVS questionnaire, such as: friends, family and leisure time.

Alternatively, and in order to illustrate the complexity and dynamics of culture across time and space, we shall use the data from Google n-grams, which reports the frequency of appearance of a word in 5% digitalized sample of all published texts across the world libraries. Namely, we use the frequency of appearance of the word *'religion'*, in order to reflect how intensely (and therefore how importantly) this notion has been employed in the construction and deconstruction of our reality throughout the last two centuries (see Tubadji 2020; Tubadji and Pattitoni 2020; Tubadji and Webber 2020). The assumption here is that the frequency of use of a word is associated with the higher importance of this notion in the narrative and constructed reality of the period. Thus, in a sense, the frequency of use of the word 'religion' in a year can be thought of as an operationalization of the idea of how important religion is in this period. In this sense, our time-series data from Google n-grams can be considered a natural counterpart of the WVS question about the attitude to the importance of religion described above.

The World Value Survey has data on 100 countries. This clearly provides us with the opportunity to easily trace the variation of culture across space within one WVS wave as well as to compare between time and space effects, tracing the development of the attitudes to religion as an important part of life throughout the time window 1981–2014 in different countries. We focus the analysis on waves 2 and wave 5, as wave 1 has a too small number of countries for comparison with the following waves, and wave 6 is not comparable with the Google n-gram data which finishes in 2008.

In addition, our WVS variables used in this analysis will include the following. As an outcome variable, we will have a proxy for wage or economic welfare (equivalent to a 10-degrees variable from the WVS, ranking standardized income). Our independent variables will include the basic components of a Mincer equation, such as: age, age squared, gender, level of education, level of urbanization of the area where the person is located (a dummy variable labelled *'city'*, equal to zero if the respondent lives in a rural area, and one otherwise).

10.5.2 Method

The technical claim throughout the empirical literature is that the use of country fixed effects (country FE) eliminates all cultural differences, and, respectively, the impact of culture has been taken away from the analysis (see Kunce and Anderson 2002; Neumayer 2003a, b). We want to test three culture and economics related hypotheses, which build on Nijkamp (2007) argument against ceteris paribus condition, and suggest that the same argument applies for rendering the use of fixed effects equally erroneous and bias-creating as the ceteris paribus condition in theoretical modelling. These cultural economics hypotheses are:

H01: Even in the presence of country FE, the regression still contains influences from cultural interactions.

*H02: Even in the presence of country and time FE, the regression still contains influences from cultural change over time and across space (*i.e. *cultural hysteresis and cultural relativity).*

*H03: Even in the presence of time FE within one country, the regression still contains influences from differences in cultural change within space (*i.e. *cultural path-dependence).*

The methodological tools for operationalizing each of these hypotheses are as follows.

To test H01, we use the Mincer equation in its simplest specification, as shown below:

$$\mathrm{Wage} = \alpha + \beta_1 \mathrm{Age} + \beta_2 \mathrm{Age\_Sq} + \beta_3 \mathrm{Female} + \beta_4 \mathrm{Edu} + \beta_5 \mathrm{City} + e \tag{10.1}$$

The estimation of Model (1) is implemented first with OLS, using the pooled dataset of the whole WVS, and including country and time fixed effects. This standardly supposes that all cultural effects are accounted for using the country fixed effects (see Kunce and Anderson 2002). Next, using the exact same Model (1), we decompose the effect for two groups: *religion_important* (those who answered the WVS question regarding important items of their life including religion among them), and *religion_NOT_important* (those who did not choose religion among the potential answers offered in the WVS questionnaire). This decomposition is clearly based on a cultural distinction. If the decomposition shows no difference between the two groups, indeed all cultural differences across space have been successfully accounted for by the use of the culture/country related fixed effects. If the decomposition still finds a significant difference between the two culturally defined categories, this means that there are certain important culture-related interaction that the country fixed effects have not been able to account for. The latter will mean that we cannot falsify hypothesis H01. In that case, *religion_important* will be included as a regressor in Model (1) as well as its relevant interaction terms with elements of the Mincer equation (such as education and gender), as stated in Model (2) below:

$$\begin{aligned}\mathrm{Wage} = {} & \beta_1 \mathrm{Age} + \beta_2 \mathrm{Age\_Sq} + \beta_3 \mathrm{Female} + \beta_4 \mathrm{Edu} + \beta_5 \mathrm{City} + \beta_6 \mathrm{Relig} \\ & + \beta_7 \mathrm{ReligInter} + e_2\end{aligned} \tag{10.2}$$

The estimation of Model (2) (expressed here with a suppressed constant, for brevity) with the same estimator as Model (1) will allow us to test the interaction with the *religion_important* as an additional regressor in order to account for these interactions of the cultural factor in the presence of country FE analytically within the regression. The results will be compared with the initial FE model.

Yet, besides the fact that interactions exist, Nijkamp (2007) claims that they also vary across time. We add here that they vary not only across time but also importantly across space, the latter containing the cultural relativity across space. This is our claim in H02. We proceed to test H02 by showing the difference in estimating (Model 1 and 2) through using different compositions of the WVS, with different time and space dimensions to it.

Moreover, within space, the cultural change over time happens in a different pace, thus a cultural hysteresis exists as a process on a regional level and the estimations of the cultural effect over time for different places can be substantially different. This is the claim reflected in our H03. We proceed to test H03 by showing the difference in estimating (Model 1 and 2) by using the data separately for individual countries in the WVS, and comparing the results about these countries by having used time fixed effects in our estimations. If the results are particularly unstable, this will mean that the use of country and time fixed effects and interaction terms are not able to account for nonlinearity and cultural hysteresis across time and cultural relativity across space.

Finally, we want to learn how exactly the cultural interactions themselves are prone to nonlinearity and complexity. In order to explore the effect of potential nonlinearity and cultural relativity across space and time, we employ a logistic regression, specified as stated in Model (3) below.

$$\text{Relig} = \alpha + \beta_1\text{Age} + \beta_2\text{Female} + \beta_3\text{Edu} + +\beta_4\text{City} + e_3 \tag{10.3}$$

The dependent variable *Relig* is defined as being religious (*religion_important* = 1), as opposed to religion not being important in one's life (*religion_important* = 0). This outcome variable is explained: (a) in parsimonious form, only in terms of the level of education in relation to gender, and alternatively (b) in its full specification as shown in model (3) above, with special attention to the effect of education by age category (below 30 or above 60 years of age, respectively). Results for Switzerland and Brazil are compared to results for the full sample of WVS countries for all years in order to illustrate the discrepancies of FE-based results in comparison to the realistic picture inside a country. Odds ratios and marginal effects for education over gender and education over age are presented for the needs of the analysis.

10.6 Results

10.6.1 Fixed Effects and Cultural Interactions

We start by exploring the distribution of wage for the entire sample in comparison to its distribution for religious and non-religious groups of men and women as well as the same cultural distinction between educated and not highly educated individuals. Figure 10.1 shows the results, which demonstrate, that the non-religious female and non-religious non-educated seem to experience cultural interactions of visible difference. In order to explore the extent of this difference analytically, we implement a Blinder–Oaxaca detailed data decomposition analysis. Table 10.1 presents the results.

Table 10.1 has five main columns with results. The first column shows the estimation of Model (1) with country and time fixed effects. The second column presents the means for the religious and non-religious groups. The last three columns

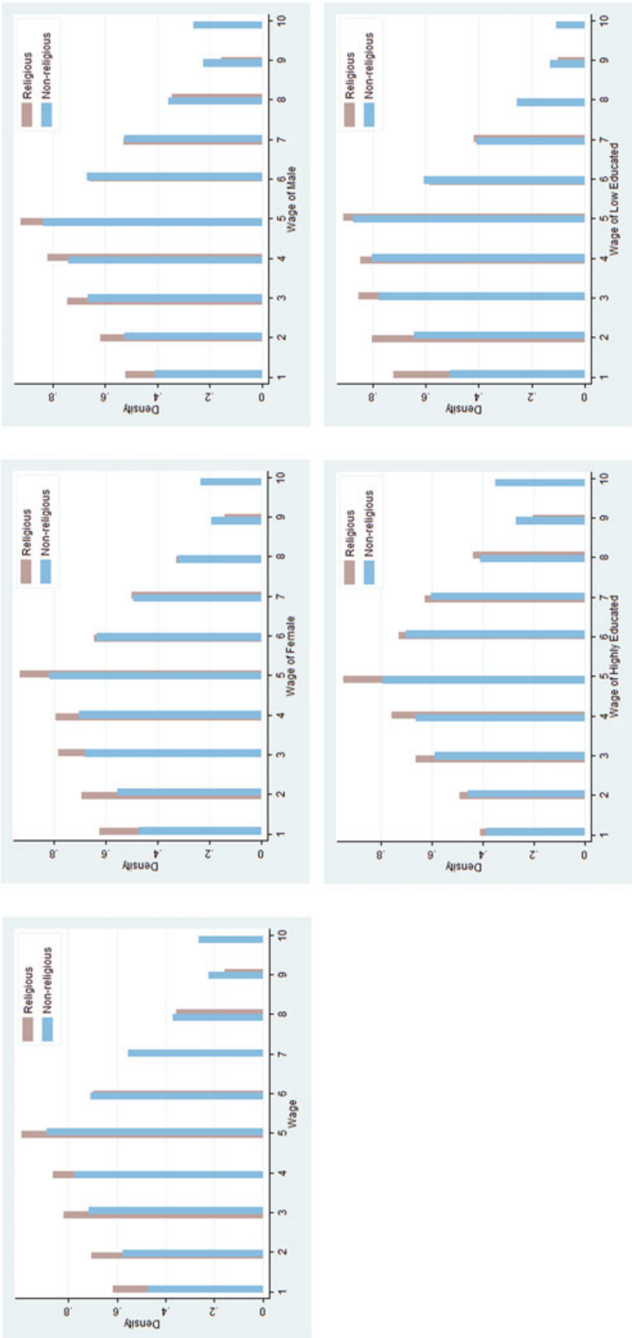

Fig. 10.1 Interactions of religion and wage—individual level. Notes: The figure represents the distribution of religiosity, in total, by gender and by education (WVS)

Table 10.1 Decomposition and cultural interactions beyond FE

dep. Var.	WAGE													
Method	OLS with country and wave FE			Mean		Decompositions								
				Religion NOT important	Religion is important	Religion NOT important			Religion is important			Pooled		
Differential	Coef.	z-value				Coef.	z-value		Coef.	z-value		Coef.	z-value	
Prediction_1						4.98	504.12	***	4.98	504.12	***	4.98	504.48	***
Prediction_2						4.63	737.85	***	4.63	737.85	***	4.63	738.06	***
Difference						0.35	29.74	***	0.35	29.74	***	0.35	29.76	***
Explained														
Age	0.031	18.93	***	41.22	40.48	0.038	10.89	***	0.062	10.93	***	0.045	13.07	***
age_sq	0.000	−23.73	***	1959.73	1898.35	−0.042	−11.67	***	−0.067	−11.65	***	−0.050	−13.29	***
Female	−0.111	−11.40	***	0.47	0.54	0.005	5.95	***	0.012	9.18	***	0.007	9.68	***
Edu	0.293	121.61	***	5.03	4.57	0.121	35.05	***	0.120	31.96	***	0.120	35.57	***
City	0.309	27.66	***	0.62	0.56	0.015	14.88	***	0.013	11.06	***	0.014	15.40	***
FE country	YES					YES			YES			YES		
FE wave	YES					YES			YES			YES		
_cons	3.631	47.16	***			0.224	20.29	***	0.362	12.91	***	0.215	25.31	***
Unexplained														
Age						0.683	4.54	***	0.659	4.54	***	0.676	4.54	***
age_sq						−0.415	−5.38	***	−0.390	−5.38	***	−0.408	−5.38	***
Female						−0.049	−4.98	***	−0.057	−4.98	***	−0.051	−4.98	***
Edu						−0.013	−0.48		−0.012	−0.48		−0.013	−0.47	
City						−0.022	−1.42		−0.020	−1.42		−0.021	−1.40	
Country dummies	YES					YES			YES			YES		
Wave dummies	YES					YES			YES			YES		
_cons						−0.005	−0.02		−0.005	−0.02		−0.005	−0.02	
Total						0.124	8.38	***	−0.014	−0.47		0.133	10.25	
Adj. R-square	0.1772					0.1728			0.1844			0.1773		
Sample size	188,285					188,285			188,285			188,285		

Notes: The table presents OLS compared to means for two groups and detailed Blinder–Oaxaca decomposition coefficients. The difference in decomposition shows the gap in economic welfare between non-religious people and religious individuals in the presence of country and year fixed effects represent the detailed decomposition for, respectively, the non-religious, the religious and the pooled estimation, as recommended by Jann (2008).

The results in Table 10.1 show that the difference in the means of wages of religious and non-religious people (presented in column two) is statistically significant, and this is true in the presence of country fixed effects, which supposedly takes away the cultural differences across countries. Clearly, the country fixed effects do not manage to clean the cultural interaction of religion with the wage outcome. As seen in columns three, four and five, the cultural distinction in terms of religiosity is associated with a difference of about more than one third (35%) in the wage of the individuals, even when the estimation includes the country fixed effects. This result means that clearly there are cultural interactions that the use of country FE cannot account for successfully. Our H01 cannot be rejected, and Nijkamp (2007) has an important implication for the empirical deficiency of the use of FE as a ceteris paribus 'curing' the cultural influences in the economic processes.

10.6.2 *Fixed Effects and Cultural Hysteresis in Time*

One potential response to the existence of remaining unaccounted for cultural interactions after the use of fixed effects is to always use a cultural variable and its interaction terms in one's regression when more than one country are present in the dataset (as suggested by Neumayer 2003a, b; Oyserman and Lee 2008; Davies et al. 2008; Tabellini 2010). However, according to Nijkamp (2007), there still are important time effects related to nonlinearities that cannot be accounted for even with the inclusion of interaction terms. We shall expand and explore here the claim of Nijkamp (2007) in the context of the cultural influence both over time and across space. I would argue that not only nonlinearities across time (cultural hysteresis) but also cultural relativity and cultural path-dependence across space and time will play a significant impact on the economic process and fixed effects cannot properly handle these effects. If we explore deeper the descriptive statistics about the cultural component, this becomes immediately evident, as seen from Fig. 10.2a and b, as well as Table 10.2.

As seen from Fig. 10.1, over time the intensity of the importance of religion for people seems to be decreasing—a disenchantment with religion, claimed by Max Weber and maintained as a thesis till nowadays (see Bénabou et al. 2015). However, the two waves of WVS (wave 2 and wave 5) coincide with the periods marked with red vertical lines in Fig. 10.1, and we see that between these two periods the importance of religiosity seems to have gone upwards. The conclusions based on viewing these different time windows of 200 and of about 35 years can clearly bring us to very different conclusions.

Also, as seen from Fig. 10.2b, a map of the world, representing the importance that the local interviewees of the WVS bestowed to religion in their lives, shows sizable cultural relativity across space. The map demonstrates that even within the same time window (the 35 years of the WVS), there is a very prominent

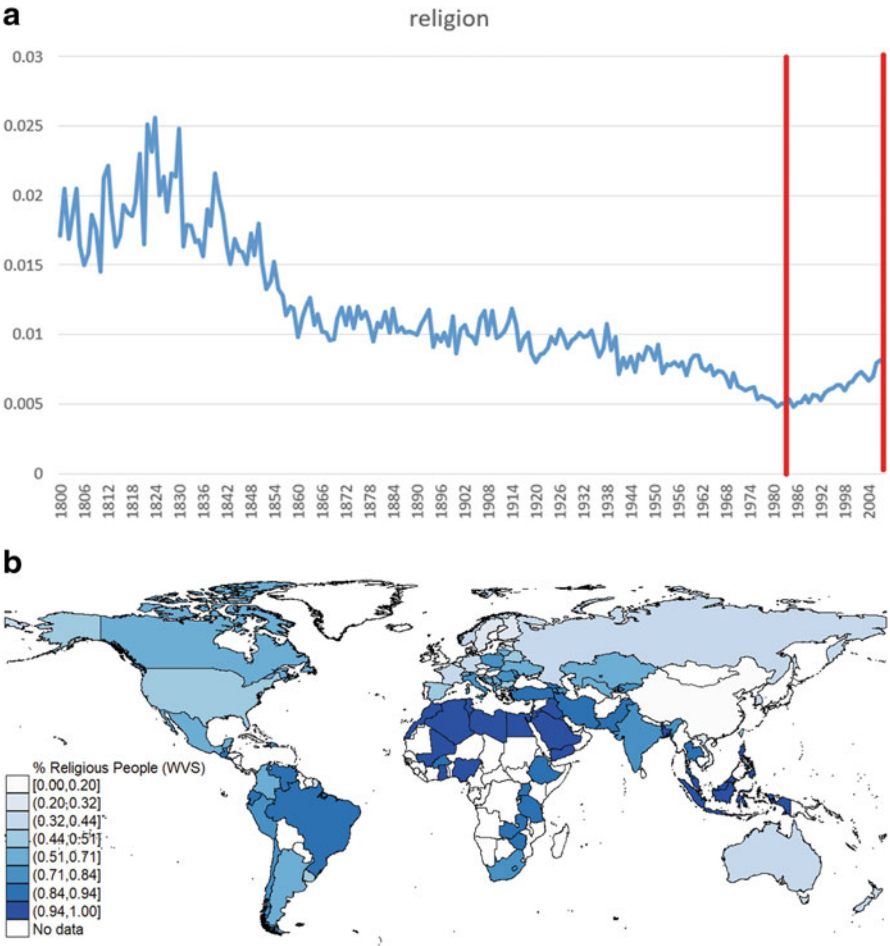

Fig. 10.2 (**a**) Religion over time. Notes: The figure represents the frequency of use of the word 'religion', 1800–2008 (Google n-grams). (**b**) Religion across space. Notes: The figure represents percentage of religious people by country, average 1981–2014 (WVS)

Table 10.2 Religion over time and across space

country	perc_relig_imp_wave2	perc_relig_imp_wave5
Switzerland	0.53	0.46
South Korea	0.58	0.49
Turkey	0.86	0.95
India	0.87*	0.85*
Brazil	0.87	0.92
South Africa	0.90	0.91

Notes: The table presents the percentage of religious people during wave 2 (1989–1993) and wave 5 (2005–2009) of the WVS. The table demonstrates that low percentage in wave 2 is followed by decrease of percentage in wave 5 and higher percentages in wave 2 are associated with increase of the percentage in wave 5, yet the effect seems not to be consistent, as shown by the *, for India, where a high percentage in wave 2 was followed by a decrease in wave 5 heterogeneity in religiosity across space. Indifferent of their religion, some places have been considering religion more important in their lives much more than other places during the same time period. These results confirm our alert about the inability even of interaction terms in a fixed-effects model to account for the complex cultural interaction and important nonlinear impacts from culture on the socio-economic process.

The information presented in Table 10.2 comes from the WVS and looks into the level of religiosity within a country and its change over time (in particular between wave 2 and wave 5 of the WVS). As we see, in most countries where the religiosity was relatively lower, it fell further lower as a percentage during wave 5; and in the countries where religiosity used to be high during wave 2, it increased even more during wave 5. Yet, even this bifurcation tendency is not systematically true for all countries, because as we see in India the religiosity was rather high during wave 2 (87%), and it fell with 2% in wave 5. These are strong descriptive indications for both nonlinearity, cultural hysteresis (as nonlinear cultural change over time) and cultural relativity across space (distinct path of the cultural process across different spaces). We use the example of Table 10.2 to choose Switzerland and Brazil as, respectively, a representative country for place that was with low religiosity that decrease over the last 35 years and a country with high religiosity which increased within the same period.

To explore our H02 regarding the remaining cultural time-sensitivity of the estimations when using FE and cultural interaction terms, we estimate Model (2) including the cultural interactions, but using different subsets of the data. The results are shown in Table 10.3.

As seen from Table 10.3, depending on the time period estimates, the impact of the cultural factor and its interaction terms with education and gender have a very different behaviour. While the pooled estimation identifies significant impact from the religiosity and its interactions with both education and gender, if we separate the sample into wave 2 and wave 5, the cultural interactions seem to entirely loose significance, together with religiosity itself, during wave 5. This means that Nijkamp (2007) and our interpretation of it for the presence of cultural hysteresis cannot be rejected with regard to FE not being able to play the role of ceteris paribus for the cultural component in empirical work.

10.6.3 Fixed Effects and Cultural Relativity Across Space

To test H03, regarding the within-country variation of culture over time, we explore Model (2) using the dataset for only one country at a time. Results are presented in Table 10.4.

According to the results in Table 10.4, the effect for Switzerland and the effect for Brazil are in contradiction. While Switzerland seems to experience a significant impact from the cultural factor of religiosity, Brazil does not seem to experience it. The effect of the interactions can no longer be captured for either country. This is

Table 10.3 Cultural FE and time

	All									Wave 2 and 5						Wave 2						Wave 5					
Dep. Var.				*WAGE*																							
	Coef.	t-value		Coef.	t-value		Coef.	t-value		Coef.	t-value		Coef.	t-value		Coef.	t-value		Coef.	t-value		Coef.	t-value		Coef.	t-value	
Age	0.03	18.93	***	0.03	18.91	***	0.03	18.93	***	0.04	14.16	***	0.04	14.16	***	0.09	9.02	***	0.09	9.05	***	0.04	12.68	***	0.04	12.67	***
age_sq	0.00	−23.73	***	0.00	−23.50	***	0.00	−23.53	***	0.00	−16.64	***	0.00	−16.66	***	0.00	−10.24	***	0.00	−10.27	***	0.00	−14.99	***	0.00	−14.99	***
Female	−0.11	−11.40	***	−0.10	−10.35	***	−0.17	−9.18	***	−0.07	−3.93	***	−0.18	−5.37	***	0.09	1.59		−0.06	−0.49		−0.10	−5.13	***	−0.19	−5.62	***
Edu	0.29	121.61	***	0.29	121.04	***	0.29	66.20	***	0.30	67.64	***	0.33	39.90	***	0.32	20.92	***	0.32	10.40	***	0.30	64.65	***	0.33	39.52	***
City	0.31	27.66	***	0.31	27.35	***	0.30	27.33	***	0.40	19.30	***	0.40	19.32	***	0.22	3.07	***	0.22	3.06	***	0.37	16.86	***	0.37	16.90	***
religion_important	-	-		−0.13	−10.26	***	−0.17	−5.81	***	−0.07	−2.78	***	0.03	0.47		−0.35	−4.70	***	−0.43	−2.11	***	−0.04	−1.51		0.06	1.16	
inter_relig_gender	-	-		-	-		0.09	4.36	***	-	-		0.16	3.93	***	-	-		0.19	1.38		-	-		0.13	3.33	***
inter_relig_edu	-	-		-	-		0.00	−0.34	***	-	-		−0.03	−3.63	***	-	-		0.00	0.05		-	-		−0.03	−3.65	***
FE country	YES			YES			YES			YES			YES			YES			YES			YES			YES		
FE wave	YES			YES			YES			YES			YES			-			-			-			-		
_cons	2.558	38.92	***	2.629	39.80	***	2.650	38.79	***	1.939	18.81	***	1.863	17.03	***	−0.169	−0.73		−0.110	−0.40		3.276	33.77	***	3.190	30.72	***
Adj. R-square	0.18			0.18			0.18			0.23			0.23			0.27			0.27			0.22			0.22		
Sample size	188,285			188,285			188,285			52,505			52,505			5534			5534			46,971			46,971		

Notes: The table presents pooled OLS with country and year fixed effects. Estimations are done with four different subsets of the WVS dataset, differing time-wise, respectively, covering all the six waves in the WVS (Specification 1 to 3), data only for wave 2 and 5 (Specification 4–5), only data for wave 2 (Specification 6–7) and data only for wave 5 (Specification 8–9). The specifications differ in terms of including (a) only the religiosity as a cultural explanatory variable and (b) including religiosity and its interactions with education and gender

Table 10.4 Cultural FE and space

Specification	All countries						Switzerland						Brazil					
	Wave 2 and 5						Wave 2 and 5						Wave 2 and 5					
Dep. Var.	*WAGE*																	
	Coef.	t-value		Coef.	t-value		Coef.	t-value		Coef.	t-value		Coef.	t-value		Coef.	t-value	
Age	0.04	14.43	***	0.04	14.43	***	0.21	7.45	***	0.21	7.53	***	0.00083	0.06		0.00056	0.04	
age_sq	−0.00052	−16.93	***	−0.00052	−16.96	***	−0.002	−8.75	***	−0.002	−8.81	***	−2.8E-05	−0.18		−2.5E-05	−0.16	
Female	−0.07	−3.92	***	−0.18	−5.51	***	−0.56	−3.77	***	−0.45	−2.1	*	−0.26	−3.78	***	−0.54	−2.62	**
Edu	0.30	67.76	***	0.33	41.01	***	0.17	3.92	***	0.27	4.43		0.32	18.64	***	0.36	8.08	***
City	0.40	19.24	***	0.40	19.26	***	−0.22	−1.48		−0.21	−1.44		0.56	6.25	***	0.56	6.26	***
religion_important	−0.07	−2.86	**	0.03	0.47		−0.54	−3.56	***	0.51	1.15		−0.20	−1.83		−0.14	−0.57	
inter_relig_gender	-	-		0.16	3.99	***	-	-		−0.24	−0.81		-	-		0.31	1.42	
inter_relig_edu	-	-		−0.03	−3.72	***	-	-		−0.20	−2.35	*	-	-		−0.04	−0.91	
FE country	YES			YES			-			-			-			-		
FE wave	YES			YES			YES			YES			YES			YES		
_cons	1.939173	17.88		1.862759	16.35		1.235867	1.82		0.669353	0.94		1.14749	3.94		1.09339	3.17	
Adj. R-square	0.2314			0.2318			0.1576			0.1609			0.2558			0.256		
Sample size	52,505			52,505			1097			1097			3069			3069		

Notes: The table presents pooled OLS with country and year fixed effects. Estimations are done with three different subsets of the WVS dataset, differing space-wise, respectively, covering all countries in the WVS (Specification 1 and 2), data only for Switzerland (Specification 3 and 4) and data only for Brazil (Specification 5 and 6). The differences across specifications are as in Table 10.4

not likely to be due to the lack of a sufficient number of observations (which in all cases is above 1000 people). Rather, it reflects the cultural homogeneity within a country, thus clarifying that the cultural interactions are significantly different in each country and the FE could not account for within-country variations and complexities, as suggested here, following Nijkamp (2007).

Finally, we look at the decomposition of the cultural interactions using a logistic regression modelling. Tables 10.5 and 10.6 below present these results.

Table 10.5 shows us the odds from the logistic regression implemented using Model (3) in order to reveal the relationship between the cultural interactions between the outcome variable here (being religious, i.e. considering religion among the important things of your life) and the two main interactions considered in this chapter: religion with education and religion and gender. We present first a parsimonious estimation of these relationships only with fixed country and time effects. Next, in the following specifications in Table 10.5, an extended version of Model (3) is estimated, where we also control for age of the individual and type of habitat (city as opposed to rural area). To demonstrate the cultural relativity across pace, we estimate these specifications once with the entire WVS sample and then separately, for Switzerland and Brazil, respectively. The results in Table 10.5 demonstrate that the strong overall effects observable on an aggregate level, when all countries are amassed, (reflected in high pseudo-R-squares) are lost when we look at the individual countries. At times, even the independent variables themselves lose explanatory power with the reduced sample. This means that cultural interactions matter as a distinction on a regional level, between contexts, much more than within a locality where perhaps the cultural variation is much weaker. This potentially would be in favour of using fixed effects for capturing culture.

However, Table 10.6 demonstrates the complexity of the cultural interaction between education and gender, on the one hand, and, between education and age (which is a previously not considered third source of cultural heterogeneity and cultural interaction, which is relevant to tap on here since we all know that the tastes of elder and younger generations tend to differ significantly, see Falk et al. 2018). The marginal effects show that there are differences in the level of the effect and differences in the magnitude of the effect for the different pairs of factors. Put differently, across-country nonlinearities in the relationship between these factors within the cultural affinity to religiosity seem to exist. The marginal effects on religiosity, decomposed (a) over education and gender and (b) over education and age, are also shown graphically in Fig. 10.3.

Figure 10.3 shows the complex web of sources of heterogeneity and nonlinearity in the cultural interactions. Most notably, in Brazil, the interactions between religiosity and education are always more sensitive for the higher educated than for the lower educated, the difference between educated women and men being double the difference between the lowest educated men and women. The same nonlinearity applies in Brazil for the relationship between religion, education and age, the elderly experiencing bigger differences than the youngsters. Moreover, the very direction of the relationship between religion and education is moderated differently by age in Switzerland (increasing with age) than in Brazil (decreasing with age). These results

Table 10.5 FE and nonlinearity in the cultural interactions—odds, logistic regression

	Reduced specification									Extended specification								
	ALL WVS			Switzerland			Brazil			ALL WVS			Switzerland			Brazil		
Dep. Var.	*religion_important*									*religion_important*								
	Odds	z-value		Odds	z-value		Odds	z-value		Odds	z-value		Odds	z-value		Odds	z-value	
Age										1.02	35.48	***	1.03	9.35	***	1.02	4.30	***
Edu	0.89	−33.88	***	0.98	−0.67		0.88	−4.31	***	0.94	−15.07	***	1.06	1.70		0.92	−2.85	**
Female	1.62	34.57	***	1.70	5.49	***	1.87	5.18	***	1.69	30.87	***	1.91	5.26	***	1.89	5.16	***
City										0.83	−9.39	***	0.71	−2.53	**	0.62	−2.71	**
FE country																		
FE wave																		
_cons	1.23	2.46		1.01	0.05		5.79	10.37	***	0.68	−3.96	***	0.22	−5.73	***	4.50	5.58	***
Pseudo R-square	0.26			0.02			0.04			0.27			0.08			0.05		
Prob > chi^2	0.0000			0.0000			0.0000			0.0000			0.0000			0.0000		
Sample size	144,025			1775			2608			98,636			1203			2529		

Notes: The table presents odds estimated with logistic regressions, respectively, for all WVS countries and separately for Switzerland and Brazil, first with a reduced model (3) and then with the full model (3), aiming to analyse the statistical nature of the interaction between religiosity, education and gender, and other factors such as age

Table 10.6 FE and nonlinearity in the cultural interactions—marginal effects

		ALL WVS			Switzerland			Brazil						ALL WVS			Switzerland			Brazil		
Dep. Var.		*religion_important*												*religion_important*								
Education	*Female*	Marginal effect	z-value		Marginal effect	z-value		Marginal effect	z-value			*Education*	*Age* < 30; *age* > 60	Marginal effect	z-value		Marginal effect	z-value		Marginal effect	z-value	
1	0	0.74	329.52	***	0.47	15.91	***	0.88	69.12	***		1	1	0.76	288.93	***	0.32	9.58	***	0.89	70.81	***
1	1	0.79	397.15	***	0.60	22.26	***	0.93	112.36	***		1	2	0.72	240.74	***	0.61	19.33	***	0.96	108.73	***
2	0	0.72	371.58	***	0.46	18.98	***	0.87	74.47	***		2	1	0.76	339.24	***	0.33	11.96	***	0.88	82.35	***
2	1	0.78	443.77	***	0.59	26.70	***	0.93	117.22	***		2	2	0.71	271.47	***	0.62	24.90	***	0.95	104.27	***
3	0	0.71	418.81	***	0.46	22.60	***	0.85	79.00	***		3	1	0.75	405.04	***	0.35	15.00	***	0.87	97.38	***
3	1	0.76	494.00	***	0.59	31.83	***	0.92	120.60	***		3	2	0.70	296.07	***	0.63	31.38	***	0.95	97.87	***
4	0	0.69	455.94	***	0.45	25.69	***	0.84	78.28	***		4	1	0.74	478.81	***	0.36	17.95	***	0.86	109.53	***
4	1	0.75	528.55	***	0.59	35.71	***	0.91	118.17	***		4	2	0.69	299.89	***	0.65	35.31	***	0.94	89.67	***
5	0	0.67	455.02	***	0.45	26.11	***	0.82	68.92	***		5	1	0.73	521.93	***	0.38	18.77	***	0.85	102.91	***
5	1	0.73	517.40	***	0.58	35.19	***	0.90	106.30	***		5	2	0.68	276.49	***	0.66	33.35	***	0.94	80.27	***
6	0	0.66	406.36	***	0.44	23.36	***	0.80	54.81	***		6	1	0.72	486.72	***	0.39	16.88	***	0.83	80.07	***
6	1	0.72	455.90	***	0.58	30.56	***	0.89	87.64	***		6	2	0.67	237.68	***	0.67	28.41	***	0.93	70.47	***
7	0	0.64	336.66	***	0.44	19.50	***	0.78	41.79	***		7	1	0.71	400.68	***	0.40	14.15	***	0.82	58.71	***
7	1	0.70	375.64	***	0.57	25.08	***	0.87	68.59	***		7	2	0.65	198.36	***	0.69	23.81	***	0.93	61.02	***
8	0	0.62	272.11	***	0.44	16.06	***	0.76	31.85	***		8	1	0.70	317.38	***	0.42	11.82	***	0.81	43.65	***
8	1	0.68	303.20	***	0.57	20.51	***	0.86	52.86	***		8	2	0.64	165.10	***	0.70	20.33	***	0.92	52.39	***

Notes: The table presents marginal effects for the effect of education on religiosity, over different genders (Specification 1–3) and over different age groups (below 30 and above 60) (Specification 4–6). The marginal effects for the entire WVS sample and separately for Switzerland and Brazil are presented for comparison

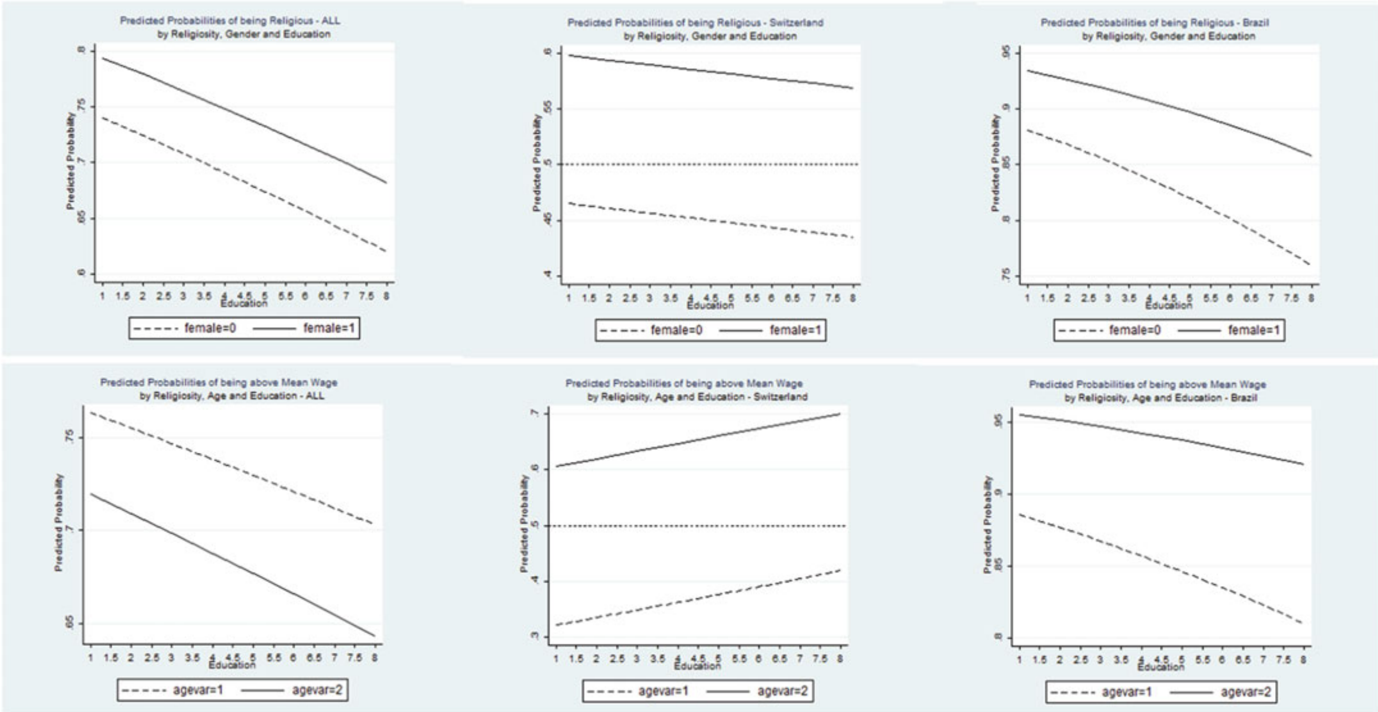

Fig. 10.3 Marginal effects from logistic regression with cultural FE. Notes: The figure represents marginal effects on religiosity from education, separately for two groups, respectively, female/male (Fig. 10.3a, b, c, first row), and for people below 30 and above 60 (Fig. 10.3d, e, f, second row). Each row presents first the entire WVS sample, and then the same information for Switzerland and finally for Brazil

show that aggregate handling of the cultural effects through fixed effects is non-advisable, as a very complex and important change may occur due to the different direction in which the changes in these cultural interactions will deviate the development of the local socio-economic system.

These results show that not only our H02 and H03 cannot be rejected, but further complexity and nonlinearity exists in the cultural interactions, both over time and space that cannot be fully accounted for through the use of cultural fixed effects and cultural interactions in a linear model. From policy implications point of view, the above-presented results have two important takes. Firstly, any model that is explored empirically through a culturally heterogeneous dataset has biased estimates if culture is not directly accounted in the model as a dependent variable, but only fixed effects are applied. This is due to under-specification of the model (as claimed by Tubadji 2014), but also because of the non-accounting for important interactions of this non-accounted for input variable (as argued here reinterpreting Nijkamp 2007). Secondly, even if a model contains cultural regressors, it needs to be carefully fitted according to its time and space statistical characteristics of the cultural component, in order to provide results with relevant and reliable economic meaning.

10.7 Conclusion

The current chapter is inspired by Nijkamp (2007) dealing with the use of ceteris paribus in theoretical modelling. I argue that the sources of bias in theoretical modelling that occurs due to the use of ceteris paribus, as outlined by Nijkamp (2007), are identical with the sources of bias that the use of fixed effects raises in empirical work.

The use of fixed effects in empirical economics is largely regarded by the community as accounting for the cultural heterogeneity across space. The current chapter argues that this is actually a misleading assumption that relies on reasonings akin to those required for applying the ceteris paribus in theoretical modelling. The sources of biases that ceteris paribus causes in theoretical work have then the same source as the biases that fixed effects causes in empirical work. Namely, these sources are the interactions of the context with the individual and the time and space nonlinearities of these interactions as major drivers for the cultural complexity in our world, which cannot be safely and easily wedged out from the analysis of the basic operation of any socio-economic mechanism of interest.

In order to empirically illustrate the remaining cultural interactions and their complexity in the presence of the use of country fixed effects, the current chapter uses the example of religion as a cultural factor which is renowned in economics and is of prominent socio-economic significance. Using data on religion from the World Value Survey, and employing a variety of statistical and econometric techniques (including detailed decomposition analysis and logistic regressions), the current chapter shows that even in the presence of use of 'cultural' fixed effects (regarding the national identity), there are still: (1) statistically and economically significant cultural interactions to account for in the model (H01); (2) the cultural hysteresis over time (H02) and (3) the cultural relativity and path-dependence across space (H03) always exist and are present conditions that cannot be safely ruled out on a ceteris paribus principle through the use of linear empirical methods.

The findings in the current chapter clearly support the existing contributions by some of the leading cultural economists demonstrating with extraordinary precision the difference between national fixed effects and cultural and context dependencies in their analysis (see Neumayer 2003a, b; Tabellini 2010). The current study generalizes them into the insight, inspired by and offered through the lens of Nijkamp (2007), explicating that the use of FE is intended as a ceteris paribus in empirical work, especially regarding cultural interactions. This, however, is an unhealthy bias-generating practice, just as ceteris paribus is in theoretical work, because as claimed by Nijkamp (2007), complexity and nonlinearity exist in the cultural context. Moreover, we show empirical evidence that the bias that FE causes with regard to ignoring the complexity and nonlinearity of the cultural interactions has the same roots as the bias that ceteris paribus generates in theoretical modelling.

The main policy implication from this chapter is that econometric modelling cannot be taken for granted as a reliable and easily transferable across place and time analytical tool for evidence-based policy making. Firstly, in order for an econometric estimation to avoid omitted variable bias, every model needs to contain cultural variables reflecting the impact of the context. Second, fixed effects assume that the cultural influence is not correlated with the rest of the factors for the economic outcome and is captured in the error term. But clearly the complexity of our socio-economic reality is embedded in a cultural context, where culture affects most of the inputs and outputs in a Toblerian manner. Moreover, this context varies over time and place and this requires further careful modelling. Only hierarchical models and Bayesian probability models could be eventually trustworthy. Yet, that is true only if their precise and flexible technique is used to estimate an accurately defined and fully specified culture-based economic model. Put differently, mathematical and statistical simplification can do miracles to enlighten policy making, but only if simplification does not lead to over-simplification and loss of touch with reality and meaning. First step towards ensuring this is through requiring the model on which evidence-based policy making is made to always account for the cultural context. Second, accounting for the cultural context has to be done in a precise and well-calibrated manner, and not through an abrupt over-simplified severing of the cultural question through reliance on the statistically unreliable for this purpose fixed effects.

In summary, the current work demonstrates one of the wider, empirical applications of the theoretical insight on the ceteris paribus condition in economic modelling offered by Nijkamp (2007). This is one of the numerous examples of the far-reaching, lateral thinking endowed and important synthesis generating scientific genius of Peter Nijkamp. His wealth of contribution to the regional science library of ideas, and to socio-economic sciences more broadly, will keep shedding light on new pathways ahead, which we still need to revisit, comprehend and integrate in our practice.

Appendix: Descriptive Statistics: WVS Individual Level Data

Variable	Obs	Mean	Std. Dev.	Min	Max
Wage	314,846	4.62	2.337	1	10
Age	344,279	40.72	16.135	13	102
age_sq	344,279	1918.43	1487.046	169	10,404
Edu	299,295	4.71	2.229	1	8
Female	343,808	0.52	0.500	0	1
City	229,132	0.58	0.494	0	1
religion_important	348,532	0.67	0.472	0	1
Waves	348,532	4.27	1.432	1	6
wave1	348,532	0.04	0.194	0	1
wave2	348,532	0.07	0.256	0	1
wave3	348,532	0.22	0.416	0	1
wave4	348,532	0.17	0.375	0	1
wave5	348,532	0.24	0.428	0	1
Country	348,532			1	100

Notes: The table presents the main descriptive statistics for the variables form the WVS used on individual level in this chapter

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Chapter 11
Horizontal Transmission of Civic Capital and the Emergence of Cooperation: An Agent-Based Modelling Approach

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Abstract Scholars in social sciences often refer to "social capital" to explain a wide list of relevant economic and social phenomena. Taking an economic perspective, as put forth by Guiso et al. (*Social Economics Handbook*, 2011), we refer in this chapter to *civic capital*, defined as "those persistent and shared beliefs and values that help a group overcome the free rider problem in the pursuit of socially valuable activities". Starting from a first analytical discussion of how civic capital (collaboration between individuals) may emerge through horizontal transmission, we develop an agent-based model to simulate transmission of civic capital in a spatial interaction setting. We do so within the context of the so-called threshold models, which allow us to hypothesize conditional cooperation between agents, based on observation of societal behaviour. In our simulations, we model horizontal transmission of civic capital as given by social influence determining how behavioural thresholds evolve over time. We test interactions at both the global and local levels (in space), and test different ranges of parameters for the transmission mechanism. Finally, we attempt to find systematic evidence on the effect of model parameters on

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the amount of civic capital and on its level of spatial clustering by means of regression analyses.

Keywords Civic capital · Horizontal transmission · Agent-based modelling · Spatial · Simulations

11.1 Introduction

Scholars in social sciences often refer to "social capital" to explain a wide list of economic and social phenomena, notably including national and regional economic performance and growth (Westlund 2006; Fazio and Piacentino 2010; Tabellini 2010), starting from the seminal work such as Putnam (2001). Notwithstanding its wide use, there is no definition of social capital which is commonly accepted, in particular across disciplines, and social capital can be easily confused with other forms of capital (for example, human capital). In this chapter, we will follow the economic perspective put forth by Guiso et al. (2011), who rephrase social capital in terms of *civic capital*, intended as "those persistent and shared beliefs and values that help a group overcome the free rider problem in the pursuit of socially valuable activities".

While the impact of social capital on economic and social outcome is well-documented, the process driving its accumulation or depreciation is still an active area of research. Guiso et al. (2011) distinguish civil capital from human capital because the former is the result of a social process of investment and requires individual values and beliefs to be shared by other members of the community. Particular attention has been paid to intergenerational transmission mechanism, in which values to transmit to children are influenced by the spatial pattern of external values and beliefs, and the process of cultural transmission evolves slowly over time, explaining the persistence of the cultural traits of a community even over centuries (Tabellini 2008). Recent contributions have also highlighted the role of spatial interaction (see Durlauf and Ioannides 2010; Fazio and Lavecchia 2013). Civic capital can be transmitted also horizontally (intragenerational transmission, i.e. among peers), although this form of transmission has received less attention. Approaches to social/civic capital analysis are very diverse, and analytical solutions for its transmission mechanisms are possible only for relatively simple hypotheses.

To overcome this obstacle, this chapter develops an agent-based model in which the emergence of cooperation and the horizontal transmission of civic capital are jointly considered in a spatial interaction setting. It does this within the context of the so-called threshold models (Schelling 1973; Granovetter 1978; Watts 2002). Threshold models are a class of models aimed at representing collective actions in which: (1) individuals have a binary choice (in our case being "cooperative" or "defective"); (2) the probability that an individual chooses a certain action positively depends on the fraction of individuals in society (or in a relevant sub-group) choosing the same action, that is, such a fraction is above an (individual-specific) threshold. These models are well-suited to represent individual behaviour in social dilemmas situations (those at risk of free-riding), since a consolidated experimental literature now exists showing that conditional cooperation, that is, to be "cooperative" *if* others are, often characterizes human behaviour, while at the same time a significant level of heterogeneity exists across subjects. In our model, the lower is the threshold, the higher is the "propensity" towards cooperation, this propensity being affected by those "beliefs and values" constituting the definition of civic capital in Guiso et al. In other words, at the social level, civic capital is inversely related to the average threshold level in the population. In addition, a distinctive feature of threshold models is that not only the average, but also the distribution of thresholds matters for determining collective behaviour. In our model, the process of horizontal transmission of civic capital is given by social influence determining how thresholds evolve over time. In other terms, it is not an actual behaviour which diffuses, but rather beliefs and values which in turn determine, mediated by individual choices, collective cooperative behaviour. Space matters as well, because interactions can be global or local, depending on the size of the group affecting both behaviour and the transmission of civic capital.

The rest of the chapter is organized as follows. In Sect. 11.2, we briefly review those streams of literature which are relevant to support our hypotheses and to which we intend to contribute. Section 11.3 describes the model. Section 11.4 derives a few analytical results which are used as benchmark for the results from the numerical simulations reported and discussed in Sect. 11.5. Section 11.6 concludes the chapter.

11.2 Literature Review

In the first part of this section, we review those studies which connect civic capital to various kinds of economic outcomes, thus supporting the relevance of our work. Secondly, we look at the mix of experimental evidence and theoretical insights which identified human regularities behaviour in social dilemma situations and mechanisms for sustaining cooperation. These streams of research are key to motivate our model assumption. Finally, we introduce the class of threshold models of collective action, to which our contribution belongs.

11.2.1 Civic Capital and Economic Outcomes

In a review of the debate about the role of social capital in economics, Guiso et al. (2011) try to overcome the vagueness of the previous literature by relabelling social capital as civic capital. According to the authors, this definition has several advantages. First, it restricts the above concept to a notion of capital that has a positive and durable economic payoff. Second, social capital as beliefs and values becomes measurable through experiments and surveys. Third, as the other notions of capital, it attributes importance to the mechanism of accumulation and depreciation of civic capital.

The literature on civic capital has analysed its antecedents and consequences. As for antecedents, the cultural transmission of cooperative values is at the core of Tabellini (2008). In this model, parents choose what values to pass on to their children, while assessing their children's welfare in terms of their values. This creates a complementarity between norms and behaviour: when more people cooperate, the payoff from cooperation increases, consequently increasing the scope of cooperation. Guiso et al. (2008) consider a model in which beliefs are transmitted by parents to children. It turns out that, in order to protect their children, parents transmit conservative priors, which could create a "mistrust equilibrium". Both models generate a distinctive feature of civic capital, which is persistence (Guiso et al. 2016; Giavazzi et al. 2019).

As for its consequences, civic capital has been shown to impact on both macro and micro phenomena. Using historical variables as instruments for civic capital, Tabellini (2010) shows how the latter strongly correlates with current regional economic development in Europe. Nannicini et al. (2013) show that civic capital may increase economic wellbeing by improving the functioning of institutions through political accountability, since the electorate punishes political misbehaviour more severely in Italian districts with higher civic capital. Using regional background as proxy for civicness, Ichino and Maggi (2000) show that it can explain shirking differentials in a large Italian firm. Bürker et al. (2013) argue that civic capital may also affect the governance of firms, and show, using Italian data, that the productivity effect of foreign ownership depends on the stock of civic capital in the area where the firm is located.

11.2.2 *Overcoming the Free-Rider Problem: The Experimental Evidence and the Theoretical Insights*

In the definition of Guiso and coauthors, civic capital is inherently seen as a solution for social dilemmas, that is, those situations in which a conflict exists between individual and social interests. In social dilemmas, each person has a dominant strategy which yields the best outcome for all possible circumstances (the non-cooperative choice), but if all individuals pursue this strategy, a sub-optimal collective outcome emerges, as everyone would be better off by cooperating. Several games exhibit these characteristics, in particular the prisoner's dilemma and public good games. In one-shot games, or finitely repeated games, if individuals are rational and self-interested, game theory predicts that they should play their dominant strategy, that is, they should not cooperate. Experimental evidence on such games does not (fully) support this view. In a summary of early work on public goods experiments, Ledyard (1995) identifies as a "stylized fact" that individuals tend to contribute positive amounts to public goods (while they should not if rational and self-interested), although their contributions decline over time across repetitions of the game. Subsequent work has tried to identify in a more precise way the deviation of the observed evidence with respect to classical game theory predictions. One strong regularity that has emerged is that individuals tend to be *conditionally* cooperative. In public good games, for instance, this means that contributions to the public good are positively correlated with expectations about average group contribution (Fischbacher et al. 2001; Chaudhuri 2011), although a self-serving bias, for which individuals contribute less than the expected average, is observed (Fischbacher and Gächter 2010). Heterogeneity across individuals also emerges as a recurrent fact: while most subjects are conditionally cooperative, unconditionally cooperative and free-riding agents are also observed (Kurzban and Houser 2005), with evidence that the distribution of such types may vary across countries (Kocher et al. 2008). Evidence of conditional cooperation has emerged also in prisoner's dilemma games (Grujić et al. 2010; Cimini and Sánchez 2014).

Although the predictions based on rationality and self-interest are not fully confirmed in the experimental evidence, the observed decay in cooperative behaviour has nevertheless reinforced the interest towards those mechanisms which are able to sustain cooperation, which we indeed observe in human interactions and, more generally, in the biological world (Nowak and Highfield 2011). Some mechanisms are known. If interaction is repeated within the same group of players, the folk theorems for repeated games (Mailath and Samuelson 2006) show that cooperative behaviour may indeed be the equilibrium outcome in the supergame. Experimental evidence also shows that cooperation may be favoured by mechanisms such as altruistic punishment (Fehr and Gächter 2000), in which cooperators bear a cost to punish defectors, or rewards (Rand et al. 2009). Finally, in an evolutionary perspective, where the frequency of individuals playing a certain strategy increases with their "fitness", local interaction has been identified as an important channel towards the emergence of cooperation (Nowak and May 1992). While with global interaction cooperators, who played a dominated strategy, tend to disappear, local interaction may lead to the emergence of clusters of cooperators which can succeed in invading the population.

11.2.3 Threshold Models of Collective Action

Threshold models of collective action find their origins in the work of Schelling (1973) and Granovetter (1978). In abstract terms, they represent binary decision problems with externalities, in which agents choose a certain action if the fraction of other agents choosing that action is above a certain threshold. The existence of such a threshold may be explicitly microfounded (Schelling 1973) or not (Granovetter 1978). Threshold models belong to a more general class of models that analytical sociologists define as the class of conditional choice models (Rolfe 2009).

Due to their generality, threshold models have been applied to various social phenomena, such as crowd behaviour, participation to social movements, voting or adoption of innovations (Watts and Dodds 2009). Most models are interested in determining the conditions for certain collective behaviour to be observed, such as a riot or the diffusion of an innovation. In this case, individuals are initially "inactive", and the probability of a cascade of active behaviour is investigated, as a function of the threshold distribution and the nature of interaction (Watts 2002). In a very simple example, Granovetter considers the case of 100 individuals considering if participating or not to a riot. He notices that if the thresholds are uniformly distributed, then the riot will be observed with probability equal to 1. However, if no agent has a threshold of 2, while two agents have a threshold of 3 (and the rest of the distribution is as before), then the riot will be observed with zero probability. This suggests that the outcome of the collective action may be very sensitive to the threshold distribution.

In Sect. 11.5, we present both analytical results on civic capital horizontal transmission and, for more complex solutions that cannot be solved analytically, an agent-based version of our model. Agent-Based Models (ABMs) are usually based on a set of autonomous agents, capable of interacting with each other, as well as with the environment, according to given behavioural rules. Such rules can be simple or complex, deterministic or stochastic, fixed or adaptive. Adaptive agents have the ability to learn, and they evolve in a learning cycle (Billari et al. 2006). Rules are typically derived from published literature (van Leeuwen and Lijesen 2016), expert knowledge, data analysis or numerical work, and are the foundation of an agent's behaviour (Crooks and Heppenstall 2012). ABMs allow one to simulate the individual actions of a diverse number of agents, assessing the resulting system behaviour and outcomes over time, and they are models that generally deal with systems that are complex, open-ended, hence emergent and thus exhibit novelty and surprise (Crooks et al. 2008). They have their roots in an interdisciplinary computing movement and in the field of artificial intelligence. Today, ABMs are often used to investigate the interplay occurring at the micro and macro structures of a given system, in which the interaction structure itself plays an important role. Furthermore, ABMs allow a flexible design of how individual entities behave and interact, since the results are computed and need not to be solved analytically (Leombruni and Richiardi 2005). They have been applied to a diverse range of subject areas, such as: archaeological reconstruction of ancient civilizations; understanding theories of political identity and stability; biological models of infectious diseases; modelling economic processes as dynamic systems of interacting agents; geographical retail markets and so on (see Crooks and Heppenstall 2012 for a more extensive overview).

11.3 The Model

We will now describe the model in its most general formulation, while for both the analytical solution and the numerical experiments we will consider specific versions of the same. Our model is dynamic in discrete time. Consider a fixed population of

N agents. At each moment of time, each agent i faces a binary choice, represented by function α_i^t: being cooperative ($\alpha_i^t = 1$) or not ($\alpha_i^t = 0$). Each agent is characterized by a threshold α^t in the unit interval, affecting her choice, with $\underline{\alpha_i}$ being the vector of thresholds in the population. From agent i's viewpoint, the rest of the individuals differ in their influence on his behaviour. The *behaviour-influencing network* g^b is a (possibly directed) graph over N such that, for each agent i, a weighting function $w_i(g^b)$ assigns a weight $w_i^j > 0$ to agent $j \neq i$, with $\sum_{j \neq i} w_i^j = 1$. This leads to define $\alpha_{-i}^t = \sum_{j \neq i} w_i^j \alpha_j^t$. If all agents are assigned the same weight, that is, the case of global interaction, then α_{-i}^t denotes the actual fraction of agents (excluding i) who are cooperative at time t (therefore $\alpha_{-i}^t = \sum_{j \neq i} \frac{1}{N-1} \alpha_j^t$). This is a case for which analytical results can be easily obtained. Alternatively, we will consider individuals located on a bounded two-dimensional grid. In this case, agents are only (equally) influenced by others in their "neighbourhood", whose characteristics will be specified in the following. Denoting with $E_i(\alpha_{-i}^t)$ the expectation for the behaviour of agent i, he cooperates if $E_i(\alpha^t) > \underline{\alpha_i^t}$, and he does not cooperate otherwise. We shall assume adaptive expectations, that is, $E_i(\alpha_{-i}^t) = \alpha_{-i}^t$, therefore leading to the following (deterministic) choice rule:

$$\alpha_i^t = \begin{cases} 0 \text{ if } \alpha_{-i}^t < \underline{\alpha_i^t} \\ 1 \text{ if } \alpha_{-i}^t \geq \underline{\alpha_i^t} \end{cases}. \tag{11.1}$$

Agents are heterogeneous in $\underline{\alpha_i^t}$, and this captures the extent to which an individual is a conditional cooperator. Notice that, for $\underline{\alpha_i^t} \to 0$, agent i (almost) always cooperates, that is, he is an unconditional cooperator. For $\underline{\alpha_i^t} \to 1$, agent i (almost) never cooperates, that is, he is a free-rider. Social capital (defined as civic capital) is then inversely related to the average value of $\underline{\alpha_i^t}$, but its overall distribution is also relevant, and a parameter we will control in our numerical experiment.

As mentioned earlier, $\underline{\alpha_i^t}$ evolves over time as the outcome of a process of social transmission. In order to model such a process, we introduce the notion of *value-influencing network* g^v, where g^v is a (possibly directed) graph over population N. For each agent i, we then introduce a weighting function $\theta_i(g^v)$ which assigns a weight $\theta_i^j > 0$ to agent $j \neq i$, with $\sum_{j \neq i} \theta_i^j = 1$. In general terms, the law of motion of $\underline{\alpha_i^t}$ can be written as $\underline{\alpha_i^t} = \underline{\alpha_i^t}[\underline{\alpha^{t-1}}; \theta_i(g^v)]$. In our simulation experiments, we will consider the process given by:

$$\underline{\alpha_i^t} = \rho \underline{\alpha_i^{t-1}} + (1 - \rho) \sum_{j \neq i} \theta_i^j \underline{\alpha_j^{t-1}}, \tag{11.2}$$

with $0 < \rho < 1$. This in an example of assimilative social influence model (Degroot 1974; Flache et al. 2017). In particular, we will consider the case of global interaction ($\theta_i^j = \frac{1}{N-1}$ for each i,j) and cases where weights are determined by the agents' location on the grid. From this last perspective, the matrix containing all the weights θ_i^j may be compared to the spatial weights matrices used in spatial econometrics.

11.4 Analytical Results

A model which can be easily studied analytically (and graphically), being substantially equivalent to Granovetter (1978), is the one of global interaction with time-invariant—but heterogenous—thresholds. In this case, the threshold of one individual is compared to the average cooperative behaviour of all the remaining agents. For tractability, let us assume that the set of individuals in the society is given by a continuum of agents of mass 1, and that $\underline{\alpha_i}$ is distributed across individuals with a cumulative (density) function $F(\cdot)$ ($f(\cdot)$).

At time t, the fraction of cooperating individuals is given by $\alpha^t \equiv \Pr\left(\underline{\alpha_i} < \alpha^{t-1}\right) \equiv F\left(\alpha^{t-1}\right)$ (notice that by considering a continuum of agents, including individual i does not affect the fraction of cooperating agents in society). Therefore, the evolution of the system is described by the difference equation $\alpha^t = F(\alpha^{t-1})$. As usual, the equilibrium is identified by $\alpha^t = \alpha^{t-1}$.

Standard graphical analysis (through staircase diagrams) can help analysing the stability properties of such equilibria. In Fig. 11.1, we represent a case of a distribution function for which a unique interior stable equilibrium is observed.

In terms of interpretation, the distribution function represented in Fig. 11.1 corresponds to a case where both (almost) unconditional cooperators and free-riders are common in the population. As a result, both cooperative and non-cooperative behaviours coexist in equilibrium.

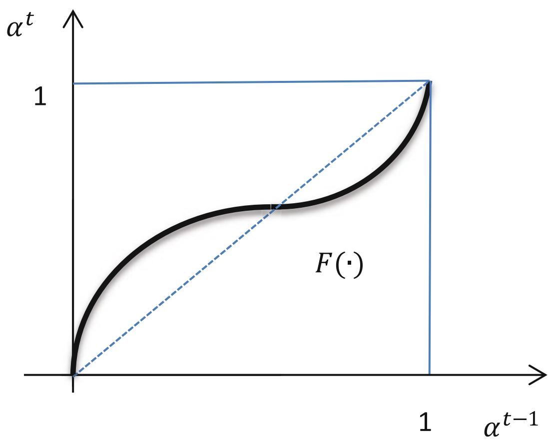

Fig. 11.1 Case with a unique interior stable equilibrium

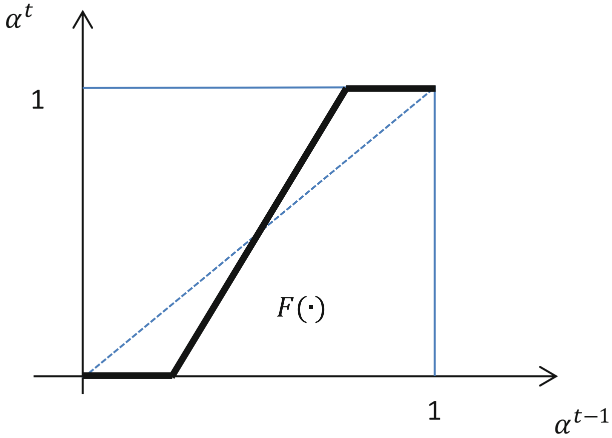

Fig. 11.2 Case with one unstable interior equilibrium and two stable corner equilibria

Consider now the case of a uniform distribution between $\underline{\alpha}_{\min} > 0$ and $\underline{\alpha}_{\max} < 1$. As shown in Fig. 11.2, we have one unstable interior equilibrium and two stable corner equilibria, where all agents cooperate or all agents do not.

In this case, initial conditions will determine which equilibrium prevails, while the min and max values will determine the basin of attractions of the equilibria (with lower values, i.e. higher values of civic capital, leading to full cooperation for a larger set of initial conditions). Notice that this case corresponds to a relatively homogenous society (in terms of types of individuals). Interestingly, social homogeneity leads to less predictable outcomes in terms of social behaviour.

11.5 Simulation Results

In this section, we report on simulation results for the different configurations of model parameters we consider, varying the value of ρ in Eq. (11.2), the global/local nature of interaction in the diffusion of values and behaviour, and the initial distribution of civic capital (distribution of $\underline{\alpha}$). In particular, we analyse five scenarios, in which the distribution of $\underline{\alpha}$ at $t = 0$ is uniform:

- Scenario 1: $\rho = 1$, with global influence for both behaviour and values. This scenario illustrates numerically the conclusion we reached analytically in the previous section.
- Scenario 2: $\rho = 1$, with local influence for behaviour.
- Scenario 3: $\rho < 1$, with global influence for both behaviour and values.
- Scenario 4: $\rho < 1$, with local influence for values and global influence for behaviour.
- Scenario 5: $\rho < 1$, with local influence on both behaviour and values.

Then, we briefly comment on what happens when the distribution of $\underline{\alpha}$ at $t = 0$ is normal. In our simulations, “equilibria” take two forms: i) a stationary state in which $\alpha^t = \alpha^{t-1}$; ii) a 2-cycle, in which very few agents (in most cases a single one) alternate between cooperative and non-cooperative behaviour.

11.5.1 Scenario 1

Focusing on the uniform distribution, we tested different values for $\underline{\alpha}_{\min}$ and $\underline{\alpha}_{\max}$. $\underline{\alpha}_{\min}$ ranges between 0.05 and 0.5 (in 0.05 increments), while $\underline{\alpha}_{\max}$ ranges between 0.6 and 0.95 (with increments of 0.05). We run 100 replications for each parameter pair $(\underline{\alpha}_{\min}, \underline{\alpha}_{\max})$.

Results for the equilibrium values of the average levels of cooperation (that is, the fraction of agents being cooperative in the population) are reported in Table 11.1. The effects of the initial random distribution of $\underline{\alpha}$ are clear: when $\underline{\alpha}_{\min} + \underline{\alpha}_{\max} < 1$, the model always ends with a fully cooperating society; when $\underline{\alpha}_{\min} + \underline{\alpha}_{\max} > 1$, the model always ends with a fully non-cooperating society. If $\underline{\alpha}_{\min} + \underline{\alpha}_{\max} = 1$, such that the expected value of $\underline{\alpha}$ at $t = 0$ is 0.5, each corner solution is almost equally likely.

11.5.2 Scenario 2

In our second experiment, the focus is on the extent to which neighbourhood effects happen. This time, the agents do not compare their personal values with the observed behaviour of society as a whole, but with the one of their neighbours. We compare the difference of being affected by the 4 nearest neighbours (rook contiguity order 1), the 8 nearest neighbours (queen contiguity order 1), 24 neighbours (queen

Table 11.1 Average levels of cooperation for different ranges of personal values

	$\underline{\alpha}_{\max}$							
$\underline{\alpha}_{\min}$	0.60	0.65	0.70	0.75	0.80	0.85	0.90	0.95
0.05	1	1	1	1	1	1	1	0.49
0.10	1	1	1	1	1	1	0.54	0
0.15	1	1	1	1	1	0.55	0	0
0.20	1	1	1	1	0.54	0	0	0
0.25	1	1	1	0.45	0	0	0	0
0.30	1	1	0.49	0	0	0	0	0
0.35	1	0.47	0	0	0	0	0	0
0.40	0.52	0	0	0	0	0	0	0
0.45	0	0	0	0	0	0	0	0
0.50	0	0	0	0	0	0	0	0

contiguity order 2) or 48 neighbours (queen contiguity order 3). Based on the literature, we expect clusters of cooperation to emerge, especially when the influence is very local, as is the case when the rook contiguity is used.

The model results, provided in Table 11.2, indicate that the more local the interaction, the larger the deviation from the results of Scenario 1. Now, simulation results are mixed also for initial personal values that are drawn from ranges that sum up to 0.9 or 1.05. In these cases, generally, no corner solutions are found, but patches of cooperating and non-cooperating agents coexist next to each other (as shown in Fig. 11.3). The number of iterations needed to reach an equilibrium lies between 5 and 54, with an average of 16.

Table 11.2 Average level of cooperation of society as a whole with different levels of neighbourhood effects and different minimum ranges for the random personal value of each agent ($\underline{\alpha}_{max} = 0.6$)

		Neighbourhood effects			
$\underline{\alpha}_{min}$	Global interaction	Rook-1	Queen-1	Queen-2	Queen-3
0.25	1	1	1	1	1
0.30	1	0.9	1	1	1
0.35	1	0.7	0.9	0.9	1
0.40	0.5	0.5	0.5	0.5	0.5
0.45	0	0.1	0.1	0.0	0
0.50	0	0	0	0	0

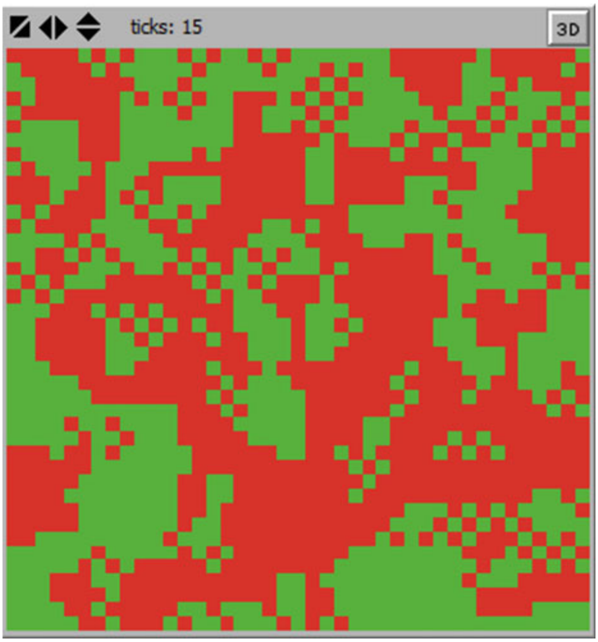

Fig. 11.3 Example of a final outcome of Scenario 2

11.5.3 Scenarios 3–4

In Scenario 3, not only behaviour, but also personal values are influenced by society as a whole. Allowing different values of ρ, values in society affect the ones of the individual agent. It means that, in each period, each agent becomes more similar to society as a whole. The results show that the outcomes are very similar to the first experiment. Again, all model runs result in corner solutions of either fully cooperating or non-cooperating society.

In Scenario 4, it is neighbouring agents that influence each other's personal values. However, the final choice to cooperate or not is still based on the average behaviour of society as a whole. Again, all model runs result in a corner solution, and only when $\underline{\alpha}_{\min} + \underline{\alpha}_{\max} = 1$, the outcome whether everyone cooperates or not depends on the (spatial distribution of the) initial values.

11.5.4 Scenario 5

In this final basic scenario, we combine the insights from all the previous ones. We combine different levels of neighbourhood effects with different combinations of values for ρ and different levels of the initial random variables. This means that neighbours influence both the choice to cooperate or not, as well as the personal values of the agent.

For this scenario, we report, in Table 11.3, the share of model runs that find an equilibrium (each configuration is repeated 100 times, with the maximum number of iterations equal to 600). The main conclusion that can be drawn here is that smaller values of ρ (that is, social influence) result in fewer model runs that reach an equilibrium: the model becomes more unstable. Furthermore, the range from which the initial values of $\underline{\alpha}$ are drawn appears to matter, since if $\underline{\alpha}_{\min} + \underline{\alpha}_{\max} \neq 1$, our simulations result much more often in an equilibrium. The average number of iterations required to reach an equilibrium lays around 20. The range of the neighbours' sphere of influence is important as well: when only the four nearest neighbours are taken into account (rook contiguity of order 1), the probability of reaching an equilibrium is higher when $\underline{\alpha}_{min} + \underline{\alpha}_{max} = 1$, and lower otherwise. This setting is the one needing on average the most iterations to find a solution (more than 200). Furthermore, when taking eight neighbours into account (queen contiguity of order 1), the share of models that reach an equilibrium is the lowest. Similarly to Scenario 2, this scenario generates coexisting patches of collaborating and non-collaborating agents, more clearly defined than before (see Fig. 11.4).

Table 11.3 The share of model runs finding an equilibrium for Scenario 5

$\underline{\alpha}_{max} - \underline{\alpha}_{min}$	Queen-3	Queen-2	Queen-1	Rook-1
$\rho = 1.00$				
0.60–0.30	100	100	100	100
0.60–0.40	100	100	100	100
0.65–0.30	100	100	100	100
0.65–0.35	100	100	100	100
0.70–0.30	100	100	100	100
0.70–0.35	100	100	100	100
$\rho = 0.95$				
0.60–0.30	100	100	100	96
0.60–0.40	30	51	7	56
0.65–0.30	100	99	89	73
0.65–0.35	38	58	8	57
0.70–0.30	46	77	6	59
0.70–0.35	100	100	90	64
$\rho = 0.90$				
0.60–0.30	100	100	100	92
0.60–0.40	15	5	1	55
0.65–0.30	97	90	59	69
0.65–0.35	11	3	1	56
0.70–0.30	15	90	1	42
0.70–0.35	99	85	66	54
$\rho = 0.85$				
0.60–0.30	100	100	100	66
0.60–0.40	4	1	2	38
0.65–0.30	97	67	49	40
0.65–0.35	7	2	3	38
0.70–0.30	7	3	2	33
0.70–0.35	96	74	52	38

11.5.5 Normal Distribution

In a further simulation exercise, we hypothesized a normal distribution for $\underline{\alpha}$ at $t = 0$, with a mean of 0.5 and a standard deviation of 0.1. When running 1600 simulations, only 79 resulted in corner solutions (of which 47 for $\rho = 0.95$, and neighbourhood radius at Queen-2 or 3). Table 11.4 shows the share of models that reach an equilibrium when the maximum number of runs is set to 600. Again, queen contiguity of order 1 results in the lowest share of models with a solution, and rook contiguity in the highest one. The average number of iterations was 142, but for $\rho = 1$, the average number of steps was 19.

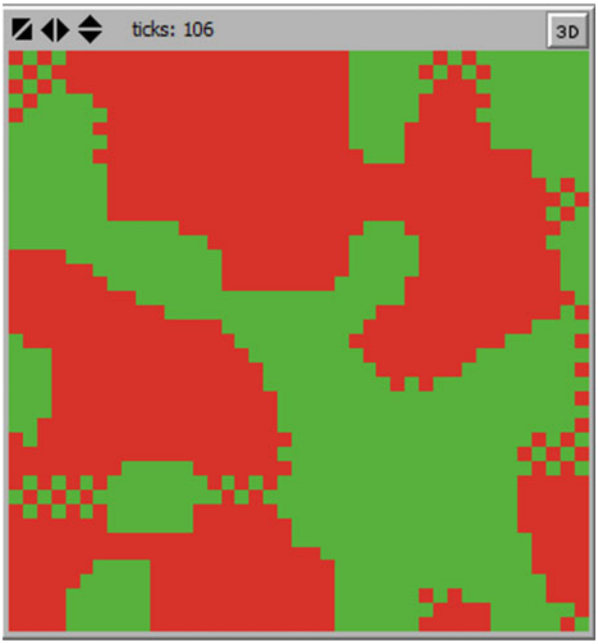

Fig. 11.4 Example of a final outcome of Scenario 5

Table 11.4 The share of model runs finding an equilibrium with a normal distribution

ρ	Queen-3	Queen-2	Queen-1	Rook-1
1.00	100	100	100	100
0.95	37	64	8	60
0.90	11	2	1	54
0.85	8	2	2	35

11.5.6 Statistical Analysis

The above simulation findings depict pictures of the average performance of the system when certain population and behavioural parameters are used. However, it is difficult, within this framework, to assess the role played by each single model parameter in shaping the final population outcome. We can go more in-depth in our analysis from this viewpoint by analysing single simulation outcomes in a regression framework, by considering their related simulation parameters. In particular, it is worth examining two types of information in this regard: (1) the share of collaborating agents in the final population (behaviour of society), that is, at time $t = T$; and (2) the related level of clustering found.

While fully cooperating or non-cooperating societies show no clustering, it is interesting to understand what are the parameters that lead to local pockets of collaborating individuals, a dichotomic population (split 50–50 either horizontally or vertically on the grid) being the strongest possible clustering. Such clustering can be measured, given the binary nature of the simulations' outcome variable, by join

Table 11.5 Regression results for Eqs. (11.3) and (11.4)

	Coeff.	Std error	Sign.	Coeff.	Std error	Sign.
Regressors	Dep. var.: α^t			Dep. var.: JC^T		
$\underline{\alpha}_{\min}$	−4.7886	0.0291	***	43.6555	2.9890	***
ρ	−0.1002	0.0444	**	−52.8988	2.7968	***
Queen-1	0.0106	0.0070		16.3274	0.3995	***
Queen-2	0.0083	0.0070		17.4224	0.3953	***
Queen-3	0.0142	0.0070	**	21.6599	0.5496	***
JC^0				0.3931	0.1722	**
Res. DoF	4794			1869		
Adj. R^2	0.85			0.70		

A constant is included in both models

count statistics. Similarly to standard spatial autocorrelation indices like Moran's I, join count statistics can signal positive or negative clustering, as well as no statistically significant clustering. Given a binary variable classified as 1 s and 0 s, and a spatial weights matrix W (in our case, a rook contiguity matrix), the number of "joins" of grid cells of the same type (1–1, or 0–0) is counted, and compared against the theoretically expected number of joins. A simple test for significance of the difference between the two can be used to detect clustering (Cliff and Ord 1981).

We then focus on Scenario 5, which has local influence on both behaviour and values, and estimate simple regression models as follows:

$$\alpha^T = \text{const} + \beta_1 \underline{\alpha}_{\min} + \beta_2 \rho + \text{neighouring}, \tag{11.3}$$

$$JC^T = \text{const} + \beta_1 \underline{\alpha}_{\min} + \beta_2 \rho + \text{neighouring} + \beta_3 JC^0, \tag{11.4}$$

where, in addition to what was defined above, *neighbouring* is a set of indicator variables—and related coefficients—for the type of neighbours influence simulated (between Rook-1, Queen-1, Queen-2, Queen-3), while JC^T and JC^0 are the join count statistics measured (for the collaborating agents) at the final iteration and at $t = 0$, respectively.

The model in Eq. (11.3) explains the final share of collaborating agents, while in Eq. (11.4) we model its level of spatial clustering. Both models employ, as explanatory variables, the lower bound of the uniform distribution of thresholds $\underline{\alpha}_{min}$ ($\underline{\alpha}_{\max}$ is fixed in Scenario 5), the inertia parameter ρ and the type of neighbours influence. In addition, Eq. (11.4) includes the level of clustering at $t = 0$. We estimate OLS regression models and present our empirical estimates in Table 11.5.

Regression results highlight the different roles played by simulation parameters in shaping the final population behaviour. Extending (downward) the range of possible individual thresholds logically increases the share of collaborating agents, but it leads to more homogeneous behaviour (less clustering). Instead, behavioural inertia (ρ) appears to have a limited effect in terms of decreasing the share of collaborating agents, as well as, to a greater degree, clustering. Coefficients for the different types of spatial influence (Rook-1 being the benchmark) suggest that the more spatially extended the observation, the higher the chances of collaborating, and the higher the clustering. As expected, the initial level of clustering has a positive correlation with the final clustering.

11.6 Conclusions

This chapter addressed the issue of civic capital development (emergence of cooperation) from a spatial viewpoint, using agent-based modelling (ABM). We first developed a simple analytical model for the most general case of a threshold model in which single individuals choose to collaborate based on a set of personal values and a minimum share of society following the same behaviour. In order to look deeper into this issue, we set up five scenarios and ran a high number of simulations to inspect regularities in the aggregate (population-level) outcomes of collaboration. We found that the most interesting cases are the ones in which interaction between agents, in terms of both reciprocal influence on values and observation of others behaviour, happens at the local (instead of global) level, that is, between nearby individuals. Finally, we conducted a preliminary regression analysis to relate aggregate behavioural outcomes (also in terms of spatial clustering) to the simulation parameters used.

Our results provide a number of insights.

- When individual behaviour responds to the aggregate behaviour, society quickly converges to homogenous choices, where all individuals behave cooperatively, or none does. Which outcome is observed depends on the initial distribution of civic capital, but it is not affected by the social process of influence in values.
- When individual behaviour responds instead to the behaviour of neighbours only, spatial clusters of cooperating and non-cooperating agents are often observed. In addition, when the propensity towards cooperation is socially affected, the system becomes less stable, and is less likely to find a stable equilibrium in the observed time horizon of our simulations. We believe this issue to be due to expectable feedback effects happening between individuals over space.
- When focussing on local mechanisms of influence, we observe, through regression models, that a behavioural inertia and the extent of the range of individual threshold for cooperation matter in shaping societal outcomes and the level of spatial clustering.
- The latter further depends on the spatial extent of observation and influence. The larger this is, the higher the level of spatial clustering observed. This finding suggests that, while neighbourhood effects matter in setting the condition for the development of pockets of heterogeneous behaviour, there is most likely an "optimal" extent of spatial influence that leads to the strongest spatial clustering and, therefore, in real-life settings, to possible issues of segregation and isolation.

The above findings represent a first exploration of how horizontal transmission of civic capital may be modelled, explored and analysed. Further experiments are of course needed in this regard. For instance, the role played by urban infrastructure (positioned on the urban grid), like highways, in causing isolation and clustering of homogeneous behaviour by interrupting proximity relations may be fruitfully explored in an ABM simulation framework. At the same time, recent advancements in urban transportation, which facilitate cross-neighbourhood mobility, could have the opposite effect, and favour interaction between more distant individuals. We leave this and other model expansions for future developments.

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Part III
Tourism and Information

Chapter 12
Peter Nijkamp on the Move: Crossing Borders Between Regional Science and Tourism Studies

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Abstract Different types of contributions from regional science emerged as useful tools for the study of tourism in a wide spectrum of perspectives, since the analysis of physical geographical attributes of destinations to the study of immaterial aspects influencing their socio-economic performance. These theoretical, conceptual or methodological influences may focus on different aspects of tourism activities, planning and management, being supported by diverse quantitative and qualitative approaches. With an extensive work in regional science and tourism studies, Peter Nijkamp has largely contributed for the symbiotic interactions between these fields of research over the last decades. Assuming the multidisciplinary character of research in both fields, this perspective article discusses how different academic disciplines contribute for the creation of synergies between tourism studies and regional science, by analysing objectives, methodologies and approaches developed or applied by Peter Nijkamp and his extensive global network of collaborators. The importance of institutional aspects for the creation and consolidation of these networks is also addressed.

Keywords Tourism · Regional science · Multidisciplinarity · Network · Epistemology

12.1 Introduction

As a place-based activity, tourism is highly dependent on territorial characteristics shaping the potential destination attractiveness and also other socio-economic, cultural or institutional features influencing tourism dynamics. Thus, different types of contributions from regional science emerged as useful tools for the analysis

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of tourism activities in a wide spectrum of perspectives, since the analysis of the most physical geographical attributes (like climate, geology, natural landscapes, etc.) to the most immaterial territorial aspects influencing socio-economic performance (innovation capabilities, agglomeration effects, regional governance models, etc.). These theoretical, conceptual or methodological influences may focus on infrastructure planning, mobility networks, transport services, resource management, human resource development, product development, destination management or strategic planning. Certainly, a diverse array of methodologies can used for the analysis of spatial effects at different territorial levels, both including quantitative and qualitative approaches. However, defining the scope of research in tourism and regional science has not been an easy or consensual task in the last decades.

The multidisciplinary character of research in regional science may be seen as an obstacle to provide a precise definition, as pointed out by Haynes and Qian (2010): "regional science uses diverse combinations of analytical and empirical research to study social problems with regional or spatial dimensions. (...) Due to this multidisciplinary feature, regional scientists have experienced difficulties in delivering a widely accepted definition of regional science". Similarly, there are also historical discussions about the definition of aims and scope of tourism as a body of knowledge, as testified by Cooper et al. (1996), when discussing if it should be considered as a discipline or as field of research. In fact, tourism is also seen as a multidisciplinary field integrating contributions from different disciplines—and even from other sources of knowledge, not necessarily scientific, as pointed out by Tribe (1997).

With an extensive work in the broad field of regional science and on more specific applications in tourism studies, Peter Nijkamp has largely contributed for the symbiotic interactions between these fields of research over the last decades. This perspective article focuses on the scientific production of Peter Nijkamp and his extensive global network of collaborators, identifying how different disciplines may be used to address different problems, supported by diverse conceptual frameworks and methodologies. The main results are discussed taking into consideration possible developments for further research and intensification of those interdisciplinary fluxes and interactions. Moreover, this analysis also offers a brief discussion of the institutional context influencing the creation and development of these networks of collaboration.

12.2 Spaces of Convergence Between Regional Science and Tourism Studies

The work developed by Walter Isard since mid-twentieth century would be crucial for the emergence of regional science as a scientific discipline. His book "Methods of Regional Analysis: an Introduction to Regional Science" (Isard 1960) would provide the most significant contribution for the clarification of its aims, scope and methodologies. At the same time, Isard devoted significant efforts to organizational and institutional aspects, by stimulating and supporting the creation of national and international associations, which would be crucial for the consolidation of the discipline through the creation of strong and very active international networks.

However, 15 years after the publication of Methods of Regional Analysis", Isard would still provide a relatively vague definition of the discipline. In spite of suggesting that "regional science concerns the careful and patient study of social problems with regional or spatial dimensions, employing diverse combinations of analytical and empirical research", Isard (1975) also claims that "it is clear from the diversity of definitions that no single one can be considered the best or most complete. Each researcher and student will need to develop or synthesize his own definition after having read this book and other studies". In this sense, the broad scope of the work developed by Peter Nijkamp, applying in diverse fields of study tools and methods from regional science, clearly contributed to question the limits and to redefine the scope of the discipline over time.

Bailly and Gibson (2017) would also emphasize the multidisciplinary character of regional science (and related problems) assumed by Haynes and Qian (2010), by claiming that "regional science should continue to track developments in other disciplines and adopt them as appropriate". Pointing out that economics and geography were the main influences in the early stages of development or regional science, aspects related to management, geographic information systems or human ecology may be seen as the most important fields of knowledge currently contributing for the contemporary evolution of the discipline. This classification will be used for the analysis of Peter Nijkamp's works.

Different authors offered systematic analyses of the evolution of research in tourism, which may be useful to frame the discussion of its interrelations with regional science. Jafari (2001) proposes a chronological approach, considering four "platforms": "advocacy", "cautionary", "adaptancy" and "knowledge-based", suggesting the existence of a path from a more normative approach (generally until the 1980s) to a more sophisticated empirical analysis (broadly starting during the 1990s). Differently, Butler (2015) proposes three major historical periods, including a stage of "factual" analysis (mostly descriptive), followed by an "early theoretical era" (the first models and theories, appearing in the 1950s) and by a "theoretical explosion" (starting in the 1970s). It is noteworthy that the contributions of Peter Nijkamp to the body of knowledge of tourism studies can be clearly classified as "knowledge-based" and framed within the "theoretical explosion" phase.

As it is observed for regional science, tourism studies also have a multidisciplinary character. In fact, as Tribe and Liburd (2016) suggest, "tourism is not just a multi-disciplinary field of enquiry but a multi-extra-disciplinary one too". In their comprehensive and systematic approach to the production of tourism studies, they also consider "extra-disciplinary" forms of knowledge (problem-centred, value-based, web 2.0 co-creation processes and indigenous knowledge), along with disciplinary forms, where Peter Nijkamp's work can be framed. These authors consider that the disciplinary component of the production of tourism knowledge comprises four broad areas (social science, business studies, science and humanities and arts), along with a high potential for interdisciplinary contributions.

Interestingly, Peter Nijkamp's research over the last three decades covers all these four disciplinary fields, revealing his broad approach to scientific production, and in particular to tourism-related aspects (which constitutes a relatively small part of his scientific production). Still adopting the formulations proposed by Tribe and Liburd (2016), this impressive and eclectic research performance can be seen as a result of personal characteristics (an extreme curiosity for many problems and phenomena, a solid theoretical background or an intense dedication to his work); his position in the knowledge production system (being an important contributor for the implementation and development of a spatial economics department [from now on refereed as "SED"] at the Faculty of Economics and Management of VU-Amsterdam, which would obtain a significant international recognition, hosting a large number of high quality researchers from different continents); his involvement, active promotion and leadership in active global networks of spatial-related research issues (mostly those with a broad approach to regional science, like RSAI or ERSA, but also others, with more specific foci, like NECTAR or The Regional Science Academy).

As a result, Peter Nijkamp developed an extremely large number of collaborations with co-authors all over the world, which is reflected in the quantity of publications (2,000 references identified in scholar.google, with more than 65,000 citations by mid April 2020) and the diversity of topics under analysis. In this analysis, Nijkamp's contributions for tourism studies are framed within this context. For this purpose, 55 publications specifically addressing questions related to tourism were identified in the list provided by scholar.google, not considering works where tourism is mentioned but not being the core aspect of the study (e.g., publications on general aspects of urban planning or regional development). Journal articles and book chapters are included, but working papers are not considered. The full list of publications under analysis is presented in appendix.

12.3 Peter Nijkamp's Fields and Networks in Tourism Studies

In order to identify potential intersections and interconnections between regionals science and tourism studies, we take into account the multidisciplinary character of both fields of research, while considering the systematizations proposed by Bailly and Gibson (2017) [from now on designated as "BG"] for the main disciplines contributing to regional science (economics and geography in the early stages; management, geographic information systems or human ecology in contemporary approaches); and by Tribe and Liburd (2016) [from now on mentioned as "TL"]for the main fields of knowledge contributing for tourism studies (business studies, social science, science and arts and humanities, along with multidisciplinary or extra-disciplinary approaches). As it will be observed, Peter Nijkamp's work covers all these topics, involving collaborations with a large number of co-authors. This diversity contributes to emphasize the importance of personal characteristics, positions and networks for knowledge production.

For these purposes, Peter Nijkamp's publications were divided into five groups, comprising aspects related to economics or transport-related studies (with a strong incorporation of knowledge coming from physics or geography). These approaches correspond to the disciplines offering the most important contributions to regional science in its early stages of development, as defined in the "BG" approach (in some cases also including aspects to geographic information systems, a novel contribution), while corresponding to the broad fields of science or social science, as defined within the TL conceptualization. Another group of works relates to marketing and management (included in the business studies according to TL and mentioned as one of the significant contemporary inputs for regional science by BG). Two smaller groups of works relate to the links between migrations, cultural studies and tourism dynamics or to processes of territorial planning and management, revealing the potential multidisciplinary approaches to tourism (TL) and also the influence of aspects related to human ecology (another contemporary influence pointed out by BG).

Completing the group of scientific fields that contribute for the study of tourism, as defined by TL, it is also worth to observe the existence of two works focused on non-business aspects of tourism activities, supported by disciplines related to arts and humanities. In this case, the analyses are strongly based on philosophical approaches to culture and communication, as a result of a partnership with Zerva (Zerva and Nijkamp 2015; Zerva et al. 2016). However, cultural aspects are also present in the multidisciplinary studies linking tourism flows, migration dynamics and cultural similarities and differences, along with their economic effects (Poel et al. 2006; Gheasi et al. 2011; Tubadji and Nijkamp 2018; Song et al. 2019). In general these authors were members or visitors of SED.

Other examples of multidisciplinary studies in the field of tourism can be found in articles published by Peter Nijkamp in the last 25 years. The concept of sustainable development (at that time becoming also adopted and generalized in tourism studies) would be applied in the context of tourism planning in Greek Islands (Nijkamp and Verdonkschot 1995; Janssen et al. 1995). In a broader context of regional development, Nijkamp (2000) integrates aspects related to tourism, telecommunications and marketing. The potential of digital communications on local tourism development would be addressed later on by Stratigea et al. (2006). By using visual tools and digital technologies, Neuts and Nijkamp (2012) address aspects related to crowding in the urban destination of Amsterdam, in order to support planning processes.

Moreover, different "clusters" of publications would emerge from collaborations with diverse researchers temporarily working with Nijkamp at SED. With De Montis, several papers focused on the utilization of multi-criteria analysis in planning processes (De Montis and Nijkamp 2006, 2008; De Montis et al. 2007). With Vaz, the integration of sensitive ecosystems into strategies for tourism and regional development in the South of Portugal was addressed, including the utilization of geographic information systems (Vaz et al. 2011, 2013). More recently, Romão et al.

(2017, 2018b) addressed issues related to planning and management of wellness tourism destinations, with a particular focus on rural areas of Japan.

A significant group of publications—also revealing the importance of networks of collaborative research and production—relates to transportation studies, a very important field within regional science and also extremely relevant in terms of tourism activities. By integrating contributions from geography or physics (e.g., gravity models or network analysis), this is a field with high integration of knowledge from "hard sciences" and also a high level of mathematical formalization. In this case, a first group of works (between 2001 and 2009, with different partners, but frequently involving Rietveld) focuses on air transport and related infrastructures (Nijkamp et al. 2001; Schipper et al. 2001; Nijkamp and Yim 2001; Lijesen et al. 2002; Pels et al. 2003; and Reggiani et al. 2009). More recently, a collaboration with Chen would lead to a detailed analysis of contemporary cruise tourism, including aspects related to infrastructures, marketing or the particular dynamics of specific segments (Chen et al. 2016a, b, c, d). Like in the previous cases, these authors were, in general, permanent or visitor researchers at SED.

As it could be expected, considering his background as an economist and his long-term affiliation in a Faculty of Economics and Business, these are the disciplines with the largest contribution to Peter Nijkamp's works in tourism. In the field of economics (a social science, according to TL, and one of the early contributors to regional science, as proposed by BG), 12 publications were identified, starting in 2006 with an analysis of multipliers for the assessment of tourism economic impacts (Van Leeuwen et al. 2006). Other four "clusters" of publications can be framed within this group, focusing on different economic aspects of the macro-environment shaping the dynamics of tourism destinations—and surely dependent on the interests, motivations and skills of the partners involved (visiting researchers hosted or supervised by Peter Nijkamp at SED).

A partnership with Cracolici lead to the publication of studies focused on Italian provinces, analysing the relation between efficiency in the utilization of resources and tourism competitiveness (Cracolici and Nijkamp 2006; Cracolici et al. 2008), also considering aspects of sustainability (Cracolici et al. 2009) or the implications of the characteristics of places on the expenditures of tourists (Bernini et al. 2017). Later on, a partnership with Ridderstaat led to the analysis of different economic characteristics of island destinations in the American continent, such as the vulnerability to exogenous shocks, the impacts of tourism on the quality of life of residents, or the effects of market concentration (Ridderstaat et al. 2013, 2016; Ridderstaat and Nijkamp 2016). More recently—with similar purposes and in both cases using spatial econometric methods—partnerships with Liu (in China) and Romão (in Europe) addressed the relations between tourism and economic growth (Liu et al. 2017; Romão and Nijkamp 2018) or between tourism and innovation dynamics (Liu and Nijkamp 2019; Romão and Nijkamp 2019), integrating concepts related to proximity, knowledge externalities or agglomeration economies, commonly used in regional science.

A final group of publications can be framed within management studies, one of the core disciplines contributing for the contemporary development of regional science, according to the BG approach. It is defined within the TL framework as business studies, one of the four major disciplines contributing for research in tourism. Peter Nijkamp's publications in this field started relatively late, with only one publication until 2010 (Masurel et al. 2008). However other 13 publications are listed after that date, involving collaborations with members of SED (Van Leeuwen and Kourtit) or visiting researchers (Neuts, Romão, Shikida and Patuelli). These works combine inputs from marketing studies (differentiation approaches or segmentation techniques, as exemplified by Katsoni et al. 2013) with spatial analysis. Different aspects of tourism dynamics (natural or cultural resources, material and immaterial heritage, or information and digital technologies) are addressed in diverse types of destinations and activities. This set of works broadly classified as management studies would become the largest group of Peter Nijkamp's publications observed in this study, confirming the importance achieved by this field within regional science, as proposed by the BG analysis.

The particular impacts of the utilization of digital technologies, communication processes and cultural aspects have high importance within this group of publications, starting with a general approach proposed by Kourtit et al. (2011). Different studies would be implemented in the city of Amsterdam, also adding aspects related to satisfaction with trips and loyalty to the destination (Van Leeuwen et al. 2013; Neuts et al. 2013a; Romão et al. 2015a) or involving also the city of Leipzig (Neuts et al. 2013b; Romão et al. 2015b). Similar conceptual approaches would be later on applied to the study of preferences, motivations, information, satisfaction and loyalty of ecotourists visiting a natural World Heritage Site in Japan (Neuts et al. 2014, 2016; Romão et al. 2014). Also, a meta-analysis specifically focused on the travel motivations of seniors was performed by Patuelli and Nijkamp (2016). Finally, a broad international analysis of determinants of urban tourism attractiveness would be performed by Romão et al. (2018a, b), while aspects related to user-generated data would be considered for the assessment of urban cultural heritage (Kourtit et al. 2019), clearly reflecting the willingness and ability to integrate new sources of information and knowledge into contemporary scientific production.

12.4 Concluding Remarks: An Actor or a Network?

This analysis of Peter Nijkamp's publications specifically oriented to tourism activities offers a clear illustration of the diversity of topics addressed during his career, along with the main disciplines contributing to his research. The analyses also reveal the diversity of partners involved and the importance of processes of collaboration. It should be noticed, however, that tourism-related works represent only a relatively small fraction of his scientific production, which has a much broader scope. Considering all the other topics and research fields covered by Peter Nijkamp during his career would surely offer important insights about the multidisciplinary character of regional science, the importance of different disciplines shaping its development in different historical moments or how the integration into different networks impacts research activities. His extensive and diversified work may constitute a relevant sample for such a study, which can be object of further analysis, eventually including institutional aspects with relevance for research policies and management.

For the particular case of the interactions between the fields of knowledge analysed in this work, the conceptual approaches proposed for regional science by Bailly and Gibson (2017) and for tourism studies by Tribe and Liburd (2016) clearly constitute useful tools in order to classify and to systematize Peter Nijkamp's contributions (and probably any others, which may be confirmed by further research). By defining the main disciplinary contributions for each of these fields of research, those frameworks helped to identify the main influences and also the main contributions in Nijkamp's work, along with the differences and the evolution observed over the last 25 years (both in regional science and tourism studies). As this work was focused exclusively on the research topics and disciplines involved, further developments can also include the analysis of methodological tools and how they reinforce the dialogue between different disciplines when converging to regional studies and tourism.

It is also noteworthy that the systematization of the system of scientific production in tourism studies proposed by Tribe and Liburd (2016) constitutes a useful tool to understand the focus, impacts and evolution of scientific work, potentially being adopted (or adapted) to other fields. This conceptual approach includes personal characteristics, institutional aspects or the relevance of networks (actor-network analysis). Within this frame, it is possible to understand the important role of the Spatial Economics Department implemented and developed at VU-Amsterdam with a very relevant contribution from Peter Nijkamp. This institutional framework is crucial to understand the quantity and diversity of issues and co-authors involved in his work. Moreover, the analysis of the impacts of different institutional arrangements and professional relations maybe also an interesting research question for which the analysis of Peter Nijkamp's career may offer substantial contributions. In this sense, the Actor-Network theoretical approach can be a useful tool for further empirical analyses.

In fact, it is also visible that Peter Nijkamp developed very intense and productive relations with researchers with different types of institutional ties (department members, visiting researchers or PhD students, among others), often persisting for long time, much beyond the conclusion of those formal institutional relations. This aspect also reveals how personal characteristics influence the creation and consolidation of networks, thus shaping scientific production: curiosity for a broad range of topics, solid theoretical background in different fields, a permanent curiosity for diverse aspects of contemporary economies and societies, a systematic willingness to support and to stimulate the ideas and efforts of other researchers, surely contributed for the creation, development and consolidation of a very broad set of national international collaborations. In this sense, Peter Nijkamp tends to dilute the distinction between an actor and a network: working regularly with him also generates opportunities to interact with researchers in all parts of the world or to get involved in a broad set of relevant international organizations and their scientific activities.

I would like to conclude, if I'm allowed by the editors of the book, with a more personal note. I had the opportunity to be a visiting researcher at SED between 2010 and 2013, when working on my PhD project in tourism studies. Peter Nijkamp did not hear about me before my request, he was not my supervisor and we had no formal relation. However, he hosted me at the Department and offered unconditional support and encouragement to my work. 7 years after my departure (in April 2020), we are still working together in a significant number of projects, including several publications, the edition of special issues or coordinating the NECTAR cluster on tourism, leisure and recreation. In average, we have two publications per year between 2013 and 2019, along with editorial work and organization of academic events. When systematizing his work on tourism for this publication, I also looked back at my 10 years of academic activity. I observe with surprise (and surely a big honour) that my name is the most frequently cited as Nijkamp's co-author within the set of tourism-related publications considered for this work. I also realize that my contributions cover a significant variety of topics in very diverse geographical areas and framed within different disciplinary contributions. This is much beyond my expectations when my PhD work started and surely it would not be possible without Peter's presence, inspiration and guidance in my academic life. With this publication I also want to express my deep gratitude and admiration to Peter Nijkamp.

Appendix

Planning	Transports	Management	Economics
Romão J, Machino K, Nijkamp P (2018) Integrative diversification of wellness tourism services in rural areas - An operational framework model applied to East Hokkaido (Japan). Asia Pacific Journal of Tourism Research	Chen J, Lijesen M, Nijkamp P (2016) Cruise tourism as quasi-two-sided market concept: an exploration of Asian markets. Journal of Tourism and Hospitality	Kourtit K, Nijkamp P, Romão J (2019) Cultural Heritage Appraisal by Visitors to Global Cities: The Use of Social Media and Urban Analytics in Urban Buzz Research. Sustainability	Romão J, Nijkamp P (2019) Impacts of innovation, productivity and specialization on tourism competitiveness – a spatial econometric analysis on European regions. Current Issues in Tourism
Romão J, Machino K, Nijkamp P (2017) Assessment of Wellness Tourism Development in Hokkaido: A Multicriteria and Strategic Choice Analysis. Asia-Pacific Journal of Regional Science	Chen JM, Neuts B, Nijkamp P (2016) Demand Determinants of Cruise Tourists in Competitive Markets: Motivations, Preference, and Intention. Tourism Economics	Romão J, Kourtit K, Neuts B, Nijkamp P (2018) The Smart City as a Common Place for Tourists and Residents: a Structural Analysis on the Determinants of Urban Attractiveness. Cities	Liu J, Nijkamp P (2019) Inbound tourism as a driving force for regional innovation: a spatial impact study on China. Journal of Travel Research

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Planning	Transports	Management	Economics
Vaz EN, Walczynska A, Nijkamp P (2013) Regional challenges in tourist wetland systems: an integrated approach to the Ria Formosa in the Algarve, Portugal. Regional Environmental Change	Chen JM et al. (2016) The Sustainability of Yachting Tourism: A Case Study on Greece. International Journal of Culture Tourism and Hospitality Research	Patuelli R, Nijkamp P (2016) Travel motivations of seniors: a review and a meta-analytical assessment. Tourism Economics	Romão J, Nijkamp P (2018) Impacts of tourism and territorial capital on regional development: a spatial econometric analysis. International Journal of Tourism Research
Vaz et al. (2011) Crossroads of tourism: A complex spatial systems analysis of tourism and urban sprawl in the Algarve. International Journal of Sustainable Development	Chen, Zhang, Nijkamp (2016) A Regional Analysis of Willingness-to-Pay in Asian Cruise Markets. Tourism Economics	Neuts et al. (2016) Market segmentation and their potential economic impacts in an ecotourism destination: An applied modelling study on Hokkaido, Japan. Tourism Economics	Liu, Nijkamp, Lin (2017) Urban-rural imbalance and Tourism-Led Growth in China. Annals of Tourism Research
Neuts, Nijkamp (2012) Tourist Crowding Perception and Acceptability in Cities: An Applied Modelling Study on Bruges. Annals of Tourism Research	Reggiani, Nijkamp, Cento (2009) Connectivity and Competition in Airline Networks. In: Vervest, Van Liere, Zheng (Eds) The Network Experience. Springer	Romão et al. (2015) Tourist Loyalty and e-Services: A Comparison of Behavioural Impacts in Leipzig and Amsterdam. Journal of Urban Technology	Bernini, Cracolici, Nijkamp (2017) Place-Based Attributes and Spatial Expenditure Behavior in Tourism.Journal of Regional Science
De Montis, Nijkamp (2008) Tourism development and collaborative evaluation: A multicriteria web based planning support system. International Journal of Environmental Technology and Management	Pels, Nijkamp, Rietveld (2003) Access to and competition between airports: a case study for the San Francisco Bay area. Transportation Research Part A: Policy and Practice	Romão et al. (2015) Culture, product differentiation and market segmentation: A structural analysis of the motivation and satisfaction of tourists in Amsterdam. Tourism Economics	Ridderstaat, Nijkamp (2016) Small Island Destinations and International Tourism. In: Ishihara, Hoshino, Fujita (Eds) Self-determinable Development of Small Islands. Springer
De Montis, Deplano, Nijkamp (2007) Multicriteria evaluation and local environmental planning for sustainable tourism. In: Matias, Nijkamp, Neto (Eds) Advances in Modern Tourism Research. Springer	Lijesen, Rietveld, Nijkamp (2002) How do carriers price connecting flights? Evidence from intercontinental flights from Europe. Transportation Research Part E: Logistics and Transportation Review	Romãoet al. (2014) Determinants of trip choice, satisfaction and loyalty in an eco-tourism destination: A modeling study on the Shiretoko Peninsula, Japan. Ecological Economics	Ridderstaat, Croes, Nijkamp (2016) A two-way causal chain between tourism development and quality of life in a small island destination: an empirical analysis. Journal of Sustainable Tourism

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Planning	Transports	Management	Economics
Stratigea, Giaoutzi, Nijkamp (2006) The potential of virtual organizations in local tourist development. In: Giaoutzi, Nijkamp (Eds) Tourism and Regional Development. Ashgate	Nijkamp, Yim (2001) Critical success factors for offshore airports - A comparative evaluation. Journal of Air Transport Management	Neuts et al. (2014) A quality assessment of tourist information: the case of nautical tourism at Shiretoko Peninsula. Almatourism	Ridderstaat, Croes, Nijkamp (2013) Tourism development, quality of life and exogenous shocks: A systemic framework. International Journal of Society Systems Science
De Montis, Nijkamp (2006) Tourism and the political agenda: towards an integrated web-based multicriteria framework for conflict resolution. In: Giaoutzi and Nijkamp (Eds) Tourism and Regional Development. Ashgate	Schipper, Rietveld, Nijkamp (2001) Environmental externalities in air transport markets. Journal of Air Transport Management	Van Leeuwen, Kourtit, Nijkamp P (2013) Residents' appreciation of cultural heritage in tourist centres: A microsimulation modelling approach to Amsterdam. Tourism Economics	Cracolici, Cuffaro, Nijkamp (2009) Tourism sustainability and economic efficiency. In: Girard, Nijkamp (Eds) Cultural tourism and sustainable local development. Ashgate
Nijkamp (2000) Tourism, marketing and telecommunication: a road towards regional development. In: Fossati, Panella (Eds) Tourism and Sustainable Economic Development. Springer	Nijkamp, Rietveld, Pels (2001) Airport and Airline Choice in a Multiple Airport Region: An Empirical Analysis for the San Francisco Bay Area. Regional Studies	Katsoni, Giaoutzi, Nijkamp (2013) Market Segmentation in Tourism: An Operational Assessment Framework. In: Matias, Nijkamp, Sarmento (Eds) Quantitative Methods in Tourism Economics. Springer	Cracolici, Nijkamp, Rietveld (2008) Assessment of tourism competitiveness by analysing destination efficiency. Tourism Economics
Janssen, Kiers, Nijkamp (1995) Private and public development strategies for sustainable tourism development of island economies. In: Coccossis, Nijkamp (Eds)Sustainable tourism development. Avebury	*Migrations*	Neuts B et al. (2013b) Describing the relationships between tourist satisfaction and destination loyalty in a segmented and digitalized market. Tourism Economics	Cracolici, Nijkamp (2006) Competition among tourist destinations: an application of data envelopment analysis to Italian provinces. In: Giaoutzi, Nijkamp (Eds) Tourism and Regional Development. Ashgate
Nijkamp, Verdonkschot (1995) Sustainable tourism development: a case study of Lesbos. In: Coccossis, Nijkamp	Song et al. (2019) The Influence of Emigration on Tourism Outward Foreign Direct Investment: Evidence	Neuts et al. (2013a) Digital destinations in the tourist sector. Letters in Spatial and Resource Sciences	Van Leeuwen, Nijkamp, Rietveld (2006) Economic impacts of tourism: a meta-analytic comparison of regional

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Planning	Transports	Management	Economics
(Eds) Sustainable tourism development. Avebury	from China. Journal of Travel Research		output multipliers. In: Giaoutzi, Nijkamp (Eds) Tourism and Regional Development. Ashgate
Non-business	Tubadji A, Nijkamp P (2018) Revisiting the Balassa–Samuelson effect: International tourism and cultural proximity. Tourism Economics	Kourtit K et al. (2011) Evaluation of cyber-tools in cultural tourism. International Journal of Sustainable Development	
Zerva, Kourtit, Nijkamp (2016) Tourism and Voyeurism in Heterotopia's In: Nijkamp, Romão, Matias (Eds.) Impact Assessment in Tourism Economics. Springer	Gheasi, Nijkamp, Rietveld (2011) Migration and tourist flows. In: Matias, Nijkamp (Eds.) Advances in tourism economics. Springer	Masurel, Nijkamp, Warmerdam (2008) Integrative assessment of tourists' satisfaction: An empirical analysis of visitors of the Anne Frank House. International Journal of Services Technology and Management	
Zerva, Nijkamp (2015) Tour guides as information filters in urban heterotopias: Evidence from the Amsterdam Red Light District. Tourism Management Perspectives	Poel, Masurel, Nijkamp (2006) The importance of friends and relations in tourist behaviour: a case study on heterogeneity in Surinam. In: Giaoutzi and Nijkamp (Eds.) Tourism and Regional Development. Ashgate		

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Chapter 13
Revisiting Bruges: Investigating the Importance of Tourist Crowding Perception in the Visitor Experience Through Computational Text Analysis

Bart Neuts

Abstract A quasi-continuous rise in tourist arrivals throughout Europe has raised increasing concerns of overtourism among destination management organizations and public administrations. While the uptick in academic attention to the topic has been significant during the past 5 years, operationalization of the crowding-indicator is still often limited to supply-sided optimization studies or traditional resident and visitor surveys. Advances in big data availability and analysis have opened up new possibilities for data collection and monitoring. In this chapter we will evaluate tourist crowding perception in Bruges by applying computational text analysis on 6580 TripAdvisor reviews. The analysis will explore the opportunities of consumer-generated data for continuous crowding sentiment tracking while avoiding the necessity for expensive and infrequent formal visitor surveys.

Keywords Crowding · Urban tourism · Thematic analysis · Computational text analysis · Latent Dirichlet allocation

13.1 Introduction

By its very nature, international tourism requires movement and spatial co-consumption and the exponential growth in arrivals has sparked increased concerns about the sustainability of tourism. Within urban destinations, the debate has particularly centred around the socio-cultural carrying capacity limits and the effect of "overtourism"—as it has been branded in popular press—on local liveability and the tourist experience (e.g. Peeters et al. 2018). Even though the phenomenon of unsustainable tourism development has received attention since the 70s, recent years

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have seen a strong increase in the research interest into determinants and consequences of overtourism (Capocchi et al. 2019). Operationalization of the concept itself has generally taken one of the following approaches: (a) conducting attitudinal surveys or semi-structured interviews among residents and/or visitors (e.g. Namberger et al. 2019; Neuts and Nijkamp 2012), (b) approaching crowding as an optimization problem with tourism supply constraints (e.g. Bertocchi et al. 2020), or (c) using geolocated travel review data (e.g. Kaufmann et al. 2019; Shi et al. 2017). Since the survey approach is costly and traditionally limited to cross-sectional/correlational studies—i.e. lacking a longitudinal timeframe—and the supply-sided capacity optimization approach does not account for the human component in overtourism perceptions, this chapter will explore alternative analytical opportunities within the framework of user-generated travel review data from online consumer review sites. Contrarily to the studies of Kaufmann et al. (2019) and Shi et al. (2017) where the focus lies on spatial dispersion and identification of hot zones, this book chapter highlights the longitudinal, rather than the spatial, component. The main research objective is to evaluate the opportunities of web scraping and computational text analysis of publicly available travel reviews over an extended time period for developing an understanding of the evolution of crowding perception and its subsequent effects on the tourist experience. The results will help to deduce whether web scraping and supervised and unsupervised computational text analysis can provide a proper alternative for traditional survey methods in studies on overtourism.

The book chapter will use Bruges, Belgium, as a case study, with TripAdvisor the selected platform to scrape travel reviews. Since tourism in Bruges has increased by 68.9% in arrivals and 58.8% in overnights between 2007—the time of the study of Neuts and Nijkamp (2012)—and 2018, it is considered an interesting case for investigating potential increases in crowding perceptions.

The next section will discuss the literature on crowding and its place within visitor experience studies, after which Sect. 13.3 discusses the methodology, particularly the method of data collection and subsequent computational text analysis. Section 13.4 will discuss the results of a qualitative thematic analysis and the supervised counting and dictionary computational text analysis. Finally, this section explores the opportunities of unsupervised machine learning. The conclusion will reflect on the proposed methodology and discuss the advantages and limitations of computational text analysis as compared to more traditional methods for studying tourism crowding and the visitor experience.

13.2 Tourism Crowding and the Visitor Experience

While tourism experience research is a well-established field, the holistic nature of the concept provides challenges for a simple conceptualization. Buchmann et al. (2010), recognizing the complexity of fully unravelling relevant elements of the tourist experience, suggest following a strategy of simplification, focusing on explaining clearly specified aspects of the total experience. As such, the focus should not be on the tourist experience as a Gestalt but to identify and study individual building blocks in order to achieve incremental progress. Therefore, this study concentrates specifically on crowding as a situational experience influencing visitor satisfaction.

Crowding research in tourism is historically rooted in the Anglo-Saxon literature on backcountry visitation norms and experiences (e.g. Shelby et al. 1989; Steward and Cole 2001; Vaske and Donnelly 2002). In the majority of cases, such studies have been inspired by the related carrying capacity concept, which originates from an engineering school of thought and attempts to find mechanical optima and maxima in population size before disruptive effects create an unsustainable situation and invite negative responses. While carrying capacity is typically focused on potential negative effects of density above capacity limits—as an objective variable—studies such as Paulus and Matthews (1980) suggested how, when concentrating on carrying capacity of the socio-cultural environment, negative effects are mediated by different control variables. These can broadly be grouped under (a) interpersonal relationships between group members, (b) type and characteristics of environment where density is experienced, (c) perception of control, and (d) preference for interpersonal distance (Aiello et al. 1981, 1977; Stokols 1976; Baum and Davis 1980). These findings have generated additional research interest into mediating variables on density perception and consequences, leading to the conceptualization of crowding as a psychological evaluation of density, thus transforming the mechanistic carrying capacity thinking.

As such, even though the crowding concept is related to mechanistic carrying capacity thinking, due to its socio-psychological nature, operationalization takes a decidedly less pure mathematical approach and is generally based on the ideas of social norm theory, whereby a societal crowding norm is distilled from individual norms on ideal density, further accounting for a range of mediating variables (e.g. Donnelly et al. 2000; Manning et al. 1999; Patterson and Hammitt 1990). Crowding is then seen to originate at the point where the minimum acceptable condition is exceeded. Neuts (2016) discusses how such a methodological operationalization links crowding to a norm/community-based sustainability approach where selected stakeholders set appropriate levels of resource use (Burns 2004; Saarinen 2006). By identifying minimum acceptable conditions through a norm-based approach, the criticism aimed at deterministic carrying capacity concepts (e.g. McCool and Lime 2001) is countered, since capacity constraints do not just depend on objectively quantifiable variables but also on situational characteristics and societal perceptions (Saarinen 2006; Saveriades 2000; Simón et al. 2004). While crowding operationalization through normative approaches has generally been accepted within the tourism literature and mediating variables on such crowding perception have been well-studied (e.g. Kyle et al. 2004; Manning 1999; Neuts and Nijkamp 2012), such operationalization also complicates the field of study. For instance, Kuentzel and Heberlein (2003) studied longitudinal changes in crowding perception at the Apostle Islands and noticed that while visitors had more than doubled, crowding perception had decreased. The authors refer to changing norms over time, indicating that crowding cannot be stably compared across time periods because of underlying subjective changes.

Another area where research findings are inconclusive is on the consequent effects of crowding on the visitor experience. For instance, Steward and Cole (2001) note how evidence for a strong influence of recreational crowding on the quality of visitor experience is weak. In an urban context, Neuts and Nijkamp (2012) similarly observed how the relationship between crowding perception and affective response, while significantly negative, is weak and dependent on individual preferences. In a study on congestion, behaviour and visitor experience at two World Heritage Sites in Macao, du Cros (2007) identified various elements of the site influencing the experience—including cost of entrance, small range of products offered for bus tours, boredom, lack of dedicated care and comfort for senior tourists—however, none related to crowding at the attractions. Multiple reasons have been offered for the weak correlation between crowding and experience. First of all, there might be weak convergence towards a shared social crowding norm, therefore suggesting that personal norms can substantially differentiate (Donnelly et al. 2000; Heywood 1993). This was the case in the study of Neuts and Nijkamp (2012) where the low Van der Eijk's A of 0.36—which measures the crystallization, or level of agreement, in ordered rating scales on a scale of -1 (i.e. complete disagreement) to +1 (i.e. complete agreement), with scores close to 0 indicating a nearly uniform distribution—suggested a lack of consensus, with significant effects of crowding on the tourist experience being limited to certain tourist groups. Cole and Steward (2002) propose a somewhat related explanation, finding some evidence that visitors acquiesce to observed conditions and personal norms might therefore be affirmations of current site conditions, rather than judgements on acceptable use levels. In other words, these authors suggest that the actual on-site experience with regard to visitor numbers forms the basis of a personal norm, rather than the personal norm being predefined a priori to the actual visit and site experience. Neuts and Nijkamp (2012) take this argument further and, building on the work of Choi et al. (1976), distinguish between objective crowding levels—unrelated to preference—and subjective emotional levels—related to preference. As such, objective crowding might not lead to a lower visitor experience, with a negative effect only expected in case where crowding levels trigger a subjective emotional response.

Considering the conceptualization of the crowding concept as being a psychological evaluation of density levels, study methodologies have most often taken the form of visitor surveys or qualitative semi-structured interviews. However, the growth of internet, user-generated content and mobile applications have opened up new research opportunities. This has particularly been true in tourism experience and opinion research, with Kirilenko et al. (2018) providing a broad overview of automated sentiment analysis approaches on big data. Most often, data is scraped from review sites or travel blogs, which are considered interesting study objects to better understand the full characteristics of the tourist experience by providing a fuller and more personal description of various experiential trip aspects (e.g. Magnini et al. 2011; Tseng et al. 2015). Clearly then, the experience vis-à-vis crowding might be a direct or indirect element of such reviews. Moving beyond static online reviews, Shi et al. (2017) based their research on geotagged data from Weibo to perform a hotspot analysis and linked this to a sentiment analysis on crowding, identifying areas with high popularity and high crowding mentions, but also recognizing that certain areas showed characteristics of high popularity—i.e. use density—but lower crowding mentions.

13.3 Methodology

13.3.1 Case Study Overview: Bruges

Bruges (Belgium) has a long and significant history, recognized in its UNESCO World Heritage List inclusion in 2000. It is appreciated for its architectural value and cultural significance, influenced by its role as a commercial and artistic centre in medieval times. The city is strongly connected with the Flemish Primitives with artists such as Jan van Eyck and Hans Memling, with an important part of their collection remaining in the city's art museums. A main attractor of Bruges is its largely intact medieval street pattern and building stock and network of canals, which has been preserved at least partly due to the fact that the nineteenth-century industrial revolution largely passed the city by. Even though Bruges is an active, living city, more recent contemporary developments have happened around the urban core which has largely preserved its architectural and urban structures such as the central Market Place, the belfry, beguinage, hospital and religious and commercial housing which now form the heart of the tourism-historic district (UNESCO n.d.).

Due to its spatial and cultural attractiveness and historic significance, Bruges—mirroring the trend in other historic European cities—has registered almost continuous growth in tourist arrivals and overnight stays. Tourist arrivals in commercial accommodation (i.e. excluding private rent and Airbnb supply) grew from 740,591 in 2007 to 1,250,589 in 2018—a compound annual growth rate of 1.99%. Similarly, overnight stays grew from 1,380,623 to 2,193,092—a compound annual growth rate of 2.11%—over this same period (Toerisme Vlaanderen 2019). On top of these overnight tourists, Visit Bruges (2019) counted 6 million day visitors in 2018, through mobile data analysis.

Due to the spatial characteristics of Bruges, and at least partly as a result of policy choices that have concentrated tourism functionalities within the historic core (Jansen-Verbeke and Ashworth 1990), much of the tourism development is predominantly taking place within a limited area of 4.6 km^2, leading to concerns about the social carrying capacity of the urban centre where the tourism intensity index averages 120 tourists per 100 residents, with days peaking at 210 tourists per 100 residents. However, even though 29% of overnight tourists and 36% of day visitors have reported experiences of overcrowding in Bruges, the visitor experience seems hardly affected, with the general satisfaction score of the destination—

collected from regular visitor surveys—scoring between 8.6 and 8.7 out of 10 (Visit Bruges 2019).

13.3.2 Data Collection and Data Characteristics

In this study, the entire data collection is based on secondary user-generated data for the period 2013–2019. There are a few advantages in the use of secondary data for the study of crowding perception and tourist experience. First of all, while primary data in the form of interviews or questionnaires can become prohibitively expensive and is generally time-consuming, secondary data—specifically when related to internet resources—is easily available and quickly consultable. Secondly, it is seldom possible to conduct a longitudinal study, with interviews and questionnaires being directed at identifying current visitor experiences. On the other hand, secondary data can assist in acquiring information over a longer time span. Thirdly, primary data collection has a higher chance of leading to an observer effect—particularly when potentially negative visitor feedback is collected—while the limitations of questionnaires for collecting complete expressions on ideas and experiences are also clear due to the constricted nature of this data collection strategy. On the other hand, secondary user-generated data provides access to first-hand, self-published tourist experiences which might offer broader insights into the reviewers' true feelings.

On the other hand, there are also a number of limitations to secondary data analysis. Particularly in relation to the investigation of correlational and causal effects, secondary data will be less useful since the collected data is not shaped specifically with a conceptual model in mind. Secondly, primary data collection can be designed to ensure maximal representativeness across a sample. Conversely, within secondary data analysis there is a risk of self-selection bias with certain language groups, age groups, and education levels likely being overrepresented (Presi et al. 2014; Xiang et al. 2017). Such limitations need to be taken into account when continuing the analysis.

Reviews were scraped from TripAdvisor, considered to be one of the leading travel websites in the world (O'Connor 2008), providing reviews and travel suggestions with a comprehensive coverage of hotels, attractions, restaurants and airlines. Analysis of such review data is pertinent, considering the increased amount of tourists consulting online reviews during the trip planning stages (Ayeh et al. 2013). A total of 6580 reviews were scraped from the TripAdvisor webpage of the Historic Centre of Bruges (https://www.tripadvisor.com/Attraction_Review-g188671-d1466553-Reviews-Historic_Centre_of_Brugge-Bruges_West_Flanders_Province.html) on 7 December 2019. Only English reviews were considered due to the requirements of the Natural Language Processing (NLP) algorithms. RSelenium was used for fetching the page and rvest for extracting page components; both libraries are available in R 3.4.0. Through the use of Document Object Model (DOM) parsing, the dynamic contents of the TripAdvisor pages could be retrieved.

Table 13.1 Frequency statistics of TripAdvisor data

Variables			Variables			Variables		
Year	*n*	%	Travel company	*n*	%	Rating	*n*	%
2013	71	1.1	Business	14	0.2	1	14	0.2
2014	1242	18.9	Couple	647	9.8	2	33	0.5
2015	1644	25.0	Family	203	3.1	3	146	2.2
2016	1231	18.7	Friends	220	3.3	4	1274	19.4
2017	1001	15.2	Solo	66	1.0	5	5113	77.7
2018	757	11.5	Unknown	5430	82.5			
2019	565	8.6						
Unknown	69	1.1						

Table 13.1 offers an overview of a few main characteristics that could be identified from the secondary data that was scraped from the TripAdvisor website. While the years scraped span 2013–2019, it is clear from Table 13.1 that 2013 only accounted for a small portion of reviews (1.1%), with older reviews being unavailable. In terms of travel company, while travelling as a couple (9.8%) was the largest group, followed by travelling with friends (3.3%) and family (3.1%), this variable was often missing from reviews, with 5430 unknowns. The only category without missing data was the rating, which is a required field for TripAdvisor reviews. The vast majority of reviews were overall very positive with 5-star ratings accounting for 77.7% and 4 star ratings for 19.4%. Only 47 out of 6580 reviews scored less than 3 stars.

One sample characteristic that can be directly compared to the known tourist population is the origin of visitors to Bruges. In order to identify the origin of reviewers, some preliminary data cleaning was needed due to the non-standard formatting of the TripAdvisor location variable. We used to R countrycode package (Arel-Bundock et al. 2018) to simplify cities, countries and American states to the ISO Alpha-3 coding scheme. While this automatized recoding process did lead to a limited data loss due to interpretability-issues with user-generated strings, a manual sample check indicated that data loss was minor. Table 13.2 compares the sample frequencies to the population frequencies for tourist arrivals in Bruges in 2018. Significant differences between the sample and the population are indicative of self-selection bias due to language choice of reviews, with English-speaking countries being overrepresented in the sample (e.g. United Kingdom = 36.3%, USA = 15.8%, Australia = 4.0%). Primary tourist markets of Bruges such as Belgium (2.7%), the Netherlands (1.8%), Germany (0.9%), France (0.8%), China (0.1%) and Japan (0.1%) are clearly underrepresented, with all Asian countries as a whole only accounting for 3.2% of scraped reviews. These differences between the real tourist

Table 13.2 Comparison of TripAdvisor and population origin statistics

Variables	Sample		Population	
	n	%	*n*	%
Origin				
Europe				
United Kingdom	2385	36.3	206,824	16.5
Belgium	177	2.7	296,046	23.7
The Netherlands	119	1.8	114,994	9.2
Ireland	89	1.4	8029	0.6
Germany	62	0.9	101,635	8.1
Other Europe	500	7.6	285,832	22.9
North America				
USA	1038	15.8	68,504	5.5
Canada	159	2.4	9623	0.8
Oceania				
Australia	266	4.0	11,887	1.0
Other Oceania	38	0.6	2617	0.2
Asia				
India	80	1.2	5203	0.4
Singapore	22	0.3	1031	0.1
Malaysia	19	0.3	948	0.1
Other Asia	87	1.3	55,196	4.4
Latin America	77	1.2	55,381	4.4
Middle East	72	1.1	16,875	1.3
Africa	57	0.9	4022	0.3
Caribbean	8	0.1	1194	0.1
Unknown	1325	20.1	4748	0.4

population and the scraped review data need to be taken into account when analysing the results, since findings will thus primarily represent an Anglo-Saxon view on the tourist experience in Bruges.

A final scraped characteristic that might be useful for interpretation of the results is the number of contributions provided by each reviewer. We might consider this attribute as a proxy to previous travel experience—even though we acknowledge that it might as well be an indication of review experience. We considered 5 classifications, with less than 10 contributions representing the lowest amount of reviews (10.4%), followed by 10–25 contributions (13.5%). A total of 14.6% of users had contributed between 26 and 50 times before on TripAdvisor, with 17.8% having written between 51 and 100 reviews. Tellingly, the largest group (42.0%) had written over 100 contributions. Finally, for 1.7% of the sample information on contributions was missing. This data might suggest that visitors to the Historic Centre of Bruges are well-travelled tourists, reflecting the maturity of the destination.

13.3.3 Computational Text Analysis

While the core text analysis of the chapter is based on large-scale automation, at the outset we first followed a traditional qualitative thematic analysis approach. For this, a random sample was selected, with 50 reviews chosen for the period 2013–2015, 50 reviews for 2016–2017 and 50 reviews for 2018–2019. On this dataset, a thematic analysis was conducted in order to identify codes and higher-level themes and analyse whether there was a periodic evolution noticeable across various themes. We followed the step-by-step coding and analysis process as described by Braun and Clarke (2006): (a) data familiarization, (b) outlining initial codes, (c) identifying final codes, (d) defining tentative themes, (e) finalizing themes, (f) identifying categories. An important function of the qualitative thematic analysis pertained to identifying dictionary keywords within each theme and code in order to create a dictionary object for the computational text analysis.

Our automatized computational text analysis focused primarily on frequencies—and not word positions—in a bag-of-words text analysis approach. While simplifying the intricacies of human language, Grimmer and Stewart (2013) note how word frequencies can already contain sufficient information for many types of basic analysis. Prior to the analysis, scraped data needs to be prepared. We followed the steps suggested by Welbers et al. (2017) and first used basic string operations such as removing html tags and punctuation, stripping surround whitespace and transforming all words to lower cases. Next, the preprocessing step transformed raw text into smaller, specific text features—tokens—while also applying normalization stemming (i.e. converting inflected forms into base forms, such as in the case of verb conjugations, through a rule-based algorithm) and removing common stop words. These tokens then formed the basis for a document-term matrix (DTM) that served as the input for text analysis with R packages.

The document-term matrix was primarily analysed using a dictionary approach, further supported by statistical text analysis. The dictionary approach, using the quanteda-package in R (Benoit et al. 2018), was based on the constructed dictionary of the qualitative thematic analysis and simply counted the number of occurrences of keywords related to the identified codes and themes. This allowed for a much more extensive analysis of reviews (i.e. $n = 6580$ instead of $n = 150$) and served as a reliability-check on the results of the qualitative analysis. Furthermore, an unsupervised machine learning algorithm was tested as a complementary inductive analysis (Grimmer and Stewart 2013). While the dictionary method adopts a deductive approach, under unsupervised machine learning, no prior coding rules or training data are supplied and instead an algorithm identifies textual patterns, with the sole input from the researcher being the specification of certain parameters. The unsupervised machine learning algorithm adopted in this chapter is Latent Dirichlet Allocation (LDA) (Blei et al. 2003), using the topicmodels R-package (Grun and Hornik 2011). LDA is guided by two principles: (a) each document is a mixture of topics, and (b) each topic is a mixture of words, with words potentially shared between topics. LDA is a generative probabilistic model that mathematically establishes the mixture of words associated with each topic, as well as the mixture of topics most closely describing entries. The topic probabilistic distribution is assumed to follow a sparse Dirichlet prior—based on the intuition that entries only cover a small set of topics and that topics only use a small set of words frequently. Each topic is then associated with probabilities of generating various words. For instance, the word “restaurant” would have a high probability for the topic “food”, and a low probability for the topic “museum”. Non-distinct function words will have roughly even probabilities across topics. The topics are identified on the basis of automatic detection of the likelihood of co-occurrence of words—therefore not being a priori semantically or epistemologically defined—with each entry then assumed to be characterized by sets of topics, similar to a standard bag of words assumption.

13.4 Results and Discussion

13.4.1 Qualitative Thematic Analysis

After gaining familiarity with the random sample of 150 reviews, initial codes were based on identifying frequent words and sentences, relating to specific experiences of the visit to the Historic Centre of Bruges. Frequent words or sentences were, for example, “loads of historic monuments”, “canals and canal tours”, “Bruges is beautiful”, “great food”, “easy to explore on foot”. Thus initially setting up relevant codes allowed for a systematic labelling across the entire data set. From these initial codes, final codes were then identified through the integration of major similar codes or the omission of non-essential codes with low frequencies. Major codes identified in the data were, for example, “history”, “architecture”, “walkability”, “touristification”, “crowding”.

Following Braun and Clarke (2006), codes were then aggregated into potential themes and reviewed, creating an overall story of the analysis by providing clear definitions and descriptions—the thematic map of the analysis (Vaismoradi et al. 2016). There needs to be correspondence with the research questions, so tentative themes might need to be revised based on the association between themes and their relevance with regard to the original scope of the research. In this study, four major themes were identified: (a) Culture: encompassing all review elements related to historic events, churches, museums, architecture and the general cityscape, (b) Atmosphere and sightseeing: combining elements related to picturesque urban elements, sightseeing opportunities and city tours, and intangible atmospheric elements, (c) Consumerism/hedonism: focusing on review elements related to shopping, food and drinks, and price elements of the tourism product, and (d) Tourist system and trip: combining codes on personal trip characteristics, as well as appreciation of the hospitality industry and level of service, and codes relating to urban transformations due to tourism. Finally, Braun and Clarke (2006) recognize a need to divide the themes into different categories in terms of positive and negative perceptions. This could be relevant for the code pertaining to “crowding”, within the

Table 13.3 Frequency of topics from qualitative thematic analysis

	2013–2015 ($n = 49$)		2016–2017 ($n = 49$)		2018–2019 ($n = 50$)	
Label	Count	%	Count	%	Count	%
Theme 1: culture	32	65.3	42	85.7	40	80.0
History	17	34.7	14	28.6	14	28.0
Museums	4	8.2	8	16.3	6	12.0
Architecture	11	22.4	20	40.8	20	40.0
Theme 2: atmosphere and sightseeing	70	142.9	78	159.2	52	104.0
Sightseeing	12	24.5	16	32.7	14	28.0
Atmosphere	15	30.6	14	28.6	5	10.0
Relax	1	2.0	1	2.0	6	12.0
Waterways	17	34.7	18	36.7	11	22.0
Walkability	16	32.7	17	34.7	13	26.0
Carriages	5	10.2	8	16.3	3	6.0
City bus	4	8.2	4	8.2	0	0.0
Theme 3: consumerism/hedonism	38	77.6	51	104.1	49	98.0
Food and drink	21	42.9	27	55.1	27	54.0
Shopping	6	12.2	13	26.5	17	34.0
Christmas market	1	2.0	3	6.1	2	4.0
Brewery	1	2.0	1	2.0	1	2.0
Price	9	18.4	7	14.3	2	4.0
Theme 4: tourist system and trip	18	36.7	37	75.5	36	72.0
Touristification	3	6.1	3	6.1	2	4.0
Crowding	6	12.2	9	18.4	11	22.0
Hospitality industry	3	6.1	0	0.0	0	0.0
Local hospitality	1	2.0	5	10.2	5	10.0
Connectivity	4	8.2	3	6.1	3	6.0
Duration	1	2.0	10	20.4	8	16.0
Return	0	0.0	5	10.2	6	12.0
Safety	0	0.0	2	4.1	1	2.0

broader theme of the "tourist system and trip", where both positive and negative crowding-related statements could be identified and needed to be distinguished.

Table 13.3 provides an overview of the themes and underlying codes and their respective occurrence over the three recognized time periods. Individual codes (e.g. "history", "museums", "architecture") have a maximum score of 100%, counting every review mentioning this particular code and comparing this total to the total sample size. On the other hand, the four themes ("Culture", "Atmosphere and sightseeing", "Consumerism/hedonism", "Tourist system and trip") can score above 100%. This is caused by the fact that a single review might, for instance, mention aspects of "atmosphere", "waterways" and "walkability", all three of which are individual codes within the theme of "Atmosphere and sightseeing". By counting each coding instance separately, rather than binary coding each review on whether or not any of the specific codes within a theme was mentioned, we ensure that the magnitude of thematic mentions is respected.

On a thematic level, mentions of cultural elements of the city within the tourist experience formation (Theme 1) increased from 2013–2015 to 2016–2017 and then remained rather stable, with the code most responsible for this rise being "architecture". This entire theme has a positive sentiment with respondents generally reflecting on the historic significance of the inner city and the interesting period architecture. For instance:

> R4077: "Bruges is a historical important city. Walking through the often narrow street gives you a glimpse of a town in medieval times. On all these cobble stones hundreds of thousands ancestors walked, lived, suffered or partied before us". (history)

And:

> R920: "All the buildings were impressive with lovely architecture. The churches were beautiful and well worth a visit". (architecture)

The second theme encompasses more codes and is, on thematic level, the most mentioned, although there was a noticeable decrease in mentions between 2016–2017 and 2018–2019. Particularly mentions of "atmosphere" and "waterways" fell back slightly. Like the previous theme, all reviews related to atmosphere of the inner city and sightseeing opportunities provided are positive in sentiment. For instance:

> R924: "All of Brugge/Bruges is a feast for the eyes. On a Summer's day it is just heaven. Even though it was raining the day we were there, it was still gorgeous". (atmosphere)

> R4189: "It is a place where you can relax and stroll around to have a wonderful day". (relax, walkability)

The third topic which focuses on more hedonistic elements of the destination is quite prevalent in the reviews and has exhibited a noticeable rise between 2013–2015 and 2016–2017, particularly within the codes "food & drink" and "shopping". Unlike the previous two themes, within the consumerism/hedonism topic we can recognize both positive and negative statements, the latter primarily related to the quality of certain restaurants (albeit the majority of reviews being positive on this code) and the price levels. For example:

> R3556: "Don't get ripped off like I did when buying a meal in Brugge! In my opinion, the food is very mediocre and exorbitantly priced . . . I can honestly say that on my extensive travels, I have never encountered such awful food served by such rude staff. If you are not a lover of meat or prefer a healthy meal as I do, stay away from restaurants in the main tourist areas, particularly those with a view of historic landmarks". (food & drink, price)

> R1800: "Great bistros to taste original Belgian waffles or cosy restaurants to taste mussels and other delicacies". (food & drink)

The final theme—relating to the tourism system and the characteristics of the trip—gained importance between 2013–2015 and 2016–2017 with an increased number of reviews mentioning duration of stay—and suggestions for trip duration—as well as repeat visitation. Interestingly for the specific chapter topic, the number of reviews mentioning "crowding" increased from 12.2% in 2013–2015 to 22.0% in 2018–2019. However, analysis of the specific reviews made clear that the sentiments regarding crowding are primarily neutral and part of a wider suggestion to travellers in terms of ideal times for visitation. Purely the number of other tourists present in Bruges was therefore seldom a reason for diminished tourist experiences. This was similar for the code on "touristification", where most of the mentions related to the positives of a tourism-centred industry. For example:

> R2866: "Arrived on one of the hottest days so far this year so the city was crowded but with a lovely sense of pleasure and enjoyment from most of the visitors". (crowding)

> R4070: "Hustle and bustle all day long but quiets down in the evening when the day trippers go home". (crowding)

> R3756: "The town is very obviously a large tourist attraction with everything focused towards visitors, great for English speaking though!" (touristification)

From the qualitative data analysis, we could make some interesting conclusions. First of all, history and culture were mentioned most often throughout the reviews. All reviewers appreciated the historic significance and architectural beauty of the building stock, and street and canal layout. The reviews therefore largely reflect the image being presented by Bruges and the original motivations of the majority of visitors. Secondly, it is interesting to note that as a single code, the culinary aspects of the destination are actually mentioned most of all (42.9% in 2013–2015, 55.1% in 2016–2017 and 54.0% in 2018–2019). The availability and general quality of eating and drinking establishments were a standard staple of many reviews with particular mentions of Belgian beers, waffles and chocolate. While the majority of reviews were positive on the food standard, a few mentions were critical on price and quality, particularly within the tourist core centre, thus providing advice to fellow travellers to find eateries outside of the tourist bubble. Thirdly, another oft-mentioned aspect of the city relates to its compact size and the absence of much motorized traffic, thereby providing ample opportunities for strolling around and enjoying the general scenery. Fourthly, the compact size and concentration of main tourist attractions has led to a central "golden triangle" for tourism, with concerns on tourist intensity and overcrowding. However, while crowding is recognized in some reviews, and these mentions have seemingly been rising over the years, there is no rising negative perception on tourist crowds. Most reviewers either perceive crowding objectively and offer recommendations on visitation times, or even see it as contributing to the general atmosphere and liveliness of the city.

13.4.2 Counting and Dictionary Computational Text Analysis

Next, we analysed the reviews per topic of the qualitative sample in order to establish a key terminology per subject-matter. For instance, from the reviews that had mentioned "Crowding" as topic, we could identify the related words and word groups "crowd", "crowds", "crowded", "calm", "queues", "busy", "hustle and

Table 13.4 Frequency of topics from computational dictionary analysis

Label	2013–2015 (n = 2893)		2016–2017 (n = 2195)		2018–2019 (n = 1302)	
	Count	%	Count	%	Count	%
Theme 1: culture	2950	102.0	2198	100.1	1338	102.8
History	1197	41.4	941	42.9	585	44.9
Museums	401	13.9	250	11.4	151	11.6
Architecture	1352	46.7	1007	45.9	602	46.2
Theme 2: atmosphere and sightseeing	4102	141.8	2852	129.9	1712	131.5
Sightseeing	558	19.3	403	18.4	253	19.4
Atmosphere	1137	39.3	868	39.5	490	37.6
Relax	80	2.8	69	3.1	44	3.4
Waterways	828	28.6	479	21.8	315	24.2
Walkability	1052	36.4	733	33.4	474	36.4
Carriages	360	12.4	245	11.2	109	8.4
City bus	87	3.0	55	2.5	27	2.1
Theme 3: consumerism/hedonism	2582	89.2	1829	83.3	1024	78.6
Food and drink	1417	49.0	1027	46.8	598	45.9
Shopping	708	24.5	481	21.9	280	21.5
Christmas market	182	6.3	155	7.1	52	4.0
Brewery	47	1.6	37	1.7	14	1.1
Price	228	7.9	129	5.9	80	6.1
Theme 4: tourist system and trip	2435	84.2	1732	78.9	1051	80.7
Touristification	50	1.7	42	1.9	20	1.5
Crowding	362	12.5	244	11.1	168	12.9
Hospitality industry	100	3.5	49	2.2	36	2.8
Local hospitality	237	8.2	163	7.4	92	7.1
Connectivity	172	5.9	115	5.2	78	6.0
Duration	982	33.9	731	33.3	440	33.8
Return	356	12.3	271	12.3	138	10.6
Safety	176	6.1	117	5.3	79	6.1

bustle", "quiet", "overtakes", and "lots of tourists". A similar analysis was conducted for each topic in order to establish a working dictionary. This dictionary then served as the basis for counting topic occurrences on the full dataset of 6580 reviews. Finally, since each topic could be mentioned and counted multiple times (e.g. a person who might have written "Bruges is a busy city with lots of tourists" would have two counts on the "crowding" topic), all counts were transformed into binary data as we were mainly interested in occurrence versus absence of topics within reviews.

Table 13.4 provides an overview of the computational statistics. It is immediately clear that, as compared to Table 13.3, the frequency distribution of the various topics is much more stable across the years, with hardly any significant changes in mentions between 2013–2015 and 2018–2019. As a second observation, we can see that the significance of topics is largely similar with "food & drink", "architecture", "history", "atmosphere", and "walkability" being the top five mentioned categories across the different time periods. Specifically focusing on the occurrence of crowding and the possibility of negative tourism pressures developing over the years, the data no longer suggest a rise in perception, with both the "crowding" code and "touristification" code stable across the three time periods.

The resulting topic frequencies—particularly the ones related to crowding can then be further analysed in order to try to identify some confounding effects in order to somewhat mirror existing conceptual crowding models. Evidently, though, identification of crowding perception drivers is limited to available public information on the TripAdvisor review pages. Only three such variables were scraped: travel company, nationality and number of contributions by each reviewer (as a proxy for prior travel experience). Via chi-square tests we tried to identify whether significant differences existed in the probability of perceiving crowding.

After excluding the "business" travel category due to a low number of observations, the chi-square test on travel company did not reject the null hypothesis that crowding perception is independent of travel group (Chi-square $= 2.823$, Df $=$ 3, p-value $= 0.420$). On the other hand, travel experience did seemingly have an influence on the probability of experiencing crowding with a chi-square $= 12.147$ (Df $= 4$, p-value $= 0.016$). From Table 13.4, it could be established that the probability of mentioning crowding-related aspects in the review increased with an increasing prior travel experience—from 10.4% for people with very limited prior experience (i.e. less than 10 written reviews) and 10.1% for people with limited experience, to 11.1% for respondents with a medium experience, 12.1% for the group that was considered quite well-travelled, and 13.7% for those reviewers with over 100 TripAdvisor contributions. In order to prevent data sparsity, the analysis of nationality-effects was only conducted for countries with at least 50 available reviews. The chi-square test did not reject the null hypothesis (Chi-square $=$ 4.496, Df $= 10$, p-value $= 0.922$) meaning that a relationship between nationality and country perception could not be established.

After establishing the relevance of potential crowding perception drivers, we can attempt to answer the question on crowding perception and tourist satisfaction. A simple and straightforward approach is to adopt a t-test and validate whether reviews which included crowding-related observations were given significantly lower ratings. Segmenting the data, we find that reviews that include crowding-related topics have an average rating of 4.63 (st. dev. $= 0.625$), while reviews without crowding-related perceptions have an average rating of 4.75 (st. dev. $= 0.527$). Although minor, the difference does appear to be significant according to the t-test (t-test $=$ -5.379, df $= 969$, p-value <0.001). So even though we mentioned earlier that in many instances, the perception of crowding did not seem to hold a negative sentiment—as observed from the qualitative thematic analysis—it does appear that in general crowding is slightly deprecating the visitor experience.

A second experiment that can be run in this regard is to compare term frequencies of two different corpora. In this analysis, we start from the review ratings as a baseline, creating two review groups: reviews with low satisfaction rates (≤ 3) and

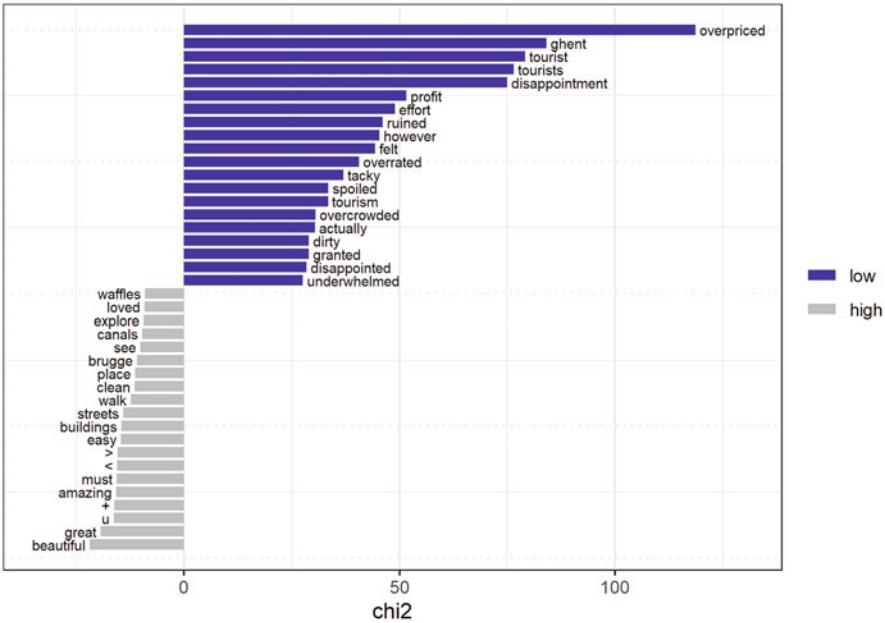

Fig. 13.1 Relative word frequencies of low and high rating scores

reviews with high satisfaction rates (>3). We are then interested to see whether certain words are more likely to appear in low-scoring reviews with a particular focus on whether crowding-related elements are appearing with greater frequency in this subset. As Fig. 13.1 indicates, the low-ranked reviews include much higher frequencies of words relating to the price level, touristification and overcrowding. So while crowding is not uniquely negatively perceived (as indicated through the qualitative analysis), within negative reviews, the level of tourism within the Historic Centre of Bruges is one of the main recurring elements.

13.4.3 Unsupervised Machine Learning as Methodological Alternative

While the count and dictionary method is often used within computational text analysis, the prior requirement of having an established dictionary does increase manual labour to a certain extent, while also potentially steering the analysis—either intentionally or unintentionally—into certain conclusions due to selective dictionary entries. Such pitfalls area avoided when adopting unsupervised machine learning algorithms which avoid the necessity of constructing a thematic dictionary a priori and are purely based on inductively identifying underlying data patterns. While such methods therefore have the potential to replace the previously presented dictionary

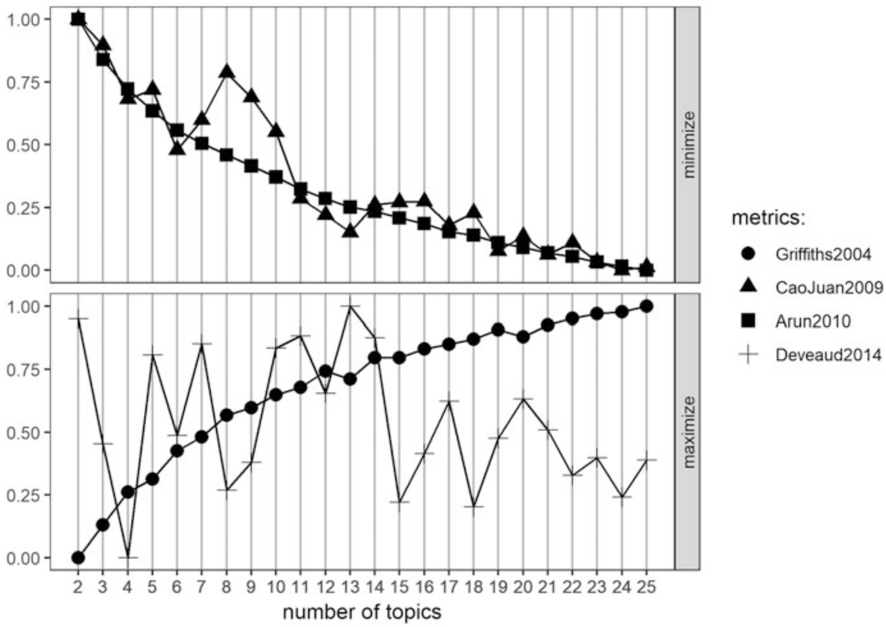

Fig. 13.2 Optimal number of topics for latent Dirichlet allocation

approach, there is no certainty on the relevance of unsupervised machine learning outcomes for the topic at hand. We therefore considered Latent Dirichlet Allocation (LDA) first and foremost as a means to verify earlier results and to investigate its future potential in crowding-related research.

Within the LDA algorithm, the number of topics to be identified needs to be set in advance. Much like in cluster analysis, there is no unambiguous method to establish the most accurate division of topics but a number of test statistics have been developed. The ldatuning package offers four metrics: Arun et al. (2010), Cao et al. (2009), Deveaud et al. (2014), and Griffiths and Steyvers (2004). From Fig. 13.2 we can surmise that the metrics of Cao et al. (2009) and Deveaud et al. (2014) find optimality in 13 topics, while the metrics of Arun et al. (2010), and Griffiths and Steyvers (2004) suggest 25 topics (the maximum number tested). Given that 25 topics seem excessive and the growth rate of both metrics also slows down after around 10 topics, we settle on 13 topics for the remainder of the analysis.

Figure 13.3 gives an overview of the probabilities of specific words per topic group. By analysing words with highest probability per topic, we can then assign underlying labels and compare these to the four manually identified topics from the qualitative thematic analysis. Under Theme 1 (Culture), we can categorize topics 1, 3 and 10. Topic 1 has a high word probability of museums, churches, the belfry tower and the various town squares, while topic 3 is linked to words on old architecture, beautiful buildings, the area around the town centre and history of the city. Quite

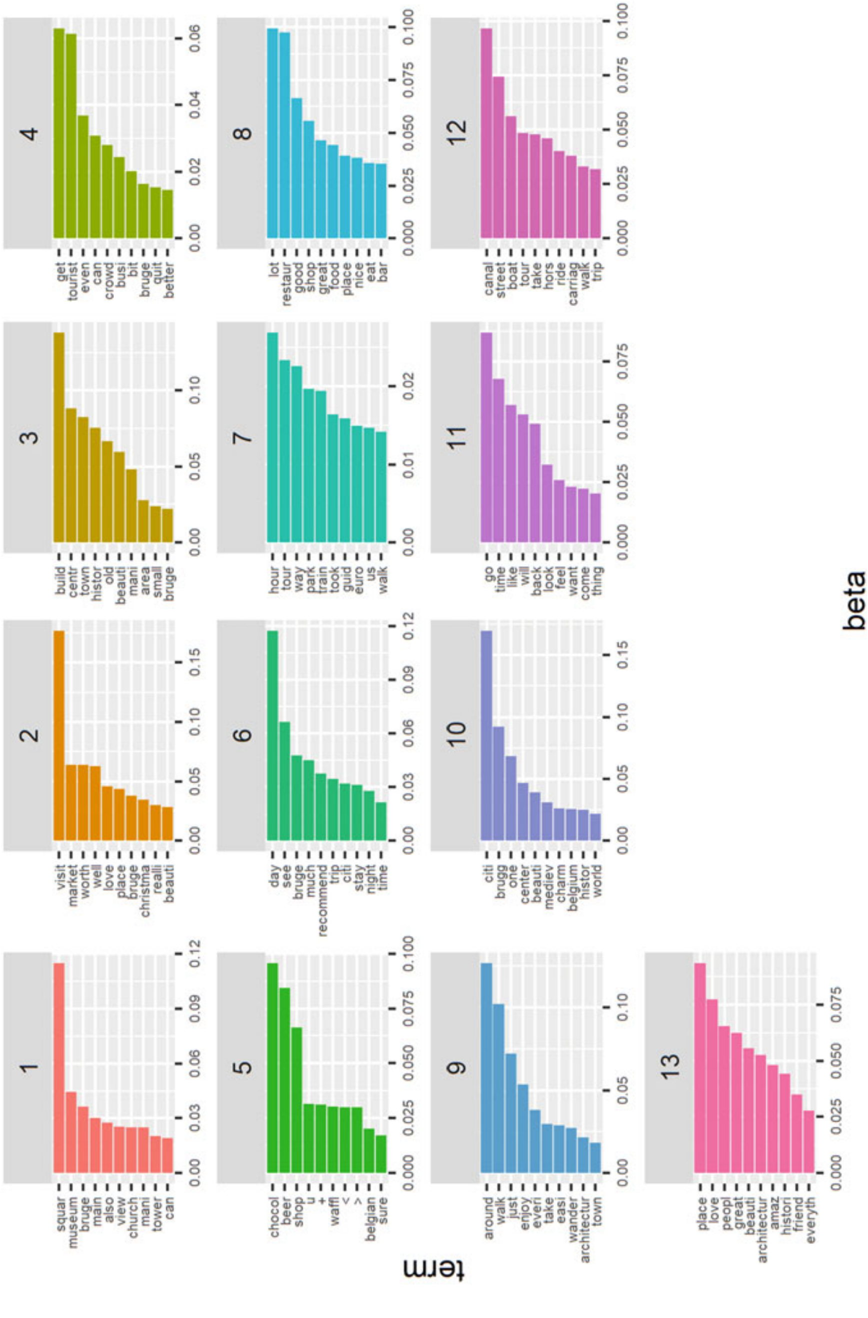

Fig. 13.3 Word probabilities for 13 topics

similarly, topic 10 includes words on medieval charm, history and the general beauty of the centre. Next, Theme 2 (Atmosphere and sightseeing) is represented in the LDA results by topic 2, with broader word categories relating to the atmosphere of the city, represented by statements such as "love", "beauty" and "worthwhile". Topic 9 is a direct representation of the walkability-code identified earlier, while topic 12 is identified by words on the canals and boat tours, as well as the carriage rides. Theme 3 (Consumerism/hedonism) is clearly reproduced in topics 5 and 8, with topic 5 mentioning shopping, chocolate (stores) and waffles, and topic 8 more broadly referring to restaurants, bars, food and eating in general. Theme 4 (Tourism system and trip) is represented by four topics. Topic 4 is of particular interest to the research since it is related to perceptions of crowding and a busy tourism atmosphere. Topic 6 is predominantly constructed through aspects of visitation time and type of trip (e.g. day visit or overnight stay), with topic 7 focusing on functional transportation aspects like parking availability and train connectivity. Topic 11 is less defined but has rather unique aspects related to destination loyalty and (potential of) return visits. Finally, the last topic identified through LDA (i.e. topic 13) crosses multiple themes, combining mentions of the friendliness of people, the beauty of the city and architecture and the history.

Furthermore, apart from calculating word probabilities per topic, LDA allows for the exploration of topic probability per review, with higher probability topics therefore indicating dominance of themes. Average probabilities per topic were, however, closely comparable, with the lowest probability of 0.0737 for topic 5 being almost equal to the highest probability of 0.0783 for topic 10. Since this analysis does not offer additional insights, we instead tried to identify the main topic per review in order to establish topical primacy. Table 13.5 gives an overview of topic counts, ordered according to the identified themes. We can surmise that, when comparing Table 13.5 with Table 13.4, on aggregate level the general dominance of culture and atmospheric aspects of the city over consumerism/hedonism is established, while also acknowledging that on an individual topical basis, topics related to the culinary experience score within the same order of magnitude as topics related to the city's cultural heritage. Notwithstanding, the relevance of the food-component seems underappreciated in the LDA results. An encouraging observation is the relative importance of topic 4—relating to the crowding of the tourist destination. With a frequency of 8.5%, the results are not that far off from the dictionary counts.

The first results from the LDA are promising in terms of topic identification, with thematic groups more or less overlapping with the qualitative themes we established manually. As such, the qualitative and unsupervised machine learning approach could be useful as complementary methods for identifying relevant dimensions within text documents. Furthermore, the word probability lists of the LDA might inform the creation of a corpus dictionary to assist the computational dictionary approach. The LDA results on their own seem less useful for establishing topic strength through frequencies, with limited difference in probabilities between the 13 topics and a general underrepresentation of topics, as seen in Table 13.5.

Table 13.5 Estimation of main topic frequency of reviews

Theme	Topic	Count	%
Culture		1730	26.3
	1	652	9.9
	3	578	8.8
	10	500	7.6
Atmosphere and sightseeing		1531	23.3
	2	630	9.6
	9	449	6.8
	12	452	6.9
Consumerism/hedonism		966	14.7
	5	417	6.3
	8	549	8.3
Tourism system and trip		1958	29.8
	4	560	8.5
	6	486	7.4
	7	498	7.6
	11	414	6.3
Miscellaneous		395	6.0
	13	395	6.0

Specifically focusing the discussion on the topic of tourism crowding, LDA could serve as a fast, automated way to identify whether crowding is a recognized concern in the first place. If none of the LDA topics would relate to aspects of overtourism, a more detailed, manual analysis might be unnecessary. However, if—as was the case for the Historic Centre of Bruges—a dedicated crowding-topic is detected, a more detailed qualitative and statistical analysis is required in order to investigate the strength of the perception, its underlying factors and its sentiment. All aspects cannot be readily determined from the LDA results.

13.5 Conclusion

Since the 2007 study on tourist crowding perception in Bruges (Neuts and Nijkamp 2012), tourism in the destination has increased by close to 70% in international arrivals. As crowding is still essentially a psychological interpretation of a given density level, one could expect that the strong tourism growth has fuelled perceptions of overtourism among visitors. Since a potential evolution in negative perceptions would be concerning for destination planners, methods have to be established for tracking public opinion.

This chapter proposed web scraping of tourist reviews and a subsequent computational text analysis as an alternative to traditional survey research for acquiring an understanding of the changes in the tourist experience. Starting from a dataset of 6580 TripAdvisor reviews, first a manual qualitative thematic analysis was undertaken on a random subset of 150 reviews, spread over three time periods: 2013–2015, 2016–2017 and 2018–2019. While the manual analysis was limited in size and scope, it served to identify common themes and gain a deeper understanding of visitor characteristics and experiences. Importantly for the further analysis, the vast majority of tourists seemed to be rather mainstream travellers for which the touristification of the historic centre—exemplified by a multitude of chocolate shops, restaurants and lace shops—was a positive, rather than a negative. This might be an indication that explorer-types who might be more susceptible to experience crowding are replaced by mass tourists in the mature destination of Bruges, with changing social crowding norms as a result.

Computational dictionary analysis complemented the qualitative thematic analysis and proved superior in terms of calculating frequencies and mapping evolutions, since the smaller sample size of the purely qualitative analysis caused inaccurate conclusions. Through the dictionary counts we could identify that crowding perception, while being a topical aspect in about 12% of reviews, had not changed significantly throughout the years. And even though the qualitative analysis suggested that crowding—when talked about in reviews—was often approached objectively and did not exhibit strong negative sentiments, the statistical relationship between crowding and review score was significant across the full sample. While limited in magnitude, this did suggest that, on average, reviewers who mention aspects of crowding or overtourism, assign slightly lower satisfaction scores to their experience. Furthermore, approaching the question from a different angle and starting from establishing two corpora—divided by satisfaction level—we could identify that the text corpus with reviews of dissatisfied visitors was more likely to include words on overcrowding.

Finally, the unsupervised LDA was tested as a complementary/alternative approach to identifying crowding-related subjects. From an unguided pattern analysis of the reviews, 13 topics were formed, one of which particularly characterized aspects of crowding. Furthermore, the other 12 topics showed significant overlap with the qualitatively identified themes and codes. As such, while unsupervised machine learning has limitations, particularly in terms of gaining deeper understanding on the meaning behind concepts and the sentiments expressed, LDA might help to develop a quick, automatic tracking system of visitor experiences and potential problem areas.

The analysis in this book chapter uncovers both opportunities and limitations of computational text analysis on online tourist reviews as a method to understand general visitor satisfaction and the perceptions of crowding at the destination. At the minimal, the method is low-cost, can be applied longitudinally, and has the advantage of capturing the sentiments of visitors in rich textual form, as opposed to the often pre-designed questionnaire scales. Therefore, the significant aspects of the tourist experience might be uncovered more fully and objectively. Particularly in terms of tracking the evolution of topics through time, the computational dictionary analysis can be a useful monitoring tool for destinations. On the other hand, there are important limitations in terms of sample representativeness, with the NLP algorithms in this case only covering English-speaking reviews. Furthermore, even though this problem is not limited to computational text analysis, the reviews might possibly be biased towards the extreme ends of the satisfaction scale, with moderately satisfied tourists less likely to post their experiences. Furthermore, if an interest lies in uncovering relationships between tourist characteristics, contextual effects, and the registered experience at the destination, user-generated tourism reviews are insufficient.

From a destination management point of view, the results of this study seem to suggest that the quality of the tourism experience in Bruges has not been decreasing throughout 2013–2019. Similar to the visitor surveys conducted by the Destination Management Organization (Visit Bruges 2019) and the earlier findings of Neuts and Nijkamp (2012), general satisfaction remains high, and crowding is generally observed as an objective state. Interestingly, from the qualitative analysis of the reviews, we could distinguish that tourists who objectively mentioned crowding did so in combination with advice on visitation pattern. In the majority of cases, it was stated that overtourism was related to day visitors, so the city could optimally be enjoyed from the early evening onwards, when excursionists are no longer present. It is not new knowledge for destinations that particularly excursionist and other day-type visitors (such as cruise tourists) are primary sources for overtourism, since their distribution in time and space is limited. Unfortunately, there are no simple solutions to limit the pressures of excursionists on historic cities.

Even though crowding did not appear to be a rising issue, it can be noted that—when specifically regarding negative reviews—crowding stood out as one of the main topics. It is therefore important to acknowledge that while overtourism might not be a concern for the average tourist, certain segments of the visitor markets do recognize the negative effects. It is important for the destination to not only focus on the general evolution of the crowding-topic (which has remained largely unchanged) but to also pay attention to potential changes in the tourism population in order to prevent a vicious circle of tourism development (Russo 2002), whereby crowding-sensitive market segments would be replaced by crowding-resistant typologies such as day tourists and cruise visitors.

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Chapter 14
Exploring User Behavior in Destination Websites: An Application of Web Mining Techniques

Maria Francesca Cracolici and Furio Urso

Abstract The development of the Internet has so strongly affected the way a tourist destination can be promoted that portals now play an important role in defining the marketing strategies of tourist destinations. Hence, investigating website surfing behavior has become crucial to understanding the needs of potential tourists. Using Web Mining techniques, our study explores the information-seeking behavior of those who log on to a website promoting the island of Sicily, a well known tourist destination in the South of Italy. The study explores whether a tourist's country of origin affects their information needs and surfing behavior. Actually, our results do show differences in behavior between users of the site from Western countries and those from China.

Keywords Tourist information search · Online browsing behavior · Web usage mining · Destination promotion · Big data

14.1 Introduction

In the network economy, the rapid development of the Internet is having an important role in the promotion and marketing of tourist destinations. For an information-intensive industry such as tourism, websites have become a huge information platform.

In recent decades there has been an increase in tourism promotion sites owned by Destination Management Organizations (DMOs) and the like. Online portals have rapidly become crucial for the marketing strategies of these organizations (Wang and Fesenmaier 2006) and are designed to act as the interface between potential visitors and the destination promoted, and to allow users to compare holiday packages (Kim et al. 2003).

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Websites promoting destination tourism (both official and unofficial) have to provide a systematic and overall picture of a destination, bearing in mind that a touristic service is complex and varied, covering various consumer goods such as transport, accommodation, recreational activities, touristic hubs, and other services. A tourism destination promotion portal should provide structured information that allows potential visitors to plan the holiday best suited to their needs, providing a single access point to the tourist destination rather than requiring visits to a number of different websites (Rita 2000).

Promotion by websites is different from the more traditional channels because the potential visitors are not known, but it is still possible to gather information about the characteristics of web users by extracting it from the server. Knowledge about the users of a website by country, information needs and surfing behavior inside a website is crucial to understanding the needs of potential tourists and consequently to creating effective online marketing strategies (Biswas and Krishan 2004; Dias and Vermunt 2007).

Despite the obvious importance of these websites to DMOs, analysis of user behavior has received little attention in tourism literature (Gretzel et al. 2006). Indeed, previous studies about the analysis of online behavior and information preferences have mainly dealt with the topic of e-commerce, rather than e-tourism and promotion sites and they mostly focused on comparative analysis (Rebón et al. 2015).

To analyze web users' information-seeking behavior we need to handle the huge amount of data which is generated as they explore the website. These big data can be managed by means of Web Usage Mining methods (WUM). These statistical techniques allow the most requested information to be identified, as well as how users reached it and how much time they spent on each page. Using this knowledge, site owners can enhance the most popular features with additional information, create new hypertext links where necessary and make the site structure easier to navigate.

In the light of these considerations, our study explores whether potential tourists differ as to their information preferences. The empirical analysis has been performed by taking Sicily, an internationally known Italian tourist destination, as a case in point. We use data from the website of PalermoTravel[1] which is an unofficial destination website promoting Sicily as a tourist destination. Using Web Mining techniques, we explore the behavior of its website users searching for information on immaterial tourism services (i.e. local attractions, experiences, seasonal events) and/or material tourist services (i.e. accommodation, transport, etc.).

Additionally, to explore regional differences in the needs of potential tourists, our analysis also takes into account the origin of users; hence we have discriminated between Italian, American, and European users. The browsing behavior of Chinese users was also analyzed in order to understand whether there are substantial differences between potential tourists from western countries and those from Asia.

[1] A pseudonym has been used, instead of using the real name of the company.

The chapter has been structured as follows: in Sect. 14.1 we will present how the web mining analysis of e-tourism portals can be used to obtain important information about the needs of potential tourists. Specifically, WUM techniques such as association analysis and Markov chains will be illustrated, as will a presentation of the dataset relating to the visits to the PalermoTravel website. In the second Section, we discuss the main results we obtained. Finally, in the last part some concluding remarks about user behavior will be made.

14.2 Web Usage Mining and Data

Web Usage Mining is the application process of Data Mining techniques used to discover hidden browsing patterns from Web Data. The goal is to determine profiles of users who are exploring the contents of a given website.

The Web Usage Mining process can be divided into three separate phases: the data collection and pre-processing phase, the pattern identification phase, and the pattern analysis phase. In the pre-processing phase the dataset containing the list of web objects requested by the users is cleaned up and the user sessions are identified. A session is the sequence of web pages that have been viewed by the same IP address in a defined short period of time and represents a user's activity on the website (Liu and Keselj 2007).

We can see in Table 14.1 a section of a Path Matrix, each row being a user session.

In the pattern identification phase, the data is processed in order to obtain the hidden patterns that reflect the behavior of the users, and indices are calculated that are representative of users, sessions, and site components. In the final phase, the patterns and statistics are further processed and aggregated to be used by Data Mining algorithms such as Association rules and the Markov chain (Cooley et al. 2000).

Table 14.1 Path matrix example

	V1	V2	V3	V4	V5	V6
1.0.153.1.0	Page 1					
1.1.176.1.0	Page 1	Page 5				
1.129.97.1.0	Page 1	Page 2	Page 3	Page 2	Page 4	
1.129.97.1.1	Page 1	Page 2	Page 6	Page 4		
1.132.105.1.0	Page 1					
1.132.110.1.0	Page 1	Page 6	Page 5	Page 4		
1.136.106.1.0	Page 1					

14.2.1 Association Rules

Association rules analysis is one of the most important Data Mining techniques as it enables us to find co-occurrence relationships among data items (Agrawal et al. 1993).

Let $I = \{i_1, i_2, \ldots, i_m\}$ be a set of items and $T = \{t_1, t_2, \ldots, t_n\}$ a set of transactions where t_i is a set of items such that $t_i \subseteq I$. An association rule is an implication of the form:

$$X \rightarrow Y, \text{where } X \subset I, Y \subset I \text{ and } X \cap Y = \varnothing \tag{14.1}$$

It is possible to measure the effectiveness of the rule by identifying whether its *Support* and *Confidence* values are greater than or equal to the user-specified minimum. The *Support* of a rule is the percentage of transactions in the set T that contains $X \cup Y$, and can be seen as an estimate of the probability $\Pr(X \cup Y)$. So, it is a measure of the rule reliability in the transaction set T. The *Confidence* of a rule is the percentage of transactions containing X that also contain Y. It can be seen as an estimate of the conditional probability $\Pr(Y|X)$ and determines the predictability of the rule. If the *Confidence* value of a rule is low, it is not possible to predict Y from X with sufficient reliability.

Another interesting index is the *Lift* which provides an estimate of the improvement in the predictive capacity of the rule. The *Lift* is calculated as the ratio between the conditional probability of an event given a sequence (the rule *Confidence*) and the probability of the event occurring in the absence of the sequence.

$$\text{Lift}(X \rightarrow Y) = \frac{\text{confidence}(X \rightarrow Y)}{P(Y)} \tag{14.2}$$

If the *Lift* value is above the unit, then visiting pages from other thematic areas increases the probability that the goal page will be displayed, whereas *Lift* values lower than one indicate that the display of the other thematic areas decreases this probability.

Association rules analysis in the context of Web Usage Mining enables us to identify which groups of objects or pages are purchased or visited at the same time and how often, providing a greater understanding of user preferences. This enables website managers to modify and organize content more efficiently and provide suggestions which take into account pages already selected by the user.

14.2.2 Markov Chain

A sequential patterns analysis is a useful tool to investigate the navigation path of users. Knowledge of such “routes” allows site owners to make visualization/nonvisualization predictions and to improve website structure. Among the methods employed to analyze user behavior is the Markov model.

A time homogeneous Markov chain of order k is a stochastic process X^n that, at each time n takes state s_n from a finite set of state S, with probability that is independent of time n and that depends only on the states attained in the previous k times. This process can be described by transition matrices P^k, where the generic element $P^k_{i,j}$ is the probability of transitioning from state i at time $n-k$ to state j at time n.

The Ching et al. (2013) variation of Raftery's model supposes that the weighted sum of the k previous transition probabilities is an approximation of state probabilities distribution X.

$$X^{n+k+1} = \sum_{i=1}^{k} \lambda_i Q_i X^{n+k+1-i} \tag{14.3}$$

$$Q_i = \left[P^i{}_{j,h}\right]_{m\times\ \mathrm{m}} = \begin{bmatrix} P^i_{1,1} & \cdots & P^i_{1,m} \\ \vdots & \ddots & \vdots \\ P^i_{1,m} & \cdots & P^i_{m,m} \end{bmatrix} \sum_{i=1}^{k} \lambda_i = 1, \lambda_i \geq 0\forall \mathrm{i}$$

with Q_i a $m \times m$ lag-specific transition probability matrix and λ_i the weight for each lag i in the model.

The Markov model, considering a sequence of possible events, allows the state of a given event to be predicted given the states of previous events. In the context of WUM, a state is a user's request for a site object (viewing a page) and the transition probabilities are the probabilities that the user requests that object knowing what objects he previously requested (Moe 2003).

14.2.3 Data

The above web mining techniques have been used to explore the behavior of users who log on to a destination website. The extracted data is related to visits to the website of a Sicilian tourism promotion company called PalermoTravel. It provides different hospitality services, such as the booking of luxury apartments, the booking of transfers, information on experiential tourism, and so on. The website is structured into thematic areas which can be divided into two macro areas.

The first macro area is "immaterial" tourism services which consists of three subsections: *Attraction* providing information on touristic hubs or general information on Sicily; *Experience* where additional activities can be booked; *Event* providing an overview of seasonal concerts, festivals or theatrical performances.

The second macro area is "material" tourism services which has two subsections: *Accommodation*, where users can view pages of bookable apartments and carry out thematic research by city, period, number of guests etc.; *Service,* which offers auxiliary services (e.g. taxi transfer service, bike rental, baby equipment rental).

In addition, the site provides general information on the company and its staff, on partners and access to bloggers and user reviews (i.e. the *Info* subsection).

Data were collected in 2017 for the months of September, October, November, and December. The dataset consists of 2,487,802 lines divided into 17 log fields. The web server log data is in *IIS-W3Cex Extended* format.

14.3 Results

The data were cleaned up, eliminating all the lines that did not concern the page views, and pre-processed. The dataset obtained consists of 95,201 lines by IP address and chronological order. Then we were able to extract 43,182 User Sessions, which allows us to follow the path of users within the site in the form of a sequence of pages viewed. We also chose not to consider the actual names of the pages viewed but only their thematic areas.

Table 14.2 reports descriptive statistics listing user accesses from Italy, the EU (except Italy; in the following we refer to it as EU users), the USA, and China.

The reported average values suggest that users accessing from Italy, EU, and the USA behave in a similar way, while those from China view a greater number of pages on average per session, spend less time on each page and also have shorter sessions.

Association rules analysis was applied to the "Area" variable referring to the thematic category of the displayed pages. We used the Paths Matrix of 43,182 user sessions. The analysis was carried out using the R "arules" package. The association rules have been obtained through an *apriori* function that allows the same algorithm to be implemented by entering in input a matrix of transactions (the sessions) and S*upport* and C*onfidence* threshold values (Agrawal and Srikant 1994). The algorithm is then implemented by selecting a 5% S*upport* threshold level and a 30% *Confidence* threshold level.

Tables 14.3 and 14.4 show association rules obtained from users who have logged on from Italy, EU, the USA, and China.

Table 14.2 Italy, EU, USA, China access

	Average page number	Average page duration (s)	Average session duration (s)
Italy	6.056	65.497	198.247
EU	5.570	64.529	175.436
USA	4.519	76.155	181.142
China	15.074	16.936	83.289

Table 14.3 Association rules for Italy access data

Rule	Support	Confidence	Lift
{Service} => {Accommodation}	0.05089323	0.5326087	1.0223199
{Info} => {Attraction}	0.06086415	0.4599686	0.8649566
{Info} => {Accommodation}	0.05068550	0.3830455	0.7352397
{Experience} => {Attraction}	0.08475280	0.4880383	0.9177407
{Experience} => {Accommodation}	0.11466556	0.6602871	1.2673931
{Attraction} => {Accommodation}	0.22642293	0.4257812	0.8172691
{Accommodation } => {Attraction}	0.22642293	0.4346093	0.8172691
{Homepage} => {Attraction}	0.29372663	0.5039202	0.9476061
{Homepage} => {Accommodation}	0.30930619	0.5306486	1.0185576
{Attraction, Experience} => {Accommodation}	0.06481097	0.7647059	1.4678206
{Accommodation, Experience} => {Attraction}	0.06481097	0.5652174	1.0628736
{Experience,Homepage} => {Attraction}	0.05670960	0.5083799	0.9559925
{Experience,Homepage} => {Accommodation}	0.08039053	0.7206704	1.3832964
{Attraction,Homepage} => {Accommodation}	0.14831741	0.5049505	0.9692311
{Accommodation,Homepage} => {Attraction}	0.14831741	0.4795165	0.9017157

Table 14.4 Association rules for EU access data

Rule	Support	Confidence	Lift
{Service} => {Attraction}	0.06324405	0.6390977	1.0565158
{Event} => {Accommodation}	0.07068452	0.5475504	1.3527717
{Event} => {Attraction}	0.05319940	0.4121037	0.6812638
{Experience} => {Accommodation}	0.06584821	0.5315315	1.3131955
{Experience} => {Attraction}	0.07068452	0.5705706	0.9432311
{Accommodation} => {Attraction}	0.20796131	0.5137868	0.8493597
{Attraction} => {Accommodation}	0.20796131	0.3437884	0.8493597
{Homepage} => {Accommodation}	0.22656250	0.3677536	0.9085678
{Homepage} => {Attraction}	0.38244048	0.6207729	1.0262224
{Accommodation, Homepage} => {Attraction}	0.13913690	0.6141215	1.0152267
{Attraction, Homepage} => {Accommodation}	0.13913690	0.3638132	0.8988327

On the left-hand side of the tables we can see the rules divided into *antecedent* and *consequent*. We notice there are just two *consequent* categories, *Attraction* and *Accommodation*, which are the most visited areas of the website. In the case of access from Italy, the EU, and the USA, we immediately notice in Table 3.2 how few rules have satisfied the thresholds established for S*upport* and *Confidence*. The rules referring to Italian access in Table 3.2 include many *Lift* values above 1 when *Accommodation* is *consequent* of the rule, for example, we have a *Lift* value of 1.467 and a *Confidence* value of 0.764 when the user has viewed *Attractions* and *Experiences*. It should be remembered that a high *Confidence* value means that assuming that *Attractions* and *Experiences* are visualized, in 76% of cases *Accommodation* was also displayed. With *Attraction* as the *consequent*, the only *Lift* value greater than 1 is related to the visualization of both the *Accommodation* and

Table 14.5 Association rules for USA access data

Rule	Support	Confidence	Lift
{Event} => {Accommodation}	0.05428954	0.4576271	1.1853814
{Event} => {Attraction}	0.07372654	0.6214689	0.9375446
{Info} => {Attraction}	0.09048257	0.6585366	0.9934647
{Service} => {Accommodation}	0.05093834	0.3877551	1.0043934
{Service} => {Attraction}	0.08981233	0.6836735	1.0313861
{Experience} => {Accommodation}	0.07640751	0.3562500	0.9227865
{Experience} => {Attraction}	0.13739946	0.6406250	0.9664434
{Homepage} => {Accommodation}	0.09517426	0.3776596	0.9782432
{Homepage} => {Attraction}	0.13873995	0.5505319	0.8305294
{Accommodation} => {Attraction}	0.20978552	0.5434028	0.8197745
{Attraction} => {Accommodation}	0.20978552	0.3164813	0.8197745
{Accommodation, Experience} => {Attraction}	0.05630027	0.7368421	1.1115960
{Attraction, Experience} => {Accommodation}	0.05630027	0.4097561	1.0613821
{Accommodation, Homepage} => {Attraction}	0.05227882	0.5492958	0.8286646
{Attraction, Homepage} => {Accommodation}	0.05227882	0.3768116	0.9760467

Experiences pages. In the case of access from another EU member country, we have two significant *Lift* values of 1.35 and 1.31 when *Accommodation* is the *consequent*, meaning that there is an increase in the probability of viewing *Accommodation* given that *Event* or *Experiences* has been viewed, and three *Lift* values greater than 1 with *Attraction* as the *consequent*, when the *antecedent* was either *Service* or *Homepage* or *Homepage* and *Accommodation*. As far as access from the USA is concerned we can see three *Lift* values greater than 1 with *Accommodation* as *consequent* when *Events*, *Services* and a combination of *Attraction* and *Experiences* have been viewed, and two *Lift* values greater than 1 with *Attraction* as *consequent* when *Service* and a combination of *Accommodation* and *Experiences* have been viewed. We chose not to display the rules related to Chinese accesses because, differently from previous cases, many rules (441 in total) satisfied the thresholds; and also all page combinations show *Lift* values greater than 1 (Table 14.5).

In general, it is noticeable that in the case of access from Italy, the EU, and the USA, visiting other areas just slightly increases the probability of visualizing the housing and touristic attractions, while in all three cases the visualization of the *Accommodation* pages decreases the probability of displaying the *Attraction* pages and vice versa.

Users from China tend to view any and all of the website areas, and the joint visualization greatly increases the probability of displaying a page in the *Accommodation* or *Attraction* category.

If we look at visits from western countries, it should be noted, however, that despite the minimum *Support* threshold of 5%, which may seem too generous, very few rules have met the requirements and rules related to users who have viewed more than three page categories are not listed because the percentages are too low.

Using Markov chains in this context enables us to follow the user movements in probabilistic terms. This analysis was conducted using the *FitMarkovChain* function of the "Clickstream" package.

Looking at the transition matrices for Italian accesses shown in Fig. 14.1, it is clear that users tend to remain in the same subject area.

For example, let us consider first order transition probabilities. A user viewing a page in the *Accommodation* category has a 78% chance of moving to another page in the same category. Similarly, a user on a page in the *Attraction* category has a 56% chance of remaining in the same category.

Other thematic areas have greater transition probabilities in the case of a passage within the same category, but to a lesser extent compared to the two previous categories (values between 27% and 52%).

When we increase the order of transition matrices, the situation remains almost the same but with slight decreases in probability in the main diagonal. At the sixth click, we note that, with the exception of the *Accommodation* and *Experiences* categories, the transition probabilities in the same category fall below 36% and users in the *Attraction* category also have a 36% probability of moving to an *Even*t page, close to the probability of remaining in the same category (42.6%).

Moving to EU and USA accesses (Figs. 14.2 and 14.3), we can see similar structures with high first order probabilities of remaining in the same category if it is *Accommodation*, *Attraction* or *Info* (probabilities greater than 50%). There is a 42% transition probability that a USA user will move from an *Event* to an *Attraction*. After six clicks we notice an increase in the probability of a move to the *Attraction* area, especially in the case of USA accesses where the transition probability values are between 23% and 57%.

As regards Chinese accesses, we notice in Fig. 14.4 high first order transition probabilities of remaining in the *Homepage* area (58%) and *Attraction* area (73%) and of moving from an event page to an attraction page (51%). The Six order transition probability matrix shows that there is a 66% probability of still being in the *Attraction* area when moving from a page in that area, and that after six clicks there is a 61% or higher probability that users will be in the *Attraction* area having come from either *Service*, *Event* or *Experiences*. Differently from other users, it seems that the Chinese do not stay in *Accommodation* very long but move to another area after one click.

Finally, we can see in Table 14.6 the session exit probabilities. Users from a western country are more likely to end their sessions either in an *Attraction* page or in an *Accommodation* page, with Americans preferring the former and Italians the latter. Chinese users tend to end their sessions in an *Attraction* area.

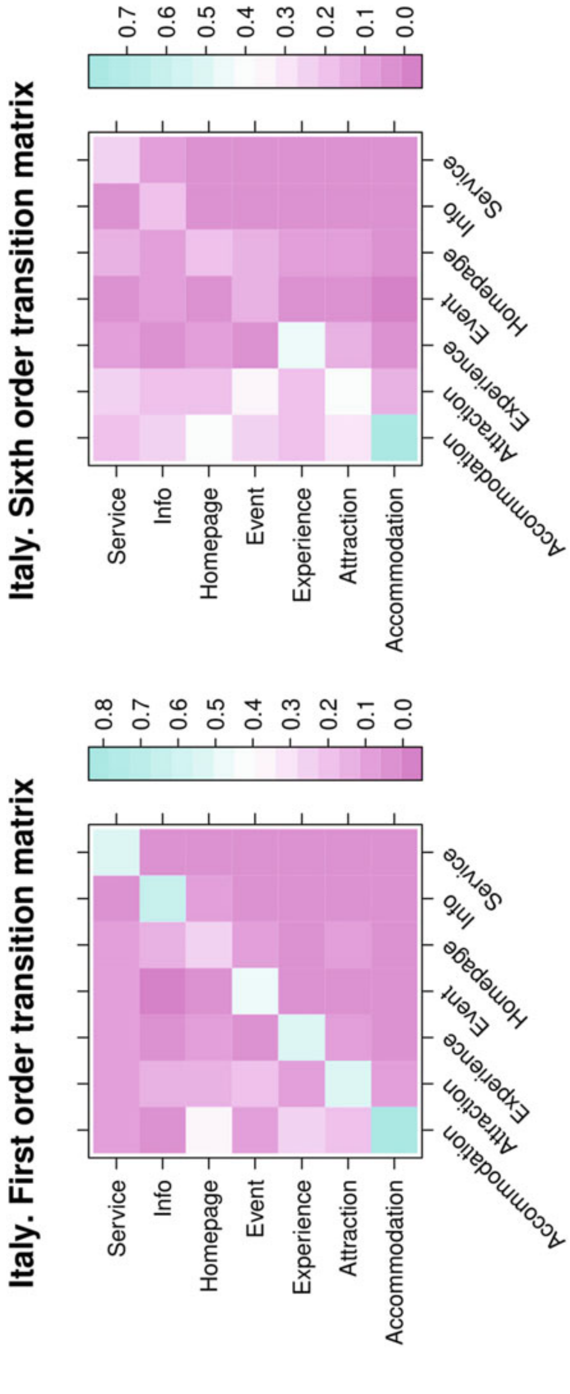

Fig. 14.1 Transition probability matrices, Italian accesses: order 1 and 6

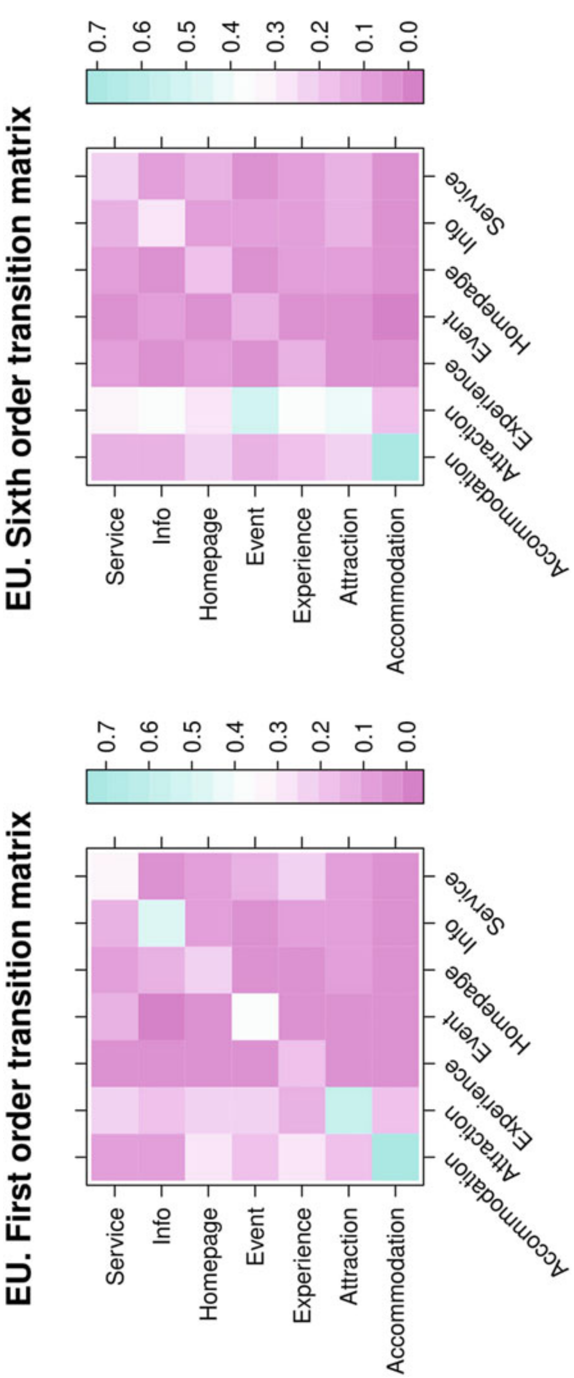

Fig. 14.2 Transition probability matrices, EU accesses: order 1 and 6

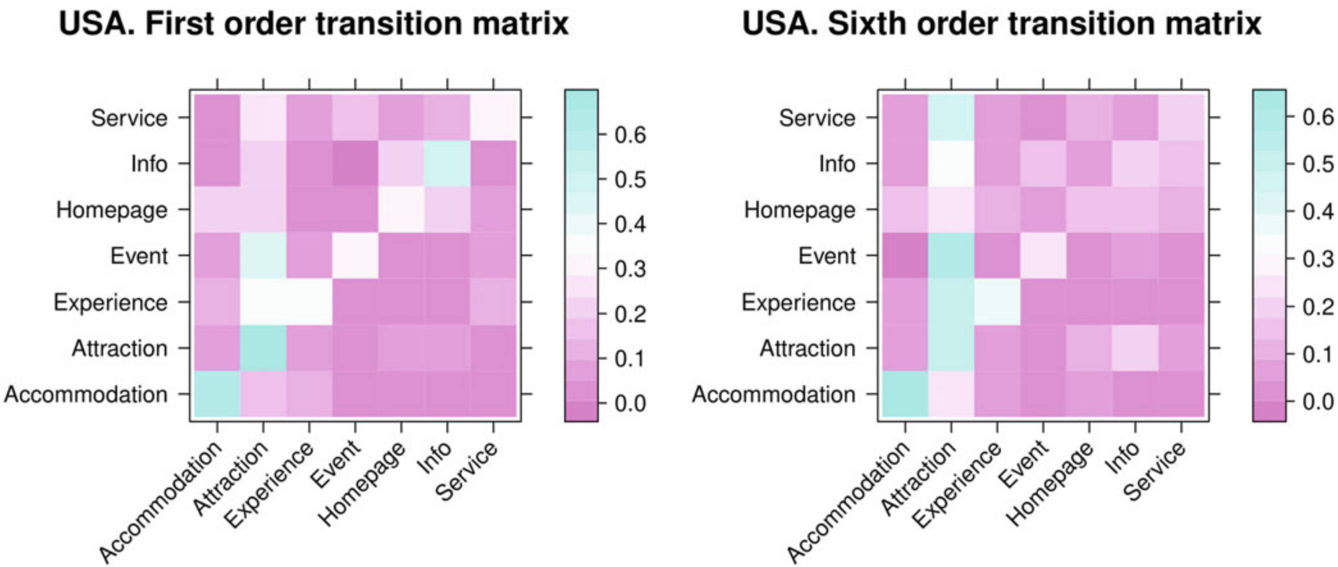

Fig. 14.3 Transition probability matrices, USA accesses: order 1 and 6

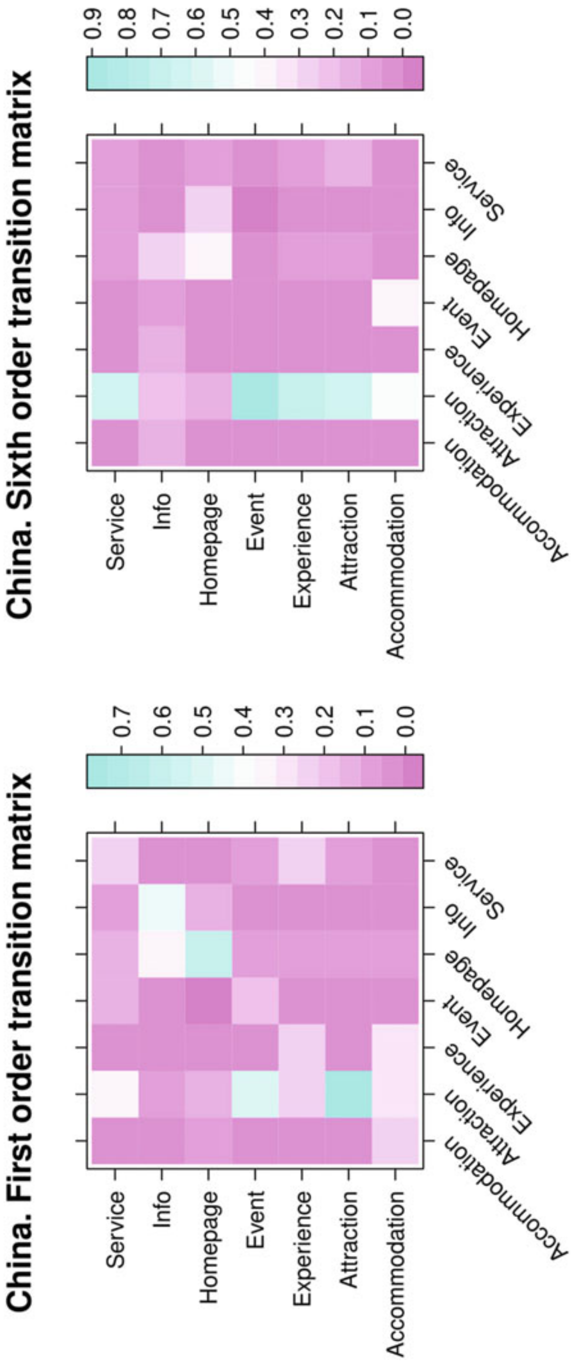

Fig. 14.4 Transition probability matrices, China accesses: order 1 and 6

Table 14.6 Exit probabilities for Italian, EU, USA, and China users

	Accommodation	Attraction	Experience	Event	Homepage	Info	Service
Italy	0.406	0.273	0.100	0.032	0.061	0.071	0.057
EU	0.327	0.367	0.039	0.059	0.076	0.076	0.056
USA	0.223	0.440	0.118	0.062	0.047	0.066	0.043
China	0.050	0.355	0.033	0.033	0.317	0.039	0.172

14.4 Concluding Remarks

The analysis we carried out has shown how WUM techniques can be used to identify the navigation patterns of users of a Sicilian tourist portal and to understand their information needs. The results obtained highlight profound differences in behavior between users who log on to the site from Western countries and those from China. The latter tend, on average, to view more pages per session, but both the time spent on each page and the total length of the session is considerably less than the time spent by other users.

Association rules analysis shows that western users tend to visit no more than three different thematic areas, and that the *Attraction* and *Accommodation* areas seem to be mutually exclusive, dividing users into those who are most interested in information about apartments from those looking for information about Sicilian cultural attractions. In contrast, Chinese users explore the site in its entirety by visiting each thematic area.

Using Markov chains we have observed that Italian users view pages in the same thematic area in sequence, showing a greater interest in the area relating to apartments, which is generally also the last area they visit, indicating that they are not interested in searching for any other kind of information. American users begin by viewing pages from either the *Attraction* or *Accommodation* areas, and after some movements they either remain in the *Accommodation* area or move from other areas to the *Attraction* area, in most cases concluding the session there. European users seem to be a mix of the two. Chinese users, on the other hand, show little interest in the *Accommodation* area and quickly move to the *Attraction* area where they conclude their session.

These results indicate important directions for further research. For instance, additional information on user behavior inside each area, like accommodation or attractions, should allow us to verify the assumption on the lack of homogeneity in search behavior in the set of the countries considered, and also to define potential visitor segments, which might also be better determined by merging information on user search and booking behavior.

In conclusion, when planning their holidays, users from different countries displayed different information needs. To be specific, the analysis reveals a sort of dependency between cultural distance and information preferences. Presumably, since Italians are already aware of the information on the region and its cultural heritage, they are more likely to explore pages on accommodation whereas users from other European countries view pages both on attractions and seasonal events and on accommodation. Americans, on the other hand, focus much more on pages of cultural interest, because Sicily is most likely unknown to many of them.

It is noteworthy that although the Chinese seem really interested in cultural heritage and naturalistic sites these results should be viewed with caution because they actually visit each area of the site at least once, as highlighted by the analysis of the association rules. In addition, the short sessions and the little time spent per page seem to indicate an erratic movement within the site, perhaps due to linguistic problems and therefore to a poor understanding of the information presented.

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Chapter 15
The Role of Visualisation in Spatial Planning: A GIS-Based Approach

Maria Giaoutzi and Chrysaida-Aliki Papadopoulou

Abstract Developments in Geographical Information Systems (GIS) have significantly empowered the role of visualisation in spatial planning. Visualisation mobilises 'visual thinking' contributing thus to the development of 'visual communication skills' through graphical representation, exploration and better understanding of spatial data and spatial relations. Furthermore, GIS support processing and analysis of spatial data as well as the investigation of spatial patterns and future visioning. In their capacity as integrated Spatial Decision Support Systems, GIS offer a critical comparative advantage to the formulation of robust decisions, concerning the future development of complex spatial systems, by enabling the visualisation of the involved elements and the efficient management of geo-referenced data. By refining the integration of Multiple Criteria Decision Analysis (MCDA) into GIS, further advancements can be achieved in spatial decision support processes. The present chapter focuses on the added value that visualisation may provide in spatial planning by integrating GIS technology into the planning process. Firstly, the concept of visualisation under the framework of GIS is analysed. Then, the potential of MCDA in visualisation for spatial analysis is illustrated and finally emphasis is placed on the role such developments may offer in participatory planning and scenario analysis.

Keywords Visualisation · Geo-visualisation · Spatial planning · GIS · MCDA · Scenario planning · Participatory planning

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15.1 Introduction

'A picture is worth a thousand words'. This famous and extensively used expression was born in the early twentieth century in the USA and has been attributed to Frederick Barnard. It is a variant of the Chinese proverb 'One picture is worth ten thousand words' and emphasises the force of optical means in conveying and communicating complex meanings and ideas. Its conceptual framework is based on the fact that sometimes graphical representations have the ability to transfer knowledge and thoughts more effectively than verbal expressions. Pictures are inherently linked to the mental capabilities of human perception and enhance consciousness through visioning. They constitute simple representations of reality while, in their more artistic form, they may also reflect thoughts and emotions.

The importance of visualisation for transferring knowledge and increasing awareness has been broadly acknowledged by a significant number of scientific disciplines and visualisation technologies were developed in order to serve several scientific purposes. Especially in the case of engineering and spatial planning, the visual representation of geographic reality, spatial entities and spatial relations is of utmost importance in order to deeply explore and understand the structure of complex physical systems and man-made environment. The term 'spatial planning' refers to a wide range of systematic activities designed to ensure that desired spatial goals are achieved in the future (Van den Brink et al. 2007). When it comes to the design and implementation of spatial interventions, visualisation/geo-visualisation is an inseparable component of the planning process and spatial decision making as it facilitates the investigation of existing problems, the elicitation of possible alternatives and the screening of their effects.

Before the advent of modern ICT, printed material such as maps, photographs, tabular data and graphs were used in order to better analyse the problem under study and seek for solutions. Nevertheless, such means offered limited capabilities for data elaboration and spatial analysis. Thus, in most cases they served as supplementary material that could simply support decision processes, however, missing the potential to 'produce' new and innovative information.

The evolvement of computer science and the advent of modern GIS technology inaugurated a new era for environmental and engineering sciences. They offered advanced visualisation and spatial analysis capabilities and contributed to the development of integrated Spatial Decision Support Systems (SDSSs) that enable storage and update of spatial data and information, data processing, structure of decision rules, argumentation mapping, production of decision maps and analysis of spatial patterns. Spatial planning takes advantage of all the above-mentioned competences and exploits visualisation technologies and GIS in order more robust, informative, efficient and concrete spatial decisions to be designed.

More specifically, the adoption of GIS and visualisation tools has been rapidly proliferated in cases where scenario analysis, participatory planning and GIS-based MCDA are performed, aiming at the future sustainable development of spatial systems and the efficient management of available resources. Mixed approaches such as participatory GIS-based MCDA and participatory scenario analysis have also capitalised on the comparative advantages that such technologies may bring to the planning process. The literature is replete of relevant applications exploiting the additive value of visualisation and spatial analysis under a spatial decision making framework. The majority of them concern the allocation of land uses, the assessment of site suitability for the establishment of activities, the protection of forest land and natural ecosystems, the improvement of transportation services, the allocation of landfills and waste management, the assessment of flood risks and the protection of coastal areas.

The starting point for the development of such applications was the evolvement of modern GIS software that integrate visualisation capabilities and algorithms supporting spatial analysis and management of spatial data (Goodchild 1992, 2004; Malczewski and Rinner 2015). Spatial analysis represents a distinguished characteristic of modern GIS technologies, underlining the key difference of GIS from software allowing simple map production (Maguire 1991; Goodchild 1988), and setting the ground for the detailed investigation of complexities and peculiarities characterising contemporary spatial systems. In this context, modern GIS represent integrated SDSSs assisting planners in producing 'new' knowledge that supports spatial decision making. GIS-produced dynamic and interactive maps are a vigorous visualisation tool in the hands of planners wishing to disseminate and better communicate the planning process (Lami et al. 2011; Xu and Coors 2012; Dunkel 2015; Fiorini et al. 2016; Wissen Hayek et al. 2016; Büttner et al. 2018).

The integration of MCDA methods with visualisation technologies and GIS can be met in various approaches and their implementation in spatial planning applications is found in a plethora of research articles, analysing their benefits and assessing their effectiveness. Most applications build on the potential that GIS bring into spatial decision making by offering the possibility for spatial analysis and production of decision maps (Goodchild et al. 1999; Malczewski 1999, 2006, 2010; Greene et al. 2010; Malczewski and Rinner 2015). This is the rationale upon which GIS-based MCDA was based and allowed for the representation and exploration of geo-referenced alternatives and criteria. The spatial variability of alternatives' scores and criteria weights has become more comprehensible and the specific framework of spatial MCDA has been scrutinised.

Participatory planning and stakeholder evaluation have also benefited from visualisation and GIS technology. Visualisation enhances visual thinking, comprehension ability and perception of the problem under study. GIS and web-GIS technology strengthen knowledge sharing, argumentation mapping, interactivity with dynamic maps and active participation in decision making processes. Participatory GIS/Public Participatory GIS (PGIS/PPGIS) technologies is a representative example of participatory initiatives promoting community planning and collaborative spatial decision aid (Hansen and Prosperi 2005; Ganapati 2011; Papadopoulou and Giaoutzi 2014; Brown and Fagerholm 2015; Wolf et al. 2015; Babelon et al. 2016).

Finally, the visualisation and assessment of scenarios by adopting GIS, photorealistic and 3D representations are is a very common practice, employed during scenario analysis and impact assessment. Scenarios are built in order to explore possible future conditions and propose likely policy packages. Visualisation means increase legibility, especially when spatial dimension is involved. Moreover, GIS-based MCDA supports scenario assessment by enabling the visualisation of impacts on a decision map. Relevant applications can be found in the works of Tress and Tress (2003), Sheppard and Meitner (2005), Sheppard et al. (2011), Kehl and de Haan (2013), Krolik-Root et al. (2015), etc.

This chapter reflects on the role that visualisation tools and technologies may play when addressing spatial problems in order to reach spatial decisions. The comparative advantages and additive value of such a potential are investigated under the framework of GIS technology. In this context, the concept of visualisation under the framework of spatial planning and GIS is explored; the potential of MCDA for visualisation in spatial analysis is presented; the role of visualisation and GIS-based MCDA in participatory planning and scenario analysis is delineated and finally a conclusive discussion is presented.

15.2 The Concept of Visualisation in the Context of Geographic Information Systems and Spatial Planning

The representation of geographical space, spatial phenomena and spatial relations requires the development of spatial models, supporting the visualisation of geographic reality. Through the potential that spatial models offer, geographic reality becomes more obvious and tangible. Visualisation mobilises the so-called visual thinking that enhances the intuitive approach of a research discipline. The scope of visualisation differs according to the purpose it serves; thus, it could vary from the artistic expression and visual communication of information to data visualisation for the development of interactive applications, etc. This explains the broad range of definitions for the term 'visualisation'.

Some indicative and popular definitions of 'visualisation', adopted by several disciplines, are:

- Visualisation is a tool that serves the comprehension/understanding of data acquired either through simulation processes or through physical measurements, by exploiting computer imaging technologies (Haber and McNabb 1990).
- Visualisation of information is the communication/transmission of abstract data through the exploitation of interactive visual interfaces (Keim et al. 2006).
- Visualisation of information exploits computer graphics and interaction in order to support problem solving (Purchase et al. 2008).
- Visualisation is a process through which patterns and relations among data become visible (Manovich 2011).
- Visualisation refers to representations of data after applying transformations, filters and visual encodings (Mclnerny et al. 2014).

- Visualisation concerns the representation and presentation of data to facilitate understanding (Kirk 2016).
- Visualisation supports data representation in order to be easily tangible by the viewer without the need for additional statistical details (Shen et al. 2019).

It is obvious that the majority of definitions place emphasis on data representation through the exploitation of interactive means in order to communicate information and make it more comprehensible. This is the primary scope of visualisation methods and a common element of all frequently used definitions. Among the available techniques supporting visualisation purposes are (Keim et al. 2005):

- *2D Visualisation*: Data are defined in 2 dimensions and represented in the Euclidian plane. Visualisation is based on geometric axioms and relations such as the distance among objects. In the case of spatial data, coordinates and spatial relations are taken into consideration.
- *3D Visualisation*: Data are defined in 3 dimensions. Except for the Euclidean space, the third dimension (height, depth, etc.) is exploited so that 3D representations to be produced.
- *Geometrically transformed display*: In this case, multi-dimensional transformations for data sets of specific interest are explored. Statistical techniques and geometrical representations of k-dimensional spaces in 2D space are exploited.
- *Stacked display*: It is used for the representation of hierarchically arranged data. In case of multi-dimensional data, the dimensions of data are used for data classification and structure of the hierarchy.

In the context of Geographic Information Science (GIScience) and spatial planning, visualisation concerns the representation of spatial data/information and aims at their processing, the implementation of spatial analysis procedures and the production of maps. According to the definition given by ESRI (2020), visualisation is the representation of data through a viewable medium or format. Its ultimate goal is the organisation of spatial data and information in a number of layers that can be analysed or represented as maps, 3D representations, charts, tables, etc. Buttenfield and Mackaness (1991) define visualisation as an important element for the comprehension, analysis or interpretation of the distribution of several phenomena on earth's surface, while the level of importance is increased with the accumulation of spatial data and the need for their effective management. Processes like spatial data modelling, analysis of trends and patterns, elicitation of conclusions and Decision Support Systems (DSSs) exploit the advantages of visualisation towards the production of 'new' knowledge and information (Buttenfield and Mackaness 1991). Data analysis, exploration and validation of geographical information enhance 'visual thinking' while visual communication is attained through synthesis and production of 'new' geographical information.

At this point it should be mentioned that the visualisation of spatial data and information is usually referred to as 'geo-visualisation'. Geo-visualisation belongs to the variety of communicative methods that exist to support social learning. Geo-visualisations are two-dimensional or three-dimensional visual representations of data having a geographic reference. They can be used to exchange spatial information in spatial planning processes (Van den Brink et al. 2007). Generally, the term 'geo-visualisation' concerns a set of methods, techniques and practices aiming at the visualisation of data, information and phenomena related to the earth's surface and geographical space (geo-referenced data and information). Geo-visualisation exploits graphics for analysing data, the location of which is used as a necessary and essential part of the analysis while it may be perceived as the intersection of cartography and scientific visualisation through computer graphics (Unwin 2008). More definitions about geo-visualisation are:

- Geo-visualisation is a scientific tool focusing on the visual investigation, analysis, synthesis and representation of geographical data and information by combining different approaches derived from GIScience, cartography and image analysis (Dykes et al. 2005).
- Geo-visualisation aims at the exploration, analysis, synthesis and representation of geo-referenced data and information (Nöllenburg 2007).
- Geo-visualisation constitutes an abbreviation of geographical visualisation referring to a set of tools and techniques that support geo-spatial communication and processing, and information analysis through the exploitation of interactive maps (Jobst et al. 2010).
- Geo-visualisation supports the representation of real or simulated 2D or 3D geographical information by enabling interaction and exploiting the experience of users (Diehl and Delrieux 2012).
- Geo-visualisation supports representation of spatial data by using more sophisticated formats like maps, info-graphics, 3D globes, pie and fever charts, etc. (Harbola and Coors 2018).

Geo-visualisation is usually categorised into *static geo-visualisation* and *dynamic geo-visualisation*. Static geo-visualisation is used to represent geographical space and phenomena with the support of 2D maps, charts, etc.; dynamic geo-visualisation, on the other hand, involves the time dimension and enables the dynamic representation of geographical reality and processes by exploiting computer graphics, 2D and 3D animations, interactive maps, virtual reality, etc. (Fabrikant and Goldsberry 2005).

Some indicative geo-visualisation techniques are (Nöllenburg 2007):

- *2D Geo-visualisation*: It constitutes the most frequent method supporting the visualisation of spatial data and is commonly referred to as '2D cartographic visualisation'. The area of interest is depicted on a map. The representation of the several map components is based on their coordinates and on available statistical or classified data (e.g. choropleth maps).
- *3D Geo-visualisation*: The evolvement of graphics technology enabled the production of 3D realistic images and 3D virtual environments. In spite of the simple 3D representations, it is now possible to create Cave Automatic Virtual Environments (CAVEs) and Power Walls, allowing for a stereoscopic vision of the

several phenomena. 3D representations approach better the human perception of space while the third dimension may represent height, depth, time, etc.

- *Visual data mining tools*: This method supports visual analysis of data and the enrichment of existing knowledge stock through the production of 'new' knowledge. It allows for the representation of multi-variable data (spatial and non-spatial attributes) in order relations and patterns to be easily understood by the user. Such kind of representations may be geometric visualisations, pixel-based visualisations, graph-based visualisations, etc.
- *Animation*: It is a dynamic geo-visualisation technique that incorporates the dimension of time as a third dimension in the relevant representations. In this case, the temporal change of the represented elements becomes visible.
- *Spatio-temporal visualisation*: It supports the visualisation of temporal evolution of spatial properties, thematic properties, etc. (e.g. population changes, climate change). The two dimensions represent geographical space and the third one represents the dimension of time.

Visualisation/Geo-visualisation constitutes one of the key features of Geographical Information Systems (GIS). The original development of GIS was based on the fundamental concepts of visualisation, processing, analysis and interpretation of spatial data and spatial information. Nowadays they have evolved into integrated SDSSs with the main advantage of allowing for the simultaneous management of spatial and attribute (non-spatial) data. Moreover, they support the connection of such attribute data with the respective spatial entities.

GIS build on the principles of GIScience which focuses on the exploration of the nature of geographical information and geographical phenomena and constitutes the theoretical background of GIS and technologies serving the visualisation and management of geographical data and information (Goodchild 1992, 2004; Malczewski and Rinner 2015). Consequently, a Geographical Information System enables collection, storage, communication, management, analysis, indexing and representation/visualisation of spatial data and geo-referenced information aiming at the production of information/'new' knowledge and the support of decision making processes (Goodchild et al. 1999; Malczewski and Rinner 2015). Emphasis is placed on addressing/performing spatial analysis (Maguire 1991); that in many cases determines a GIS and differentiates it from systems that simply produce maps (Goodchild 1988).

GIS support the visualisation of the shape, size, position and orientation of spatial entities. This is achieved through the exploitation of two basic spatial models: the *field-based model*, representing continuous phenomena (e.g. temperature), and the *object-based model*, representing geographical space through distinct spatial entities (e.g. buildings). The field-based model is implemented by the raster data structure (canvas), while the object-based model is implemented by the vector data structure (lines, points, polygons or complex geometries).

Particularly in the case of spatial planning, geo-visualisation supports the exploration and analysis of interventions aiming at meeting future 'spatial goals'. These planning processes deal with complex planning issues involving multiple urban functions that compete for land, such as housing, employment and infrastructure (Van den Brink et al. 2007). Accordingly, geo-visualisation allows for the investigation of possible problems, the definition of relevant goals and objectives, the exploration of current situation and future trends, the analysis of future scenarios and their evaluation, as well as the definition of future policy options. A significant number of visualisations, like maps, satellite images, charts, tables, pies, etc., put an additive value to the whole spatial planning process by enabling the visual representation of all elements involved in the planning process. Moreover, visual means facilitate collaborative decision making, management of trade-offs and elimination of possible conflicts by making data and information more comprehensible, perceivable and tangible.

Andrienko et al. (2007) introduced the concept of *'Geo-Visual Analytics for Spatial Decision Support'* in order to determine an interdisciplinary scientific area, focusing on the development of computational methods, techniques and tools that deal with spatial problems through reinforcing human capabilities to analyse, envision, reason and deliberate. The complex structure of modern GIS and the multiple factors, criteria and knowledge involved in spatial decisions constitute the main characteristics differentiating 'Geo-Visual Analytics for Spatial Decision Support' from the general discipline of 'Visual Analytics'.

Geo-information technologies, embodying several bottom-up processes (e.g. PGIS, PPGIS), enhance also participatory planning (McCall and Dunn 2012). Such technologies offer the possibility for the development of applications enabling the implementation of (online) discussions onto map backgrounds or other visualisation means, the formulation of comments and suggestions, the design of sketches and symbols on maps, etc. The development of PGIS/PPGIS technologies has been strengthened by the evolvement of web-GIS and web-mapping technologies. Among the advantages of such technologies are the possibility for broad and asynchronous public participation, the extensive dissemination of spatial decisions and the better understanding of spatial problems.

In the literature, there is a significant number of indicative examples where visualisation applications have been used for supporting spatial planning and spatial decisions. In the region of Ruhr (Germany) dynamic maps were built in order to represent/visualise territorial transformations related to the possible implementation of three alternative scenarios for improving the rail line; Analytic Network Process (ANP) was combined with geo-visualisation tools in order results of the ANP (subnets and scenarios) to be shown and support users to better understand the parameters and effects of each scenario (Lami et al. 2011). For a better management of issues related to Maritime Spatial Planning (MSP) (e.g. management of traffic volumes, reduction of ship emissions, etc.) and the spatio-temporal distribution of human activities in marine areas, worldwide route density maps were created by exploiting Automatic Identification System (AIS) records, providing vessel positions, in order to process ship routes (Fiorini et al. 2016). In the Canton of Zurich, Switzerland, a web-based visualisation platform, incorporating ecosystem services indicators, was developed in order to support municipal authorities to identify watercourse corridors based on the revised Swiss Waters Protection Act (Wissen Hayek et al. 2016).

Other indicative examples originate from: Carsjens and Ligtenberg (2007), dealing with the STEPP tool that allows for the assessment of land use environmental impacts and the design of new spatial arrangements through the analysis of human activities, on the basis of land use data, and the visualisation of relevant environmental impacts in order zones of influence to be identified and 'environmental impact' and 'environmental quality' maps to be produced; Xu and Coors (2012), addressing the assessment of urban residential development through the exploration of trends of sustainability indicators and the visualisation of results in 2D density maps (ArcGIS) and 3D representations (CityEngine); Dunkel (2015), focusing on the contribution of crowdsourced data (photos) from Flickr to the visualisation of landscape perception and evaluation of scenarios supporting the development of landscape and urban planning; Büttner et al. (2018), presenting the development of the Technical University of Munich (TUM) accessibility Atlas for the metropolitan region of Munich in order to explore accessibility issues (e.g. accessibility by the public and private transport, future trends in mobility costs, etc.) as part of the integrated land use and transport planning of the area, through the adoption of a GIS toolbox supporting map production and visualisation of spatial and socioeconomic disparities; Bouattou et al. (2018), dealing with the issue of producing real-time visual summaries of spatio-temporal patterns through the adoption of a multi-agent system approach; Ma et al. (2020), concerning the development of a virtual reality tool that enables the visualisation of spatial systems dynamics and supports the management of urban infrastructure ecosystem.

In the above context, visualisation supports a variety of spatial procedures by enabling the integration of multiple factors affecting spatial planning, facilitating the assessment of alternative future scenarios, enhancing participatory initiatives, reinforcing the analysis of geo-referenced data and strengthening visual thinking and reasoning. In the following sections, such issues are analytically presented in an attempt to deeply investigate the added value that visualisation may bring into GIS-based MCDA, scenario analysis and participatory planning.

15.3 The Potential of MCDA in Visualisation for Spatial Planning

The adoption of interdisciplinary approaches for managing spatial problems is a very popular practice supporting the integration of methods, techniques and tools in the spatial planning process. Towards this end, the integration of MCDA with GIS and the resulting geo-visualisation capabilities have determined a new 'era' in the field of spatial decision making and the development of SDSSs. The outcome of all the steps of a MCDA process namely definition of alternatives, criteria and weights may be visualised and analysed with the support of GIS technology, where the spatial dimension of the several components involved in a MCDA process can be considered.

GIS-based MCDA is defined as a process that: a) allows the transformation of geographical data and their combination with assessments and b) supports decision making through the generation of robust and integrated knowledge (Malczewski 2006, 2010). Moreover, the integration of MCDA methods in GIS tools and software may support participatory evaluation, enabling convergence of possible conflicts, comprehension of spatial interactions and communication among the participants involved in a decision making process. Ideally, an integrated MCDA-GIS system combines the advantages of multi-criteria assessment and spatial analysis. The user has the possibility to interact with the system, explore the consequences of several alternatives and produce decision maps by overlaying layers that represent evaluation criteria.

Spatial decision support focuses on the management of problems with particular characteristics. The final decision on the most suitable solution is based on two main questions: (1) *what* should be done? (Action) and (2) *where* it should be implemented (Location)? (Malczewski 1999; Chakhar and Mousseau 2008; Malczewski and Rinner 2015). The first question refers to the decision making process per se, while the second concerns the 'receptor' of the final decision, namely, the most suitable location for the development of a specific activity. Accordingly, in the cases where GIS-based MCDA is applied, emphasis is placed on the spatial variability of alternatives' scores and criteria weights. Thus, parameters of spatial homogeneity and heterogeneity are taken into consideration when defining and standardising criteria weights.

The most popular MCDA methods, incorporated in GIS software include the Weighted Sum Method, the TOPSIS method, the Analytic Hierarchical Hierarchy Process (AHP), the Analytic Network Process and a number of hierarchical methods (Malczewski and Rinner 2015). Indicative GIS software/routines, employing GIS-based MCDA methods are: the IDRISI (Multi-criteria Evaluation Model) package, the ArcGIS Overlay Toolset and the MCDA4ArcMap. Such computational tools allow for the management and spatial analysis of either vector or raster data by exploiting map algebra and MCDA algorithms (Rinner and Voss 2013; Malczewski and Rinner 2015).

In general, MCDA involves assessments regarding the performance of alternatives with respect to a number of evaluation criteria and judgments concerning the importance of criteria (criteria weights) with respect to the main goal of the problem (Nijkamp and van Delft 1977; Roy and Vincke 1981; Nijkamp et al. 1990; Beinat and Nijkamp 1998; Montibeller and Franco 2010; Cinelli et al. 2014; Roy 2016). Spatial analysis focuses on the profound exploration of spatial relations, the examination of spatial attributes and the assessment of several spatial procedures through the exploitation of spatial methods, spatial models and algorithms (Rogerson and Fotheringham 1994; Goodchild and Longley 1999; Longley and Batty 2003; Steinberg and Steinberg 2015).

Under a GIS context, spatial analysis and visualisation are inseparable. Visualisation allows for the visual representation of spatial analysis procedures such as data processing, investigation of spatial correlations, analysis of spatial relations and spatial patterns, production and mapping of innovative spatial information. Moreover, visualisation supports the elaboration of various types of data such as text content, statistical and tabular data and topographic/geodetic data on map backgrounds, establishing an integrated framework for a robust analysis of the problem under study, the consideration of all parameters involved and the generation of novel outcomes.

MCDA, on the other hand, provides a comparative advantage on spatial analysis, as it sets the ground for the assessment of geo-referenced alternatives on the basis of geo-referenced evaluation criteria. This comes through the visualisation potential that modern visualisation tools and technologies offer. The visual representation of alternatives and criteria and the execution of MCDA algorithms—implementing relevant MCDA methods—on a map background contribute to a better formulation of spatial decision problems, the deep comprehension of the components involved in a MCDA process, the enhancement of visual thinking during the spatial decision making processes, the elicitation of more realistic conclusions and the design of effective interventions.

GIS-based MCDA comprises a number of distinct steps through which a spatial problem is analysed and possible alternatives are assessed. Such steps include (Fig. 15.1): (a) the explicit definition of the problem under study, (b) the de-composition of the problem into several sub-models in order to reduce complexity, (c) the determination of evaluation criteria and their transformation into map layers, (d) the reclassification of values referring to different numbering systems in order layers to be comparable (standardisation), (e) the assignment of weights to the relevant criteria-layers, (f) the aggregation of all map layers and the production of a decision map and g) the analysis of outcomes.

The implementation of the aforementioned procedure allows for the visualisation and experimentation with geo-referenced alternatives and criteria, the contemporaneous analysis of both spatial and non-spatial data, the production of new visualised information, the visual interaction of all elements and dimensions of the problem under study and the visual representation and interpretation of the respective results. The spatial variability of all involved factors is considered and figured out with the support of relevant map backgrounds and spatial models. In this context, the specific characteristics of each location are considered.

Common applications of GIS-based MCDA include evaluation of site suitability, assessment of land use changes, appraisal of natural disasters, risk assessment, allocation of several activities, etc. Evaluation criteria, represented as map layers, incorporate concepts like ‘accessibility’ to transportation networks, ‘proximity’ to areas of interest (e.g. urban centres, markets), ‘distance’ from hydrographical network or protected areas, slope suitability, etc. Possible alternatives are included in such layers. The visualisation of all necessary data and information offers the potential for screening feasible alternatives by eliminating those which are totally unsuitable, inspecting one by one the evaluation criteria, making suggestions as to their importance and getting familiarised with the particular characteristics of the study area.

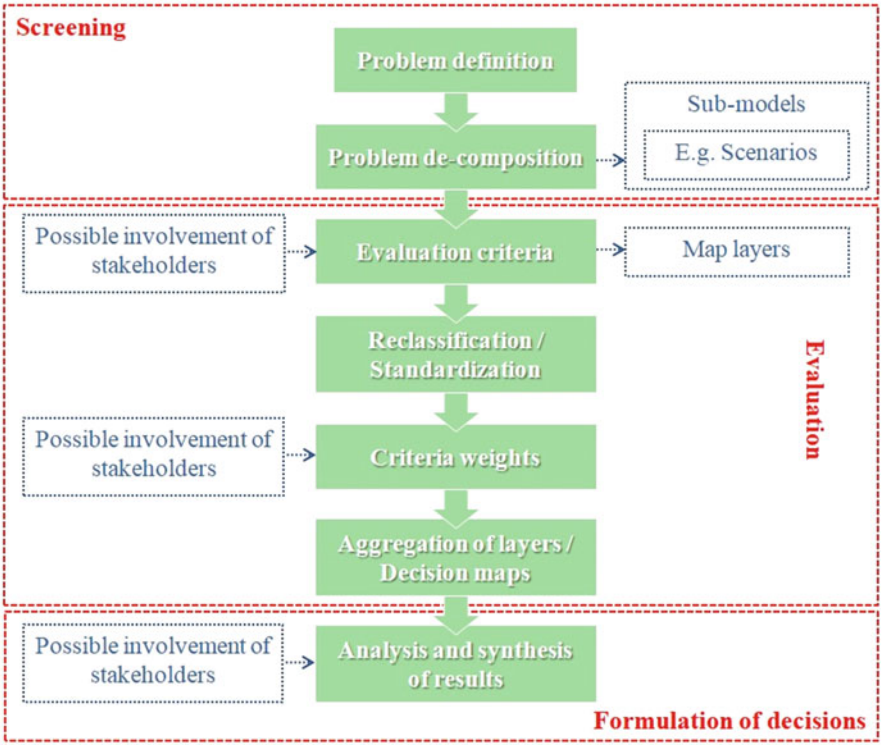

Fig. 15.1 GIS-based MCDA process (adapted from ESRI 2020)

The literature reports on a significant number of GIS-based MCDA applications referring to various spatial decision problems where the visualisation of MCDA components and the analysis of spatial entities are of utmost importance for the robust output of spatial decision processes. De Feo and De Gisi (2014) implemented a GIS-based MCDA for selecting the most suitable location for the establishment of a landfill; a land use map enabled the visualisation of possible locations and the initial exclusion of unsuitable areas. Meng et al. (2011) employed GIS-based AHP and 'Ordered Weighted Averaging' (OWA) for mapping accessibility patterns of housing development sites in Alberta. Papadopoulou and Hatzichristos (2019) applied Weighted Sum and Fuzzy Overlay Analysis in order to explore the most suitable location for the establishment of an agro-tourist infrastructure in Crete, Greece.

Other indicative examples include: the investigation of suitable sites for the location of a landfill in the urban area of Pondicherry (India) through the implementation of MCDA and overlay analysis in GIS where visualisation capabilities and spatial analysis allowed for the elimination of environmentally unsuitable areas (initial screening) and the assessment of possible suitable sites on the basis of a number of criteria, represented as map layers (Sumathi et al. 2008); the selection of the most appropriate site for industrial development in Vojvodina (Serbia) through site screening and site evaluation supported by GIS-based AHP and Weighted Linear Combination (Rikalovic et al. 2014); the exploitation of a GIS-based MCDA approach, involving fuzzy AHP and TOPSIS, for the development of a refugee camp in south-eastern Turkey (Çetinkaya et al. 2016); the production of landslide susceptibility maps by adopting GIS-based MCDA methods and their combination with logistic regression analysis and association rule mining in order to assess risks related to landslide hazards (Erener et al. 2016); the identification of proper areas for the establishment of healthcare facilities by employing GIS-based MCDA in order suitability maps to be produced (Dell'Ovo et al. 2018).

The successful implementation of such applications depends on both, the adoption of an appropriate MCDA method and the use of visualisation means and technologies in support of spatial analysis. Evaluation criteria are visualised and represented as thematic maps; constraint maps, enabling the identification of unsuitable areas, are created; screening of possible alternatives is carried out, and decision maps are generated through the aggregation of the relevant layers. This is the common place of all applications utilising MCDA in combination with GIS technology and targeting at addressing spatial decision problems.

15.4 The Role of Visualisation and GIS-Based MCDA in Participatory Planning

Participatory planning implies the engagement of stakeholders in decision making processes and constitutes a significant tool supporting the elicitation of valuable knowledge and expertise. In the case of spatial planning, the involvement of stakeholders and the exchange of information greatly influence the degree of mutual understanding, consensus and support for proposed changes.

According to Van Asselt and Rijkens-Klomp (2002), participatory planning allows participants to get involved in processes concerning the design of initiatives and decisions that are going to affect them. In this context, participatory planning is directly connected to the involvement of interested parties (e.g. citizens) in plan-making and problem solving procedures (Dietz 1995; Innes 1996) while it is strongly related to the concept of democracy (Woltjer 2002). Participatory planning contributes to the improvement of management decisions as it builds on the concepts of 'collaboration' and 'co-creation' and sets the ground for the undertaking of broadly accepted solutions (Kovács et al. 2017).

The role and influence of stakeholders in such processes vary according to the level of participation that is practised. The levels of participation differ, ranging from the 'simple provision of information' up to 'citizen control' (highest level of participation) (Arnstein 1969). In its highest level, participatory planning takes the form of 'co-design' and 'co-decide' as participants are invited to actively 'co-shape' their future by reporting existing problems, expressing their preferences, specifying their needs and discussing possible future perspectives. Thus, participatory planning represents a learning and retroactive process that feeds decision making with new and innovative knowledge which in turn, leads to the design of informative and robust decisions (Dalal-Clayton and Dent 1993; Rowe and Frewer 2000).

In recent times the shift from 'top-down' to 'bottom-up' approaches has gradually evolved and participatory initiatives have been dynamically incorporated in spatial decision making. The rationale behind such an approach is that spatial decisions affect people's daily life and standards of living as they set the ground for the development of several productive sectors. Moreover, people/citizens may offer into the planning process additive knowledge related to the specific characteristics, comparative advantages and peculiarities of 'their' own city/neighbourhood. As a result, participatory planning has evolved into a critical dimension of spatial planning, supporting among others the efficient management of environmental resources, social relations and economic assets.

The exponential proliferation of visualisation/geo-visualisation tools, GIS technology and GIS-based MCDA routines has empowered participatory planning initiatives as they enable the visualisation of parameters and variables involved in a study problem, the illustration of the area of interest on map backgrounds and the graphical representation of alternative solutions and evaluation criteria upon which decisions are based. The exploitation of such technologies allows participants to better understand the study problem through visual thinking and visual communication skills (Fig. 15.2). However, visualisation practices should satisfy certain prerequisites in order to be appropriate for public participation purposes (Warren-Kretzschmar and Von Haaren 2014), namely orientation capabilities, spatial understanding, ability to consider landscape changes and credibility (Warren-Kretzschmar 2011). Participants on the other hand should enhance their digital skills in order to be able to interact with the relevant technologies. 'Maps and graphics are active instruments in the end-users' "thinking process" and help them comprehend the study problem and its spatial dimensions' (MacEachren and Kraak 2001, p. 3).

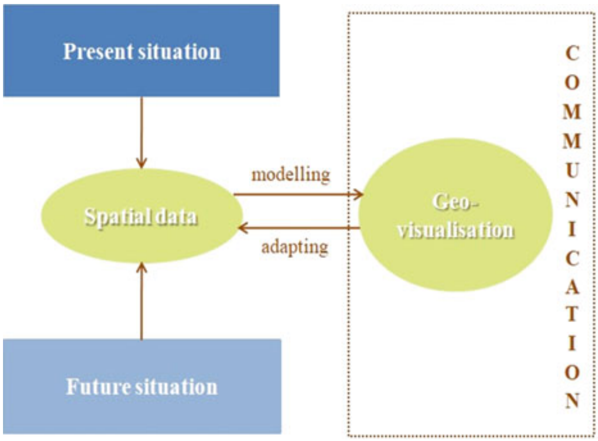

Fig. 15.2 Geo-visualisation and communication of spatial data (adapted from Van den Brink et al. 2007)

Among the most commonly used visualisation technologies in participatory spatial planning are PGIS and PPGIS. PGIS/PPGIS are applications that include published maps and real/dynamic GIS software, allowing users to interact with geographic information, suggest spatial interventions, make annotations and distribute/share spatial data and information (Papadopoulou and Giaoutzi 2014). They constitute popular tools enhancing the willingness of a community to take part in evaluation processes where spatial decisions are to be taken (Hansen and Prosperi 2005). Visualisation potential along with user-friendly interfaces facilitates public participation even for lay participants. PGIS/PPGIS enhance mutual understanding, support knowledge dissemination, promote the participatory dimension of spatial problems and reinforce co-decision making. The adoption rate of PGIS/PPGIS has been increased during the last decades in environmental studies, urban and regional planning, decision making, political and social science, etc. Some representative examples include: the exploitation of PPGIS in order to facilitate e-government procedures and evolution of debates (Ganapati 2011); the application of PPGIS/PGIS methods for the identification and mapping of ecosystem services (Brown and Fagerholm 2015); the adoption of a PPGIS in combination with GPS tracking for monitoring bikers, visiting national parks for tourism and recreation in Northern Sydney (Australia) (Wolf et al. 2015); the establishment of a web-based PPGIS serving municipal planning purposes through the assessment of urban densification (Babelon et al. 2016).

Volunteered Geographic Information (VGI) is another participatory approach where crowdsourced geographic information is gathered through the mobilisation of volunteers. GPS, remote sensing, statistical and tabular data, and data provided by sensors may be visualised on map backgrounds and support participatory mapping, spatial planning, allocation of activities and resource management. VGI has been used among others for the assessment of natural hazards (De Longueville et al. 2010); the organisation of emergency response in case of earthquakes (Camponovo and Freundschuh 2014); the validation of land cover maps (Fonte et al. 2015); and the exploration of vehicles' mobility patterns on roads based on Global Navigation Satellite System (GNSS) traces (Mozas-Calvache 2016).

The evaluation process and the relevant GIS-based MCDA approaches have profited from the introduction of visualisation in participatory planning. As a result, a new concept, that of *participatory evaluation*, has been introduced for the development of a joint evaluation framework where a number of stakeholders cooperate in order alternatives to be assessed and evaluation criteria to be determined. In the spatial planning context, participatory evaluation offers the chance to enrich the existing knowledge stock, analyse the complex dimensions of spatial problems, indulge into the specific characteristics of each problem and reinforce the content of spatial decisions by exploiting special and locally oriented knowledge, gained experience and expertise emanating from stakeholders (see Cousins and Earl 1992; Garaway 1995; Fawcett et al. 2003; Daigneault and Jacobs 2009; Chouinard and Cousins 2015).

Participatory evaluation is strengthened by visualisation as it involves the use of maps, photographs, 3D representations, augmented reality and a variety of other visual means that enable the graphical/cartographic representation of a study problem. All the above enhance the inherent optical intuition and perception of human mind and empower comprehension capabilities. GIS-based MCDA constitutes an ideal tool for the analysis of spatial problems, in a participatory context, as it allows for the illustration of alternative solutions and criteria. These are depicted in map backgrounds and participants have the chance to 'inspect' and formulate assumptions as to their effectiveness. They can easier understand all the steps of the selection process of alternatives. They are offered the opportunity to perform an initial screening of the study area and a rough/generic assessment of all possible alternative solutions. Evaluation criteria may be collaboratively defined while they are translated into map layers in order to be further elaborated through the implementation of spatial analysis. The visualisation of evaluation criteria offers participants the opportunity to understand their relative importance but also their correlation with the objectives selected. But the most important advantage that visualisation could provide in participatory evaluation is that it makes explicitly clear the spatial variability of criteria, criteria weights and alternatives' scores.

A vast number of scientific publications report on the usability and advantages of GIS-based MCDA in community planning and decision support. Typical examples refer to: the management of land uses and urban control in urban regions of Iran through the development of a web-based SDSS, enabling argumentation mapping and participatory GIS-based MCDA processes in order suitability maps to be produced (Mansourian et al. 2011); the identification of protected/management zones in the Yunnan Province (China) through the creation of suitability maps by adopting GIS-based participatory MCDA (Zhang et al. 2013); the selection of appropriate parking sites in the city of Tehran by using a web-based group GIS-MCDA approach that gives the chance to interested stakeholders to get involved (Jelokhani-Niaraki and Malczewski 2015); the search for solutions for the renovation of Urban Blighted Areas in Tehran (UBAs) by involving owners, investors and urban managers through the adoption of PPGIS in combination with MCDA (Omidipoor et al. 2019); the allocation of residential areas in the island of Mykonos (Greece) where a GIS-based participatory evaluation took place in a living lab environment in order suitable areas for housing development to be explored (Papadopoulou and Hatzichristos 2020).

Such applications were developed on the basis of potentialities provided by visualisation means, which make MCDA data more comprehensible by the broad audience of participants, engaged in spatial decision making procedures. In this context intuition is enhanced and the several dimensions of spatial problems are clarified, while a more integrated assessment of possible solutions is achieved.

15.5 The Role of Visualisation and GIS-Based MCDA in Scenario Analysis

Spatial interventions constitute the main tool in the hands of planners for addressing spatial problems. A range of objectives such as sustainable management of natural resources, reinforcement of social cohesion and bettering of economic prosperity may correspond to the outcome of spatial planning processes and lead to policy packages aiming among others, at the management of conflicts and trade-offs, the establishment of synergies and the confrontation of discrepancies, towards the attainment of future goals.

In this context, integrated solutions, taking into account all possible factors that may affect future developments, should be explored. To this end, scenario analysis comprises an effective approach for structuring informative decisions that incorporate the likely prospects of a study system and suggest potential options for their efficient management.

Scenario planning requires the detailed analysis of elements shaping the unique profile of a study system and the key variables which may affect its future development. Moreover, it builds upon the investigation of complex direct and indirect interrelations existing among the components of the system; the exploration of relevant actors and their power relations; the analysis of forecasts concerning system's future trends, and the formulation of future assumptions. The process of structuring future scenarios represents a multifaceted and complicated process as a considerable number of factors should be taken into account and possible future risks should be assessed. Scenario planning has its foundations in strategic thinking and its main benefits include: the possibility to investigate an extensive number of alternative future options, the analysis of future trends and the assessment of uncertainties (Shoemaker 1995; Ringland 1998; Peterson et al. 2003; Lindgren and Bandhold 2009; Star et al. 2016). A considerable number of scenario planning techniques have been developed such as 'qualitative' and 'quantitative' ones, techniques based on 'backcasting' and 'forecasting' approaches, simplistic practices, etc. The selection of the most appropriate approach depends on the particular needs and characteristics of each problem.

Visualisation technologies have greatly contributed to scenario planning as they enable the graphical representation of proposed spatial interventions. Future scenarios may be presented on map backgrounds that support the investigation of possible changes, such as change of land use patterns, as well as the assessment of impacts resulting from the implementation of the respective scenarios. Thus, visualisation enhances the ability to foresee future conditions and deal with uncertainty as it supports future visioning and provides meaningful information for increasing awareness.

In addition, GIS-based MCDA supports the assessment and prioritisation of alternative scenarios on the basis of geo-referenced evaluation criteria. After the application of a GIS-based MCDA, decision maps are produced, that may greatly support participatory scenario planning. In principle they constitute excellent tools for communication among politicians, technicians and stakeholders involved, as they support argumentation mapping, explicit representation of all suggested interventions and mutual understanding.

Scenario visualisation and GIS-based evaluation of scenarios have been applied for communicating future landscape changes in the Danish countryside by creating photorealistic landscape scenarios (Tress and Tress 2003); evaluating forest management scenarios in British Columbia (Canada) by adopting 3D visualisations and MCDA (Sheppard and Meitner 2005); assessing scenarios that concern the impacts of climate change at the local scale in British Columbia (Canada) (Sheppard et al. 2011); assessing flood risks through the simulation and visualisation of flood scenarios in the Netherlands (Kehl and De Haan 2013); creating visual representations of managed retreat scenarios concerning coastal planning in Southern UK through the exploitation of LiDAR data for landscape visualisation (Krolik-Root et al. 2015).

The above-mentioned cases are only indicative examples as literature provides a great variety of applications, having been implemented for the support of spatial decision making. Such applications enable the visual communication of suggested alternative scenarios, capture the attention of the interested parties, increase awareness on the issues being dealt in each case, enhance the comprehension and dissemination of the proposed spatial interventions and mobilise the undertaking of joint initiatives leading to the formulation of broadly accepted solutions.

15.6 Discussion

Visual representation and visual communication of spatial and non-spatial data and information are of great importance in spatial planning processes. Spatial planning is directly related to changes and transformations occurring in the geographical space which impact physical environment, social coherence and economic activities. These planning processes deal, among others, with complex planning issues involving multiple urban functions that compete for land, such as housing, employment and infrastructure, and enable decision makers to meet with scientific methods that set the framework for analysing key factors, and designing effective solutions (Van den Brink et al. 2007).

A common way of dealing with such complex issues is inviting citizens, pressure groups, public organisations and private enterprises to participate in the planning process. Spatial planners consider the expertise, involvement and support of participants to be essential for an effective planning procedure and successful realisation of spatial transformations. The engagement of stakeholders and the information exchange during the process greatly influence the degree of mutual understanding, consensus and support for proposed changes. The role and influence of stakeholders in such processes vary according to the level of participation that is practised (Arnstein 1969; Dalal-Clayton and Dent 1993; Rowe and Frewer 2000).

The power of visualisations to influence the perception and decisions of people, and therefore to influence participants in the planning process, is widely acknowledged (e.g. Lange and Bishop 2001; Appleton and Lovett 2005). In this context two-dimensional (2D) geo-visualisations have traditionally been used to exchange information about transformations in the spatial units. These visualisations were and still are difficult to be understood for a considerable number of stakeholders, who generally have little experience with interpreting maps that represent spatial information (Darken and Peterson 2002). Moreover, 2D geo-visualisations are limited to visualising differences between the current and future situation, presenting scenario studies and switching between scales and viewpoints. Therefore, more effective geo-visualisations had have to be used to communicate spatial information to all participants. Using such visualisations may help to avoid unfocused design discussions, unjustified expectations, and expensive and unchangeable planning decisions (Al-Kodmany 2002). The spatial information that is communicated via geo-visualisations needs to be adjusted to the planning context because the information exchange takes place in diverse combinations of stakeholders, planning phases and participation levels (Al-Kodmany 1999; Kingston et al. 2000; Al-Kodmany 2002).

Within this changing planning context, geo-visualisations must be able to meet the changing requirements for visual representations in terms of subject, level of detail, scale, interaction possibilities, etc. New methods and techniques that do meet these criteria for communication in spatial planning can be provided by 3D geo-visualisations. 3D geo-visualisations are three-dimensional visual representations of data that have a geographic reference and can be used to exchange spatial information in spatial planning.

Geo-referenced spatial data are involved in almost all cases where spatial planning initiatives take place and represent a substantive tool supporting the formulation of spatial decisions. In this respect, cartographic representations offer the possibility such data to be mapped and visually communicated to several interested parties, engaged in decision making processes. Except for spatial data, statistical, tabular and textual data can also be visualised and analysed with the support of modern GIS/web-GIS technology. Visualisation means mobilise visual thinking, enhance visual communication skills, and contribute to a better understanding of spatial patterns.

Visualisation and GIS together with MCDA and scenario planning constitute decision aid tools playing a fundamental role in participatory planning, as they allow for knowledge dissemination and sharing, assessment of alternative solutions, visualisation of evaluation criteria, scenario analysis and argumentation mapping. There seems to be a need for a conceptual framework to structure the use of geo-visualisations in participatory spatial decision making frameworks. Such issues were thoroughly analysed in this chapter through the exploration of relevant benefits and capabilities that visualisation and spatial analysis technologies provide in spatial decision making.

Literature review indicated that GIS-based MCDA, participatory scenario analysis, participatory GIS and mixed approaches are extensively adopted by researchers in order to design, communicate, analyse and assess the impacts of spatial interventions. The majority of applications address environmental problems, urban and regional planning issues where the effects of possible future options should be considered on the basis of a number of criteria. The widespread adoption of such approaches demonstrates their comparative advantages as to the management of complex problems and the design of effective decisions targeting at the sustainable development of urban centres, rural areas and natural ecosystems. Most researchers claim that such spatial planning practices entail multifaceted advantages in the planning process and planning outcomes as they integrate multiple tools and methods under a unique decision framework. In this context, knowledge stock is enriched, subjectivity is reduced, democratic procedures are strengthened and wide-accepted solutions are figured out.

Conclusively, technological advancements have prescribed the evolvement of traditional planning methods and techniques by bringing the potential of visualisation and spatial analysis of data involved in spatial decision making frameworks. They have enabled the simultaneous management and processing of spatial and attribute data, the development of interactive and dynamic maps supporting visual communication and cartographic analysis, the incorporation of MCDA methods in GIS software and the establishment of integrated SDSSs that produce innovative knowledge. Such a progress has led to the undertaking of more objective and efficient decisions while it has also stimulated the openness of planning processes to the public, the final 'receptor' of spatial decisions and interventions.

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Part IV
City, Environment and Sustainability

Chapter 16
Towards the Implementation of the Circular Economic Model in Metropolitan Cities: The Case of Naples

Luigi Fusco Girard

Abstract The general thesis of this contribution is that metropolitan cities—mostly port cities, also characterized most of the time by a relevant historical-architectural landscape—can reduce their agglomeration diseconomies if they adopt a 'circular' model of organization. The 'territorialized' model of circular economy is the 'circular city' model, which puts its centre with its suburbs, its historical centre with the port, and the consolidated city with the suburban territory in virtuous relationships. This chapter focuses on the multidimensional benefits of the circular economy and circular city model from an evaluation perspective, identifying an analytical list of indicators emerging from operational practice and the scientific literature. A multidimensional and multicriteria assessment method is used in the metropolitan city of Naples, Italy, to support the planning process for development of the port area from the perspective of the circular economy and circular city model. The originality of this assessment consists, on the one hand, in assuming evaluation criteria emerging from the strategy of the European Green Deal and, on the other hand, in focusing on the integration of the indicators proposed by the World Health Organization related to the Health Impact Assessment in a perspective that integrates environmental, economic and social impacts assessments.

Keywords Circular economy · Circular port city · Metropolitan cities · Multicriteria evaluation · Historic landscape · Cultural heritage

16.1 Introduction

The general thesis of this contribution is that metropolitan cities, mostly port cities characterized in Europe by a relevant historical-architectural heritage, can reduce their agglomeration multidimensional diseconomies if they adopt a 'circular' model

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of organization, starting with the way they organize the production of economic wealth and its redistribution.

The 'territorialized' circular economy model is the 'circular city' model (Circle Economy 2016a, b; Gemeente Rotterdam 2016; LWARB 2017; Mairie De Paris 2017; Forum World Economic 2018), able to put its centre with its suburbs; its historical centre, with the port that is often a real economic engine of the city, but also a source of negative external effects; and the consolidated city with the suburban and rural territory in virtuous relationships.

Port metropolitan cities represent a fertile entry point to the circular urban economy if they activate virtuous circular processes, starting from improvement of the connection between the port and the city, whose planning and management strategies are particularly complex and frequently conflicting, often with negative impacts for both.

The first hypotheses assumed here are those of the Intergovernmental Panel on Climate Change (IPCC) reports (IPCC 2014, 2019) on climate change and the (consequent) documents of the United Nations (Agenda 2030 for Sustainable Development (United Nations 2015) and the New Urban Agenda (United Nations 2016), as well as of the European Union and the European Commission (European Union 2016), about the adoption of the European Urban Agenda and the circular economy model.

In particular, in the literature there is a focus on the circular economy model and its territorial transposition into the circular city, and the different definitions and attributes of a circular city are considered. At the same time, systemic solutions in this direction are being tested practically in the international field.

The first part of this chapter focuses on the benefits of the circular economy and circular city model that the empirical evidence demonstrates in economic, environmental and social terms: reduction of climate-altering and polluting gases, and economies from synergies from which greater economic profits are obtained with additional employment. Moreover, this work identifies an analytical list of indicators emerging not only in the operational practice of the various circular cities, but also from the scientific literature.

The second part of this chapter is focused on the implementation framework of metropolitan cities in Italy in terms of approved, adapted, or elaborated strategic and territorial plans. In this context, the analysis of the Metropolitan City of Naples and its guidelines on the strategic plan are introduced. The attention then shifts to the analysis of the relations between the port (a real economic engine) and the historic city, identifying two reference preliminary projects related to the regeneration of a portion of the waterfront in the city of Naples, Italy.

The methodological process starts with the selection of suitable indicators taken from the scientific literature and operational practice of some port cities.

A multicriteria analysis was structured on the basis of multicriteria evaluation methods such as ANP (Saaty and Vargas 2013) and PROMETHEE (Corrente et al. 2014) and was applied to the evaluation of the two preliminary planning design hypotheses, identifying complementary effective actions towards the circular model.

The originality of this assessment consists on the one hand in having assumed evaluation criteria emerging from the strategy of the new Green Deal (European Commission 2019c) of the European Union, and on the other hand from integration with the indicators proposed by the World Health Organization (WHO) related to the Health Impact Assessment (HIA) (Fusco Girard and Nocca 2019), in a way that integrates environmental (EIA) (National Environmental Policy Act (NEPA) 1969), economic and social (SIA) impacts assessments.

In fact, the European Union Green Deal assumes the circular economy model as an essential factor to face the challenges and competition in the globalized economy, introducing a series of indications that take the form of evaluation criteria: waste minimization, reuse, recycling, material regeneration, use of renewable energy sources, promotion of second-hand markets, strengthening of green areas, etc.

The following sections analyse the general European framework for the circular economy and circular city implementation (Sect. 16.2); the systemic approach through the lens of the landscape and its implications (Sect. 16.3); the circular economy as a hybrid model of economic development (Sect. 16.4); and the role of cities as 'laboratories' for the implementation of the circular economy, exploring recent implementations in the metropolitan city and the port of Naples (Sect. 16.5). Based on the experience of Naples, the circular relationship between the city and the port infrastructure is investigated (Sect. 16.6), and the application of hybrid evaluation methods to assess different transformation hypotheses is presented (Sect. 16.7), with two preliminary projects for the waterfront of the metropolitan city of Naples (Sect. 16.8). Finally, conclusions are drafted to pave the way towards implementation of the circular city model also in other metropolitan cities (Sect. 16.9).

16.2 The General European Framework

The general framework represented by the European Union's development strategy has been adopted. It can be summarized in the following points.

16.2.1 The European Green Deal

The European Green Deal (EGD) takes as its starting point the conclusions of the latest IPCC reports on global warming; the increasing pollution of air, water and soil; and the effects of climate change.

In anticipation of the forthcoming Action Plan for Air, Water and Soil, the Green Deal (European Commission 2016, 2019a) insists on the features that should connote action by all institutions in Europe towards zero emissions by 2050: the efficient use of natural resources; the ability to decouple economic growth from the production of climate-altering/pollutant gas, and the production of waste; the ability to conserve natural capital (today only 12% of the materials used come from recycling, and the extraction of new materials accounts for almost 50% of climate-altering emissions), ecosystem health (EGD §2.1.6) and the health/well-being of the population; and the capacity to promote a development model that is not only ecologically compatible but also inclusive and socially just. The reference to the Pillar of Social Rights (European Commission 2017) is explicit.

The proposals range from the reconfiguration of energy policies to new infrastructure policies, from transport to construction, to the diffusion of new digital technologies.

More specifically, proposals are made in the various sectors.

In the construction sector, a new phase of recovery and renewal of the existing building stock is foreseen (EGD §2.1.4). It is necessary to update the implementation tools in order to overcome all factors blocking upgrading of the building stock, also with reference to new energy standards.

In the transport sector (EGD §2.1.5), it is foreseen that greenhouse emissions, which now account for 25% of total emissions, must be reduced by 90% by 2050, while at the same time promoting rail transport.

One very important point is that 'the cost of transport must incorporate external effects on the environment and health' (European Commission 2019c). In particular, it is hoped that technological innovations will be introduced in cities to reduce the climate-altering and polluting load on the sector.

In the energy infrastructure sector, smart grids and digital tools are promoted for continuous monitoring of air/water consumption and pollution. Decarbonization, an improvement in energy efficiency, use of renewable energies, capture of CO_2 and the introduction of hydrogen as an energy carrier are all stressed (EGD §2.2.3).

Finally, the European Green Deal calls for climate change adaptation measures and new business models that reflect the perspective of use rather than ownership of goods, together with the possibility of co-use, linking with the sharing economy business models. It opens many new opportunities for people, for entrepreneurs and for cities.

16.2.2 The European Environment and Air Quality Directive

The European Environment and Air Quality Directive (issued on 28 November 2019) (European Commission 2019b) further emphasizes that reduced air quality is a source of chronic diseases such as asthma, respiratory crises, cardiovascular crises, cancer, etc., resulting in around 400,000 premature deaths in the EU. This pollution is caused by elements such as SO2, PM10, PM2.5, NO2, CO, ozone, benzene and benzopyrene, which particularly affect urban/metropolitan areas where production, industrial activities, transport and more intense mobility are concentrated. Here, combustion for heating houses is at its highest due to the building density, and the microclimate is more compromised. It emerges that Italy is rated highest for levels of PM10, NO2 and benzene, and is in second place in the EU for levels of SO2 (European Commission 2019c). Road transport in the EU contributes to the highest percentage of NO (39%), followed by energy (17%) and the commercial and residential sector (14%). The transport sector is the major source of PM10 and PM2.5, with 10–11% incidence.

Thus, the transport sector (infrastructure/mobility) appears to require immediate investments to improve the status quo, improving the well-being/health/quality of life of European citizens, as well as ecosystem health. 'Air quality is essential for human health. It is also essential for environmental sustainability and to ensure social and economic benefits' (European Commission 2019b). In other words, air quality is a global common good to be managed by all with the utmost care.

16.2.3 Health and Circular Economy

In 2019, the WHO published the second report on Assessing the Health Impacts of Circular Economy, exploring the relationship between health impacts and well-being in the circular economy model, proposing to incorporate the HIA, EIA, SIA and multicriteria assessments into urban planning and design/programming tools in order better to assess, control and manage transformations towards the necessary transition (WHO 2018, 2019).

In fact, in 2018, the WHO had already focused on the interdependencies between circular economy and health and social impacts, also based on European Environment Agency (EEA) monitoring. This monitoring revealed that air quality in European cities has been degrading over the years, especially through emissions from the transport, housing and industry/tertiary sectors. To highlight its percentage incidence, the cost of pollution in relation to GDP reaches about 6% if economic data are aggregated on the basis of monetization of morbidity.

16.2.4 The International Panel on Climate Change (IPCC) Reports

The starting point of the climate change issue is the IPCC reports. The IPCC established in 1988 on the basis of an agreement between two United Nations organizations (the United Nations Environment Programme (UNEP) and the World Meteorological Organization) proposed the first in 1990. The report recognized that emissions due to human activities have increased over time, leading to concentrations of CO_2, methane, nitrogen oxide, chlorofluorocarbons and other climate-altering gases, with a consequent rise in the average temperatures on Earth. The negative impacts of this global warming were concentrated in some coastal regions characterized by intense poverty. Subsequent reports have only confirmed the above with increasing concern.

In 2010, the NASA Earth Observatory highlighted this rapid global temperature increase and attributed it not to natural causes but to human activities. For example, the graph of air and ocean temperature between 1750 and 1950 showed a substantially constant trend, while it began to rise from 1950 onwards (IPCC 2014, Graph 3). Negative impacts on agriculture, coastal areas, urban/metropolitan concentrations, water resources, energy, migration processes, conflicts, health/morbidity and quality of life/well-being were clearly highlighted. Adaptation and mitigation measures were therefore explicit to reduce the risk associated with temperature rise in order to avoid irreversible processes (IPCC 2014, pp. 103–104).

The WHO has repeatedly stressed the risk posed by the combination of climate-changing gases and polluting emissions. For example, the WHO has repeatedly pointed out that about 7 million premature deaths are due to pollution outside the home (World Health Organization 2018a)—i.e. the urban environment, 80% due to cardiovascular complications and the remaining 20% to respiratory causes and cancer.

In its 2018 report, the WHO addressed in particular the problem of the relationship between health and the circular economy—i.e. between climate change/pollution and damage to human health.

The Countdown Report monitors the impacts of climate change and pollution on people's health/well-being on the basis of 41 indicators. In other words, it highlights the responsibility of the human dimension/cause of climate change.

In fact, the 2017 report highlighted the risks of climate change for many diseases of viral and/or bacterial origin. The subsequent 2018 report monitored the above report with indicators 1.7 and 1.8, concluding that 'climate change conditions are a critical cause in determining the spread and impact of many diseases' (Watts et al. 2019). The 2019 report, confirming the above with further data, underlined that the economic cost of not taking timely action will lead ex-post to a much greater economic/financial effort without the restoration of ex-ante conditions.

From the annual loss of forestation, the increase in energy consumption, the multiplication of air transport, the increase in carbon monoxide, etc., it follows that there is a need to act with the highest priority in the energy sectors, with decarbonization of the local economy, the recovery of vast and natural areas in cities, and urban and organic agriculture.

16.2.5 Multidimensional Impacts of Port Cities: From Climate Change/Pollution to Economic and Social Impacts

The following Fig. 16.1 (Watts et al. 2019) provides the general framework adopted in this paper. It highlights the intense climate-changing and polluting impacts that cities, and in particular port metropolitan cities, have on the atmosphere, water and soil, and their mutual interdependencies. These impacts, due to their intensity, cause

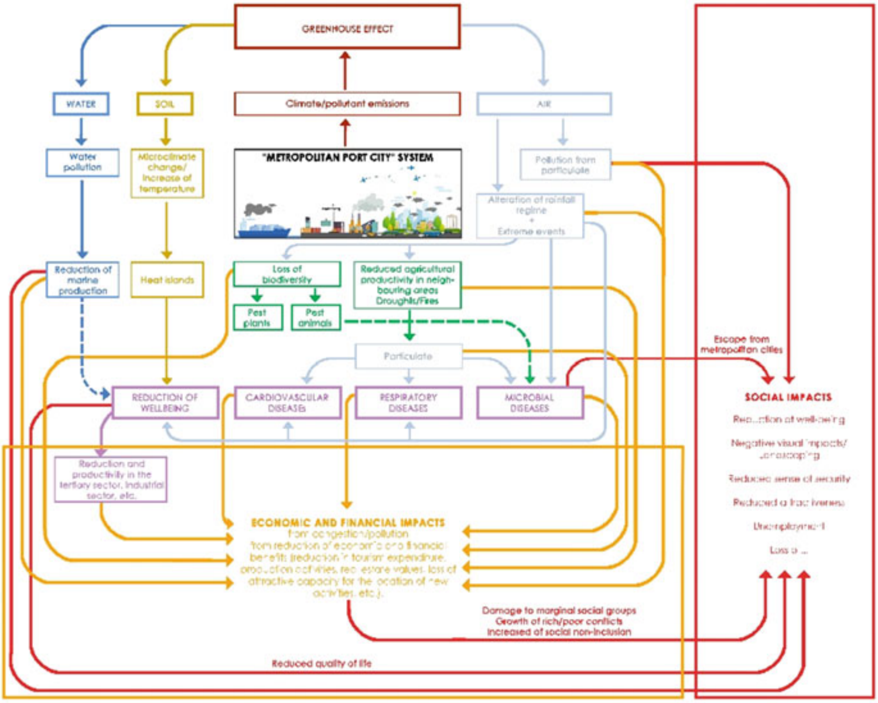

Fig. 16.1 Multidimensional impacts of port city (Source: IPCC 2018)

damage primarily to human health and well-being, which in a human-centred perspective is a priority. This damage, together with the other effects, then turns into economic and financial costs, as well as social costs. For example, the transport sector is responsible for 23% of climate-altering gases; the industrial sector is responsible for 20% through energy industries, 12.6% through manufacturing industries, and 8.1% through industrial processes. Finally, the residential/services sector is responsible for 19.5% of these impacts (ISPRA - Istituto Superiore per la Protezione e la Ricerca Ambientale 2018).

The circular economy model can reduce negative impacts, producing economic/ financial, social and environmental benefits.

Local urban/metropolitan regeneration projects must be characterized by the ability to be instrumental in the pursuit or realization of the circular model. In particular, they should be able to reduce the economic, environmental and social costs mentioned above, thus improving cities' conditions.

Figure 16.1 refers to the ex-ante conditions—i.e. without an intervention project. It shows the increase of some significant economic, social/human and environmental cost items. With a careful intervention project, many economic, environmental and social cost items can be reduced. They are the multidimensional benefits of a circular approach.

16.2.6 Human-Centred Development

The human-centred approach that is emerging in development strategies and in urban planning, especially after Covid-19, is introduced here. It gives a cultural and social ground to the European 'Green' Deal.

The human-centred city development approach reshapes the city project towards a project that links, generates and multiplies relationships and bonds in space and time between human beings, between people and spaces, and between people and nature (the Mother Earth). The latter is the specific characteristic of New Humanism compared to the traditional interpretation: the symbiosis between people and nature. In particular, it assumes the health of eco-systems as the condition of the health of human beings. Human-centred development and green development are interdependent, because the health of nature is a global common good.

Human-centred development assumes the dignity of the human being and therefore the implementation of human rights (health/well-being, work, housing, services, quality of life, etc.) in order to determine a flourishing capacity implementation, interpreted in a relational rather than an individualistic perspective. The humanistic approach interprets the new technical digital urban landscape not in terms of the traditional 'smart city' (advanced technologies, short horizon, rent as a development engine, etc.), but in terms of the capacity to orient all technological innovations towards the fulfilment of human needs.

The humanization process is linked to values, and thus to culture. Cultural built heritage is an expression of culture characterized by a human scale and by the beauty of squares, public spaces and landscapes. Beauty is a humanistic value because it satisfies specific individual needs and contributes to the well-being and health of human beings (Sacco and Teti 2017; Grossi et al. 2012). The beauty of places contributes to humanization processes in planning.

Cultural values such as cooperation, collaboration, coordination, etc. become more and more relevant if we want reduce social fragmentation, through a culture characterized by long-term, commons-oriented and civic dimension oriented.

Human-centred development assumes the key role of tangible, material, quantitative values together with intangible, qualitative, immaterial values, such as trust and cooperation as the engine of developments. The unifying perspective is that of human flourishing (Prendeville and Bocken 2017). It is linked to the capacity to orient all innovative technologies (IoT, AI, robotization, sensors, screens, new bio-materials, etc.) not towards surveillance and control, etc., but towards goals that reflect human dignity. Citizens, and not algorithms, should be put at the centre of development. Big data management through AI, for example, should be able to improve social inclusion, citizen responsibility, well-being level, etc. Human-centred innovations allow the achievement of human flourishing and human creative capacity as the main goal of development.

Human-centred development requires a key role of the (urban) community in terms of active citizenship, pro-active participation and self-organization.

Work is the key condition for implementing the human scale, the social inclusion, the community dynamic.

Commons and their management are an effective entry point for stimulating the community.

To implement a humanization strategy grounded on cooperation, trust and coordination of actions, it is necessary to introduce hybridization—between economic productivity and environmental productivity, between economic and social productivity, between ancient processes and new ones—into conventional economy processes.

Human-centred city development needs to be grounded on the principle of subsidiarity to making participative decisions as close as possible to the local level. A specific strategic plan for culture is required because culture is considered in this approach as the key resource for human scale development.

The human scale project is thus able to place people and culture at the centre of sustainable development (human sustainable development), making abandoned and neglected heritage places attractive to human beings and for talents and creative and innovative activities, accepting the challenge of heritage regeneration and embracing the new circular economy development paradigm to make people and places flourish through culture.

Many EU documents pay attention to the human challenge. For example, in the Action Plan for the Circular Economy (European Commission 2015), the social economy is evoked (§5) on the basis of the Madrid Declaration (23/5/2017) (European Parliament 2017). The social economy includes cooperatives, associations, social enterprises, ethical banks, foundations which concur on an inclusive economy grounded in the society. Another EU document is the European Pillar of Social Rights (European Commission 2017), also evoked in the European Green Deal (11/12/2019, at §2.1) and the New Industrial Strategy for Europe (European Commission 2020) (10/3/2020), which assumes the social rights for orienting the required transition towards the economy de-carbonization.

16.3 The Circular Economy as a Hybrid Model of Economic Development

The circular economy model is interpreted here as a hybrid model between nature's economy and man's economy, between economy and ecology, between competition and cooperation, and between market economy and social economy. This model is capable of taking into account instrumental values based on a utilitarian approach and intrinsic values based on a non-utilitarian approach (respect for ecological thresholds, reference to short but also long time periods, to material and immaterial values, etc.).

The ecological economy inspires the circular economy. In nature, every living organism not only consumes resources/energy, but in turn, being related to other living organisms, contributes to nourishing their lives, providing a flow of services to them. It is characterized by a perfect metabolism, made perfect over millennia, that allows every by-product and all waste to be recycled.

Linking different programmes/logics requires a participatory evaluation of the pursuit of intrinsic values and the opportunity costs to achieve them.

Circular economy

- decouples the economic growth from resource consumption and negative environmental impacts (Ellen MacArthur Foundation 2015a) (Ellen MacArthur Foundation 2015b).
- offers a new perspective to generate values and profits, reduce production costs, natural resources consumption and greenhouse gas impacts, and generate new employment (European Commission 2014).
- is interested to produce services to be consumed instead of goods to be appropriated (through property rights, etc.) (Galalae et al. 2020).
- is interested to use values more than market values (Hansjürgens et al. 2017).
- reduces the trade-off between economic productivity and ecological conservation (and social goals) (Liu et al. 2020).
- is attentive to relationships between state and market, between public and private; it is attentive to the civic sector (third sector) between them (Evers 2005).
- is grounded on cooperation, collaboration, integration between multiple subjects and activities (European Commission 2018).
- is attentive to all interdependences (UNESCO 2011). The attention is on the capacity to avoid underuse and waste of all kinds of capital: not only of natural capital and man-made capital, but also of human capital and social capital. These forms of capital are as important as the natural and man-made ones (Preston et al. 2019).

Waste is interpreted not only in terms of natural or man-made resources, but also in terms of human and social capital. The city is not only a great source of waste or discarded elements, but is often also the set for discarded people: unemployed, marginalized people, etc. The circular economy is focused to valorise the human being in terms of his capacity, intelligence, creativity and self-entrepreneurship. Employment is a key element.

16.4 The Systemic Approach Through the Lens of the Landscape and Its Implications

Many metropolitan cities in Europe offer a high-quality landscape.

All metropolitan port cities in the Italian context are characterized by a specific cultural landscape (see Table 16.1).

The historic urban landscape (HUL) approach, as a unifying/holistic approach, incorporates the principles of the challenge to climate change. In other words, it can

Table 16.1 Italian metropolitan cities (2016)

Localization	Metropolitan city	Municipalities (n)	Population (2014)	Density (pop/km^2)	Port City	UNESCO WHS	Other significant CH
North	Bologna	56	1,001,170	270			*
	Genova	67	868,046	473	*	*	*
	Milano	134	3,176,180	2015		*	*
	Torino	315	2,297,917	337		*	*
	Venezia	44	857.841	347	*	*	*
Centre	Firenze	42	1,007,252	287		*	*
	Roma	121	4,231,244	789		*	*
South	Bari	41	1,261,964	327	*	*	*
	Napoli	92	3,127,390	2653	*	*	*
	Reggio Calabria	97	559,759	174	*		*
Islands	Palermo	82	1,275,598	255	*	*	*
	Messina	108	648,371	199	*		*
	Catania	58	1,115,704	312	*	*	*
	Cagliari	16	542,277	142	*		*
Metropolitan cities		1.273	21,970,713 (35% of total for Italy)	446	65%	70%	100%
Total Italy		8.046	60,476,650	47			

be argued that this approach is achieved through the circular economy model and vice versa.

In fact, the HUL recommendation recognizes first of all a close relationship between the design/planning of cultural heritage conservation and economic development (Nijkamp and Voogd 1990): heritage conservation and management should be included in the framework of economic development strategies (§VI, Comma), and in particular in the framework of sustainable development strategies (VII Comma, §10, §11).

The notion of sustainable development returns several times in the text (§24/b etc.), as does the economic strategy in which conservation activity should be included/integrated.

The HUL recommendation suggests a landscape-based approach to the conservation and management of cultural heritage (see HUL Recommendation Preamble). This landscape perspective is structurally unifying because multiple and multidimensional approaches converge in it: it integrates the social perspective with the environmental, economic, physical, cultural and juridical ones.

All current problems are incorporated into the landscape, from climate change to pollution, health, social marginalization, economic wealth production, poverty, etc.

The landscape is a prism that allows us to adopt a human-centred perspective that is focused on the human dimension. There is no landscape if it is not perceived by a subject through its different senses. On the other hand, landscape is only the result of a series of choices made by each subject and the community. Landscape reflects the culture of a society—the way in which each person relates to others and to nature and the environment—and culture represents the human product, human creation par excellence.

The landscape is therefore configured as a vital, living resource, able to change continuously under the pressure of people's needs, interests and hopes.

Indeed, in HUL, the economic model is not only that of sustainability. The UNESCO recommendation on HUL repeatedly suggests that the landscape should not be preserved, but rather carefully managed in its transformations (§12): that is, it has to be sustainable, taking into account cultural, social and economic values (§5). This means producing development that is not only sustainable but also human and social (§10, §18), attentive to people's well-being and quality of life (§17, §18).

Throughout the text, the different values and attributes with which to evaluate the landscape in an integrated and comprehensive way emerge (§10): cultural and environmental values (§3, §21), intangible and visual values (§9), perceptive values (§13), social values (§24, §6), environmental values (§19), ancient values and contemporary values (§22).

Emphasizing the key role of creativity (§12), HUL calls for the integration of old and new. The notion of hybridization is evoked here, albeit implicitly. It is not a mere juxtaposition, but a reflection of complementarity, generating synergies and circularity; it is not only multifunctionality, but a juxtaposition of heterogeneous programmes, calculating rationality and relational rationality, cashflow control and creativity, analysis of economic/financial convenience and construction of sense/meaning.

It should also be noted that the issue of climate change is incorporated into the UNESCO recommendation (see Preamble, paragraph VIII and §19).

The circular economy model is not formally expressed, but many principles characterizing the circular economy model are nevertheless evoked. In §11, the need for productive and sustainable use of space resources is stressed. In §19, reference is made in particular to efficient use of the environmental resources represented by water and energy, while §2 calls for a strategic vision that goes beyond the short term: it stresses the importance of a long-term vision, which is typical of the circular economy.

Furthermore, §24/d stresses the need for self-financing—i.e. self-regeneration of financial resources in order to preserve the regenerated heritage over time. In addition, §22 stresses the need for 'harmonious' cooperation between different private and public actors. These are two typical characteristics of the circular economy model.

Finally, it should be noted that together with the notion of sustainable development (within which the conservation/management of heritage/landscape is placed) the notion of human development is mentioned in §12 and the notion of human and social development in §18. These are once again characteristics that are in perfect alignment with the circular economy model, careful to avoid waste and the under-utilization of different forms of capital, from natural to manufactured, human and social.

In conclusion, the HUL approach finds its implementation within the circular economy model, which is evoked even if indirectly.

The above has implications in terms of evaluation tools, which are increasingly required to 'support decision-making processes' (§24/b) both in design/planning and in change management. In §10, it is recognized that evaluation has to be integrated and comprehensive.

In Part IV, concerning tools, the need for evaluation tools is stressed (in §24/b) to 'monitor and manage change in order to improve the quality of life and urban space'. It introduces an assessment of cultural (heritage impacts), social and environmental impacts to improve choices, also calling for new financial tools (§24/d). These are therefore integrated evaluation tools (Fusco Girard and Nijkamp 2005; Fusco and Nijkamp 1997). More precisely, they are hybrid evaluation tools that combine heterogeneous approaches and procedures.

16.5 Cities as 'Laboratories' for the Implementation of the Circular Economy: the Metropolitan City and the Port of Naples

Cities and networks of cities (small, medium and large) are the main protagonists in the new evolutionary dynamics. The territorial spatial dimension of the circular economy is represented by the circular city. The 'ideal' circular city is present in many experiences that are already taking place in Europe and abroad (Circle Economy 2016a, b; Gemeente Rotterdam 2016; LWARB 2017; Mairie De Paris 2017). Some cities in Italy and in the South of Italy also seem today to be configured as 'laboratories' for the circular model: Salerno, under the Horizon 2020 CLIC project, Taranto as the city of hydrogen, Matera as a circular city for over 2000 years (Fusco Girard et al. 2019).

Sustainable development of the South of Italy strongly depends on the capacity to adopt circular development strategies, putting in relation of synergy, symbiosis and/or mutual interdependence, public, private and third sector investments; investments in logistics, culture/cultural heritage and tourism, in the agri-food sector, renewable energies, building sector, etc., improving the administrative procedures for the effective and efficient use of EU funds.

The metropolitan city of Naples comprises 92 municipalities, with a population of 3.117 million inhabitants (2015). By demographic size, it is second only to Rome and it is almost equivalent to Milan (see Table 16.1); 172,213 companies operate in the metropolitan city (ISTAT 2011).

The ports of the metropolitan city of Naples are those of Naples, Castellammare, Pozzuoli and Torre Annunziata.

The port of Naples shows a complex set of port activities with over 370 companies operating, employing more than 5200 employees and with a turnover of around 516 million euros.

Already in 2005, more than 20.8 million tons of goods were loaded and unloaded in the Neapolitan port system and more than 370,000 containers were handled.

In 2005, over 9 million passengers passed through the Neapolitan port system. In recent years, the Neapolitan port has confirmed a growth trend in the goods sector, too; thus, qualification as a Mediterranean logistics platform is looming.

Pleasure boating represents a sector with strong growth. In 2017, in the Gulf of Naples and the Amalfi Coast, direct expenditure linked to the movement of large yachts was estimated at over 30 million euros. The potentiality of large yachts is evident and is developing in all the ports of the AdSP (Port System Authority) of the Central Tyrrhenian Sea.

The main companies in the shipbuilding sector are Cantieri del Mediterraneo S.p. A., that occupies the area between Carmine dock and Calata Marinella and develops activities related to the transformation and repair of ships and pleasure boats with the management of three basins; and Palumbo S.p.A., that operates in three distinct areas: dock 28, dock 37 and dock 40. The distribution is due to the impossibility of using a single large concession area and the constant expansion of the company's business.

The Megaride shipyards occupy dock 36. The Nuova Meccanica Navale has two operating sites: the Vigliena shipyard and Carmine dock.

The 'Palumbo' and 'La Nuova Meccanica Navale' also set up a company called Napoli DRY Docks srl (with an investment of 20 million euros) for the management of a common area at the Martello dock to be allocated for ship repairs, with a new floating dry dock.

In addition, in the port of Naples there are about 34 companies and/or individual businesses defined as naval mechanical workshops that operate in the sector of repair, transformation, plant engineering, engines, etc.

The port is a real engine in the metropolitan economy. But at the same time it is the source of many negative externalities. The impact caused by emissions from ships in transit has been estimated on the basis of different models that simulate the concentration and dispersion of PM10, NO2, SO2 and VOCs (Giovanni Libralato et al. 2020; de Luca and Fiori 2020).

16.6 Towards the Circular Relationship Between the City and the Port Infrastructure

Some hypotheses have been elaborated for the transformation of the status quo, and particularly one specific portion of it, from the perspective of the circular model. These hypotheses are not yet real projects but are preliminary planovolumetric reference schemes through which it was intended to open a circular relationship between the port and the city (Fusco Girard et al. 2020).

They have been elaborated on the basis of the results of studies (Figs. 16.2 and 16.3) at the Interdepartmental Research Centre on Urban Planning, Alberto Calza Bini, for the Urban integration of the expansion towards the east of the port of

Fig. 16.2 Preliminary planning hypothesis 1

Fig. 16.3 Preliminary planning hypothesis 2

Naples, and within the activities of the Master's Degree Course Level II in Sustainable planning and design of port areas of the Department of Architecture of the University of Naples Federico II.

These proposals are the entry points for the transition to the systemic and circular model always evoked but not concretely implemented. As a matter of fact, the existing port business model is also careful to improve internal efficiency and competitiveness with respect to other port infrastructures: it is separate from the urban dynamic and its socioeconomic goals.

There is not a clear choice between the business models: port as an enterprise, the port as a hub in a logistic chain and the port as a waterfront.

On the one hand, the planovolumetric design scheme is configured as an innovative element of the waterfront, with its spaces capable of attractiveness for their spatial, visual-perceptual and cultural quality. On the other hand, it is proposed to guarantee reciprocal circularity—for example, with the transport system and local mobility. The recovery of the architectural and historical heritage configures the proposal as generating an attraction pole, almost a square, with public spaces offering specific quality services that are usable by both users of the port infrastructure and citizens.

At the same time, the design idea is connected to the logistic model as it involves moving the containers not with the trucks, but on rails. In this way, it is possible to avoid affecting the local traffic while reducing impacts on air pollution and on the emission of climate-changing gases, reaching locations in the Centre-North in a more ecological way. The assumption is to prepare rail transport thanks to nine daily up and down trains. This is the maximum capacity proposed by the Port Authority and Trenitalia.

In this way, the urban attractive waterfront project is integrated with other logistics platforms in order to improve productivity.

16.7 Towards Hybrid Assessment Methods: The Assessment of Different Transformation Alternatives

Definitely, the above was premised to proceed with the development of a hybrid evaluation approach that is consistent with the circular model and capable of taking into account the human-centred perspective, already incorporated in many EC documents, and which finds its foundation in human rights: health, well-being, quality of life, work, housing, services, etc.

Health, as already noted, is a fundamental element of this approach. Health represents one of the Sustainable Development Goals—SDGs (n. 3), being a central element in the pursuit of sustainability in its three dimensions. People's health must be integrated with the health of the ecosystem and the health of the economy. The approach in Fig. 16.1 suggested not only the assessment of financial, economic, social but also of all environmental items.

In particular, the Health Impact Assessment is the assessment tool proposed by the WHO to 'assess the potential impacts on the population and their distribution on the various social groups, resulting from policies, programs and projects' (World Health Organization 2018b). The HIA allows minimization of the negative effects on human health that can be a direct consequence of public policies or projects or plans, while the EIA and the CBA (cost-benefit analysis) evaluate only environmental and economic health (World Health Organization 2018b). The HIA has been proposed in Italy by a new Law 29/03/2019 (Ministry of Health). It requires a specific metric, both quantitative and qualitative which supports a participative approach.

The assessment of the health impact of emissions has been evaluated in particular for the pollutants PM2.5, NO2 and O3, deducing the risks. Assessments of annual emissions of NO, NO2, NOx, PM10 and PM2.5 caused by container traffic in the port of Naples have been elaborated, allowing an evaluation of ground concentrations and mortality risks associated with this form of pollution.

The thesis, as already pointed out, is that Italian metropolitan cities can find economic, environmental and social benefits if they adopt the circular model, in which health impacts are clearly highlighted.

The case study that is proposed does not refer to the entire metropolitan system, but only to a portion of the waterfront, which is in any case configured as a strategic 'hinge' between the port and the city (Cerreta et al. 2020, n.d.). It represents the entry point to implement further urban/metropolitan regeneration processes (Acierno et al. 2020). The multi-objective matrix of the most significant indicators is shown in

Table 16.2 Indicator matrix: selected environmental indicators

Category	Indicator
Air	Emissions of pollutants
Energy	Energy produced from renewable sources
	Surface used for energy saving in buildings
	Annual energy savings
	Projects implemented to maximize energy efficiency
Waste	Differentiated urban waste
	Municipal waste going to landfill
	Start-ups active in the circular economy sector
	Plastic packaging recycling plants
Water	Waterproofed surface
	Drinking water consumption
	Precipitation absorbed by green roofs
Well-being and quality of life	Pedestrian areas
	Cycle paths
	Urban public green
	Health risk induced by air pollution

Table 16.3 Indicator matrix: selected economic indicators

Category	Indicator
Cargo handling	Container traffic in the port of Naples
	Ro-Ro traffic in the port of Naples
	Various goods traffic in the port of Naples—infused liquids
	Various goods traffic in the port of Naples—solid bulk
	Various goods traffic in the port of Naples—GNL
	Exports
	Imports
Enterprises	Innovative start-up companies—trade sector
	Innovative start-up companies—tourism sector
	Innovative start-up companies—services sector
	Incidence of innovative start-up companies—trade sector
	Incidence of innovative start-up companies—tourism sector
	Incidence of innovative start-up companies—services sector
Pendolarism	Daily mobility for study or work
	Mobility outside the municipality for study or work
Real estate market	Real estate price of buildings for residential use
	Real estate price of buildings for commercial use

Tables 16.2, 16.3 and 16.4. They have been selected analysing indicators adopted in many port cities' circular projects. The impacts have been identified through specific working groups, the quality of the air and emissions due to ships' movement, and the quality of air coming from transport mobility, integrated with financial-economic analysis.

Table 16.4 Indicator matrix: selected socio-cultural indicators

Category	Indicator
Demography	Natural balance
	Migration balance
	Change in population under 18 years of age
Employment	Spare population turnover index
	Employment rate
	Rate of non-participation in youth work (15–24 years)
Cultural and creative system	Incidence of cultural and creative enterprises
	Incidence of the number of employees in cultural and creative enterprises
	Tourist expenditure activated by the cultural and creative productive system
	Wealth produced by the cultural and creative production system
	Incidence of cultural and creative non-profit organizations
Social vitality	Incidence of volunteers in non-profit organizations
	Innovative cultural associations
	Social reuse index of assets confiscated from mafias
Tourism and cultural heritage	Hotel accommodation rate
	Extra-hotel accommodation rate
	Tourism rate
	Cultural activities and events
	Cultural demand index
	Museums, monuments and archaeological sites
	Museums, monuments and archaeological site visitors
	Museums/institutes performing digitalization of goods and collections
	Museums/institutes belonging to a museum system to share resources and coordinate activities
	Museums/institutes offering the possibility of a virtual visit via the internet
	Evening and night-time opening museums/institutions
	Museums/institutes collaborating with other cultural institutions in the territory

The values obtained from the financial analysis (which takes into account the cost of construction, management, maintenance and revenues) discounted at a rate of 5% allow deducting internal rates of return between 12 and 24%. These assessments are some of the ones incorporated in Fig. 16.1. They have been integrated into the multicriteria analysis with social and environmental impacts, identifying the preferred actions in activating circular processes.

Through the ANP method, the main impacts of different proposals have been identified. The PROMETHEE method helped to recognize actions consistent with the circular economy model (Fusco Girard et al. 2020).

16.8 Characteristics of the Two Preliminary Projects for the Waterfront in Naples

The two preliminary planning hypotheses (Figs. 16.4 and 16.5) transform a 'non-place' into a place characterized by a capacity for attraction—i.e. an area characterized by a field of gravitational forces capable of resisting and opposing the many degraded/decaying areas in which a 'repulsive capacity' prevails.

Benefits are not only financial and economic, but also environmental and social. A particular first benefit is linked to human health.

The starting point is the recognition that in Naples, as in many other metropolitan cities, there is an under sizing of mobility on rail. Then there are high levels of polluting and climate-changing emissions.

The proposed projects highlight how a synergistic port/city relationship can achieve lower climate-changing and polluting impacts, with further benefits of an economic, ecological and social nature. In fact, the port is a fundamental economic engine for the metropolitan city of Naples, as well as in other metropolitan cities (see Table 16.1).

However, it also has strong negative impacts on the city. A study was carried out on the annual emissions of NO, NO2, NOX, PM10 and PM2.5 due to the transport of goods in container in the port of Naples (Fusco Girard et al. 2020; Libralato et al. 2020).

Fig. 16.4 Preliminary planning hypothesis 1: visualization

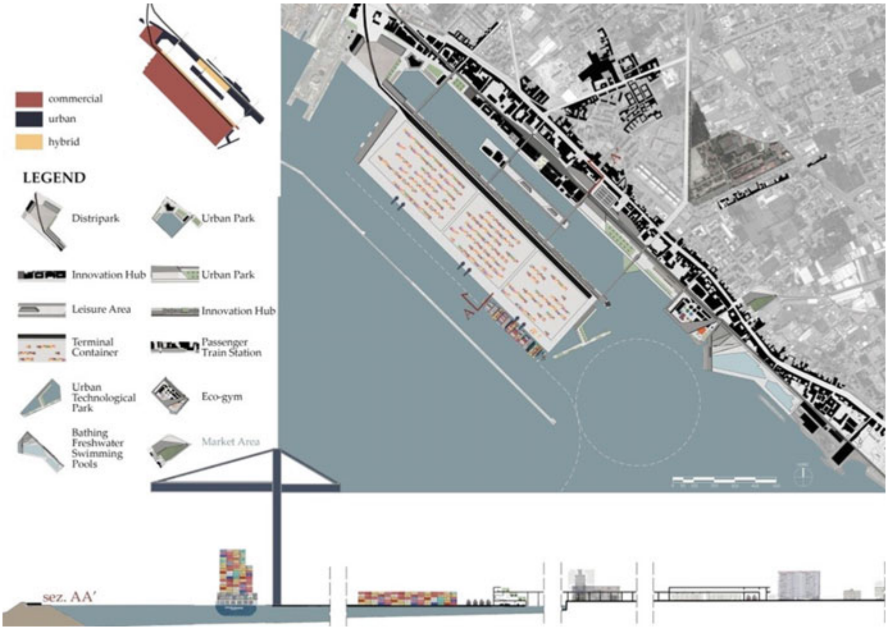

Fig. 16.5 Preliminary planning hypothesis 2: visualization

These data, appropriately processed, have been used as input for the CALPUFF dispersion model (www3.epa.gov) to estimate NO2, PM10 and PM2.5 concentrations in the urban area surrounding the port (Fusco Girard et al. 2020)

The results of the dispersion model were used in an assessment of the increased risk of mortality associated with air pollution in the urban port area.

With reference to the latest data available (2016) for the definition of weather conditions, it was found that moving the goods from road to rail transport (9 + 9 trains/day) would reduce deaths by two per 1000 for the 600 kTEU hypothesis and by three deaths per 1000 for the 1000 kTEU hypothesis, due to the reduction of nitrogen dioxide (there are no significant benefits related to the reduction of PM10 and PM2.5). Positive impacts are also achieved for the reduction of cardiovascular and respiratory system diseases.

The benefits in terms of reducing greenhouse gas impacts, which should be added to those due to pollution, have not been evaluated.

The net benefits (especially if one assumes the context/reference of the very recent EU documents) can significantly increase with the use of renewable energy sources, forms of energy efficiency, the use of bio-eco-compatible materials, the use of micro-electricity for mobility and transport, the multiplication of green areas, the introduction of digital technologies, etc.

The hybrid evaluation method is therefore a tool that integrates the different and multidimensional impacts (from environmental to social/human to economic) and helps identify those combinations of projects/actions characterized by the promotion of greater synergies, for their complementarities: therefore, capable of multiplying the net benefits implementing the human scale of the development strategy.

The two preliminary projects determine impacts whose final results are almost equivalent.

In order to make the city/port relationship a more virtuous one (or more circular), and in order to improve net positive impacts, further specific integrative characteristics of the transformation preliminary project are needed to be included. A participative process involving many stakeholders helped in this direction.

Also a new 'circular business model' has been recognized to be useful, for better reflecting economic, ecological and social values: a 'triple layered business model' (Joyce and Pasquin).

These characteristics can be recognized as included also in the list of the 17 SDGs of Agenda 2030.

In particular, they refer to the better pursuit of the objectives of the general European framework (see §3) and also of Agenda 2030 for the reduction in the quantity of climate-altering gases released into the atmosphere (SDGs 3, 7, 8, 11, 13); reduction in the amount of pollutant gases (SDGs 3, 11):

- Repair, reuse, maintenance and regeneration of materials and manufactured articles (SDGs 12).
- Waste collection (including from drainage, demolition, glass, plastic, iron, wood, etc.) (SDGs 11, 12).
- Water reuse/recycling (including from cruise ships, etc.) (SDGs 6, 12, 14).
- Reuse of heat produced (for residential purposes, etc.) (SDGs 8, 11).
- Multiplication of green spaces, green corridors, biomass, and green and blue infrastructure to contribute to the local microclimate (SDGs 11, 13).
- Mobility based on electricity (lorries, micro-electric, etc.) (SDGs 7, 11, 13).
- Use of digital technologies (including IoT, AI, etc.) to improve connection levels and synergies (SDGs 8, 9, 17).
- Location of innovative start-ups linked with port activities and services (SDGs 8, 9).
- Promotion of industrial ecology processes (SDGs 12, 7).
- Reduction of arrival/manoeuvre/departure times (just in time) through rational time programming to reduce CO2, etc. (SDGs 3, 12, 13).
- Implementation of the multi-helix model (SDGs 8, 9, 17).
- Moving from the production of goods to the production of insurance services, financial services, software, design, etc. (SDG 12).
- Use and production of renewable energy (SDGs 7).
- Energy efficiency of buildings (SDGs 7, 11).
- Use of bio-materials (SDG 12).
- Production of bio-gas (SDG 3).
- Valorisation of existing (and underused) share capital (SDGs 8).
- Reuse of cultural/landscape capital (SDGs 7, 11).
- Continuous monitoring and evaluation of impacts (SDGs 12, 17).

– The New Industrial Strategy for a global competition, green and digital Europe mentions, inter alia, the use of hydrogen as an energy carrier to accelerate the decarbonization of the industrial system.

The European Strategic Research Innovation Agenda states that hydrogen is an essential component of decarbonization, as about two-thirds of CO2 emissions are produced by the steel, chemical and cement industries.

Obviously, the production of hydrogen requires the use of renewable energy sources to achieve the electrolytic process.

The application of hydrogen in the port infrastructure, with the use of fuel cells, is evoked not only for the construction of fixed equipment, but also for industrial vehicles, railway wagons, various plants, etc.

Good practices are being tested in many port cities around the world in this direction—for example, by transforming CO2 into CH4 using hydrogen produced from renewable sources (www.marseille-port.fr).

The above characteristic/initiatives reshape the previous planning alternatives and can help to identify a new more effective project solution. In particular, they can better contribute to employment and self-employment, as a key condition of the human-centred strategy (in coherence with the Social Pillar of European framework and European culture), avoiding any 'human waste' through the valorization of underused human capital.

16.9 Conclusions

The evaluation carried out with the ANP and PROMETHEE suggests to better improve the benefits compared to the status quo. Some impacts are quantified; others, in the absence of significant data, are only assessed in qualitative terms (Fusco Girard et al. 2020). However, this preliminary test suggests moving from the preliminary planning proposal to a more in-depth solution proposal in which the impacts of Fig. 16.1 in §2.5 are better identified.

In order to improve these benefits, some new actions have been identified for the transformation of the status quo, in addition to those resulting from the 'Special economic zone' recognized officially for Naples port area. New synergy economies can thus be developed, based on symbioses, with positive socio-economic impacts.

This evaluation approach can be tested on a larger scale and proposed again in other metropolitan cities.

The financing with EU funds is justified on the basis of what has already been stated about the Green Deal approved by the European Union. The effective fight against climate change is a key objective of Agenda 2030 and of the Pact of Amsterdam. But it is also a precondition for many other social objectives to be achieved. This is in fact a general interest that any political majority should adhere to, regardless of the dynamics linked to democratic change between political majorities and opposition.

In short, it is a commitment and not just an option for any local government.

Cities and networks of cities (small, medium, large) are in fact the protagonists of the new evolutionary dynamics.

In reality, the fight against climate change is not a constraint, but an opportunity for cities of any size because it enables them to improve their overall productivity.

New tools are required to support decision-making processes, sharing outcomes with the involved stakeholders (people, entrepreneurs, public institutions, etc.), stimulating the institutional culture of evaluations.

Finally, it is worth pointing out that the above appears to be all the more true in the South of Italy (Mezzogiorno), where it is necessary to invest according to a systemic rather than a sectorial approach, as all too often happens.

Sustainable development in the South strongly depends on the ability of cities to adopt not only adaptation and mitigation strategies with respect to the risk of climate change, but also circular development strategies, linking synergy, symbiosis and/or mutual interdependence between public, private and third sector investments: in logistics, culture/tourism and the agri-food sector, improving administrative procedures for better use of EU funds and overcoming purely bureaucratic constraints, since the focus is mainly on the results achieved.

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Chapter 17
Large Cities as the Cradle of Sustainable Energy Innovation

Marina van Geenhuizen, Razieh Nejabat, and Pieter Stek

Abstract Large cities have empirically confirmed to act as the cradle of innovation. We explore whether this is also true for sustainable energy technology. We pose the question to what extent large cities act as concentrations of sustainable energy inventions and market introduction, and to what extent agglomeration and network factors are involved and large cities offer specific advantages. Our empirical outcomes tend to be mixed. In the past years, large cities have remained clusters of sustainable energy inventions, however, spread over a larger number of (single) cities. With regard to market introduction, large cities tend to be slightly more successful than smaller cities, however, this is not true for early market introduction. The weak and somewhat ambiguous relationships with large cities may be connected with the typical location of some sustainable energy sources, namely, as fixed natural assets in sparsely populated areas, like windy seashore and hills, strong coastal water currents, extended woodland, etc., favouring research in nearby small university towns. At the same time, the abundant knowledge (diversity) in large cities may enhance inventions with larger risk-taking in newness, specialization and global markets, and concomitantly, delay and longer time to market.

Keywords Sustainable energy technology · Invention · Market introduction · Agglomeration · Network factors

JEL Codes L21 · L26; O31 · Q4 · R11

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17.1 Introduction

To fight climate change, in particular reducing greenhouse gas emission has become a pressing issue in recent years on many levels, i.e. global, European Union, country governments, cities and universities, as evidenced by various assessment reports and long-term strategic visions (e.g. European Commission 2013, 2019; International Energy Agency 2019a, b; United Nations 2015). Technology, both existing and emerging ones, is an important source of new solutions, alongside knowledge on practical application.

Many empirical studies have confirmed that invention and innovation in large cities benefit from agglomeration economies. This study addresses the question whether this is also true for sustainable energy inventions aimed at mitigating greenhouse gas emission and broader use of renewable sources of energy. Agglomeration economies are often summarized as knowledge spillovers, non-traded local inputs and local skilled-labour pool (e.g. Anselin et al. 1997; Audretsch and Feldman 1996; Capello 2009; McCann 2006). Knowledge spillovers work through meetings and informal gatherings of researchers and business people, in which specific (tacit) knowledge easily circulates, an advantage that tends to be crucial in technology and markets with rapidly changing information. Non-traded local inputs refer to a more efficient (and cheaper) provision of highly specialized services if clients are grouped together in the same city (region) compared to being dispersed. And local skilled-labour pool refers to the potential of firms (research labs) to reduce labour acquisition and training costs, due to the presence of a pool of workers with already specialist skills. Agglomeration economies do not stop at the border of cities or clusters, meaning that high performing neighbouring regions have a positive influence on innovation performance in (main) clusters (e.g. Charlot et al. 2014; ÓhUallacháin and Leslie 2007). A connected but more recent approach—entrepreneurial ecosystems—has a strong focus on entrepreneurship and entrepreneurial risk-taking, mainly of young firms (Acs et al. 2017; Hayter 2016). Emphasis is put on institutional and organizational conditions, in particular on networks that facilitate entrepreneurial identification and commercialization of opportunities by these firms in their strategic choices.

Since the early 2000s, an alternative or extended concept of proximity has been developed, namely, *relational* proximity (e.g. Asheim and Isaksen 2002; Bathelt et al. 2004; Boschma 2005; Breschi and Lissoni 2001; Ertur and Koch 2011; Ponds et al. 2009). In this context, emphasis is put on actual demand for (new) knowledge and presence of common sets of values (beliefs) that facilitate knowledge spillovers over larger distances around the globe, for example, by travelling of key persons and using ICT support. Accordingly, the characteristics of knowledge networks can be seen as important conditions for invention and market introduction in large cities, and this moves our focus to multinational corporations (MNCs). MNCs account for a large share of worldwide research investment and they have an ability to connect cities and clusters through their internal global networks by maintaining a presence in different locations (Stek 2020). However, there is no consensus about influence of

MNCs on knowledge flows and benefits for invention performance in large cities. Within MNCs, a high level of trust may facilitate research collaboration between different cities and introduction of new knowledge to cities through MNCs acting as connecting pipelines (Bathelt et al. 2004; Gertler and Levitte 2005). This in contrast with evidence suggesting that the presence of MNCs in a city may have a detrimental effect due to 'reverse knowledge flow', taking place when important and highly innovative local firms are acquired and integrated (Ambos et al. 2006; Frost and Zhou 2005; Ostergaard and Park 2015).

Finally, we discuss a mechanism of a different kind, namely, path dependence, drawing on growing doubt about strength of agglomeration factors (Fitjar and Rodrı́guez-Pose 2017) and on emphasis put on an evolutionary perspective. Path dependence can be seen as a collective attitude of major actors in cities (clusters) that is influencing change (or lack of change) in innovation activity and its spatial pattern (Boschma and Frenken 2006; Crescenzi and Rodrı́guez-Pose 2011). Path dependence grows on the basis of capabilities, skills, experience, institutions, resources, networks, etc. developed in the recent past. In a cluster's development trajectory, path dependence is low in the stage of new path creation in which a cluster produces radically new technologies and products (Martin and Sunley 2003; Neffke et al. 2011; Tidd et al. 2005). In contrast, path dependence tends to be relatively high in a stage where industries, universities, and policymakers in a cluster become locked into initially successful paths that may block further progress (Martin and Simmie 2008).

Against the above theoretical background, we address the question as to what extent innovation in sustainable energy is concentrated in large cities (clusters) and how its performance is connected to agglomeration factors and network factors, and concomitant entrepreneurial advantages, in the presence of different path dependence.

The first novelty of this essay is the attention to technology on sustainable energy, e.g. solar PV, wind energy, advanced biofuels, hydrogen and fuel cells, river-based and sea-based hydro energy (currents, tides), and also sustainable transport technology. This choice is of course inspired by the need for climate change, in particular to reduce CO_2 and other greenhouse gasses and to avoid dependence on fossil energy. A second novelty is the attention to two different and sometimes overlapping stages in innovation processes, namely, knowledge creation/invention and bringing the inventions to market (market introduction) (Tidd 2001; Tidd et al. 2005). In the first part of this essay, the focus is on inventions in sustainable energy technology in localized clusters, while in the second part, the focus is on young university spin-off firms as a channel of commercialization of such inventions.

This essay is written to express gratitude to Peter Nijkamp. Personally speaking by the first author, Peter Nijkamp acted as co-promotor of my PhD research (1993) and later as co-author of several related studies, thereby favouring open-mindedness in choices concerning theory and research design, while keeping strict quality standards. This essay includes several of these choices, namely, spatial innovation theory and entrepreneurial orientation approach; scientometric data (patents) and qualitative interviews on firm behaviour; standard regression modelling and rough-set analysis.

17.2 Sustainable Energy Transition

Energy systems often act as rigid systems in response to technical innovation. This situation follows from the systems' nature as a socio-technical system, consisting of many interacting physical/technology elements, such as power plants, distribution grids, technology firms, metering systems, etc. but also of related social elements, including end-consumers, firms, government policy, regulation, legitimacy, standards, pricing-regimes, etc. All these elements together with strong linkages constitute the socio-technical system of energy, and partially also of transport systems (engine, fuel) (e.g. Dóci et al. 2015; Geels 2011, 2012; Markard et al. 2016). As a result, bringing about changes in energy systems, particularly substitution of energy sources, is not just an act of new technology creation (improvement) and market introduction, instead, it implicates the involvement of large numbers of actors—on the technical and social side—along with their networks and interconnections, which may cause certain 'resistance' to transitional change.

In a conceptual approach to socio-technical transitions, the so-called regime is seen as the solid structure that accounts for stability in the system, referring to sets of rules that direct and coordinate social and economic groups in reproducing system activities, for example, through lock-in mechanisms, in particular sunk cost impacts, vested interests, established user preferences and practices, experienced business models, etc. (Geels 2011, 2012). Under these circumstances, experimentation in real life with sustainable technology solutions and 'attacking the regime', seems only possible in protected *niches*, outside the influence of conventional market forces and regulation (Lopolito et al. 2011; Quitzau et al. 2012; Raven et al. 2016; Smith and Raven 2012). Niches provide room for nurturing novel projects enabling learning about market introduction (user preferences, business models) and adjustment in regulation (standards) by means of real-life experimentation. The previously addressed agglomeration economies point to large cities (clusters) as better endowed with diversity in knowledge flows and higher levels of specialized advanced services and labour markets compared to smaller cities, and therefore as better facilitator of real life experimentation in niches.

It needs to be mentioned that there is difference in knowledge demand and interaction, i.e. between science-based activity and engineering-based activity (Binz and Truffer 2017; Tidd 2001). In the first, communication can stretch easily over larger distances, due to a stronger standardization of knowledge like in chemistry (new materials). By contrast, in engineering-based research, closer distances are required due to less standardized situations, e.g. in electric vehicle industry and wind turbines, eventually causing more or new concentrations.

17.3 Invention Activity in Sustainable Energy Clusters

17.3.1 Introduction

In this section we investigate first, the extent in which invention activity in sustainable energy is concentrated in large cities (clusters) and whether this has been subject to change in the past decade, and secondly, to what extent invention performance in clusters is connected to agglomeration and network factors. Clusters in this section are conceived as 'geographic concentrations of industries related by knowledge, skills, inputs, demand, and/or other linkages' (Delgado et al. 2016). We make use of patents because the focus is on invention performance, which is primarily reflected in patent output (e.g. Acs et al. 2002; Hagedoorn and Cloodt 2003; Jaffe et al. 1993) and we draw on the database of United States Patent & Trademark Office (USPTO). Concentration refers to the intensity of patent output in geographic space based on the stated place of residence of inventors. Because patents may, in some cases, be assigned to organizations far away from where the actual invention activity took place, inventor locations are the more reliable geographic indicator of invention activity. In the cluster identification process, addresses involved are geo-located by using TwoFishes, an open source geocoder. Next, the location of inventors is plotted on a map and clusters are identified by using the standard 'heat map' algorithm, formally known as kernel density estimation (for technical details, see Stek 2020).

17.3.2 Spatial Patterns of Invention, Agglomeration and Network Factors

We focus on changing patterns of spatial concentration of patents (clusters) in years between 2000 and 2011 and on estimation of a model of invention performance, including agglomeration, knowledge networks, and path dependence in most recent years (2008–2011). With regard to spatial patterns, we observe the following (Table 17.1). The number of sustainable energy clusters rapidly increases during the years 2000–2011 from 89 to 171 (+92%). Although the number of clusters is growing, the overall share of clustered patents remains almost similar as indicated by 60 and 57%. Accordingly, growth of the number of clusters goes along with reduced average size of clusters, as indicated by a reduction from 33.2 to 18.8 patents

Table 17.1 Number and size of clusters of sustainable energy invention activity

	2000–2003	2004–2007	2008–2011
Total patents	4950	4769	5661
Total clusters	89	108	171
Clustered patents (share in all patents)	2958 (60%)	2835 (59%)	3215 (57%)
Av. number of patents per cluster	33.2	26.2	18.8

Table 17.2 Model estimation of cluster invention performance (2008–2011)[a]

Indicators	Agglomeration	Knowledge Networks	Path Dependence	Agglomeration and Knowl. Networks
Agglomeration				
Cluster size	0.11 (0.056)*			0.14 (0.057)**
Adjacent clusters	−0.086 (0.017)***			−0.082 (0.016)***
Specialization	0.13 (0.042)***			0.12 (0.044)***
Corporate R&D	0.11 (0.20)			0.13 (0.19)
Knowledge networks (flow)				
Inbound (MNC)		0.039 (0.063)		0.028 (0.044)
Outbound (MNC)		−0.33 (0.17)*		−0.37 (0.15)**
Simple degree centrality		0.053 (0.079)		
Weighted degree centrality		0.30 (0.10)***		0.32 (0.089)***
Path dependence				
Past invention performance			0.32 (0.059)***	
Constant	−0.48 (0.30)	−1.0 (0.24)***	−1.2 (0.080)***	−0.082 (0.34)
Adj. R^2	0.193	0.054	0.271	0.249
Clusters (n)	103	103	103	103

[a]Beta-coefficients with standard error in brackets; significance: *p<0.1, **p<0.05, ***p<0.01

(−43%). In accord, inventive activity in sustainable energy technology has not grown in a few large clusters but spread over a large number of small clusters. A development like this is in line with rapid expansion of a sector's spatial distribution and formation of newer and smaller clusters, as tends to be typical for a technology sector's initial growth phase (Ter Wal and Boschma 2011).

In the next step, invention activity in the years 2008–2011 is explored using OLS estimation. In order to limit heterogeneity in the sample, the estimation is limited to science-based invention activity (Table 17.2). The estimation encompasses four sub-models, agglomeration and knowledge networks, past performance and a combined agglomeration and knowledge network model. A detailed description of the model indicators is provided in Appendix 1, and model diagnostics like VIF and heteroscedasticity are available in Stek (2020), which shows that the diagnostics are within accepted boundaries.

The agglomeration model consists of two scale-based indicators (cluster size and adjacent clusters), a specialization-based indicator and an indicator which describes the presence of corporate R&D. The partial model's predictive power is quite modest (0.19). Both scale-based indicators are statistically significant, however, adjacent clusters has a negative association with invention activity. Accordingly, clusters tend to benefit from agglomeration economies while invention in adjacent clusters has a negative influence, potentially connected to competition or short in resources (knowledge) as many small clusters have emerged. In addition, the specialization indicator is positively associated with cluster invention performance and it is significant. The benefits of specialization may among others include availability of more scientifically advanced knowledge and stronger expertise in the labour market. Next, the extent in which private sector companies are involved (as owners of patents) is positive but not significant.

The knowledge network part of the model encompasses two indicators on knowledge inflow and knowledge outflow and two indicators related to the cluster's position in knowledge networks (degree centrality) (Appendix 1). The knowledge flow indicators are calculated using the inventor-assignee network between clusters which are typically embedded within MNCs, with an outbound link indicating knowledge outflow (from a remote lab in the cluster to headquarters elsewhere) and an inbound link indicating inflow (from a remote lab elsewhere to headquarters in the cluster). Further, the centrality indicators are calculated using the co-invention network, and they provide insight into the number of other (different) sustainable energy clusters with which a cluster is connected (simple degree centrality), indicating network diversity. The average number of co-invention links per inventor (weighted degree centrality) is a measure of the size of the co-invention network relative to the size of the cluster. The predictive power of the network model is rather weak (0.054) and also below that of the agglomeration model. This suggests that proximity in more basic scientific research activity, like in advanced material science, photonics, advanced aerodynamics, etc. still matters and that networking outside the cluster is of minor importance at this stage. In detail, two indicators are statistically significant. Knowledge outflow is negatively associated with cluster invention performance. A possible explanation is the phenomenon of 'reverse knowledge flow', in which locally produced MNC knowledge flows out to a large extent and corporation-controlled remote labs are less connected to the local cluster (Ambos et al. 2006; Frost and Zhou 2005). In addition, the weighted degree centrality is positively associated with cluster invention performance, suggesting that other forms of research collaboration (non-MNC) tend to strengthen local linkages and knowledge spillovers.

As a final step, we explored a combined agglomeration and network model (deleting those indicators evidencing multicollinearity). The result is an overall strength of 0.249 which is almost similar to that of the path dependence factor (0.271). We need to mention that it is difficult to read strength of the relationship between path dependence and invention performance without results from comparable studies, but it seems plausible that due to dynamic changes in location patterns and needs of sustainable energy research, the relationship has remained rather weak.

In sum, our results indicate that invention activity in sustainable energy technology has remained concentrated in large cities (clusters) in the past years, be-it with a substantial shift to a large number of smaller clusters and that agglomeration factors play a weak or modest role, however, more in single large cities and less in extended metropolitan areas. Network factors tend to be less important, including somewhat contradictory influences of newly created knowledge that is leaving clusters through

MNCs' internal flows and knowledge collaboration outside MNCs' internal networks.

17.4 Market Introduction of Sustainable Energy Inventions

17.4.1 Introduction

In this section we pay attention to the entrepreneurial side, namely development and market introduction of inventions by specific young firms, i.e. university spin-offs. We address the following question: to what extent is (early) market introduction concentrated in large cities (clusters) and in which ways are strategic choices in market introduction related to advantages of agglomeration and networking in large cities? University spin-off firms are defined as independent ventures established by graduates or university staff with the mission to bring novel university knowledge to market (some definitions are limited to only patented knowledge). Compared to other start-ups, university spin-offs lack market knowledge and practical skills in management and marketing but they enjoy more benefits from university support, not only concerning technology but also important additional knowledge and networks (Pirnay et al. 2003; Shane 2004; Van Geenhuizen and Soetanto 2009). We need to mention that in general market introduction is not only achieved through spin-off firms, but also through channels like collaborative research projects between university and large firms and licensing to firms (Taheri and van Geenhuizen 2016).

The empirical study draws on the population of university spin-off firms active in energy sustainability in the Nordic countries and The Netherlands, and on a selected sub-sample (Nejabat and Van Geenhuizen 2019). Selecting the northwest 'corner' of Europe is justified given the innovation profiles on the country level that are relatively strong compared to other EU countries; this with the exception of Norway and also The Netherlands in the past 10–15 years, given the end of the observation period in 2018 (Fagerberg and Fosaas 2014). A focus on Denmark, Finland, and Sweden, facing relatively favourable opportunities, enables us to 'picture' in more detail later stages following market introduction, not mainly early failure. Data on market introduction of sustainability inventions in above five countries were collected retrospectively for the years 2000–2018 using a multiple source approach, including face-to-face and/or telephone interview, questioning by email, web-site information, and other sources, like branch journals and reports of financial investors, etc.

17.4.2 Market Introduction, Strategic Choice and Role of Cities

Addressing market introduction of sustainable energy products, processes, etc. by university spin-off firms is rather new, and conforms to an overall weak attention to firm-specific factors and urban agglomeration conditions (Bjørnali and Ellingsen 2014; Pacheco et al. 2017; Triguero et al. 2013). Taking a firm's perspective, market introduction is connected to several strategic choices which are summarized in entrepreneurial orientation (EO) of a firm, as a posture that reflects innovativeness, risk-taking, pro-activeness, and competitive aggressiveness, etc. (Covin and Lumpkin 2011; Lumpkin and Dess 1996; Shan et al. 2016). The choices involved include the energy technology itself (some solutions have already been accepted in the market, while others face fierce resistance) (IEA 2018); the strategy archetype including first mover, followers, etc. coming with different opportunities but also risks (e.g. Lieberman and Montgomery 1998) and product/market focus or diversification and related choices in avoiding the risk of the 'valley of death' (Auerswald and Branscomp 2003); all of them reflected in practical business models and plans (Mohr et al. 2013; Roper and Tapinos 2016; Teece and Leih 2016). In the context of risk-taking and learning, we also use the competence-based view. This view posits that owning competence to better use resources, including identifying needs for new resources and how to acquire them with the risks involved, may increase competitiveness of firms and enhance a shorter time to market (Barney and Clark 2007; Rasmussen et al. 2014).

Market introduction is measured as 'reported first sales', eventually including a launching customer. We observe market introduction among 61% of the spin-off firms, and this market introduction is more often reached in the largest city and adjacent area compared to small cities, as indicated by 67 versus 53% (Table 17.3). The *p*-value suggests a weak trend of market introduction being favoured by advantages in large city areas.

If we zoom in on firm age at market introduction, we observe that most market introduction takes place at early age of the spin-off firms, a majority of almost 70% (Table 17.4) (Nejabat and Van Geenhuizen 2019). Regarding time to market introduction, we may assume that in large cities with abundant diversity in knowledge and advanced levels of specialization, market introduction is at earlier age of spin-offs compared to smaller cities and towns (e.g. Duranton and Puga 2001). Our results, however, suggest an opposing pattern, as indicated by a share of 63% of early market introduction in large cities, compared with 76% outside large cities (though without significance and drawing on a small sub-sample) (Table 17.4). This

Table 17.3 Market introduction (MI) of sustainable energy inventions over type of cities

Type of city	Success in MI	Failure in MI	Total
Large cities	41 (67.2%)	20 (32.8%)	61 (100%)
Small cities	25 (53.2%)	22 (46.8%)	47 (100%)
Total	66 (61.1%)	42 (38.9%)	108 (100%)

p-value: 0.13

Table 17.4 Firm age at market introduction (MI) over type of city

Type of city	Early MI (age 0–5)	Late MI (Age > 5)	All firms
Large cities	26 (63.4)	15 (36.6%)	41 (100%)
Small cities	19 (76%)	6 (24%)	25 (100%)
Total	45 (68.2%)	21 (31.8%)	66 (100%)

p-value: 0.28

opposing pattern could indicate that for certain energy technologies which require specific natural land sites for developing and testing, like windy hills and coastal sites (river mouths), but also huge wood-covered areas, etc., favourable laboratory environments and outdoor experimentation have been created in the nearest university town, like in Trondheim, Norway, a few rural areas in Denmark, like Odense, and in Finland, Lappeenranta. However, the pattern could also indicate an *ambiguous trend* among spin-offs in large cities in which they more often take up investigation of fundamental solutions and advanced technologies (in fact being stronger innovative and risk-taking) but these choices require more years of development and experimentation. As examples, we mention advanced materials research to improve conversion efficiency of solar cells, new membranes for use in upgrading in gasification, and completely new sources of biomass.

In order to gain deeper understanding of factors connected to market introduction and risks taken, we consciously composed (theoretical sampling) a small sample ($n = 37$) to perform rough-set analysis and identify meaningful types of spin-off firms given the ‘dependent’ variable’ (decision attribute) of positive development or problematic (risky) development, the latter referring to substantially later market introduction or no introduction at all. We collected details on strategic choices, network building with diverse partners and access to financial capital (qualitative data), etc., as explained in Appendix 2.

We applied rough-set analysis to the selected sample (Pawlak 1991; Polkowski and Skowron 1998) for the following reasons. In contrast to traditional regression analysis, small samples can produce acceptable results (however, without statistical generalization), no assumption is made about a normal distribution of the data, and no emphasis is put on linear and cumulative ways of thinking. Instead, causal relations may be indicated by multiple interaction effects as expressed as combinations of conditions (rules) (Fiss 2011). The procedure is stepwise and works through attribute reduction, i.e. finding a smaller set of condition attributes with the same or close classificatory power as the original set of attributes. The analysis composes *decision rules* that are presented in an ‘IF condition(s) THEN decision’ format. Rough-set analysis is increasingly recognized in literature as a useful classificatory method, including elements of causal relations (e.g. Dimitras et al. 1999; Nijkamp et al. 2002; Taheri and van Geenhuizen 2016).

We discuss the two strongest decision rules, first the ones concerning a positive development in the past 10 years (Nejabat and Van Geenhuizen 2019) (Table 17.5):

- Rule 1 indicates that the combination of operating in an Innovation Leader country (at the time Denmark, Finland, Sweden) and employing multiple

Table 17.5 Rules on bringing sustainable energy inventions to market ($n = 37$)

	Rules as combinations of condition attributes	Decision attribute[a]	Coverage[b]	Strength %[c]
Positive development				
1	Country (innovation leader, e.g. Sweden) & employing multiple networks	Positive	11	50.0
2	Practical competence (MSc) and gaining investment capital	Positive	7	31.8
Problematic/risky development				
1	Energy technology (solar PV) and employing a single network and strategy archetype (follower)	Risky/ problematic	7	46.7
2	Country (Norway) and maintained focus and scientific competence (PhD)	Risky/ problematic	4	26.7

Source: Adapted from Nejabat and Van Geenhuizen (2019)
[a]Similar to dependent variable
[b]Absolute number of cases covered by a rule
[c]Strength: share of such cases in all cases with the same value of the 'dependent' variable

collaboration networks, makes a positive development towards the market very likely, at strength of 50%.

- Similar, but weaker (at a strength of 32%), Rule 2 indicates that the combination of mainly Master level as highest founder education (practical orientation) and gaining of substantial investment capital, makes a positive development to market likely.

With regard to a problematic development, the two strongest rules are as follows:

- Regarding Rule 1, the combination of solar PV technology, a poor collaboration network and acting as follower, makes a problematic development likely, at strength of 47.5%. The rule means that despite taking smaller risks (as follower) strong network collaboration is required in bringing solar solutions to market, and this refers to (price) competition by Chinese solar cell producers emerging since the early 2000s.
- Rule 2 is less strong, at 27%, and indicates that spin-offs in Norway that employ high scientific skills (PhD) and maintain focus on the invention, are likely to develop in a problematic way. This rule suggests problematic risks of continuing basic research and scientific orientation, and neglecting closer interaction with the market. Such spin-offs may face the 'valley of death' or have gained substantial investment capital at unfavourable conditions (short refunding period).

We summarize the previous results as follows in view of what type of advantages large cities may provide. The strongest rules on positive development inform us about relevance of facilitating building of multiple networks (rich composition of stakeholders) and networks of financial investors in a multi-level situation where also the country level (NIS) counts.

In a final step we connect previous understandings by addressing which strategic choices and competence situations among university spin-of firms are facilitated in

Table 17.6 Tentative city-size advantages for spin-offs' strategic choice and competence

		Relative advantages	
		Large cities	Small ones
Strategic choice	– Scientific orientation and involved in advanced/ basic technology	+[a]	–
	– Involved in technology connected to local land/sea site assets (coastal currents, wind, etc.)	–	+
	– Acting as first mover, coming with high risks, including failure	+[a]	–
	– Involved in highly specialized solutions (need for early internationalization)	+[a]	–
	– Multiple networking, specifically with regard to financial investment and signalling constraints	+	+
Competence	– 'Easy-going' mentality in a 'creative milieu'	+[a]	–

[a]Often not known how risks are eventually mitigated

large cities and which in smaller cities. The tentative picture that arises is the following (Table 17.6). A larger scale and potentials of specialization in an overall information-rich environment in large cities enable young firms to adopt more risky strategies, like being engaged in fundamental/basic technology, acting as first mover and creating a new market, targeting small specialized markets requiring internationalization from start, and with regard to competences, an 'easy-going' mentality in firm foundation, etc. Concomitant risks tend to be severe, but most probably cannot be quickly mitigated in large cities, despite generic advantages of enabling multiple networking locally, including financial investment and signalling constraints, e.g. from regulation and emerging competition. In contrast, a part of small cities enables to develop specialization connected to natural endowment of the nearby region with sustainable energy resources (wind, current water, wood, oil/gas), while external networks tend to compensate lack of local networks facilitating quick market introduction. According to these trends, our results conform to ambiguity about the role of large cities in (speed of) market introduction.

17.5 Final Remarks

We have addressed the question as to what extent innovation in sustainable energy is concentrated in large cities (clusters) and how its performance is connected to agglomeration and network factors and concomitant entrepreneurial advantages, given different presence of path dependence. Our results on invention activity and bringing inventions to market, indeed indicate importance of large cities for sustainable energy invention, be-it in an increasing number of *smaller* large cities, but also weak importance of large cities in market introduction. The pattern suggests *low* *path dependence*, pointing to quickly changing location qualities and networks in a period of rapid technological change and emergence of new clusters. In more detail, with regard to time to market introduction, we observed a weak trend of more often *early* market introduction in small cities. These preliminary outcomes, (somewhat) contradicting agglomeration advantages, may be connected with specificities of sustainable energy sources as being partially land-based and seashore-based and consequently exploited outside large cities in research in small (university) towns. In addition, large cities provide opportunities for highly creative and scientific inventions and bringing them to market by young firms, however, with market introduction taking a longer time, compared to more practical inventions in smaller cities.

The limitations faced in our study call for further research. First, the results have been derived from sustainable energy technology, while *other technologies* may be less connected to characteristics of specific landscapes and coastal sites, producing other results on the role of large and small cities. Secondly, the methodologies used (quantitative and qualitative modelling) and the explorative character of the underlying studies call for developing larger databases that enable a rigorous testing and extending of the results, thereby taking advantage of complementarity of quantitative and qualitative research. And finally, there is a need to investigate the ways in which entrepreneurial risks connected to higher levels of innovativeness in large cities are mitigated, e.g. through training programmes in incubators or accelerators.

Appendix 1: Measurement and OLS Model Indicators after Transformation (*n* Clusters = 103)

Indicator	Measured as	Min	Mean	Max
Dependent variable				
Invention performance	Citations per inventor 2008–2011	−2.3	−0.68	2.6
Independent variables				
Agglomeration				
Cluster size (log)	Number of patents	−0.35	1.7	6.3
Size adjacent clusters (log)	Patents outside main cluster within 0–200 km from this cluster	−2.3	2.6	8.6
Specialization (log)	Sustainable energy patent share in all patents	−9.5	−6.4	−2.0
Corporate R&D	Corporate patent share in all sustainable energy patents	Nil	0.87	1.0
Knowledge networks				
Inbound flow	Assignee-inventor links per inventor, e.g. from MNC remote lab toward headquarter in cluster	Nil	0.61	6.7
Outbound flow	Inventor-assignee links per inventor, e.g. from MNC remote lab in cluster toward headquarter elsewhere	Nil	0.52	2.2

(continued)

Indicator	Measured as	Min	Mean	Max
Simple degree centrality	Co-invention network, total number of connections to different (unique) clusters	−2.3	1.7	3.6
Weighted degree centrality	Co-invention network, number of connections to other clusters per inventor	−2.3	−1.1	0.90
Past invention performance	Citations per inventor 2004–2007	−2.3	−0.20	2.5

All data are drawn from scientometric sources

Appendix 2: Measurement and Descriptive Results of Selected Sample in Rough-Set Analysis (n = 37)

Variables	Attributes' share
Condition attributes ('independent' variables)	
Strategic choice	
Energy technology	Solar: 35.1%; wind: 18.9%; other (biofuels, fuel cells, combination, etc.): 27.0%; automotive: 18.9%
Value creation	Core (fundamentals) of energy technology: 67.6% Additional application of technology: 32.4%
Strategy archetype	First mover: 35.1% Otherwise (follower/customer intimate): 64.9%
Diversification/focus	Diversification: 27.0%; focus: 73.0%
Competence	
Market/business experience	Business experience: 56.7%; no business experience: 43.3%
Technical/practical competence	PhD: 70.3%; only master: 29.7%
Interaction in entrepreneurial ecosystems	
Developing networks	Multiple: 54.1%; otherwise (no/one-sided): 45.9%
Accessing investment capital	No: 54.0%; yes: 46.0%
Countries' profile in innovation	Finland, Denmark, Sweden (innovation leaders): 43.2% Norway (innovation follower): 18.9% Netherlands (innovation follower): 37.8%
Decision attribute ('dependent' variable)	
Development in bringing inventions to market	Positive: 59.5%; problematic: 40.5%

Source: Adapted from Nejabat and van Geenhuizen (2019)

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Chapter 18
Are CO_2 Emission Targets of C40 Cities Realistic in View of Their Mayoral Powers Regarding Climate Policy?

Martina Siskova and Jeroen van den Bergh

Abstract We evaluate the level of cities' ambition regarding CO_2 emission targets and implementation of climate policies, and factors explaining this. Our empirical analysis explores a dataset for a subset of C40 cities. The reason for studying these cities is that they supposedly are at the forefront of mitigation action. For example, they were the first to disclose their self-imposed emission targets. We determine the targeted future emission levels based on the targeted reduction from the baseline emissions. We calculate these for discrete 10-year periods: 2020, 2030, 2040 and 2050. Next, we contrast the resulting emission levels with those in the base year 2015. In addition, we study how distinct explanatory variables, notably mayoral powers regarding climate policy, city characteristics and geographical location affect target emission levels.

Keywords Climate policies · Cities · CO_2 emission targets · C40 cities · Policy stringency · Urban policy

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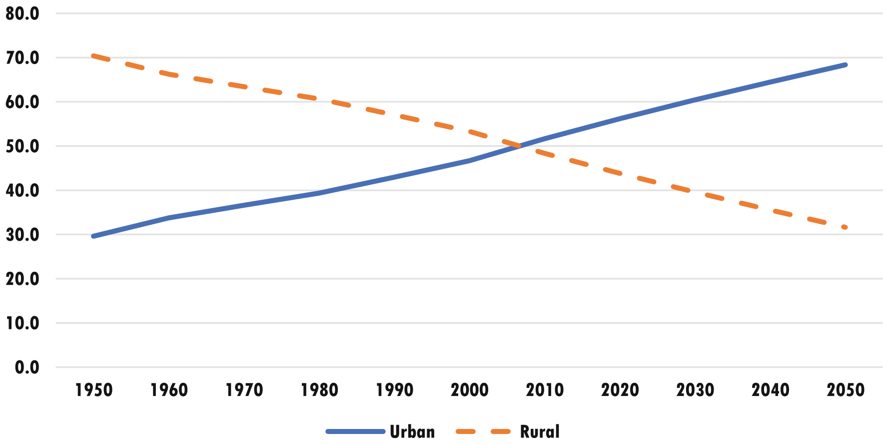

Fig. 18.1 Past and predicted urban and rural population shares between 1950 and 2050 (Source: OWID, based on UN World Urbanization Prospects 2018 and historical sources)

18.1 Introduction

In the last decade, cities have moved to the forefront of policy debates about effectively combating climate change through reducing greenhouse gas emissions. Currently, about 4.2 billion of the world's population (55%) reside in urban areas, a tremendous increase from 0.75 (29%) in 1950 (United Nations 2018). World population is expected, according to the most likely scenario, to grow from 7.7 billion in 2019 to 8.5 billion in 2030 and to 9.7 billion in 2050, while much higher projections are available too (United Nations 2019). Figure 18.1 depicts the trend in population shares of rural and urban populations since the 1950 and projected until 2050.

According to the UN World Urbanization Prospects 2018, a settlement is considered urban if it is inhabited by at least 30,000 people. However, the definition of an urban settlement varies among countries, which may result in inconsistent reporting and complications for comparing nations. For instance, in Denmark, Greenland, Iceland and Sweden a locality is considered urban if 200 or more inhabitants live there. Conversely, in Japan, it requires the number of inhabitants to exceed 50,000. The second highest threshold to define urban is set by Mali, namely 30,000 inhabitants, followed by a threshold of 20,000 in the Netherlands, Nigeria and Syria. This diversity of thresholds is summarized in Fig. 18.2. It complicates comparison and representative samples of cities worldwide. Any results for city studies in this respect have to be taken with a grain of salt.

The economic activities and household consumption conducted within city boundaries account for about 70% of global CO_2 emissions, while using about 78% of the world's energy (UN Habitat 2011). The relationship between emissions and urbanization was extensively covered in the literature (e.g. Arnott (2004), Borck and Pflueger (2019), Cavailhès et al. (2007), Gaigne et al. (2012), Lucas and Rossi-

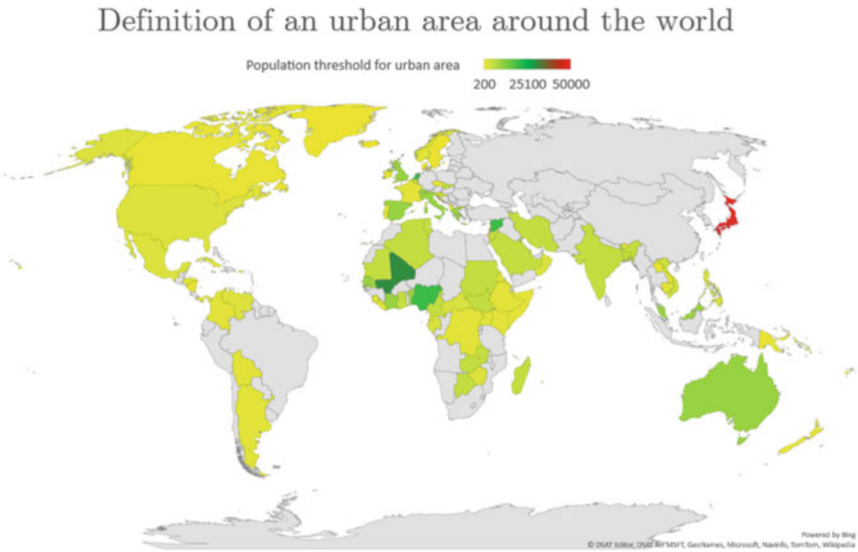

Fig. 18.2 Population threshold to define an urban area (own figure; Data from UN World Urbanization Prospects 2018)

Hansberg (2002), Kyriakopoulou and Xepapadeas (2013, 2017), Regnier and Legras (2018), Rossi-Hansberg (2005), Schindlera et al. (2017), Verhoef and Nijkamp (2002, 2003), Xepapadeas (2005), etc.). Given projected population growth in cities, as well as economic growth in developing countries where most of future urbanization will happen, the emissions created within the city boundary are expected to rise with future urbanization (Seto et al. 2014). However, not all the emissions created within the city boundary or by the people living in the cities are controlled by urban climate policies. The reason is that cities have limited control over environmentally relevant decisions by businesses (e.g. energy use and pollution abatement by industries) and households (e.g. car ownership and miles driven, purchase and use of energy-using equipment), as well as over fossil fuel prices and electricity generation.

Nevertheless, in order to mitigate climate change, many cities have begun to implement new climate policies. In order to account for their progress, these cities set their future emission targets. In addition, some cities have joined networks and coalitions, such as C40 Cities Climate Leadership Group (henceforth C40), Local Governments for Sustainability (ICLEI) or the Covenant of Mayors, in order to share experiences and learn from each other. Several studies have examined emission targets at city level. Liu et al. (2018) study the efficient distribution of carbon emissions reduction targets of Chinese cities. They suggest that emission targets which are being allocated to individual cities should not be assigned according to the cities' GDP as is the current practice, but instead more ambitious emission targets should be assigned to cities with greater emission abatement and financial capacities. Zhang et al. (2019) model the time of peak CO_2 emissions for Baoding—a city which is designated to be a pilot for Chinese low-carbon cities and associate sectoral transitions. They find that the emission structure of this city's emissions is composed primarily of industrial emissions (80%) which have been driven by the consistent economic growth and energy intensity. Population growth was concluded to have little contributions to emission increase. According to their estimates, the city's peak emissions (54 million tons of CO_2) will be reached in 2024 and the estimated emissions for 2040 were 80.18 million tons of CO_2. A study by Kuramochi et al. (2017) analyses the impact of U.S. sub-national and non-state actions on national greenhouse gases (henceforth GHGs). The authors show that by following the sub-national and non-state commitments, GHG emissions can be reduced to 12–14% below 2005 level by 2025. However, in their estimates they assume all of the commitments to be implemented and fully exercised, which is a rather strong assumption given that they are voluntary. ICLEI (2015) discusses the policies and results of actions which were implemented in four U.S. cities—Atlanta, Cincinnati, Minneapolis and Portland. Though the actions here are relevant, the common issue in all was how to integrate their efforts and policies with other governmental bodies as the powers of municipalities to reduce greenhouse gas (GHG) emissions are limited.

In this chapter we assess emission targets and how these relate to city features and mayoral powers. Prior to the actual analysis we normalize future emission targets by expressing them as percentages of change relative to a common baseline for each city. Despite numerous reports on emission targets, exact levels often remain unclear. This is due to discrepancies among cities' baselines. It is difficult to immediately associate the emission targets based on past emissions with current emissions since they might differ greatly. For instance, a 40% reduction from 1990 levels may represent only 10% in 2015 levels. These discrepancies in baseline settings are partly summarized in UNEP (2018) and Bansard et al. (2017).

Furthermore, in order for national and sub-national governments to combat climate change, it is vital that their emission targets are set below the estimated business-as-usual (BAU) levels. BAU emissions are by definition insufficient to offset climate change, as BAU represents the scenario without climate mitigation policies being implemented. The relevance of BAU, New policies and The Sustainable Development scenarios is depicted in WEO (2019) under the "World primary energy demand and energy-related CO_2 emissions by scenario". According to these estimates, "New Policies", representing the policies that are implemented, leading to fewer emissions in comparison to BAU. However, "New Policies" far exceed the emissions from the desirable "Sustainable Development" scenario.

Henceforth, we wish to explore why some cities are more ambitious in their future emission targets than others. We focus on cities from the C40 group, which are considered to be at the forefront among cities in terms of climate change policies. We investigate whether cities adapt their emission targets for the future according to their mayoral powers (ARUP 2015). In other words, we want to assess if the two are consistent. If not, then the targets may be unrealistic and impossible to achieve. The reason for us to focus on emission targets rather than current levels of emissions is that we expect the impact of current policies to be reflected with some time lag. Our hypothesis is that levels of mayoral powers today are reflected in level of ambition regarding future emission targets.

18.2 Stylized Facts

In this section we explain the terminology and concepts used throughout the chapter as well as provide some further details regarding the trends found in our dataset.

18.2.1 Mayoral Powers

We use the term mayoral powers, used by C40 cities, to denote the jurisdictional opportunities and legislative capabilities of a city to enforce environmental actions in distinct sectors. The data originate from a survey among C40 cities on Mayoral Powers (ARUP 2015). Here cities stated the type and extent of their power over various climate policies. The survey categorized these into the following four dimensions: (a) own or operate, (b) set or enforce policy/regulations, (c) control budget and (d) set vision. Each of these dimensions covers nine distinct sectors within every city, where discrete performance scores range from 0 to 3. A score of 0 implies no power, 1 implies very limited power; 1–2 represents partial power and a score of 2–3 indicates strong power over the respective emission-producing sector. In our estimates we use the average values of each of the mayoral power categories over all sectors. The emission-producing sectors included in the analysis as defined in the data collection of the C40 cities are the following nine:

[1]Private buildings	Finance and economy	Urban land use
Public buildings	Public transport	Waste
Energy supply	City roads	Water

Here we first examine whether emission targets depend on the mayoral powers. If mayoral powers were to have no impact on the emission targets, then this would imply that cities' targets could be decoupled from actual policies. In this case targets could easily be too ambitious given the policies in place. We normalize the mayoral powers in our sample using a logarithmic transformation, which will also be used in our regressions. Among the cities included, Melbourne was the smallest with a value of 0.48, as depicted in Fig. 18.3. On the contrary, Heidelberg has the highest average mayoral power with value of 1.01, followed by Los Angeles (0.97) and New York (0.94). Heidelberg has employed various policies over the past decades to promote low-carbon options, including the use of electric trams and electric railways, the use of bicycle transport and a subsidy for electric vehicles. The most significant urban policy includes a city district called Bahnstadt—an old freight yard turned into a new city district for jobs and living. It is considered an exemplary case of sustainable

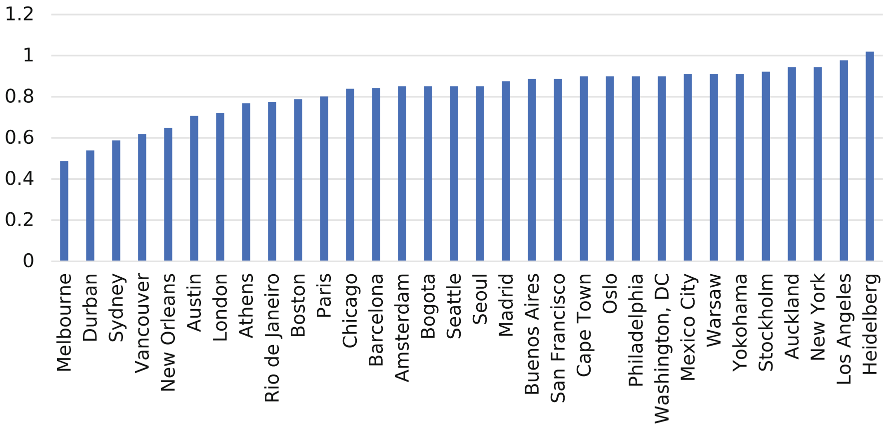

Fig. 18.3 Average mayoral powers normalized by the mean and ranked

urban construction, making use of high energy-efficient buildings and sustainable energy supply (C40 2019). Los Angeles is also pro-active in terms of climate policy, making use of rebates for more energy- and water-efficient appliances, such as washers, providing free resources such as trees for households, and undertaking projects studying efficient water use and sanitation projects (LA City 2020).

18.2.2 Correlations of Emission Targets with City Features

Cities included in our analysis, in terms of population size (accounting for population residing within the city boundary and not its metropolitan area), fall into the following three categories: below two million, two to four million and above four million inhabitants. The cities included represent all different continents. This is displayed in Fig. 18.4. The smallest city included is Melbourne and the largest is Seoul.

We calculated the emissions targets for years 2020, 2030, 2040 and 2050, for which these cities reported (fully or partly) their commitments. Given the inconsistency of target years in the reports, we estimate emissions directly, either by using the emission baseline and targeted reduction, or by a proxy based on an average of two emission target or a target and baseline emissions.[1] This results in normalized emission targets that are comparable among all cities. They are depicted in Table 18.1. Emissions calculated directly from targets are highlighted in grey. The remaining estimates were based on proxies, assuming a linear relationship between baseline emissions and target emissions. Zero values in the table represent a city's ambition to become a city with zero net emissions by that year (e.g. Melbourne). On

[1]Table 18.5 in Appendix presents the complete data used to obtain these estimates.

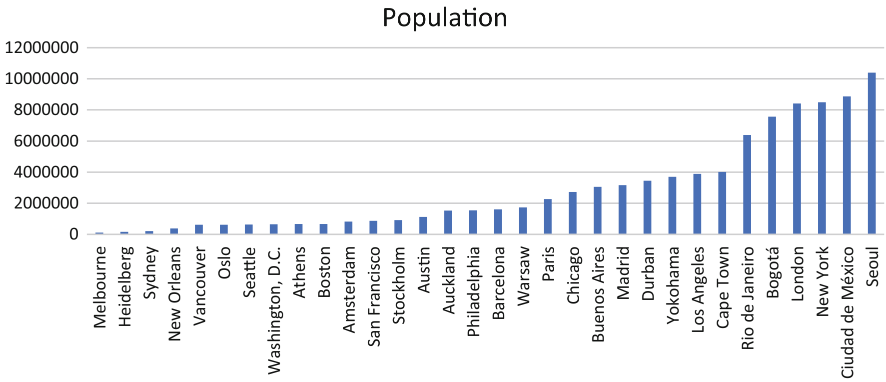

Fig. 18.4 Cities included in our study ordered by population size for the year 2015

Table 18.1 Target emission levels for years 2020, 2030, 2040 and 2050 and emission in 2015 as a reference

City	2015	2020	2030	2040	2050
Amsterdam	4471000	3100500	1860300	1033500	206700
Athens	4711576	4147141.33	3041424	1935706.67	829989.333
Auckland	11309000	8002800	6669000	5335200	4446000
Austin	15200000	13057859.5	9173578.63	5289297.71	1405016.8
Barcelona	3433000	3323460	2608859	1894258	1179657
Bogotá	13217521	15465314.1	12372251.3	9279188.46	6186125.64
Boston	6900000	5512701	3675134	1837567	0
Buenos Aires	19667128	13230000	12,742,478	12,254,956	11,767,434
Cape Town	22683041	18,798,711	14893569	13282888.1	11672207.2
Chicago	33500000	24225000	18303333.3	12381666.7	6460000
Durban	22587081	16167499	11364696.7	7988640.15	5615492.69
Heidelberg	806000	697392.857	480178.571	262964.286	45750
London	40750490	29510000	16218000	12614000	9010000
Los Angeles	29024807	29350000	25650000	18000000	10800000
Madrid	10257048	8885900	7771800	6797384.08	5945138.89
Melbourne	5805437	0	0	0	0
Mexico City	24084942	29409567	36038443	44161458.5	54115390.5
New Orleans	4600000	3201549.75	1803099.5	1015498.14	571924.326
New York	50692754	46212000	36636000	24424000	12212000
Oslo	1298000	600000	60000	30000	0
Paris	5195663	4694571.75	3755657.4	2660257.33	1564857.25
Philadelphia	19212870	17084200.6	12977410	8595427.39	4213444.8
Rio de Janeiro	20268045	9121744	4160310.68	1897464.45	865409.248
San Francisco	4574578	4418888.5	3225013.6	2232702	1240389.8
Seattle	3171000	2652453.33	1557360	778680	0
Seoul	48550952	42555666.7	29667000	20681872.9	14418035.7
Stockholm	2511000	2000000	1500000	0	0
Sydney	5052256	3992000	1776000	790124.248	351518.203
Vancouver	2625609	1879350	1358444.78	981920.459	709758.544
Warsaw	12706696	10362387.2	8259928.34	6584044.29	5248185.87
Washington DC	8204579	3367298.33	2244865.56	1122432.78	0
Yokohama	21000000	16413600	14850400	9379200	3908000

Note: The highlighted (grey) values represent the stated emission targets set by cities and the non-highlighted numbers are estimates based on stated targets and baseline emissions (see text for explanation)

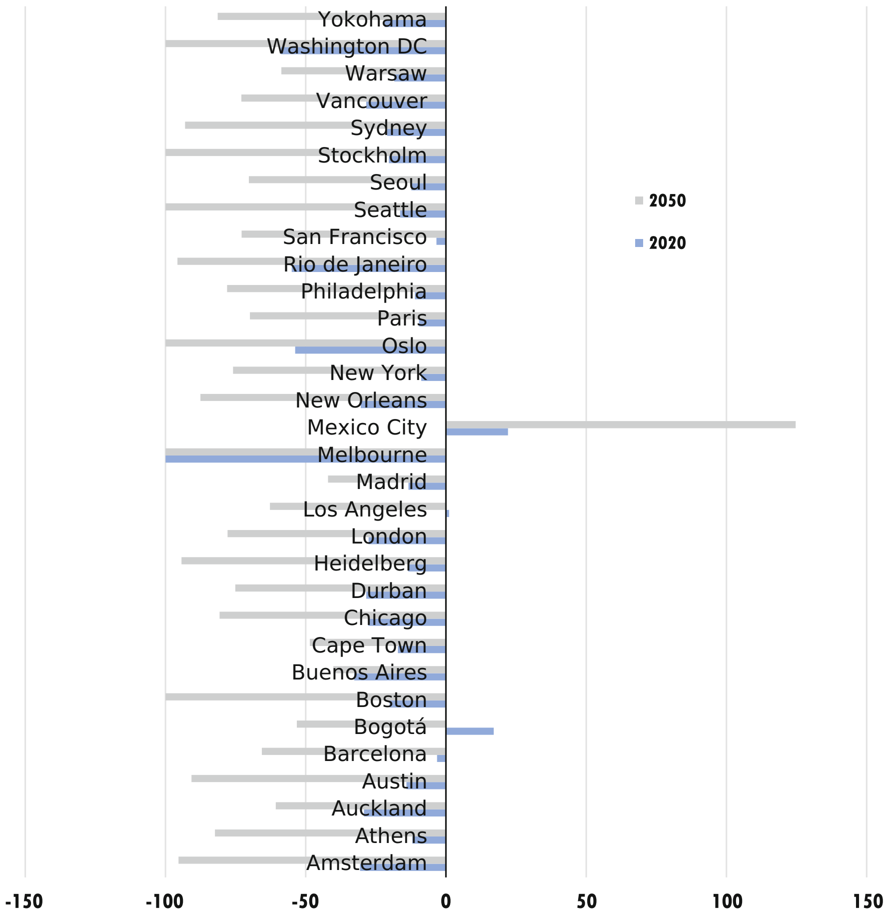

Fig. 18.5 Emission targets for years 2020 (blue) and 2050 (grey) compared to 2015 (baseline) emissions

the other hand, some cities are far less ambitious with their targets, setting them very close to their expected business-as-usual values, such as Mexico City. Furthermore, some cities increase the ambition of their emission target over time, such as Heidelberg, while others remain close to their 2020 levels even in 2050, such as Buenos Aires.

Figure 18.5 depicts the emission targets (%) for 2020 (blue) and 2050 (grey) in contrast to the 2015 baseline. In both, Mexico City has the highest emission targets, which is consistent with the fact that only a small deviation from its BAU scenario is expected. Bogota is also not very ambitious. On the other hand, cities such as Boston, Oslo, Seattle and Stockholm are ambitious and intend to reduce emissions by 100% by the year of 2050. Melbourne wants to accomplish this goal by 2020 already.

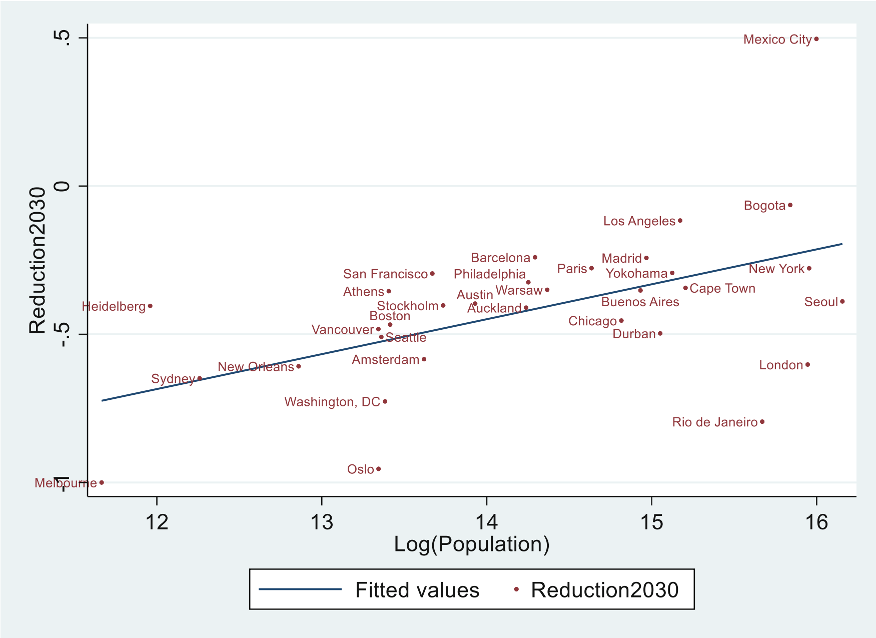

Fig. 18.6 Correlations between population size and emission targets for 2030

Figure 18.6 depicts the correlation between emission targets (%) and logarithmic transformation of population size. The relationship's trend is upward sloping, implying that with the increase in population size, the emission targets become less ambitious (due to higher emission targets).

Figure 18.7 displays the relationship between the logarithmic transformation of GDP per capita and emission targets (%) for 2030. The downward sloping trend indicates that the greater the per capita GDP is, the higher is the reduction of emissions (%) which are being targeted. Henceforth, cities which are more ambitious in their targets tend to have a higher per capita GDP.

Figure 18.8 is the visual representation of the average mayoral powers and emission targets (%) for 2030. As we may observe, the relationship demonstrates that the greater the average mayoral power, the greater the emission targets and hence the lower the city ambition.

18.3 Database and Estimation Strategy

In this section we aim to provide insight about how emission targets relate to city attributes and mayoral powers. The database we have constructed consists of 32 C40 cities that have defined emission targets for coming decades. The data on variables such as emission targets, current emission levels, population and GDP was accessed

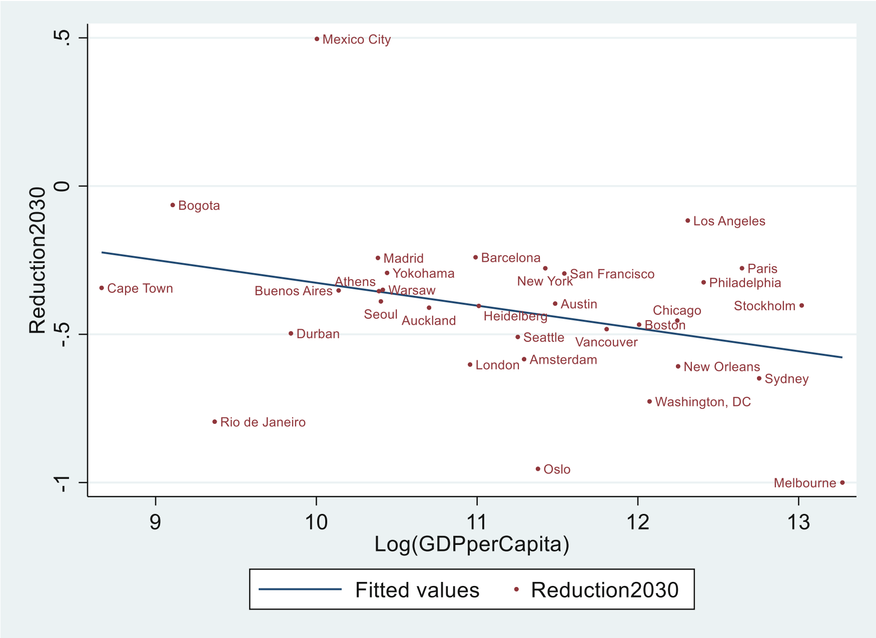

Fig. 18.7 Correlation between GDP per capita and emission targets for 2030

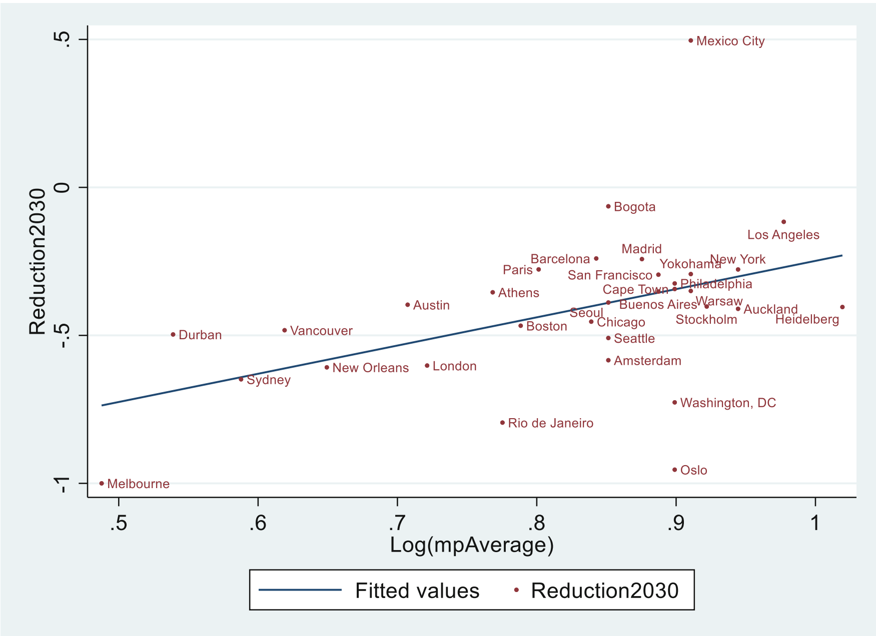

Fig. 18.8 Correlation between average mayoral powers and emission targets for 2030

Table 18.2 Descriptive statistics

Variable	Mean	Std. dev.	Min	Max
Reduction2020	−0.2185	0.22455	−1	0.22108
Reduction2030	−0.4176	0.26942	−1	0.49631
Reduction2040	−0.5864	0.32246	−1	0.83357
Reduction2050	−0.7192	0.40023	−1	1.24686
Log(Population)	14.2678	1.20703	11.6651	16.1562
Log(GdpCap)	11.1867	1.15284	8.66389	13.2725
Log(mpOwn)	0.84513	0.14813	0.55962	1.0116
Log(mpSetEnforce)	0.86954	0.15409	0.53063	1.06471
Log(mpBudget)	0.76871	0.14987	0.36772	0.98083
Log(mpSetVision)	0.79512	0.15057	0.44183	1.06087
Log(mpAverage)	0.82243	0.12869	0.4877	1.01936
Africa	0.0625	0.24593	0	1
LatinAmerica	0.125	0.33601	0	1
AsiaOceania	0.15625	0.3689	0	1
Europe	0.3125	0.47093	0	1

through the CDP database on C40 cities (CDP 2019a, b, c, d, e, f) and complemented by data on cities' emission targets from Yokohama (2019) and Buenos Aires (2019). Data on mayoral powers was accessed through the official C40 website (C40 2019). The descriptive statistics of data for the 32 cities used in our analysis is depicted in Table 18.2.

We aim to determine the impact of city attributes and mayoral powers on emission targets by accounting for multiple factors simultaneously. To this end, we use a quantile regression, using bootstrap repetition of 100 to correct for the small sample size.[2] The advantage of using a quantile regression is that its coefficients are fitted to the median and not the mean of the distribution, allowing for inclusion of outliers without distorting the results. Furthermore, this approach also allows us to analyse how different parts of the distribution behave, by dividing the distribution into quantiles. This enables us to estimate coefficients of the independent variable for distinct parts of the distribution. This approach considers that distinct parts of the distribution may behave differently. We test for each type of mayoral powers (own and operate, set or enforce policy/regulations, control budget, set vision) separately and we also run one regression including an overall average of mayoral powers. The regression specification used to arrive at estimates is based on the minimization problem as formulated in Eq. (18.1):

[2]Because of extensive computational time required for estimates, we resorted to using bootstrap of 100, which is sufficiently high to improve confidence intervals.

$$\min_{\beta \in R^k} \left[\sum_{i \in \{i: y_i \geq x_i'\beta\}} \theta |y_i - x_i'\beta| + \sum_{i \in \{i: y_i < x_i'\beta\}} (1-\theta) |y_i - x_i'\beta| \right] \tag{18.1}$$

Here θ represents the quantile estimated ($0 < \theta < 1$), y_i the dependent variable, x_i the vector of explanatory variables (with $k\,x1$ vector) for city i.

The small sample size refrained us from using many additional independent explanatory variables. This also narrowed down and specified our research question. Hence, we determine which cities are more ambitious: (1) those with lower population size (alternately population density) as suggested by the correlations shown in the previous section, (2) cities with greater mayoral power or (3) those with greater GDP per capita. We expect to find that mayoral powers encourage cities to be more ambitious in their targets and that cities' size may be a constraint to lowering emission targets.

18.4 Results

We display some of our regression results for emission targets in this section. We only display those which found at least one explanatory variable significant at 10%, 5% or 1% levels. The rest of the regressions found none of the explanatory variables to be statistically significant. Full regression results for years 2020, 2030, 2040 and 2050 are depicted in the Appendix in Tables 18.6, 18.7, 18.8, and 18.9. For our quantile regression we used quantiles equal to 10%, 25%, 50%, 75% and 90%.

Table 18.3 depicts results for quantile regressions for emission targets in 2020. In the short run, the impact of population size on emission targets is positive and significant at 5% (eq. 1) and 10% (eq. 2). The impact of a city being from Latin America is found to be significant at 5% (eq. 11, 16) for the bottom 10% of the distribution of emission targets in the presence of mayoral powers with budgetary policies or policies of setting a vision. Mayoral policies for budgetary measures were found to be significant at 5% for the 90th quantile (eq. 15) with impact of 0.429. Moreover, with 1% increase of average mayoral powers, the emission targets increase by 0.576% at significance level of 5% (eq. 25), implying lower ambition levels for the 90th quantile of our distribution. Therefore, the impact of mayoral powers is relevant only for the top 10% of the sample distribution of cities' emission targets and the direction of the impact is positive, implying lower ambition levels in cities.

Table 18.4 summarizes all variables, significance levels and sign of impact with number of occurrences among the remaining regressions. Population tends to have a positive impact on emission reduction targets, pointing towards lower ambition levels of these cities. The ambition in this case refers to the difference between the starting point and a future reduction. Distinct types of mayoral powers were found to have a positive impact on emission targets. On the contrary, GDP per capita has a

Table 18.3 Quantile regression for dependent variable: Reduction 2020, representing emission targets for 2030

Regression (eq.)	(1)	(3)	(11)	(15)	(16)	(21)	(25)
Quantile	0.1	0.5	0.1	0.9	0.1	0.1	0.9
Mayoral power	Own/operate	Own/operate	Budget	Budget	Set vision	Average	Average
Variables							
Log(Population)	0.201**	0.080*	0.02	−0.003	0.06	0.057	−0.01
	(−0.079)	(−0.044)	(−0.09)	(−0.051)	(−0.089)	(−0.085)	(−0.045)
Log(GdpCap)	0.063	0.005	−0.326*	−0.022	−0.22	−0.224	0.011
	(−0.164)	(−0.082)	(−0.177)	(−0.047)	(−0.188)	(−0.2)	(−0.059)
Africa	0.243	−0.103	−0.75	−0.086	−0.642	−0.664	−0.017
	(−0.436)	(−0.21)	(−0.503)	(−0.172)	(−0.469)	(−0.609)	(−0.175)
LatinAmerica	−0.274	−0.259	−0.958**	0.2	−0.912**	−0.925*	0.282
	(−0.413)	(−0.299)	(−0.382)	(−0.254)	(−0.436)	(−0.531)	(−0.28)
AsiaOceania	0.016	−0.137	−0.204	−0.073	−0.293	−0.307	−0.031
	(−0.26)	(−0.159)	(−0.263)	(−0.16)	(−0.276)	(−0.276)	(−0.17)
Europe	0.028	−0.055	−0.171	−0.002	−0.304	−0.317	0.04
	(−0.211)	(−0.106)	(−0.207)	(−0.059)	(−0.23)	(−0.25)	(−0.102)
Log(mpOwn)	0.516	0.3					
	(−0.598)	(−0.284)					
Log(mpSetEnforce)							
Log(mpBudget)			−0.491	0.429**			
			(−0.736)	(−0.201)			
Log(mpSetVision)					−0.096		
					(−0.662)		
Log(mpAverage)						−0.114	0.576**
						(−0.868)	(−0.281)
Observations	32	32	32	32	32	32	32

(continued)

Table 18.3 (continued)

Regression (eq.)	(1)	(3)	(11)	(15)	(16)	(21)	(25)
Bootstrap	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Reps	100	100	100	100	100	100	100

Note: Standard errors in parentheses, $^{***}p < 0.01$, $^{**}p < 0.05$, $^{*}p < 0.1$

Table 18.4 Summarized number of regressions from quantile regression for dependent variable: Reduction for years 2020, 2030, 2040 and 2050, with assigned sign and significance levels

Sign		Positive impact (+)			Negative impact (−)		
Significance level		10%	5%	1%	10%	5%	1%
2020	Log(Population)	1/25	1/25				
	Log(GdpCap)				1/25		
	LatinAmerica				1/25	2/25	
	Log(mpBudget)	1/25					
	Log(mpAverage)	1/25					
2030	Log(Population)	4/25					
	Africa					1/25	
	LatinAmerica	2/25					
	AsiaOceania				2/25		1/25
	Europe				2/25		
	Log(mpSetEnforce)	1/25					
	Log(mpBudget)	1/25	1/25				
	Log(mpSetVision)		2/25				
2040	Log(Population)	7/25	2/25				
	Log(GdpCap)				1/25		
	LatinAmerica	3/25	2/25				
2050	Log(Population)	4/25	8/25	1/25			
	Log(GdpCap)				2/25		
	LatinAmerica	3/25	2/25				

negative impact on emission targets, implying higher levels of ambition in cities. Being part of a European, Asian, African or Latin American continent has proven to have a weakly significant (10%) and negative impact on emission targets, but the results were not as consistent as in the case of population size. Even though one might expect the reduction in the wealthy nations to be greater—and hence having a greater ambition—possibly industries and the size of their economies do not permit considerable emissions reduction without seriously affecting the economy in the short and medium run. Note we do not explore the practices of each particular city in terms of specific policy implementation. Rather, we look at the overall impact of policies grouped by their objectives.

18.5 Conclusions

This chapter analysed the relationship between emission targets, mayoral powers and city attributes. We assessed whether mayoral powers reflect ambition regarding future emission targets. We first had to calculate future emission targets for years 2020, 2030, 2040 and 2050 using a common baseline for consistency. Statistical correlation and regression analysis suggest that mayoral powers have no impact on the emission targets in the long run (2040 and 2050). However, some of them impact emission targets in the years 2020 and 2030 positively, implying lower levels of ambition in cities. However, most of the impacts on cities' emission targets do not depend on mayoral powers but rather on city attributes such as population size and geographical location. We find that higher GDP per capita makes cities more ambitious in the long run, but not in the short run. Population size is relevant for both long and short run, impacting emission targets positively, implying lower levels of ambition.

Further work is needed to expand the database to reinforce these results as well as higher number of bootstrap repetitions (e.g. 10,000). Our goal is to create a dynamic panel database in order to track the impact of the environmental policies of mayors on emission targets over time. This would contribute to improving the quality of our estimates and allow exploring additional research questions. Finally, one could also decompose the emission targets by production sectors and test for a relation with the associated sectorial mayoral powers.

Appendix

Table 18.5 Target emission levels for years 2020, 2030, 2040 and 2050 based on emission targets (grey) with baseline 2015

City	2015	2017	2020	2022	2025	2030	2032	2035	2040	2050
Amsterdam	4471000		3100500		2480400	1860300			1033500	206700
Athens	4711576		4147141.33			3041424			1935706.67	829989.333
Auckland	11309000		8002800			6669000			5335200	4446000
Austin	15200000		13057859.5			9173578.63			5289297.71	1405016.8
Barcelona	3433000		3323460			2608859			1894258	1179657
Bogotá	13217521		15465314.1			12372251.3			9279188.46	6186125.64
Boston	6900000		5512701			3675134			1837567	0
Buenos Aires	19667128		13230000			12,742,478			12,254,956	11,767,434
Cape Town	22683041		18,798,711	17,930,902		14893569			13282888.1	11672207.2
Chicago	33500000		24225000			18303333.3			12381666.7	6460000
Durban	22587081		16167499			11364696.7			7988640.15	5615492.69
Heidelberg	806000		697392.857			480178.571			262964.286	45750
London	40750490		29510000		18020000	16218000			12614000	9010000
Los Angeles	29024807		29350000		29700000	25650000		21600000	18000000	10800000
Madrid	10257048		8885900			7771800			6797384.08	5945138.89
Melbourne	5805437		0			0			0	0
Mexico City	24084942		29409567			36038443			44161458.5	54115390.5
New Orleans	4600000		3201549.75			1803099.5			1015498.14	571924.326
New York	50692754		46212000			36636000			24424000	12212000
Oslo	1298000		600000			60000			30000	0
Paris	5195663		4694571.75			3755657.4			2660257.33	1564857.25
Philadelphia	19212870		17084200.6		15168401.3	12977410			8595427.39	4213444.8
Rio de Janeiro	20268045		9121744			4160310.68			1897464.45	865409.248
San Francisco	4574578	4651461.75	4418888.5		3721169.4	3225013.6			2232702	1240389.8
Seattle	3171000		2652453.33			1557360			778680	0
Seoul	48550952		42555666.7			29667000			20681872.9	14418035.7
Stockholm	2511000		2000000			1500000			0	0
Sydney	5052256		3992000			1776000			790124.248	351518.203
Vancouver	2625609		1879350			1358444.78			981920.459	709758.544
Warsaw	12706696		10362387.2			8259928.34			6584044.29	5248185.87
Washington DC	8204579		3367298.33			2244865.56	2020379		1122432.78	0
Yokohama	21000000		16413600			14850400			9379200	3908000

Note: The reference baseline emission level is set at 2015. The highlighted (grey) values are the targets set by individual cities and the non-highlighted numbers are the estimates for years 2020, 2030, 2040 and 2050 based on these targets and baseline levels

Table 18.6 Quantile regression for dependent variable: Reduction 2020

Regression	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)	(13)	(14)	(15)	(16)	(17)	(18)	(19)	(20)	(21)	(22)	(23)	(24)	(25)
Quantile	0.1	0.25	0.5	0.75	0.9	0.1	0.25	0.5	0.75	0.9	0.1	0.25	0.5	0.75	0.9	0.1	0.25	0.5	0.75	0.9	0.1	0.25	0.5	0.75	0.9
Mayoral Power	Own/ Operate	Own/ Operate	Own/ Operate	Own/ Operate	Own/ Operate	Set/ enforce policies	Set/ enforce policies	Set/ enforce policies	Set/ enforce policies	Set/ enforce policies	Budget	Budget	Budget	Budget	Budget	Set Vision	Set Vision	Set Vision	Set Vision	Set Vision	Avg	Avg	Avg	Avg	Avg
Variables																									
Log(Population)	0.201**	0.034	0.080*	0.017	0.006	0.086	0.034	0.028	0.017	0.019	0.02	0.034	0.044	0.024	-0.003	0.06	0.014	0.072	0.029	0.006	0.057	0.021	0.05	0.023	-0.01
	(-0.079)	(-0.042)	(-0.044)	(-0.041)	(-0.046)	(-0.085)	(-0.065)	(-0.049)	(-0.06)	(-0.061)	(-0.09)	(-0.076)	(-0.05)	(-0.049)	(-0.051)	(-0.089)	(-0.061)	(-0.048)	(-0.041)	(-0.05)	(-0.085)	(-0.076)	(-0.052)	(-0.043)	(-0.045)
Log(GdpCap)	0.063	-0.151	0.005	0.021	0.024	-0.091	-0.165	-0.007	0.004	0.029	-0.326*	-0.165	-0.018	0.016	-0.022	-0.22	-0.134	-0.003	0.022	-0.015	-0.224	-0.138	-0.012	0.031	0.011
	(-0.164)	(-0.123)	(-0.082)	(-0.067)	(-0.058)	(-0.157)	(-0.13)	(-0.066)	(-0.056)	(-0.054)	(-0.177)	(-0.133)	(-0.077)	(-0.037)	(-0.047)	(-0.188)	(-0.13)	(-0.083)	(-0.05)	(-0.049)	(-0.2)	(-0.168)	(-0.08)	(-0.057)	(-0.059)
Africa	0.243	-0.474	-0.103	-0.011	-0.058	-0.181	-0.437	-0.016	-0.052	-0.065	-0.75	-0.507	-0.086	-0.088	-0.086	-0.642	-0.462	-0.164	-0.091	-0.225	-0.664	-0.427	-0.069	-0.037	-0.017
	(-0.436)	(-0.322)	(-0.21)	(-0.213)	(-0.212)	(-0.513)	(-0.404)	(-0.215)	(-0.217)	(-0.225)	(-0.503)	(-0.374)	(-0.227)	(-0.158)	(-0.172)	(-0.469)	(-0.341)	(-0.215)	(-0.165)	(-0.166)	(-0.609)	(-0.538)	(-0.263)	(-0.2)	(-0.175)
LatinAmerica	-0.274	-0.41	-0.259	0.283	0.278	-0.452	-0.34	-0.154	0.282	0.273	-0.958**	-0.411	-0.278	0.25	0.2	-0.912**	-0.377	-0.272	0.256	0.194	-0.925*	-0.368	-0.272	0.292	0.282
	(-0.413)	(-0.365)	(-0.299)	(-0.274)	(-0.258)	(-0.451)	(-0.375)	(-0.264)	(-0.312)	(-0.254)	(-0.382)	(-0.317)	(-0.261)	(-0.27)	(-0.254)	(-0.436)	(-0.399)	(-0.329)	(-0.252)	(-0.249)	(-0.531)	(-0.469)	(-0.321)	(-0.276)	(-0.28)
AsiaOceania	0.016	-0.255	-0.137	-0.002	-0.037	-0.129	-0.236	-0.048	-0.036	-0.11	-0.204	-0.268	-0.202	-0.065	-0.073	-0.293	-0.333	-0.2	-0.064	-0.107	-0.307	-0.269	-0.18	-0.048	-0.031
	(-0.26)	(-0.171)	(-0.159)	(-0.171)	(-0.163)	(-0.281)	(-0.212)	(-0.16)	(-0.147)	(-0.169)	(-0.263)	(-0.217)	(-0.178)	(-0.162)	(-0.16)	(-0.276)	(-0.208)	(-0.172)	(-0.159)	(-0.177)	(-0.276)	(-0.264)	(-0.186)	(-0.161)	(-0.17)
Europe	0.028	-0.17	-0.055	0.003	0.091	-0.102	-0.154	-0.01	0.02	0.011	-0.171	-0.208	-0.065	-0.037	-0.002	-0.304	-0.187	-0.067	-0.043	-0.039	-0.317	-0.143	-0.071	-0.039	0.04
	(-0.211)	(-0.163)	(-0.106)	(-0.101)	(-0.11)	(-0.238)	(-0.175)	(-0.091)	(-0.096)	(-0.08)	(-0.207)	(-0.16)	(-0.101)	(-0.052)	(-0.059)	(-0.23)	(-0.154)	(-0.113)	(-0.092)	(-0.085)	(-0.25)	(-0.247)	(-0.118)	(-0.099)	(-0.102)
Log(mpOwn)	0.516	0.245	0.3	0.286	0.393																				
	(-0.598)	(-0.462)	(-0.284)	(-0.245)	(-0.349)																				
Log(mpSetEnforce)						0.461	0.398	0.428	0.057	0.159															
						(-0.829)	(-0.654)	(-0.369)	(-0.284)	(-0.298)															
Log(mpBudget)											-0.491	0.095	0.333	0.27	0.429**										
											(-0.736)	(-0.552)	(-0.285)	(-0.18)	(-0.201)										
Log(mpSetVision)																-0.096	0.429	0.272	0.241	0.261					
																(-0.662)	(-0.48)	(-0.246)	(-0.243)	(-0.335)					
Log(mpAverage)																					-0.114	0.489	0.484	0.335	0.576**
																					(-0.868)	(-0.679)	(-0.439)	(-0.292)	(-0.281)
Observations	32	32	32	32	32	32	32	32	32	32	32	32	32	32	32	32	32	32	32	32	32	32	32	32	32
Bootstrap	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Reps	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100

Note: Standard errors in parentheses, $^{***}p < 0.01$, $^{**}p < 0.05$, $^{*}p < 0.1$, regressions highlighted (grey) have at least one result which is statistically significant

Table 18.7 Quantile regression for dependent variable: Reduction 2030

Regression	(26)	(27)	(28)	(29)	(30)	(31)	(32)	(33)	(34)	(35)	(36)	(37)	(38)	(39)	(40)	(41)	(42)	(43)	(44)	(45)	(46)	(47)	(48)	(49)	(50)
Quantile	0.1	0.25	0.5	0.75	0.9	0.1	0.25	0.5	0.75	0.9	0.1	0.25	0.5	0.75	0.9	0.1	0.25	0.5	0.75	0.9	0.1	0.25	0.5	0.75	0.9
Mayoral Power	Own/ Operate	Own/ Operate	Own/ Operate	Own/ Operate	Own/ Operate	Set/ enforce policies	Set/ enforce policies	Set/ enforce policies	Set/ enforce policies	Set/ enforce policies	Budget	Budget	Budget	Budget	Budget	Set Vision	Set Vision	Set Vision	Set Vision	Set Vision	Avg	Avg	Avg	Avg	Avg
Variables																									
Log(Population)	0.091	0.081	0.054	0.075*	0.104*	0.128	0.035	0.053	0.08	0.08	0.105	0.048	0.066	0.077*	0.068*	0.182*	0.063	0.068	0.089*	0.068	0.104	0.051	0.059	0.08	0.086
	(-0.094)	(-0.067)	(-0.05)	(-0.039)	(-0.055)	(-0.085)	(-0.078)	(-0.064)	(-0.053)	(-0.054)	(-0.086)	(-0.073)	(-0.059)	(-0.041)	(-0.037)	(-0.104)	(-0.089)	(-0.061)	(-0.051)	(-0.075)	(-0.086)	(-0.077)	(-0.053)	(-0.056)	(-0.057)
Log(GdpCap)	-0.088	-0.03	-0.041	-0.014	0.013	-0.046	0.027	-0.033	-0.026	-0.026	-0.08	-0.022	-0.029	0.004	-0.009	0.122	-0.05	-0.03	0.006	-0.009	-0.083	0.007	-0.038	-0.001	0.013
	(-0.177)	(-0.119)	(-0.062)	(-0.044)	(-0.063)	(-0.163)	(-0.11)	(-0.067)	(-0.043)	(-0.053)	(-0.162)	(-0.121)	(-0.088)	(-0.054)	(-0.048)	(-0.166)	(-0.123)	(-0.067)	(-0.032)	(-0.038)	(-0.181)	(-0.123)	(-0.08)	(-0.056)	(-0.047)
Africa	-0.318	-0.088	-0.138	-0.161	-0.157	-0.256	0.334	-0.072	-0.158	-0.225	-0.373	-0.056	-0.126	-0.087	-0.116	0.289	-0.178	-0.112	-0.192**	-0.21	-0.346	0.039	-0.14	-0.125	-0.147
	(-0.485)	(-0.32)	(-0.199)	(-0.154)	(-0.234)	(-0.593)	(-0.396)	(-0.23)	(-0.168)	(-0.209)	(-0.545)	(-0.37)	(-0.223)	(-0.162)	(-0.141)	(-0.465)	(-0.336)	(-0.199)	(-0.096)	(-0.14)	(-0.519)	(-0.373)	(-0.261)	(-0.19)	(-0.165)
LatinAmerica	-0.654	-0.057	0.099	0.043	0.57	-0.645	0.295	0.209	0.099	0.587	-0.661	-0.019	0.135	0.096	0.574	-0.145	-0.05	0.18	0.082	0.574*	-0.686	0.046	0.132	0.123	0.601*
	(-0.444)	(-0.364)	(-0.411)	(-0.391)	(-0.404)	(-0.596)	(-0.424)	(-0.434)	(-0.432)	(-0.443)	(-0.458)	(-0.397)	(-0.261)	(-0.339)	(-0.355)	(-0.469)	(-0.43)	(-0.383)	(-0.371)	(-0.334)	(-0.522)	(-0.436)	(-0.374)	(-0.383)	(-0.343)
AsiaOceania	-0.211	-0.131	-0.07	-0.062	-0.105	-0.191	0.044	-0.049	-0.054	-0.121	-0.224	-0.032	-0.07	-0.156*	-0.171***	0.046	-0.126	-0.077	-0.145	-0.171*	-0.225	-0.04	-0.085	-0.072	-0.118
	(-0.231)	(-0.152)	(-0.122)	(-0.095)	(-0.127)	(-0.304)	(-0.176)	(-0.113)	(-0.101)	(-0.113)	(-0.248)	(-0.179)	(-0.135)	(-0.083)	(-0.06)	(-0.206)	(-0.143)	(-0.117)	(-0.093)	(-0.093)	(-0.214)	(-0.156)	(-0.123)	(-0.102)	(-0.096)
Europe	-0.407*	-0.148	0.046	0.022	0.061	-0.397	0.124	0.07	0.067	0	-0.370*	-0.126	0.027	-0.017	-0.014	-0.196	-0.116	0.073	-0.026	-0.014	-0.404*	-0.089	0.047	0.027	0.03
	(-0.232)	(-0.156)	(-0.097)	(-0.074)	(-0.107)	(-0.293)	(-0.199)	(-0.11)	(-0.086)	(-0.091)	(-0.212)	(-0.203)	(-0.144)	(-0.106)	(-0.083)	(-0.213)	(-0.167)	(-0.141)	(-0.08)	(-0.084)	(-0.229)	(-0.179)	(-0.14)	(-0.129)	(-0.118)
Log(mpOwn)	-0.17	0.533	0.273	0.352	0.289																				
	(-0.773)	(-0.591)	(-0.375)	(-0.264)	(-0.354)																				
Log(mpSetEnforce)						-0.188	1.062*	0.239	0.19	0.189															
						(-0.944)	(-0.644)	(-0.446)	(-0.298)	(-0.339)															
Log(mpBudget)											-0.299	0.764	0.228	0.447*	0.456**										
											(-0.664)	(-0.55)	(-0.375)	(-0.25)	(-0.202)										
Log(mpSetVision)																0.475	0.515	0.3	0.382**	0.456**					
																(-0.709)	(-0.532)	(-0.355)	(-0.193)	(-0.214)					
Log(mpAverage)																					-0.26	1.041	0.277	0.39	0.434
																					(-0.953)	(-0.657)	(-0.55)	(-0.359)	(-0.319)
Observations	32	32	32	32	32	32	32	32	32	32	32	32	32	32	32	32	32	32	32	32	32	32	32	32	32
Bootstrap	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Reps	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100

Note: Standard errors in parentheses, ***$p < 0.01$, **$p < 0.05$, *$p < 0.1$, regressions highlighted (grey) have at least one result which is statistically significant

Table 18.8 Quantile regression for dependent variable: Reduction 2040

Regression	(51)	(52)	(53)	(54)	(55)	(56)	(57)	(58)	(59)	(60)	(61)	(62)	(63)	(64)	(65)	(66)	(67)	(68)	(69)	(70)	(71)	(72)	(73)	(74)	(75)
Quantile	0.1	0.25	0.5	0.75	0.9	0.1	0.25	0.5	0.75	0.9	0.1	0.25	0.5	0.75	0.9	0.1	0.25	0.5	0.75	0.9	0.1	0.25	0.5	0.75	0.9
Mayoral Power	Own/ Operate	Own/ Operate	Own/ Operate	Own/ Operate	Own/ Operate	Set/ enforce policies	Set/ enforce policies	Set/ enforce policies	Set/ enforce policies	Set/ enforce policies	Budget	Budget	Budget	Budget	Budget	Set Vision	Set Vision	Set Vision	Set Vision	Set Vision	Avg	Avg	Avg	Avg	Avg
Variables																									
Log(Population)	0.08	0.017	0.067	0.1	0.088	0.107*	0.014	0.06	0.105*	0.110**	0.09	0.015	0.046	0.105**	0.088*	0.09	0.015	0.051	0.103*	0.088*	0.091	0.016	0.034	0.099*	0.094
	(-0.06)	(-0.068)	(-0.062)	(-0.067)	(-0.058)	(-0.061)	(-0.045)	(-0.052)	(-0.058)	(-0.054)	(-0.059)	(-0.055)	(-0.045)	(-0.05)	(-0.051)	(-0.063)	(-0.059)	(-0.064)	(-0.059)	(-0.052)	(-0.066)	(-0.068)	(-0.06)	(-0.059)	(-0.061)
Log(GdpCap)	-0.037	-0.135	-0.06	-0.028	-0.017	-0.018	-0.137	-0.071	-0.03	-0.033	-0.036	-0.137*	-0.052	-0.014	-0.049	-0.036	-0.136	-0.045	-0.029	-0.049	-0.033	-0.136	-0.061	-0.013	-0.044
	(-0.093)	(-0.094)	(-0.078)	(-0.054)	(-0.051)	(-0.097)	(-0.09)	(-0.083)	(-0.073)	(-0.064)	(-0.08)	(-0.07)	(-0.076)	(-0.06)	(-0.05)	(-0.093)	(-0.083)	(-0.072)	(-0.065)	(-0.054)	(-0.099)	(-0.094)	(-0.079)	(-0.067)	(-0.071)
Africa	-0.122	-0.227	-0.04	-0.117	-0.073	-0.15	-0.225	-0.16	-0.086	-0.14	-0.192	-0.221	-0.023	-0.037	-0.189	-0.138	-0.224	-0.021	-0.138	-0.207	-0.156	-0.226	-0.042	-0.064	-0.177
	(-0.27)	(-0.234)	(-0.258)	(-0.218)	(-0.211)	(-0.343)	(-0.257)	(-0.221)	(-0.257)	(-0.254)	(-0.217)	(-0.203)	(-0.244)	(-0.215)	(-0.177)	(-0.205)	(-0.204)	(-0.186)	(-0.206)	(-0.164)	(-0.326)	(-0.287)	(-0.282)	(-0.241)	(-0.249)
LatinAmerica	-0.401	0.001	0.096	-0.023	1.115**	-0.474	0.007	0.073	0.024	1.064*	-0.426	-0.001	0.104	0.049	1.045*	-0.426	0.008	0.123	-0.017	1.045**	-0.439	0.001	0.1	0.023	1.052*
	(-0.492)	(-0.495)	(-0.55)	(-0.55)	(-0.542)	(-0.497)	(-0.442)	(-0.415)	(-0.631)	(-0.578)	(-0.373)	(-0.354)	(-0.354)	(-0.568)	(-0.56)	(-0.444)	(-0.437)	(-0.46)	(-0.549)	(-0.521)	(-0.329)	(-0.352)	(-0.328)	(-0.61)	(-0.616)
AsiaOceania	-0.076	-0.06	-0.06	-0.077	-0.066	-0.103	-0.058	-0.054	-0.061	-0.035	-0.101	-0.068	-0.067	-0.022	-0.115	-0.101	-0.059	-0.075	-0.105	-0.115	-0.101	-0.063	-0.048	-0.068	-0.065
	(-0.127)	(-0.143)	(-0.124)	(-0.079)	(-0.089)	(-0.169)	(-0.118)	(-0.113)	(-0.134)	(-0.125)	(-0.135)	(-0.118)	(-0.12)	(-0.103)	(-0.102)	(-0.128)	(-0.113)	(-0.137)	(-0.135)	(-0.12)	(-0.153)	(-0.134)	(-0.122)	(-0.102)	(-0.101)
Europe	-0.196	-0.136	0.043	-0.009	0.055	-0.239	-0.134	0.037	0.028	-0.006	-0.179	-0.14	-0.041	0.041	0.003	-0.179	-0.133	-0.045	-0.012	0.003	-0.207	-0.137	-0.098	-0.005	0.004
	(-0.121)	(-0.125)	(-0.138)	(-0.113)	(-0.106)	(-0.186)	(-0.147)	(-0.153)	(-0.124)	(-0.109)	(-0.12)	(-0.149)	(-0.158)	(-0.113)	(-0.102)	(-0.122)	(-0.123)	(-0.135)	(-0.106)	(-0.099)	(-0.142)	(-0.157)	(-0.177)	(-0.103)	(-0.099)
Log(mpOwn)	-0.136	0.017	0.154	0.243	0.297																				
	(-0.561)	(-0.417)	(-0.442)	(-0.426)	(-0.365)																				
Log(mpSetEnforce)						-0.214	0.027	0.107	0.196	0.218															
						(-0.677)	(-0.438)	(-0.317)	(-0.411)	(-0.444)															
Log(mpBudget)											-0.259	0.036	0.341	0.378	0.203										
											(-0.489)	(-0.414)	(-0.36)	(-0.311)	(-0.264)										
Log(mpSetVision)																-0.259	0.022	0.287	0.134	0.203					
																(-0.358)	(-0.342)	(-0.313)	(-0.272)	(-0.202)					
Log(mpAverage)																					-0.207	0.028	0.429	0.263	0.267
																					(-0.575)	(-0.507)	(-0.507)	(-0.426)	(-0.494)
Observations	32	32	32	32	32	32	32	32	32	32	32	32	32	32	32	32	32	32	32	32	32	32	32	32	32
Bootstrap	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Reps	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100

Note: Standard errors in parentheses, ***$p < 0.01$, **$p < 0.05$, *$p < 0.1$, regressions highlighted (grey) have at least one result which is statistically significant

Table 18.9 Quantile regression for dependent variable: Reduction 2040

Regression	(76)	(77)	(78)	(79)	(80)	(81)	(82)	(83)	(84)	(85)	(86)	(87)	(88)	(89)	(90)	(91)	(92)	(93)	(94)	(95)	(96)	(97)	(98)	(99)	(100)
Quantile	0.1	0.25	0.5	0.75	0.9	0.1	0.25	0.5	0.75	0.9	0.1	0.25	0.5	0.75	0.9	0.1	0.25	0.5	0.75	0.9	0.1	0.25	0.5	0.75	0.9
Mayoral Power	Own/ Operate	Own/ Operate	Own/ Operate	Own/ Operate	Own/ Operate	Set/ enforce policies	Set/ enforce policies	Set/ enforce policies	Set/ enforce policies	Set/ enforce policies	Budget	Budget	Budget	Budget	Budget	Set Vision	Set Vision	Set Vision	Set Vision	Set Vision	Avg	Avg	Avg	Avg	Avg
Variables																									
Log(Population)	0.074**	0.081**	0.079*	0.076	0.109*	0.083**	0.07	0.001	0.086	0.11	0.071*	0.074**	0.061	0.117**	0.143**	0.071***	0.075**	0.061	0.117	0.136*	0.074	0.071	0.026	0.116*	0.138**
	(-0.029)	(-0.033)	(-0.045)	(-0.058)	(-0.066)	(-0.041)	(-0.047)	(-0.067)	(-0.07)	(-0.074)	(-0.038)	(-0.032)	(-0.045)	(-0.055)	(-0.068)	(-0.024)	(-0.034)	(-0.066)	(-0.077)	(-0.073)	(-0.047)	(-0.045)	(-0.052)	(-0.064)	(-0.07)
Log(GdpCap)	-0.019	-0.032	0.016	-0.052	-0.071	-0.015	-0.023	-0.034	-0.024	-0.109*	-0.017	-0.007	0.014	-0.06	-0.101*	-0.017	-0.003	0.014	-0.072	-0.074	-0.016	-0.015	0.01	-0.052	-0.108
	(-0.056)	(-0.063)	(-0.075)	(-0.078)	(-0.084)	(-0.075)	(-0.071)	(-0.089)	(-0.077)	(-0.065)	(-0.046)	(-0.061)	(-0.058)	(-0.058)	(-0.058)	(-0.044)	(-0.048)	(-0.068)	(-0.067)	(-0.07)	(-0.065)	(-0.083)	(-0.065)	(-0.061)	(-0.066)
Africa	0.083	0.051	0.352	-0.015	-0.138	0.07	0.034	0.253	0.07	-0.288	0.031	0.026	0.327	-0.1	-0.256	0.048	0.067	0.308	-0.12	-0.143	0.062	0.036	0.239	-0.056	-0.275
	(-0.201)	(-0.199)	(-0.254)	(-0.265)	(-0.272)	(-0.274)	(-0.22)	(-0.243)	(-0.266)	(-0.258)	(-0.217)	(-0.226)	(-0.241)	(-0.246)	(-0.245)	(-0.156)	(-0.173)	(-0.261)	(-0.27)	(-0.282)	(-0.246)	(-0.25)	(-0.224)	(-0.25)	(-0.27)
LatinAmerica	-0.162	0.156	0.436	0.158	1.612*	-0.192	0.2	0.388	0.213	1.503*	-0.154	0.258	0.407	0.104	1.506**	-0.177	0.261	0.407	0.087	1.569**	-0.167	0.243	0.39	0.134	1.494*
	(-0.475)	(-0.462)	(-0.62)	(-0.908)	(-0.832)	(-0.392)	(-0.391)	(-0.551)	(-0.873)	(-0.888)	(-0.365)	(-0.384)	(-0.717)	(-0.879)	(-0.735)	(-0.366)	(-0.367)	(-0.498)	(-0.866)	(-0.783)	(-0.317)	(-0.325)	(-0.284)	(-0.792)	(-0.842)
AsiaOceania	0.04	0.01	0.029	0.043	-0.009	0.021	0.066	0.034	0.053	-0.037	0.083	0.063	0.048	0.014	0.118	0.06	0.062	0.048	0.031	0.039	0.051	0.068	0.075	0.043	0.084
	(-0.085)	(-0.098)	(-0.142)	(-0.175)	(-0.173)	(-0.15)	(-0.114)	(-0.124)	(-0.148)	(-0.153)	(-0.095)	(-0.094)	(-0.126)	(-0.104)	(-0.105)	(-0.063)	(-0.101)	(-0.146)	(-0.156)	(-0.14)	(-0.144)	(-0.147)	(-0.15)	(-0.157)	(-0.148)
Europe	0.01	-0.013	0.119	0.032	-0.017	-0.008	-0.012	0.072	0.013	-0.02	0.031	0.007	0.015	-0.023	0.006	0.008	0.003	0.07	-0.012	0.046	0.009	-0.007	0.073	-0.006	0.001
	(-0.088)	(-0.109)	(-0.147)	(-0.141)	(-0.127)	(-0.115)	(-0.103)	(-0.116)	(-0.121)	(-0.128)	(-0.094)	(-0.1)	(-0.125)	(-0.115)	(-0.116)	(-0.055)	(-0.066)	(-0.12)	(-0.117)	(-0.126)	(-0.068)	(-0.107)	(-0.129)	(-0.13)	(-0.135)
Log(mpOwn)	-0.044	0.059	-0.046	0.177	-0.197																				
	(-0.296)	(-0.292)	(-0.463)	(-0.466)	(-0.503)																				
Log(mpSetEnforce)						-0.045	-0.122	0.389	0.239	-0.37															
						(-0.394)	(-0.364)	(-0.419)	(-0.456)	(-0.556)															
Log(mpBudget)											-0.191	-0.177	0.209	-0.152	-0.203										
											(-0.345)	(-0.351)	(-0.424)	(-0.41)	(-0.399)										
Log(mpSetVision)																-0.191	-0.163	0.209	-0.158	-0.255					
																(-0.258)	(-0.28)	(-0.414)	(-0.409)	(-0.387)					
Log(mpAverage)																					-0.127	-0.173	0.571	-0.084	-0.271
																					(-0.467)	(-0.459)	(-0.404)	(-0.463)	(-0.515)
Observations	32	32	32	32	32	32	32	32	32	32	32	32	32	32	32	32	32	32	32	32	32	32	32	32	32
Bootstrap	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Reps	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100

Note: Standard errors in parentheses, ***$p < 0.01$, **$p < 0.05$, *$p < 0.1$, regressions highlighted (grey) have at least 1 result which is statistically significant

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Chapter 19
Economic Impact Analysis of Installing Renewable Energy: A Multiregional Input–Output Model for a Small Region and the Rest of the Country

Yoshifumi Ishikawa

Abstract This chapter investigates the regional economic and mitigative effects on CO_2 from installing renewable energy facilities, such as mega solar and wind power generation systems. The economic effects of renewable energy are often estimated using a regional input–output (I–O) model. However, when analyzing the economic effects on a small region, such as a municipality, an I–O table for the region may not be available. Therefore, we propose a versatile multiregional I–O model for estimating the regional economic effects of installing renewable energy. As an example, we analyze the effects of installing renewable energy facilities in an affected region of the Great East Japan Earthquake. As a result, it was observed that installing renewable energy facilities in the affected region and the supply of electricity by a conventional power source to the rest of Japan have larger effects on the regional economy.

Keywords Input–output model · Economic effects · Renewable energy · CO_2 emission · Nonsurvey method

19.1 Introduction

To ensure energy security and address climate change simultaneously, many countries are promoting the development of renewable energy. Between 1990 and 2017, the average annual growth rate of renewable energy sources in the world was 2.0%. This was larger than the world's total primary energy supply at 1.7%. Growth for solar photovoltaic (PV) and wind power has been exceptionally high, growing at average annual rates of 37.0% and 23.4%, respectively (International Energy

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Agency 2019). In terms of the share of global electricity production, the share of electricity generation from renewables reached 24.5% in 2017, ahead of gas (23.0%) and nuclear (10.3%). Renewable electricity generation has been growing on average 3.8% per year since 1990, which is greater than the average growth rate of total electricity generation of 2.9% (International Energy Agency 2019). According to REN21's Renewables 2019 Global Status Report, more renewable power was installed than fossil fuel and nuclear power combined, including 100 GW of solar PV added in 2018. Thus, power generated from solar and wind has become mainstream. At least nine countries, including Denmark, Germany, and Spain generated more than 20% of their electricity from solar and wind power (REN21 2020). As the issue of global warming increases in severity, the need to accelerate the introduction of renewable energy has become increasingly urgent. If this trend continues, the share of renewable energy in electricity generation is expected to rise further.

With increasing awareness of the risks of climate change, not only countries, but municipalities are also promoting the development of renewable energy for a transition to low carbon economies. Local municipalities play an important role in the context of the transition from large centralized energy generation based on fossil fuels to renewable sources. In Japan, the Feed-in Tariff (FIT) scheme for renewable electricity was introduced in 2012 just after the Great East Japan Earthquake. Subsequently, strategic energy plans have been formulated in many regions, especially in regions affected by the earthquake. The municipalities and companies in the affected regions are working to mitigate climate change and boost the recovery from the Great Earthquake.

Installing renewable energy is expected to have economic effects on the regional economy besides lowering CO_2 emissions. The transition from imported electricity to local energy sources such as solar and wind is believed to enhance the intraregional circulation of the economy. This expectation will lead to ambitious objectives for many municipalities. Therefore, we must investigate the economic impacts on the regional economy.

The aim of this chapter is to investigate the regional economic and mitigative effects on CO_2 from installing renewable energy facilities such as mega solar and wind power generation systems. The expansionary effects of renewable energy have been discussed in numerous studies. However, most literature evaluates the impact at a national level (e.g., Hillebrand et al. 2006, Lehr et al. 2008, and Lehr et al. 2012 for Germany; Bulavskaya and Reynes 2018 for the Netherlands; Wei et al. 2010 and Garrett-Peltier 2017 for the USA; Malik et al. 2014 for Australia; Nakano et al. 2017 for Japan). The effects of renewable energy on the national economy have been analyzed using various methods such as input–output (I–O) models, econometric methods, and computable general equilibrium (CGE) models. Out of these, I–O models are often used to examine the economic benefits of a clean energy transition because they have the advantage of being transparent, have few assumptions built-in, are easily replicable, and are built from current or recent data from national accounts (Garrett-Peltier 2017).

In the context of regional impacts, Jenniches (2018) provides a literature review on assessing regional economic impacts of a transition to renewable energy generation. The review is conducted from the viewpoint of evaluated regions, technologies, impact indicators, periods, and analytical methods. As described in the study, the approaches applied in the literature are categorized into four types: employment ratios, supply chain analyses, I–O models, and CGE models. Methods such as employment ratios and supply chain analyses may be useful in relatively small regions. However, these approaches do not consider the economic impacts of inputs of enterprises, which are not directly related to renewable energy activities. I–O models are particularly characterized by their ability to estimate indirect and induced effects, and have been widely used to estimate the effect of various types of policies. Using I–O models, it is also possible to calculate the impacts of a transition to renewable energy generation such as output, value-added, and CO_2 emissions.

In the USA, ready-made regional economic impact models such as impact analysis for planning (IMPLAN), regional input–output modeling system (RIMSII), and Regional Economic Model, Inc. (REMI) are often used to estimate impacts of renewable energy development on the regional economy. For instance, the National Renewable Energy Laboratory (NREL) developed the Jobs and Economic Development Impact (JEDI) model, an I–O model that can calculate the project impacts of renewable energy development at the state level in the USA. The multipliers are derived from the IMPLAN system, which is one of the most widely used tools for I–O analysis. It provides multipliers for every county in the USA. Many U.S. publications use data originally from IMPLAN or the JEDI model with data from IMPLAN (Jenniches 2018). Bae and Dall'erba (2016) calculate the economic impact of a new solar power plant in Arizona using JEDI and IMPLAN, and point out the differences in the results obtained with these tools. Other than these ready-made models, Coon et al. (2012) estimate the economic contribution of renewable energy activities in North Dakota, applying the expenditure data to a North Dakota I–O model.

In Europe, Fanning et al. (2014) examine the expected regional employment returns due to the development of marine energy projects such as a tidal stream and wave-based electricity generation in Wales, UK. Madlener and Koller (2007) calculate the economic and CO_2 mitigation impacts of biomass promotion in the Austrian federal province of Vorarlberg. However, since they use an I–O analysis with the national table in a regional context, attention should be paid to the interpretation of the results and the bias of the estimates may be large.

In Japan, Ishikawa et al. (2014) estimate the effects of installing mega solar and wind power generation systems in the Tohoku region, in particular, Iwate, Miyagi, and Fukushima prefectures—areas substantially damaged by the Great East Japan Earthquake. Nakano et al. (2018) also calculate induced production at a regional level using an interregional I–O table for analysis of a next-generation energy system developed by the authors. These studies are based on the interregional I–O table published by the Ministry of Economy, Trade, and Industry (METI). The table covers the whole of Japan and is divided into nine comparatively large regions, including prefectures.

Thus, the economic effects of renewable energy are often estimated using a regional I–O model. However, when analyzing economic effects on a small region, such as a municipality, an I–O table for the region is not available in many regions. Even if the I–O table is available, the conventional I–O model using the tables does not take into consideration interregional feedback effects and income distribution between the small region and other regions. Therefore, we propose a versatile multiregional I–O model for estimating regional economic effects of installing renewable energy. By using this model, it is possible to estimate the economic effects without regional I–O tables.

As an example, we analyze the effects of installing renewable energy facilities for Minamisoma city in Fukushima prefecture, a region affected by the Great East Japan Earthquake. The simulation analyses are conducted based on scenarios for installing renewable energy facilities.

When analyzing the transition from conventional energy generation based on fossil fuel-based systems to renewable energy systems, it is important to estimate the impacts, both from the economic and environmental viewpoints. We also investigate the impacts on CO_2 emissions.

Section 19.2 presents the methodology applied and data used. Section 19.3 describes the model building and scenario setting for the study area. Section 19.4 presents the simulation results. Section 19.5 draws the main conclusions and provides some policy implications.

19.2 Methodology

19.2.1 Multiregional I–O Model for a Small Region and the Rest of the Country

As mentioned in the previous section, studies on the impacts of renewable energy on the regional economy apply various methodologies. While each approach has advantages and disadvantages, we employ an I–O model to assess the impacts of renewable energy. I–O models enable us to calculate the direct and indirect effects on the economy. Furthermore, they can calculate additional effects known as induced effects. That is, the part of income spent on consumer goods and services that generates additional output. In the case of renewable energy, the renewable energy project directly impacts the construction and service sectors related to electricity production. This leads to an indirect impact on related sectors because the construction and service sectors purchase input materials and services to support their activity. In addition, income generated from the direct and indirect effects are spent on goods and services, which creates a ripple effect.

The purpose of this study is to analyze the impact of renewable energy development on a small region, such as a municipality. Because renewable energy development influences not only small regions but other regions as well, we employ a

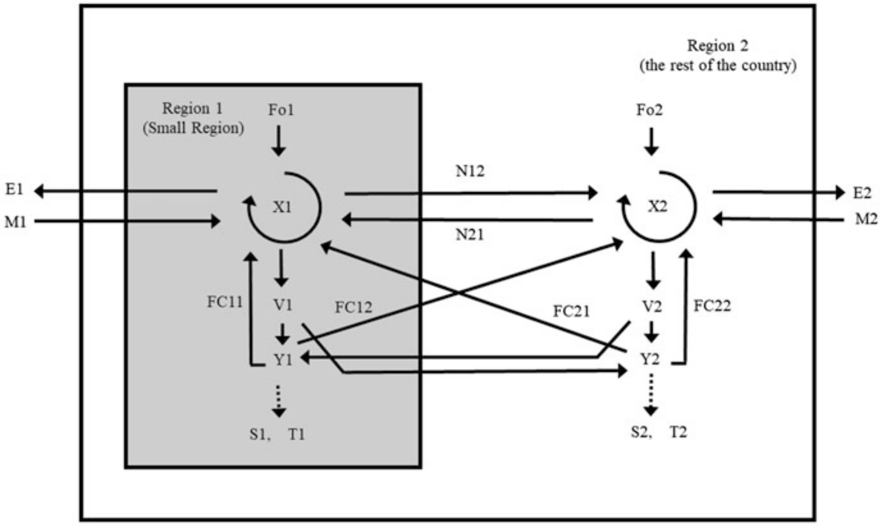

Fig. 19.1 Regional economic circulation between the small region (Region 1) and the rest of the country (Region 2)

multiregional I–O model that consists of the small region and the rest of the country. The conventional model does not consider interregional commuting and consumption. In the case of a small region, many people commute and consume between the region of interest and other regions. Therefore, we use a multiregional I–O model with interregional commuting and consumption factors (Ishikawa 2019a).[1] The I–O analysis has been widely employed in many studies to measure the economic impact of renewable energy development because it can reflect the structure of a regional economy.

The model shown in our previous study endogenously determines consumption expenditure, and interregional income distribution and trade. However, it is based on an intraregional I–O table for a single region and the national I–O table. This study covers smaller regions like municipalities where I–O tables are not available. Therefore, we propose a versatile multiregional I–O model for renewable energy development, which estimates economic effects without the regional I–O tables. Because most municipalities do not have I–O tables, the model proposed in this study is useful for decision-makers and researchers.

First, we explain the framework of the model. We divide the whole country into a small region (Region 1) and the rest of the country (Region 2); the regional economic circulation between the small region and the rest of the country is shown in Fig. 19.1. As illustrated, production activity in a small region (X1) is induced by the final demand of the region (Fo1). At the same time, the production of the rest of the

[1]The theoretical framework of the extended I–O framework considering these points was given by Miyazawa (1976). Sonis and Hewings (1999) described the methodology in more detail.

country, Region 2 (X2), is induced through the domestic imports of Region 1 (N21); that is, the export demand for Region 2. Moreover, employee income in Region 1 increases with production inducement (X1). The income is distributed to each region (V1, V2) according to the region where workers live, with consumption in each region. As seen in Fig. 19.1, the two regions have the same structure.

The economic effects of introducing renewable energy power can be estimated using the following equilibrium model with interregional commuting and consuming factors. The model is obtained from the supply–demand balance for a small region and the rest of the country.[2] In this model, household consumption, regional import and export, and international import are endogenously dealt with. For imports, the competitive imports method is used, because a national I-O table for Japan is a competitive import type. It must be noted that imports consumed in a given region are included in the in-region supply of in-region product.

$$\begin{bmatrix} X_1 \\ Y_1 \\ X_2 \\ Y_2 \end{bmatrix} = \begin{bmatrix} \left[I-\left(I-\overline{M}_1\right)A_{11}\right] & -c_1(I-C_{21}-C_{w1}) & -A_{12} & -c_2C_{12} \\ -D_{11}V_1 & I & -D_{21}V_2 & 0 \\ -A_{21} & -c_1C_{21} & \left[I-\left(I-\overline{M}_2\right)A_{22}\right] & -c_2(I-C_{12}-C_{w2}) \\ -D_{12}V_1 & o & -D_{22}V_2 & I \end{bmatrix}^{-1}$$

$$\begin{bmatrix} I-\overline{N}_1-\overline{M}_1 & 0 & \overline{N}_2 & 0 \\ 0 & I & 0 & 0 \\ \overline{N}_1 & 0 & I-\overline{N}_2-\overline{M}_2 & 0 \\ 0 & 0 & 0 & I \end{bmatrix} \begin{bmatrix} F_{o1} \\ F_{\mathrm{DY}1} \\ F_{o2} \\ F_{\mathrm{DY}2} \end{bmatrix} + \begin{bmatrix} E_1 \\ 0 \\ E_2 \\ 0 \end{bmatrix} \tag{19.1}$$

where X_r is the vector of gross outputs of sectors in region r; A_{rr} is the intraregional input coefficient matrix of region r; A_{sr} is the interregional input coefficient matrix of region r; F_{or} is the vector of final demand other than household final consumption expenditures in region r; N_r is the regional import coefficient matrix of region r; M_r is the international import coefficient matrix of region r; E_r is the vector of export coefficient in region r; C_{rs} is the distributed consumption rate matrix from region r to region s; Y_r is the regional income vector in region r; D_{rs} is the distributed income rate matrix from region r to region s; V_r is the income rate in region r; F_{DY} is the autonomous consumption vector in region r; and c_r is the marginal propensity to consume for region r.

To estimate economic effects without the regional I–O tables, we apply a non-survey approach for obtaining the regional input coefficients. Regional input coefficients are generally estimated by regionalizing the national input coefficients. This approach assumes that regional technologies are the same as national technologies. The regional input coefficients are estimated as follows.

[2]Ishikawa (2019a) proposed the multiregional I–O model which uses an existing intraregional I–O table and a national I–O table. In this study, a revised model is proposed based on this model.

$$a_{ij}^r = \beta_{ij} \cdot a_{ij}^n \tag{19.2}$$

where a_{ij}^r is the regional input coefficient; a_{ij}^n is the national input coefficients; and β_{ij} is the regional trading coefficient. a_{ij}^r measures the amount of regional input i needs to produce one unit of regional gross output j.

A traditional simple way of regionalizing the national coefficients is to apply a set of location quotients (LQs). Most widely used LQs are the simple location quotients (SLQs) and the cross-industry location quotient (CILQ), defined as:

$$\mathrm{SLQ}_i = \frac{Q_i^r / \sum_i Q_i^r}{Q_i^n / \sum_i Q_i^n} = \frac{Q_i^r}{Q_i^n} \cdot \frac{\sum_i Q_i^n}{\sum_i Q_i^r} \tag{19.3}$$

$$\mathrm{CILQ}_{ij} = \frac{Q_i^r / Q_i^n}{Q_j^r / Q_j^n} = \frac{\mathrm{SLQ}_i}{\mathrm{SLQ}_j} \tag{19.4}$$

where SLQ_i is the SLQ of sector i; CILQ_{ij} is the CILQ of sector i for sector j; Q_i^r is the output of regional sector i; and Q_i^n is the corresponding national figure. i and j refer to the supplying and purchasing sectors, respectively. Abundant empirical researches have demonstrated that the conventional LQ approaches, such as SLQ and CILQ, tend to underestimate the regional input coefficients (e.g., Morrison and Smith 1974; Harrigan et al. 1980). While some studies pointed out that the relative size has influenced the propensity to import (Richardson 1972), these methods do not take the relative size of a region into consideration. Therefore, to estimate much better regional trade than SLQ and CILQ, Flegg et al. (1995) proposed their FLQ formula, which was subsequently refined by Flegg and Webber (1997).[3] The formula considers the relative size of the regional purchasing and supplying sectors when adjusting interregional trade.

Some researchers who carried out empirical tests of the performance of the FLQ formula verified that FLQ could produce much better results than the SLQ and CILQ (Flegg and Webber 2000; Tohmo 2004; Flegg and Tohmo 2013; Kowalewksi 2015).

However, there is an issue of choosing a value for the unknown parameter δ in Eq. (19.6). In this respect, Flegg and Webber (1997) indicate a value of $\delta = 0.3$ in the empirical research for Scotland, while Flegg and Webber (2000) indicate a value of $\delta = 0.2$ for the same. These empirical studies are based on the strong assumption that the value of the exponent δ is equal for all industries. A consideration is that the exponent in the FLQ formula might also differ across sectors (Kowalewksi 2015). Therefore, Kowalewksi (2015) proposed a revised formula of FLQ, relaxing the assumption that δ is invariant across sectors. Kowalewksi's (2015) industry-specific FLQ (SFLQ) is defined as

[3] A further refinement was proposed by Flegg and Webber (2000).

$$\begin{cases} \mathrm{SFLQ}_{ij} = \mathrm{CILQ}_{ij} \cdot \lambda_j & \text{for } i \neq j \\ \mathrm{SFLQ}_{ij} = \mathrm{SLQ}_i \cdot \lambda_j & \text{for } i = j \end{cases} \tag{19.5}$$

where:

$$\lambda_j = \left[\log_2\left(1 + \sum_i Q_i^r \big/ \sum_i Q_i^n\right)\right]^{\delta_j} \tag{19.6}$$

$$a_{ij}^r = \begin{cases} a_{ij}^n & \text{if } \mathrm{SFLQ}_{ij} \geq 1 \\ \mathrm{SFLQ}_{ij} \cdot a_{ij}^n & \text{if } \mathrm{SFLQ}_{ij} < 1 \end{cases} \tag{19.7}$$

Kowalewksi (2015) carried out an empirical analysis to identify optimal industry-specific values of δ_j using a survey-based regional I–O table—the German Federal State of Baden-Württemberg and the national I–O table. As a result, it is shown that the optimal values range between $\delta_j = 0.43$ for the manufacture of iron and metal, foundry, steel forming, and $\delta_j = 0.03$ for trade. Ishikawa (2019b) also identifies the optimal value δ_j for 86 industries using regional I–O tables for 47 prefectures in Japan. The optimal value δ_j is measured in a range of 0.03 for advertising services to 0.41 for metal products for construction and architecture. In this study, the optimal value that produces the lowest absolute deviation is identified by an iterative approach. The average value of the mean absolute errors between the Leontief inverse using actual I-O data and that of the estimates using SFLQ is 0.05, which is extremely small.

To estimate the impacts of a transition from fossil fuel-based systems to renewable energy systems, we need to obtain data of the input structure of renewable energy operation and maintenance. In this study, we use an I–O table for the analysis of next-generation energy systems (IONGES) (Washizu and Nakano 2019). The latest version of the I–O table is constructed based on the Japanese government's 2011 I–O table. It divides the electric power sector into some electricity generation sectors and an electricity transmission/distribution sector. Electricity generation sectors include renewable energy sectors such as solar and wind. The extended tables are provided for 2011 and 2030, and sectors such as electricity transmission/distribution, renewable energy facility construction, and renewable energy power generation are incorporated into the original 108 sectors in the published I–O table.

19.2.2 Greenhouse Gas Emissions

In Japan, the Embodied Energy and Emission Intensity Data for Japan using I–O tables (3EID) are provided by the National Institute for Environmental Studies (NIES). These data are useful in environmental analysis using the I–O model.

However, these data do not include the data for renewable energy such as solar and wind. On the contrary, IONGES provide a CO_2 emission coefficient table: the CO_2 emission generated by the unit production of a sector. We use the data from IONGES to estimate the impact of renewable energy development on CO_2 emissions. The emissions are determined by multiplying CO_2 emission coefficients on the production by sector.

19.3 Model Building and Setting of Scenarios for the Study Area

19.3.1 Characteristics of the Region

The Japanese government formulated the Strategic Energy Plan (SEP) as the basis for the orientation of Japan's new energy policy towards 2030 and further towards 2050 (Agency for Natural Resources and Energy of Japan 2018). Based on this plan, the government is pursuing the policies of reducing nuclear power dependency, reducing fossil resources dependency, and expanding renewable energy.

Minamisoma is a city located in Fukushima Prefecture, Japan. It covers approximately 399 km^2, with a population of 57,797, as of 2015. The city was directly affected by the Great East Japan Earthquake in 2011 and the nuclear power plant accident. In total, 636 people lost their lives and many people were forced to evacuate from Minamisoma to other regions. The population of the city has decreased due to deaths, those declared missing, and the evacuation of people from their hometowns. Minamisoma is proceeding with activities for recovery and reconstruction. It is also promoting the development of renewable energy for transition to a low carbon economy for economic revitalization. The local municipality, Minamisoma, wants to increase the share of renewable energies from approximately 5% as of now to around 100% by 2030. To attain this goal, the local government is installing renewable energy facilities such as mega solar and wind power generation systems.

19.3.2 Data

To evaluate the impact of the development of renewable energy using the model proposed in Sect. 19.2, we need the regional input coefficients, international import coefficient, propensity to consume, distributed consumption rate, and the distributed income rate for Minamisoma and the rest of the country. As described in Sect. 19.2, the regional input coefficient for Minamisoma is estimated with SFLQ (Ishikawa 2019b). In addition to the 86 sectors represented in the estimated regional input coefficients, we define 22 additional sectors for 19 electricity sectors, including renewable energy sectors, using IONGES. Each of the 22 new sectors is defined as a new column in the I–O transactions, describing the input structure, and a new row, describing the output structure. Data on consumption and income are available from the Statistics Bureau of Japan.

19.3.3 Scenarios

Minamisoma has had a thermal power plant and a hydroelectric power plant since before the Great East Japan Earthquake. First, we estimate the impacts of these conventional power plants on the region and the rest of Japan (Scenario 1). Minamisoma municipality formulated an energy plan after the earthquake to increase the share of renewable energy sources such as solar and wind from approximately 5% to around 100% by 2030. Hence, we estimate the impact of renewable energy plants supplying electricity instead of conventional power plants such as thermal and hydroelectric plants (Scenario 2). In fact, thermal and hydroelectric power plants in Minamisoma supply electricity to the rest of Japan. Therefore, we set a case that adds supplying electricity to the rest of Japan by conventional power plants to Scenario 1 (Scenario 3). Scenario 4 presents a case of installing renewable energy and supplying electricity by conventional generation to the rest of Japan. Because Minamisoma was directly affected by the earthquake and the nuclear power plant accident, many people subsequently moved out of the city and commuted for work. Since the model proposed in this study takes interregional commuting into account, we can estimate the effects of the change to the ratio (percentage of workers that live in the city to all workers) at which workers live in the city. In Scenario 5, we assume that all renewable energy operations and maintenance workers live in the city.

I–O models are often used to estimate indirect and induced gross impacts of new renewable energy development. In that sense, Scenario 2 is useful in evaluating the net economic effect of a transition from fossil fuel-based systems to renewable energy-based systems. Scenarios 4 and 5 also estimate the impacts of a mix of conventional electricity generation and renewable energy. Since renewable energy investments imply a shift from conventional electricity generation by fossil fuel to electricity generation by renewables, positive effects of renewable energy development and the supply of electricity by conventional generation in Minamisoma are diminished by the negative effects of the decrease in the electricity generation in the rest of Japan. Therefore, we evaluate the net impacts of Scenario 6 that consider the reduction in electricity generation in the rest of Japan with Scenario 4.

In general, we distinguish two effects: (1) an effect resulting from investments and (2) an effect caused by the operation and maintenance (O&M) of the plant. In this study, we estimate only the latter: the effects during O&M. The annual final demand for electricity in Minamisoma is estimated at 2.3 billion yen by multiplying Japan's per capita electricity demand by the population of Minamisoma (Table 19.1).

Table 19.1 Summary of analytical scenarios

	Scenario description	Type of power source		Demand for electricity	Electric power supply to rest of Japan	The ratio at which workers live in the city
		Minamisoma	Rest of Japan			
Scenario 1	Conventional generation	Thermal 94.3% hydro-electric 5.7%	Nuclear 0.9% thermal 88.9% hydroelectric 8.9% PV 0.5% wind 0.5% geo-thermal 0.3%	2.325 billion yen	–	Actual value e.g. electricity 62.3%
Scenario 2	Installing the renewable energy	Hydroelectric 5.1% PV 52.4% wind 42.5%	Nuclear 0.9% thermal 88.9% hydroelectric 8.9% PV 0.5% wind 0.5% geo-thermal 0.3%	2.325 billion yen	–	Actual value e g. electricity 62.3%
Scenario 3	Conventional generation and supply to rest of Japan	Thermal 94.3% hydro-electric 5.7%	Nuclear 0.9% thermal 88.9% hydroelectric 8.9% PV 0.5% wind 0.5% geo-thermal 0.3%	2.325 billion yen	Thermal (112.331 billion yen) hydroelectric (859 million yen)	Actual value e g. electricity 62.3%
Scenario 4	Installing the renewable energy and supply electricity by the conventional genera-tion to rest of Japan	Hydroelectric 5.1% PV 52.4% wind 42.5%	Nuclear 0.9% thermal 88.9% hydroelectric 8.9% PV 0.5% wind 0.5% geo-thermal 0.3%	2.325 billion yen	Thermal (114.027 billion yen) hydroelectric (860 million yen)	Actual value e.g. Electricity 62.3%
Scenario 5	Scenario 4 and all workers of renewable energy industry live in the city	Hydroelectric 5.1% PV 52.4% wind 42.5%	Nuclear 0.9% thermal 88.9% hydroelectric 8.9% PV 0.5% wind 0.5% geo-thermal 0.3%	2.325 billion yen	Thermal (114.027 billion yen) hydroelectric (860 million yen)	Electricity 100% and actual value for other sectors
Scenario 6	Scenario 4 and reduction of electric generation in rest of Japan	Hydroelectric 5.1% PV 52.4% wind 42.5%	Nuclear 0.9% thermal 88.9% hydroelectric 8.9% PV 0.5% wind 0 5% geo-thermal 0.3%	2.325 billion yen	Thermal (114.027 billion yen) hydroelectric (860 million yen) reduction of electric generation in rest of Japan	Actual value e.g. electricity 62.3%

19.4 Simulation Results

The simulation results by scenario are presented in Tables 19.2, 19.3, and 19.4. The impacts were estimated by 107 sectors, and these tables show the total value of production, income, and CO_2 emissions by scenario.

First, the conventional power source brings about a production inducement effect, which is valued at approximately 2.6 billion yen in the Minamisoma region and 1.2 billion yen in the rest of Japan (Scenario 1). On the contrary, renewable energy brings about an inducement effect that is valued at approximately 2.5 billion yen in the Minamisoma region and approximately 1 billion yen in the rest of Japan (Scenario 2). The effects of renewable energy are slightly lower than those of the conventional power source. However, regarding income, the effect of renewable energy on Minamisoma is slightly higher than that of the conventional power source. This is because the income rate of renewable energy sectors like solar and wind power is relatively large compared to a conventional power source like a thermal power plant.

Table 19.2 Production in different scenarios (million yen)

	Minamisoma		Rest of Japan		Total (Japan)
Scenario 1	2556	67.4%	1233	32.6%	3789
Scenario 2	2487	71.4%	996	28.6%	3483
Scenario 3	162,133	80.4%	39,610	19.6%	201,744
Scenario 4	164,079	81.2%	38,106	18.8%	202,185
Scenario 5	166,330	81.8%	36,939	18.2%	203,269
Scenario 6	164,048	198.2%	−81,269	−98.2%	82,780

Table 19.3 Income in different scenarios (million yen)

	Minamisoma		Rest of Japan		Total (Japan)
Scenario 1	178	36.7%	306	63.3%	484
Scenario 2	190	40.8%	275	59.2%	465
Scenario 3	10,626	48.0%	11,489	52.0%	22,115
Scenario 4	10,912	48.9%	11,398	51.1%	22,310
Scenario 5	13,302	59.0%	9249	41.0%	22,552
Scenario 6	10,909	61.7%	6769	38.3%	17,677

Table 19.4 CO_2 emissions in different scenarios (ton-co$_2$)

	Minamisoma		Rest of Japan		Total (Japan)
Scenario 1	70,468	97.4%	1882	2.6%	72,350
Scenario 2	210	30.1%	487	69.9%	698
Scenario 3	4,705,519	97.7%	111,551	2.3%	4,817,070
Scenario 4	4,149,128	97.6%	100,803	2.4%	4,249,931
Scenario 5	4,191,177	98.6%	59,961	1.4%	4,251,137
Scenario 6	4,148,413	3885.6%	−4,041,650	−3785.6%	106,763

Next, let us look at scenarios where electricity generated by thermal power plants in Minamisoma is supplied to the rest of Japan (Scenarios 3 and 4). In these scenarios, the economic effects, such as on production and income, are considerably large. Because there are two large-sized thermal power plants in Minamisoma, a significant amount of electricity is exported to the rest of Japan. This has considerable effects on the regional economy and the whole country. However, with respect to CO_2 emissions, the export of electricity by thermal power plants has negative effects due to high emission intensity. In Scenario 4 with renewable energy development, the economic effects on Minamisoma are a little higher than that of Scenario 3. This is because the region can supply more electricity through conventional power plants to the rest of Japan.

In Scenario 5, it is assumed that all workers of renewable energy O&M live in the city, leading to greater economic effects. On the contrary, the economic effects on the rest of Japan are lower as compared to Scenario 4.

Finally, we evaluated the net impacts of Scenario 6 that considers Scenario 4 along with the reduction of electric generation in the rest of Japan. While the reduction of electricity in the rest of Japan has negative economic effects on the rest of Japan, CO_2 emissions from Minamisoma is offset by the CO_2 reduction for the rest of Japan.

Figure 19.2 shows how much effect the demand of renewable energy has on each sector in terms of production and income. In terms of production, the Electricity sector accounts for a much larger portion in total while there are fewer effects on the

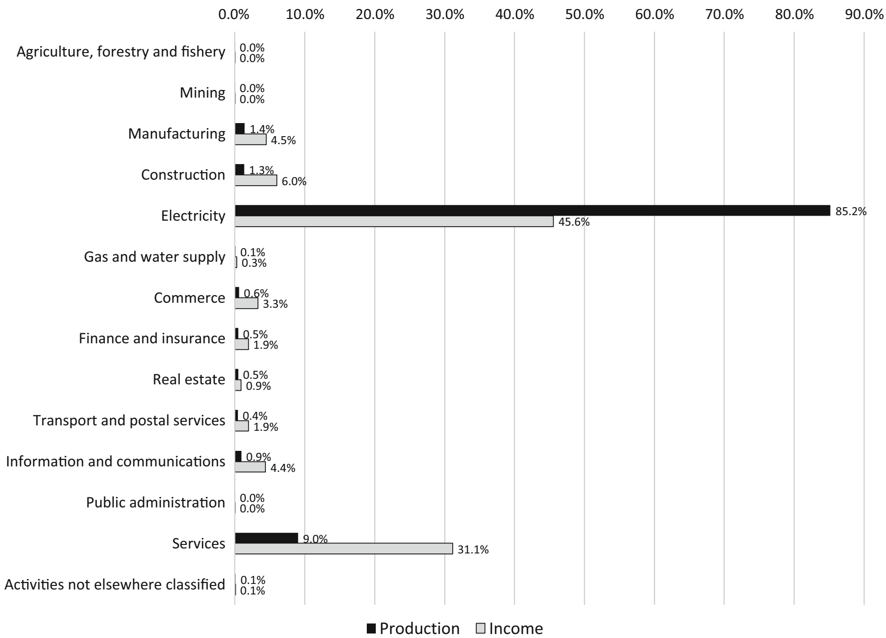

Fig. 19.2 Ratio of total production and total income in the results of Scenario 2 by sector

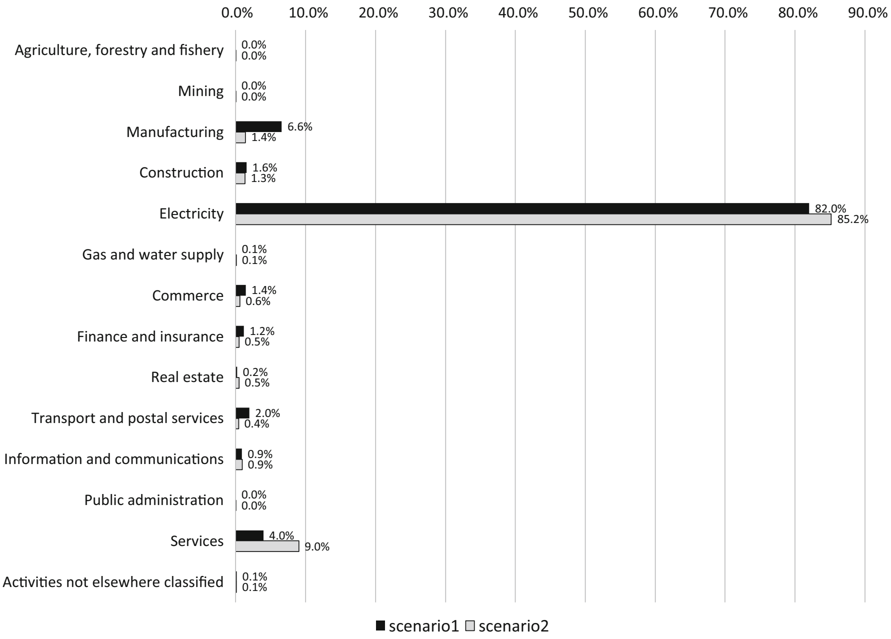

Fig. 19.3 Ratio of total production in the results of Scenario 1 and Scenario 2 by sector

others. In terms of income, the effect on Electricity is relatively small while that on Services is large. This is caused by the high ratio of employee compensation to production output.

Figure 19.3 shows the ratio of each sector to total products in Minamisoma; in the case of conventional power (Scenario 1), production of Manufacturing is higher than in the case of renewable energy (Scenario 2). In contrast, production of Services in case of conventional power (Scenario 1) is lower than in the case of renewable energy (Scenario 2). The reason is that the renewable energy input results in a greater amount of production in the Services sector.

19.5 Conclusion

With the increasing awareness of the risks of climate change, cities (not just countries) have strategies for a transition to low carbon economies using renewable energy sources. In fact, many local municipalities are promoting the introduction of renewable energy sources because of their potential to mitigate global warming. Installing renewable energy is expected to have economic effects on the regional economy in addition to lowering CO_2 emissions.

In this chapter, we proposed a versatile multiregional I–O model for estimating regional economic effects of installing renewable energy. Using this model, it is possible to estimate the economic effects without regional I–O tables. The economic effects of renewable energy are often estimated using a regional I–O model. However, when analyzing economic effects on a small region such as a municipality, I–O tables for the region are not available for many regions. Even if the I–O table is available, the conventional I–O model does not reflect interregional feedback effects and income distribution between the small region in question and other regions. The model proposed in this chapter takes these structures into consideration and is useful in estimating the regional economic and mitigative effects on CO_2 from installing renewable energy facilities.

As an example, we analyzed the effects of installing renewable energy facilities for a region affected by the Great East Japan Earthquake: Minamisoma. Simulation analyses were conducted based on some scenarios for installing renewable energy facilities. The results show that installing renewable energy facilities and the supply of electricity by a conventional power source to the rest of Japan have a larger effect on the regional economy. In this model, a non-survey approach, such as SFLQ, was applied to estimate the regional input coefficients because real regional input coefficients are not available. To assess the accuracy of this approach, it is necessary to construct a survey-based I–O table for the same region.

Municipalities are the main driver for the transition to renewable energy with the aim of having a positive regional economic effect. Assessing the regional economic impacts of renewable energy using the model proposed in this chapter will help decision-makers understand the necessity of renewable energy projects in their regions.

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Chapter 20
A Performance Assessment of Japanese Cities by Means of Data Envelopment Analysis

Soushi Suzuki

Abstract This chapter aims to provide an advanced dynamic efficiency assessment methodology for city performance strategies in Japan, based on an extended and super-efficient Data Envelopment Analysis (DEA). The use of this efficiency-improving approach originates from earlier research based on the so-called Distance Friction Minimisation (DFM) method. In this chapter we introduce a multi-period model from a blend of a Target-Oriented (TO) DFM model including a dynamic approach. This model is able to present a more realistic efficiency-improvement projection comprising a dynamic system of target-settings to achieve a target improvement level so as to programme more realistic policy actions. The above-mentioned Dynamic TO-DFM model applies to and test for a multidimensional efficiency assessment of several large Japanese cities. In this chapter, we consider two inputs (population and city budget) and two outputs (GDP and tax revenues). Based on these items, this chapter assesses the relative economic performance of 16 Japanese big cities by means of the above described, extended super-efficient DEA model. Finally, we present an efficiency-improvement programme based on the Dynamic TO-DFM model for enhancing the position of inefficient cites.

Keywords Data Envelopment Analysis (DEA) · Distance Friction Minimisation (DFM) · Super-efficiency · Target-oriented (TO) model · Dynamic DEA model · Performance assessment · Japanese cities

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20.1 Introduction

Japan shows a high degree of spatial and demographic dynamics. Compared to other nations in Asia, the Japanese economy is characterised by quite some turbulence in the past decades. Japan is already in a transition process towards a depopulating society as a result of the structural ageing process. It should be added that the spatial distribution of people—despite declining growth rates of the population—is not showing a stable pattern over the past decades. On the contrary, we observe that an increasing share of people lives in urban areas. Thus, population decline and urbanisation rise appear to become two parallel phenomena. Consequently, the position of cities is becoming more strategic in this new and dynamic societal development.

The megatrend of structural population concentration in urban areas does clearly not come to a standstill, even not in a depopulating nation like Japan. The unprecedented increases in urban population in Japan—and all over the world—have close links with the magnet position and the economic performance of cities. And therefore, it is important to assess the real socio-economic performance of urban agglomerations. An urban agglomeration comprises not only the central city, but also its suburban areas that form a functional unity with the city concerned.

There is an avalanche of literature on the driving forces of urban agglomerations (see for an overview Barufi and Kourtit 2015). Most explanations for the emergent dominance of cities and urban agglomerations stem from economic arguments related to spatial-economic externalities. But it should be added that also sociological explanations (ranging from Weber 1947 to Sassen 1991) and institutional explanations (see Scott 2003) have been provided to understand the backgrounds and force fields of modern urbanisation phenomena.

The growth of cities is historically explained from the presence of agglomeration economies, in particular Marshall–Arrow–Romer (MAR) externalities, Jacobs externalities, and Porter externalities. It is also often assumed that such positive returns to scale may be affected by negative externalities, such as environmental pollution, high energy consumption, traffic congestion, etc. Clearly, such negative factors are abundantly present in an urban economy, but if one corrects these phenomena for population size, joint use of alternative energy generation or supply (e.g., CHP, solar installations, etc.) or degree of technological innovation, one often finds that urban agglomerations are rather efficient ecological entities, compared to a completely dispersed pattern of the population.

In recent years, many efforts have been made to create a classification or ranking of cities based on their actual performance or their perceived success (see, e.g., Taylor et al. 2009; Grosveld 2002; Arribas-Bel et al. 2011; Kourtit et al. 2012). A main challenge in current empirical research is the creation of a consistent, quantitative database that is suitable for a comparative, strategic urban benchmark analysis. In the extant literature on comparisons of cities one finds a great diversity of such approaches. Urban efficiency performance has been assessed from a broad standpoint based on various quantitative models (Qiu et al. 2015; Hao et al. 2015; Saaty and Sagir 2015; Guan and Rowe 2016; Lalehpour 2016).

The measurement of urban performance calls for an appropriate methodological approach, in which the output–input ratio of cities will be interpreted as a performance measure (in economics usually called efficiency or productivity). The assessment of urban output achievement and urban input efforts is, however, fraught with many operational problems. In the past decades, a very effective instrument has been developed and employed, called Data Envelopment Analysis (DEA), which is able to confront a multidimensional set of outputs with a multidimensional set of inputs (see Charnes et al. 1978; Suzuki and Nijkamp 2017a, 2017b). DEA has become an important performance method. This approach will be adopted here, be it in various adjusted forms.

DEA has become an established quantitative assessment tool in the evaluation literature. Seiford (2005) mentions that there are at least 2800 published articles on DEA in various management and planning fields, but nowadays this number is already much higher. The DEA methodology has also expanded its scope towards other disciplines. Currently, in the urban performance context, there are several assessment studies that have applied DEA models to measure economic efficiency among cities, which are regarded as the so-called Decision Making Units (DMUs) in the DEA jargon.

Various introductions into DEA and applications to city efficiency rankings can be found in Borger and Kerstens (1996), Worthington and Dollery (2000), Afonso and Fernandes (2006), Suzuki et al. (2008), Nijkamp and Suzuki (2009), Kourtit et al. (2013) and Suzuki and Nijkamp (2017b). This large number of applied studies shows that an operational analysis of city efficiency in a competitive environment is an important, but also intriguing research topic in the urban and regional science literature. DEA has in the meantime demonstrated its great potential in providing a quantitative basis for comparative and benchmark studies in efficiency or productivity analysis.

It should be noted that DEA was originally developed to analyse the relative efficiency of a DMU by constructing a piecewise linear production frontier, and projecting the performance of each DMU onto that frontier. A DMU that is located on the frontier is efficient, whereas a DMU that is below the frontier is inefficient. The idea of DEA is that an inefficient DMU can become efficient by reducing its inputs or by increasing its outputs. In the standard DEA approach, this is achieved by a uniform reduction in all inputs (or a uniform increase in all outputs). However, in principle, there are an infinite number of possible improvements that could be implemented in order to reach the efficiency frontier, and, hence, there are many solution trajectories, if a DMU wants to enhance its efficiency.

It is noteworthy that, in the past few decades, the existence of many possible efficiency-improvement solutions has prompted a rich literature on the methodological integration of Multiple Objective Linear Programming (MOLP) and DEA models. Here, we provide a concise overview (see also Suzuki et al. 2010). One of the first contributions was offered by Golany (1988), who proposed an interactive MOLP procedure, which aimed to generate a set of efficient points for a DMU. This model allows a decision-maker to select the preferred set of output levels, given the prior input levels. Later on Thanassoulis and Dyson (1992), Joro et al. (1998), Halme et al. (1999), Frei et al. (1999), Korhonen and Siljamäki (2002), Korhonen et al. (2003), Silva et al. (2003), Lins et al. (2004), Washio et al. (2012), and Yang and Morita (2013) also proposed complementary efficiency-improvement solutions. In particular, Suzuki et al. (2010) proposed a new projection model, called a Distance Friction Minimisation (DFM) model. In this approach, a generalised distance indicator is employed to assist a DMU to improve its efficiency by a movement towards the efficiency frontier surface. Of course, the direction of the efficiency improvement depends on the input/output data characteristics of the DMU. It is then plausible to approximate suitable projection functions for the minimisation of distance by using a Euclidean distance in weighted space. As mentioned earlier, a convenient form of multidimensional projection functions that serves to improve efficiency is given by a Multiple Objective Quadratic Programming (MOQP) model, which aims to minimise the aggregated input reductions, as well as the aggregated output increases. Thus, the DFM approach can generate a new contribution to efficiency enhancement problems in decision analysis by employing a weighted Euclidean projection function, while, at the same time, it might address both an input reduction and output increase.

The DFM model is able to calculate either an optimal input reduction value or an optimal output increase value in order to reach an efficiency score of 1.0. Clearly, in reality this might be hard to reach for low-efficiency DMUs. Recently, Suzuki et al. (2015) presented a newly developed adjusted DEA model, which emerged from a blend of the DFM and the target-oriented (TO) approach based on a Super-Efficiency (SE) model (Andersen and Petersen 1993), in order to generate an appropriate efficiency-improving projection model. The TO approach specifies a target efficiency score (TES) for inefficient DMUs. This approach is able to compute both an input reduction value and an output increase value in order to achieve a TES. Recently, Suzuki and Nijkamp (2017a) also developed a new model from a blend of the TO-DFM and a Time-Series (TS) approach which incorporates a multi-temporal time horizon and a stepwise target score to achieve a final target efficiency score so as to generate a more appropriate efficiency-improving projection. This model is also able to incorporate a catch-up effect in the efficiency projection.

However, this initial TS approach assumes that the efficiency frontier is fixed at any time period. But, in reality, efficiency frontiers may vary—and do vary—from year to year. That is to say, the earlier TS approach does not incorporate a frontier-shift effect in setting the target improvement level. Therefore, it is desirable to develop a more realistic efficiency-improvement projection which includes a dynamic system of target settings so as to achieve a target improvement level in order to programme more realistic future policy initiatives.

The aim of this chapter is now to introduce a multi-period DEA model from a blend of the TO-DFM approach and a dynamic TS approach which incorporates a flexible multi-period perspective and a stepwise target score to achieve a final target efficiency result in order to programme a more appropriate efficiency-improving projection. The above-mentioned Dynamic TO-DFM model will in the present chapter be applied to a broad efficiency assessment of several large Japanese cities.

The chapter is organised as follows. Section 20.2 summarises briefly our DFM methodology, while Sect. 20.3 presents the newly developed model, which is a Dynamic TS model in the framework of a TO-DFM model. Next, Sect. 20.4 presents an application of this new methodology to an efficiency study on the economic performance of Japanese cities. Finally, Sect. 20.5 draws some conclusions.

20.2 Outline of the Distance Friction Minimisation (DFM) approach

The standard Charnes et al. (1978) model (abbreviated hereafter as the CCR-input model) for a given DMU_j ($j = 1, \cdots, J$) to be evaluated in any trial k (where k ranges over 1, 2 ..., J) may be represented as the following fractional programming (FP_k) problem (see Suzuki and Nijkamp 2017b):

$$(\mathrm{FP}_k) \quad \max_{v,u} \quad \theta = \frac{\sum_s u_s y_{sk}}{\sum_m v_m x_{mk}}$$

$$\text{s.t.} \quad \frac{\sum_s u_s y_{sj}}{\sum_m v_m x_{mj}} \leq 1 \quad (j = 1, \cdots, J) \tag{20.1}$$

$$v_m \geq 0, \quad u_s \geq 0,$$

where θ represents an objective variable function (efficiency score); x_{mj} is the volume of input m (m = 1,..., M) for DMU_j (j = 1,..., J); y_{sj} is the output s (s = 1,.. ., S) of DMU j; and v_m and u_s are the weights given to input m and output s, respectively. Model (1) is often called an input-oriented CCR model, while its reciprocal (i.e., an interchange of the numerator and denominator in the objective function (20.1) with a specification as a minimisation problem under an appropriate adjustment of the constraints) is usually known as an output-oriented CCR model. Model (1) is obviously a fractional programming model, which may be solved stepwise by first assigning an arbitrary value to the denominator in (20.1), and next maximising the numerator (see also Cooper et al. (2006) and Suzuki et al. (2010)).

The improvement projection $(\widehat{x}_k, \widehat{y}_k)$ can now be defined in (20.2) and (20.3) as:

$$\widehat{x}_k = \theta^* x_k - s^{-*}; \tag{20.2}$$

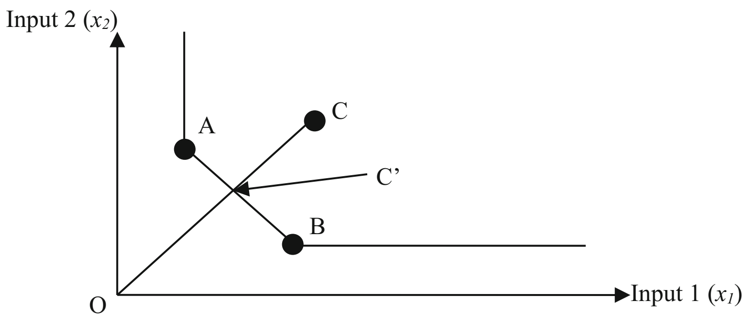


Fig. 20.1 Illustration of original DEA projection in input space

$$\widehat{y}_k = y_k + s^{+*}. \tag{20.3}$$

These equations indicate that the efficiency of (x_k, y_k) for DMU$_k$ can be improved if the input values are reduced radially by the ratio θ^* and the input excesses s^{-*} are eliminated (see Fig. 20.1).

The original DEA models presented in the literature have focused on a uniform input reduction or on a uniform output increase in the efficiency-improvement projections, as shown in Fig. 20.1 ($\theta^* =$ OC'/OC).

The (v^*, u^*) values obtained as an optimal solution for formula (20.1) result in a set of optimal weights for DMU$_k$. Hence, (v^*, u^*) is the set of most favourable weights for DMU$_k$, measured on a ratio scale. Thus, $v_m{}^*$ is the optimal weight for input item m, and its magnitude expresses how much in relative terms the item is contributing to efficiency. Similarly, $u_s{}^*$ does the same for output item s. These values show not only which items contribute to the performance of DMU$_k$, but also the extent to which they do so. In other words, it is possible to express the distance frictions (or alternatively, the potential increases) in improvement projections.

We use the optimal weights $u_s{}^*$ and $v_m{}^*$ from (20.1), and then describe the efficiency-improvement projection model (see also Suzuki et al. (2010)). In this approach, a generalised distance indicator is employed to assist a DMU in improving its efficiency by a movement towards the efficiency frontier surface. Of course, the direction of the efficiency improvement depends on the input/output data characteristics of the DMU. It is now appropriate to define the projection functions for the minimisation of distance by using a Euclidean distance in weighted space. As mentioned earlier, a suitable form of multidimensional projection functions that serves to improve efficiency is given by a Multiple Objective Quadratic Programming (MOQP) model, which aims to minimise the aggregated input reductions as well as the aggregated output increases. This DFM approach can generate a new contribution to efficiency enhancement problems in decision analysis by employing a weighted Euclidean projection function, and, at the same time, it might address both an input reduction and output increase. Here, we will only briefly sketch the various steps (for more details, we refer to Suzuki and Nijkamp 2017b).

First, the distance function Fr^x and Fr^y is specified by means of (20.4) and (20.5), which are defined by the Euclidean distance. Next, the following MOQP is solved by using d^x_{mk} (a reduction of distance for x_{mk}) and d^y_{sk} (an increase of distance for y_{sk}) as variables:

$$\min \quad \mathrm{Fr}^x = \sqrt{\sum_m \left(v^*_m x_{mk} - v^*_m d^x_{mk}\right)^2} \tag{20.4}$$

$$\min \quad \mathrm{Fr}^y = \sqrt{\sum_s \left(u^*_s y_{sk} - u^*_s d^y_{sk}\right)^2} \tag{20.5}$$

$$\text{s.t.} \quad \sum_m v^*_m \left(x_{mk} - d^x_{mk}\right) = \frac{2\theta^*}{1+\theta^*} \tag{20.6}$$

$$\sum_s u^*_s \left(y_{sk} + d^y_{sk}\right) = \frac{2\theta^*}{1+\theta^*} \tag{20.7}$$

$$x_{mk} - d^x_{mk} \geq 0 \tag{20.8}$$

$$d^x_{mk} \geq 0 \tag{20.9}$$

$$d^y_{sk} \geq 0, \tag{20.10}$$

where x_{mk} is the amount of input item m for any arbitrary inefficient DMU_k, while y_{sk} is the amount of output item s for any arbitrary inefficient DMU_k. The constraint functions (20.6) and (20.7) refer to the target values of input reduction and output augmentation. The proportional distribution of the input and output contributions in achieving efficiency is established as follows. The total efficiency gap to be covered by inputs and outputs is (1 − θ*). The input and the output side contribute according to their initial levels 1 and θ*, implying shares θ*/(1 + θ*) and 1/(1 + θ*) in the improvement contribution. Clearly, the contributions from both sides equal (1 − θ*) [θ*/(1 + θ*)], and (1 − θ*) [1/(1 + θ*)]. Hence, we derive for the input reduction targets and the output augmentation targets the following expressions:input reduction target:

$$\sum_m v^*_m \left(x_{mk} - d^x_{mk}\right) = 1 - (1-\theta^*) \times \frac{1}{(1+\theta^*)} = \frac{2\theta^*}{1+\theta^*}. \tag{20.11}$$

output augmentation target:

$$\sum_s u^*_s \left(y_{sk} + d^y_{sk}\right) = \theta^* + (1-\theta^*) \times \frac{\theta^*}{(1+\theta^*)} = \frac{2\theta^*}{1+\theta^*}. \tag{20.12}$$

An illustration of this approach is given in Fig. 20.2.

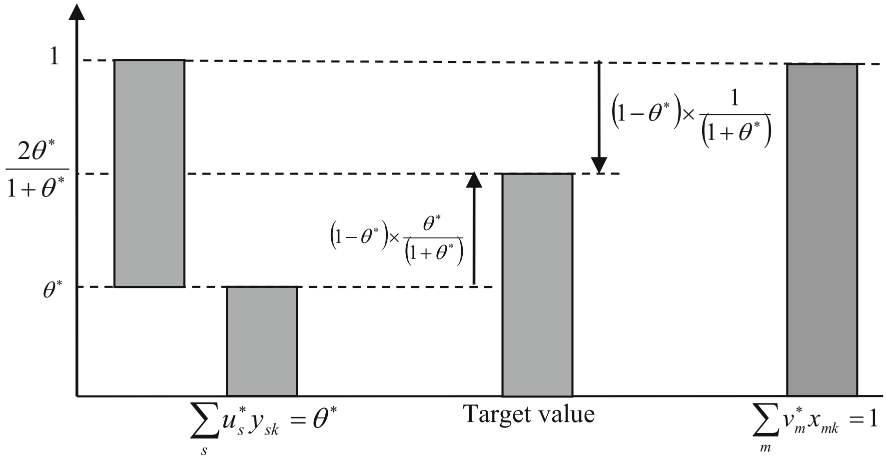


Fig. 20.2 DFM model with an illustration of the relative contribution of inputs and outputs to closing the efficiency gap

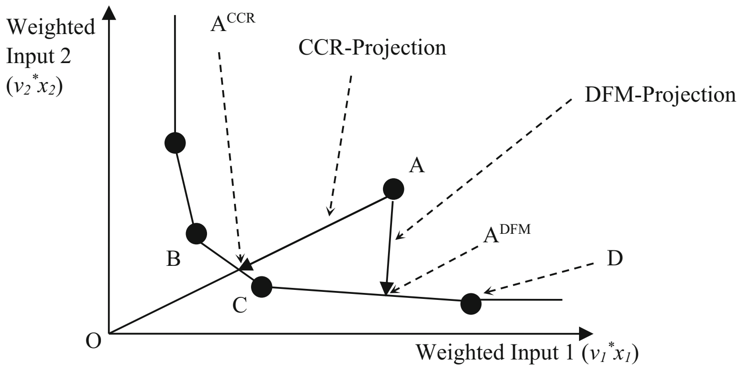


Fig. 20.3 Degree of improvement of the DFM and the CCR projection in weighted input space

It is now possible to determine each optimal distance d_{mk}^{x*} and d_{sk}^{y*} by using the MOQP model (20.4)–(20.10). The distance minimisation solution for an inefficient DMU_k can be expressed by means of formulas (20.13) and (20.14):

$$x_{mk}^* = x_{mk} - d_{mk}^{x*}; \tag{20.13}$$

$$y_{sk}^* = y_{sk} + d_{sk}^{y*}. \tag{20.14}$$

By means of the DFM model described above, it is possible to present a new efficiency-improvement solution based on the standard CCR projection. This means an increase in new options for efficiency-improvement strategies in DEA. The main advantage of the DFM model is that it yields an outcome on the efficient frontier that is as close as possible to the DMU's input and output profile (see Fig. 20.3). This approach has functioned as an ingredient for many recent DEA studies by the authors of this paper.

20.3 Dynamic TO-DFM model

Many urban policy strategies call for a multi-temporal perspective, so that appropriate adjustments can be made before the end of the programming horizon.

The Dynamic TO-DFM model designed in the present chapter comprises the following steps:

Step 1 The final Target Efficiency Score during the target achievement period P in period $p = 0$ (i.e., the origin period) for DMU_k (hereafter FTES^P) is set arbitrarily by the decision- or policy-maker. The improvement projections are divided into two types, depending on the score of the FTES^P as follows:

- $\theta_0{*} < \mathrm{FTES}^P < 1.000$; *Non-Attainment* DFM projection (score does not reach the efficiency frontier). This may make sense for DMUs that are far below the efficiency frontier;
- $\mathrm{FTES}^P = 1.000$; *Normal* DFM projection (solution just reaches the efficiency frontier);

where θ_0^* is an efficiency score for DMU_k in period 0.

Step 2 The Total Efficiency Gap at the target achievement time P for DMU_k in period 0 (hereafter TEG_0^P) is calculated by formula (20.15):

$$\mathrm{TEG}_0^P = \mathrm{FTES}^P - \theta_0^*. \tag{20.15}$$

The Target Efficiency Score at any arbitrary period t ($t = 1, 2, \ldots, P$) for DMU_k in period 0 (hereafter TES_0^t) is calculated by formula (20.16):

$$\mathrm{TES}_0^t = \theta_0^* + \frac{t}{P} \times \mathrm{TEG}_0^P. \tag{20.16}$$

The FTES^P, TEG_0^P, and TES_0^t values at an arbitrary period t ($t = 1, 2, \ldots, P$) in period 0 are illustrated in Fig. 20.4.

Step 3 Solve

$$\mathrm{TES}_0^t = \frac{\theta_0^* + \mathrm{MP}_0^t\left(1 - \theta_0^*\right) \times \frac{\theta_0^*}{\left(1+\theta_0^*\right)}}{1 - \mathrm{MP}_0^t\left(1 - \theta_0^*\right) \times \frac{1}{\left(1+\theta_0^*\right)}}. \tag{20.17}$$

The essence of formula (20.17) is closely associated with formula (20.11) and (20.12). The numerator is formed by output augmentation targets that correspond to

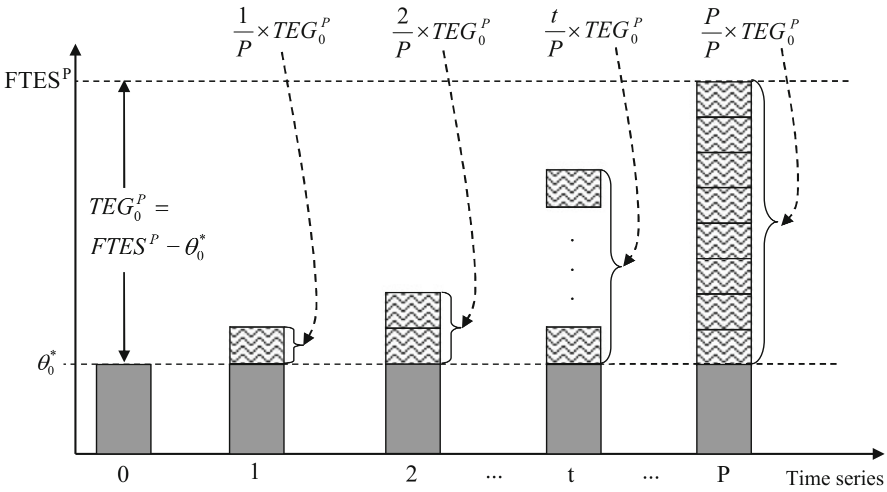


Fig. 20.4 Illustration of the FTES^P, TEG$_0^P$, and TES$_0^t$ at arbitrary period t in period 0

formula (20.22), while the denominator is the input reduction target corresponding to formula (20.21), in formula (20.17), so as to reach TES$_0^t$. Then, we get MP$_0^t$, which is a Magnification Parameter of TES$_0^t$. MP$_0^t$ assumes an intermediate role by adjusting the input reduction target and the output augmentation target in formulas (20.20) and (20.21) in order to ensure an alignment of the TES$_0^t$ and DFM projection score for DMU$_k$.

Step 4 Solve the Dynamic TO-DFM model using formulas (20.18)–(20.25). Then, an optimal input reduction value and output increase value to reach a TES$_0^t$ can be calculated as follows:

$$\min \quad \mathrm{Fr}^x = \sqrt{\sum_m \left(v_m^* x_{mk} - v_m^* d_{mk}^{xt}\right)^2}; \tag{20.18}$$

$$\min \quad \mathrm{Fr}^y = \sqrt{\sum_s \left(u_s^* y_{sk} - u_s^* d_{sk}^{yt}\right)^2}; \tag{20.19}$$

$$\text{s.t.} \quad \mathrm{TES}_0^t = \frac{\sum_s u_s^* \left(y_{sk} + d_{sk}^{yt}\right)}{\sum_m v_m^* \left(x_{mk} - d_{mk}^{xt}\right)}; \tag{20.20}$$

$$\sum_m v_m^* \left(x_{mk} - d_{mk}^{xt}\right) = 1 - MP_0^t\left(1 - \theta_0^*\right) \times \frac{1}{\left(1 + \theta_0^*\right)}; \tag{20.21}$$

$$\sum_s u_s^* \left(y_{sk} + d_{sk}^{yt} \right) = \theta_0^* + MP_0^t \left(1 - \theta_0^* \right) \times \frac{\theta_0^*}{\left(1 + \theta_0^* \right)}; \tag{20.22}$$

$$x_{mk} - d_{mk}^{xt} \geq 0; \tag{20.23}$$

$$d_{mk}^{xt} \geq 0; \tag{20.24}$$

$$d_{sk}^{yt} \geq 0. \tag{20.25}$$

Step 3 and Step 4 are of course repetitive computations using the values $t = 1, 2, \ldots, P$.

Step 5 Now, we make a shift to period p ($p = 1, 2, \ldots, P$).

Calculate an efficiency score for DMU_k in period p based on a dataset for all DMUs in period p. We then get θ_p^* for DMU_k.

The "Total Efficiency Gap" at the target achievement time P for DMU_k in period p (hereafter TEG_p^P) is calculated by formula (20.26):

$$\text{TEG}_p^P = \text{FTES}^P - \theta_p^*. \tag{20.26}$$

The Target Efficiency Score at any arbitrary period t ($t = 1, 2, \ldots, P$) for DMU_k in period p (hereafter TES_p^t) is calculated by formula (20.27):

$$\text{TES}_p^t = \theta_p^* + \frac{(t - p)}{(P - p)} \times \text{TEG}_p^P. \tag{20.27}$$

TEG_p^P and TES_p^t at an arbitrary time t ($t = 1, 2, \ldots, P$) in period p are illustrated in Fig. 20.5 (this is an example in the case of $p = 1$).

From Fig. 20.5, we notice that $\theta_0^* + \frac{1}{P} \times \text{TEG}_0^P \neq \theta_1^*$ in t (and period p) $= 1$. This means that there is a gap between the target improvement efficiency score at period 1 in period 0 $\left(\theta_0^* + \frac{1}{P} \times \text{TEG}_0^P \right)$ and the real improved efficiency score in period 1 $\left(\theta_1^* \right)$. Of course, this might coincidentally be in accordance with these values, but this may be considered as an extremely rare case. Therefore, we need to adjust a target efficiency score incorporating these gaps to set an adjusted target in the next period in order to reach a FTES in the target achievement period P. This adjustment is described here as a difference between TEG_1^P and TEG_0^P.

We also notice that $\theta_1^* - \theta_0^*$ includes both a catch-up effect and a frontier-shift effect. That is to say, our new Dynamic TO-DFM model can incorporate these two effects in the efficiency-improvement projection.

Step 6 Solve

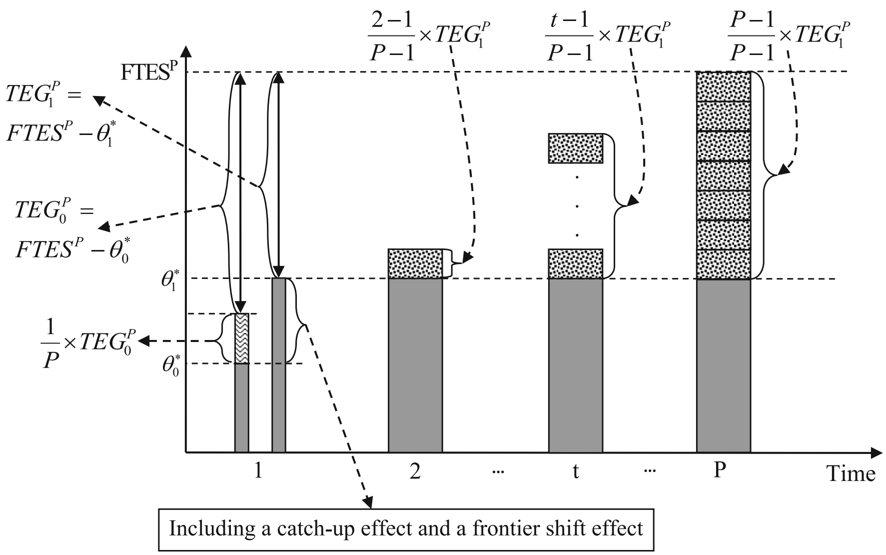


Fig. 20.5 Illustration of the FTES^P, TEG$_0^P$, and TES$_0^t$ at arbitrary period t (in the case of period 1)

$$\mathrm{TES}_p^t = \frac{\theta_p^* + \mathrm{MP}_p^t\left(1 - \theta_p^*\right) \times \frac{\theta_p^*}{\left(1+\theta_p^*\right)}}{1 - \mathrm{MP}_p^t\left(1 - \theta_p^*\right) \times \frac{1}{\left(1+\theta_p^*\right)}}. \tag{20.28}$$

Then, we get MP_p^t, which is a Magnification Parameter of TES_p^t. MP_p^t assumes an intermediate role by adjusting the input reduction target and the output increase target in formulas (20.32) and (20.33) in order to ensure an alignment of the TES_p^t and DFM projection score for DMU$_k$.

Step 7 Solve the Dynamic-TO-DFM model using formulas (20.29)–(20.36); then, an optimal input reduction value and output increase value to reach a TES_p^t can be calculated as follows:

$$\min \quad \mathrm{Fr}^x = \sqrt{\sum_m \left(v_m^* x_{mk} - v_m^* d_{mk}^{xt}\right)^2}; \tag{20.29}$$

$$\min \quad \mathrm{Fr}^y = \sqrt{\sum_s \left(u_s^* y_{sk} - u_s^* d_{sk}^{yt}\right)^2}; \tag{20.30}$$

$$\text{s.t.} \quad \mathrm{TES}_p^t = \frac{\sum_s u_s^* \left(y_{sk} + d_{sk}^{yt}\right)}{\sum_m v_m^* \left(x_{mk} - d_{mk}^{xt}\right)}; \tag{20.31}$$

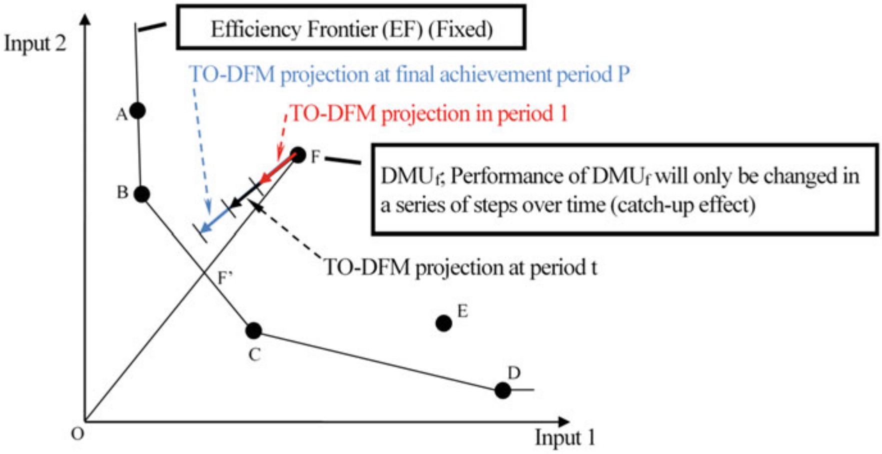


Fig. 20.6 Illustration of TS-TO-DFM model

$$\sum_m v_m^* \left(x_{mk} - d_{mk}^{xt}\right) = 1 - \mathrm{MP}_p^t \left(1 - \theta_p^*\right) \times \frac{1}{\left(1 + \theta_p^*\right)}; \tag{20.32}$$

$$\sum_s u_s^* \left(y_{sk} + d_{sk}^{yt}\right) = \theta_p^* + \mathrm{MP}_p^t \left(1 - \theta_p^*\right) \times \frac{\theta_p^*}{\left(1 + \theta_p^*\right)}; \tag{20.33}$$

$$x_{mk} - d_{mk}^{xt} \geq 0; \tag{20.34}$$

$$d_{mk}^{xt} \geq 0; \tag{20.35}$$

$$d_{sk}^{yt} \geq 0. \tag{20.36}$$

Step 6 and Step 7 are repeated computations using the values $t = 1, 2, \ldots, P$.

Step 8 Period p makes a shift to period P; then the Dynamic-TO-DFM model is completed.

Step 9 Decision—or policy—makers may next conduct a feasibility analysis for these improvement plans. If the plan proposed still remains out of reach at p, then the decision—or policy—maker may set an adjusted Final Target Efficiency Score at the target achievement period P, like $\mathrm{FTES}^P_{\mathrm{Adjustment}}$. Then Step 2 to Step 7 are again repeated computations.

An illustration of the TS-TO-DFM model is given in Fig. 20.6, while an illustration of the Dynamic TO-DFM model is given in Fig. 20.7.

From Fig. 20.6, we notice that our TS-TO-DFM model assumes that the efficiency frontier is fixed at any time period. That is to say, the TS approach does not incorporate a frontier-shift effect in setting the target improvement level, as shown in Fig. 20.6.

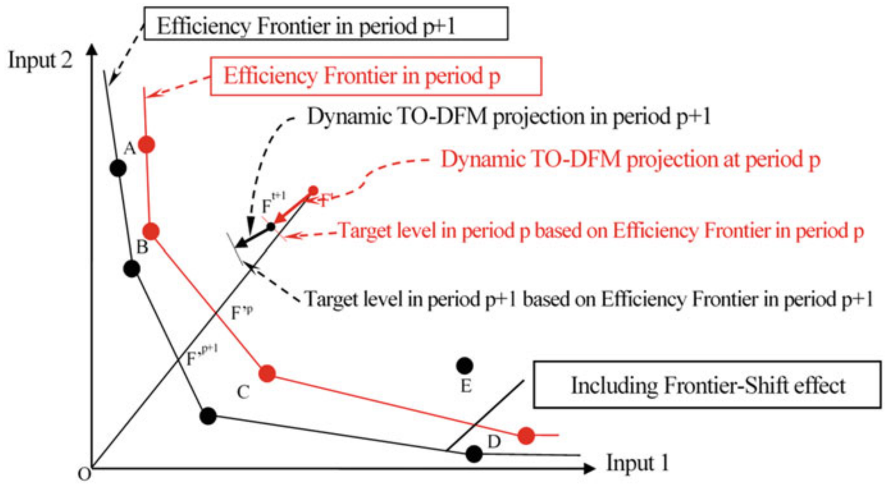


Fig. 20.7 Illustration of Dynamic TO-DFM model

In contrast, from Fig. 20.7 we notice that a new Dynamic TO-DFM model includes both a frontier-shift effect and a catch-up effect of target-settings to achieve a target improvement level in order to programme more realistic policy initiatives, as is suggested in Fig. 20.7.

20.4 An Evaluation of the Economic Performance of Japanese Cities

20.4.1 Database and Analytical Framework

As mentioned at the beginning, recent population and economic changes in urban systems in Japan call for a careful policy assessment of cities. For our empirical analysis we use a set of relevant input and output data from 2007 to 2013 for a set of 16 Japanese big cities (the so-called government-ordinance-designated cities, in Japan) in order to evaluate and compare their broad economic efficiency. The DMUs used in our analysis are listed in Table 20.1. We note that Sagamihara, Sakai, Okayama, and Kumamoto are also government-ordinance-designed cities we note that at present, but these cities were announced officially only after 2007 (while the GRP data of Sakai city were undocumented from 2007 to 2013). Consequently, these cities were omitted from the list, for reasons of institutional change of the executive authority and data restrictions.

For our comparative analysis of these 16 cities, we consider two Inputs (I):

(I1) Population (Reference: population data from the Basic Resident Register in Japan; source: data acquisition from each city’s website);

Table 20.1 A list of Japanese big cities

No.	City	No.	City
1	Sapporo	9	Hamamatsu
2	Sendai	10	Nagoya
3	Saitama	11	Kyoto
4	Chiba	12	Osaka
5	Yokohama	13	Kobe
6	Kawasaki	14	Hiroshima
7	Niigata	15	Kitakyushu
8	Shizuoka	16	Fukuoka

(I2) City budget (Reference: Ministry of Internal Affairs and Communications; source: Statistical Yearbook of Local Government Finance 2007–2013.
http://www.soumu.go.jp/iken/zaisei/toukei.html

In our extended DEA model also two Outputs (O) are incorporated:

(O1) GRP (Gross Regional Product) (Reference: municipal accounts; data acquisition from each city's website);
(O2) Tax revenues (this is tax revenues for local governments; it is composed by independent revenue which is not including a subsidy from the national government)
(Reference: Ministry of Internal Affairs and Communications, Statistical Yearbook of Local Government Finance 2007–2013, http://www.soumu.go.jp/iken/zaisei/toukei.html).

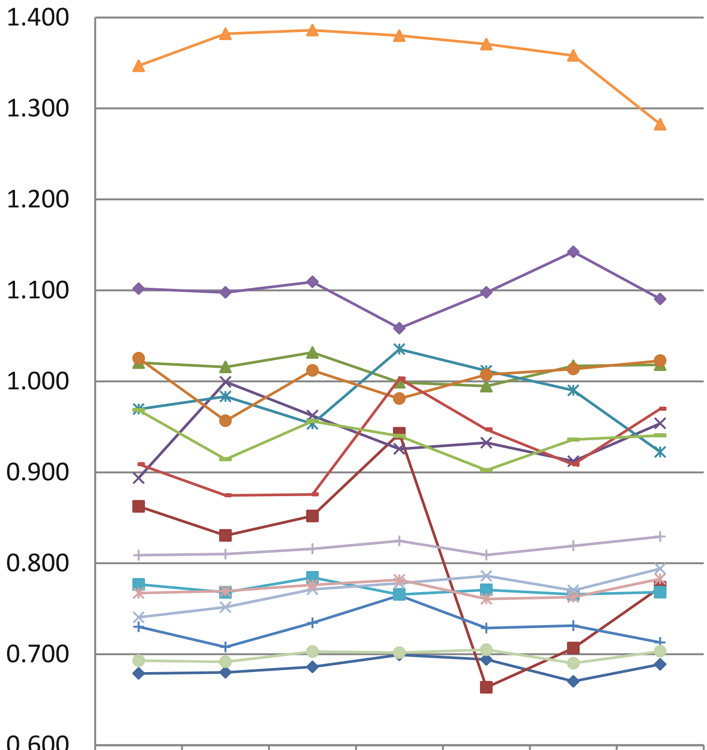
20.4.2 *Efficiency Evaluation Based on the Super-Efficiency CCR-I Model*

The efficiency assessment result for the 16 cities from 2007 to 2013 based on the Super-Efficiency CCR-I model is presented in Fig. 20.8. Clearly, various cities in Japan have a DEA score above 1.0.

From Fig. 20.8, it can be seen that Osaka, Nagoya, Kawasaki, and Saitama in 2013 may be regarded as super-efficient cities. Osaka city is central to the vitality of the Kansai regional economy, while Nagoya city is essential for the vitality of the manufacturing hub in Japan. Kawasaki and Saitama are situated in the Tokyo metropolitan area. Furthermore, these cities are characterised by a maximum population density, as shown in Table 20.2.

As a next step in our chapter, we have carried out a correlation analysis between population density and DEA scores, as shown in Fig. 20.9.

The coefficient of correlation in Fig. 20.9 is 0.756, while, in particular, it shows a statistical significance (*P* value is 0.000697, significant at a 1% level). From these facts, we can infer that these cities have a prerogative of economic, geographical, and population density.



	2007	2008	2009	2010	2011	2012	2013
Sapporo	0.679	0.680	0.686	0.699	0.694	0.670	0.689
Sendai	0.862	0.831	0.852	0.943	0.664	0.707	0.774
Saitama	1.021	1.016	1.032	0.999	0.995	1.017	1.018
Chiba	0.894	0.999	0.962	0.926	0.932	0.912	0.954
Yokohama	0.969	0.983	0.953	1.035	1.012	0.990	0.922
Kawasaki	1.025	0.957	1.012	0.981	1.007	1.014	1.023
Niigata	0.730	0.708	0.734	0.765	0.729	0.731	0.713
Shizuoka	0.909	0.875	0.876	1.003	0.947	0.909	0.970
Hamamatsu	0.968	0.914	0.956	0.940	0.902	0.936	0.941
Nagoya	1.102	1.098	1.109	1.058	1.098	1.142	1.090
Kyoto	0.777	0.768	0.784	0.766	0.771	0.766	0.768
Osaka	1.347	1.382	1.386	1.380	1.371	1.358	1.283
Kobe	0.741	0.752	0.771	0.778	0.786	0.770	0.794
Hiroshima	0.767	0.769	0.776	0.782	0.761	0.763	0.783
Kitakyushu	0.693	0.692	0.703	0.702	0.705	0.690	0.703
Fukuoka	0.809	0.810	0.816	0.824	0.809	0.819	0.829

Fig. 20.8 Efficiency scores for Japanese big cities based on the SE-CCR-I model

Table 20.2 list of population density

	population density
Sapporo	1742.5
Sendai	1376.3
Saitama	5814.5
Chiba	3579
Yokohama	8517.1
Kawasaki	10316.8
Niigata	1115.7
Shizuoka	499.5
Hamamatsu	512.3
Nagoya	7033.5
Kyoto	1781.2
Osaka	11952.1
Kobe	2760.9
Hiroshima	1317.7
Kitakyushu	1955.1
Fukuoka	4480.5

(Source: Kawasaki city web site, Comparison of large cities based on national population census 2015, http://www.city.kawasaki.jp/170/cmsfiles/contents/0000075/75504/h27kokucho-daitoshi.pdf)

It can also be seen that the efficiency scores of Sendai 2011 decline drastically compared to their 2010 score. It is plausible that this reflects the serious impact of the Great East Japan Earthquake in 2011. We also notice that Sapporo city has the lowest efficiency scores. Sapporo city may also suffer from an indirect influence of the earthquake from 2011. Sightseeing (e.g., nature) is one of the main industries of Sapporo in Hokkaido prefecture (total tourist income of Hokkaido in 2015 is 1.43 trillion Yen, while total economic ripple effect is 2.09 trillion Yen. More detail, see report from Hokkaido prefecture; http://www.pref.hokkido.lg.jp/kz/kkd/toukei/6th_Economic_impacts_research_20170922_58.pdf).

The number of total tourism visitors to Hokkaido is ranked secondly among all prefectures in Japan. A time-series comparison of the number of visitors to Hokkaido is shown in Fig. 20.10. From Fig. 20.10, we notice that the number of visitors show a steep decline in 2011, as a result of a negative effect of radiation contamination by the Fukushima nuclear accident.

It seems thus necessary to make a serious effort to improve the urban economic performance of this city. We will now address here in particular the city of Sapporo.

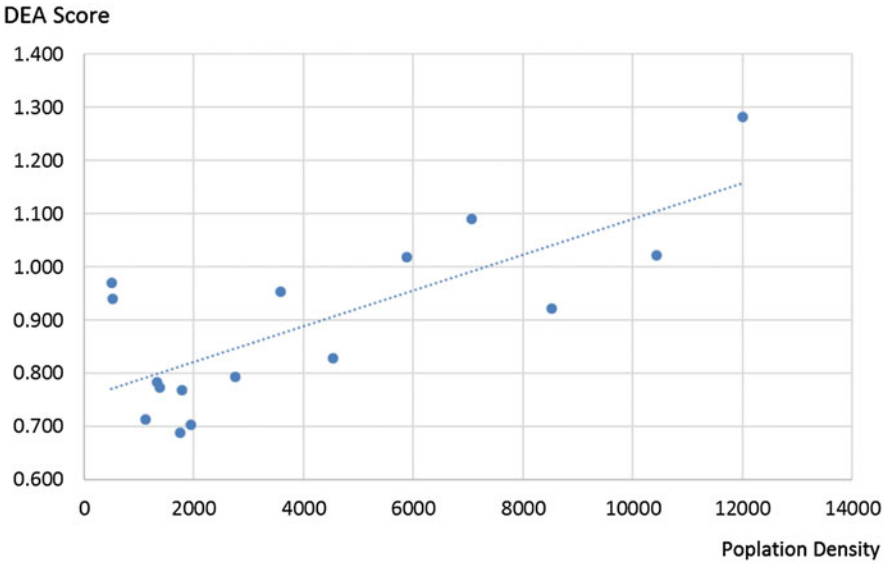


Fig. 20.9 Correlation analysis between population density and DEA score

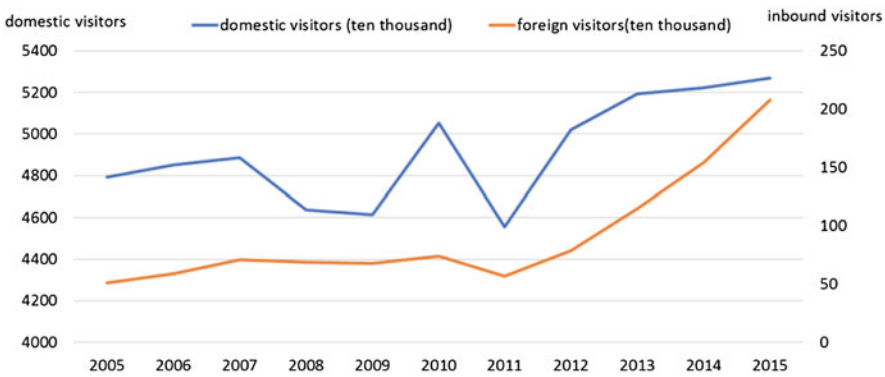


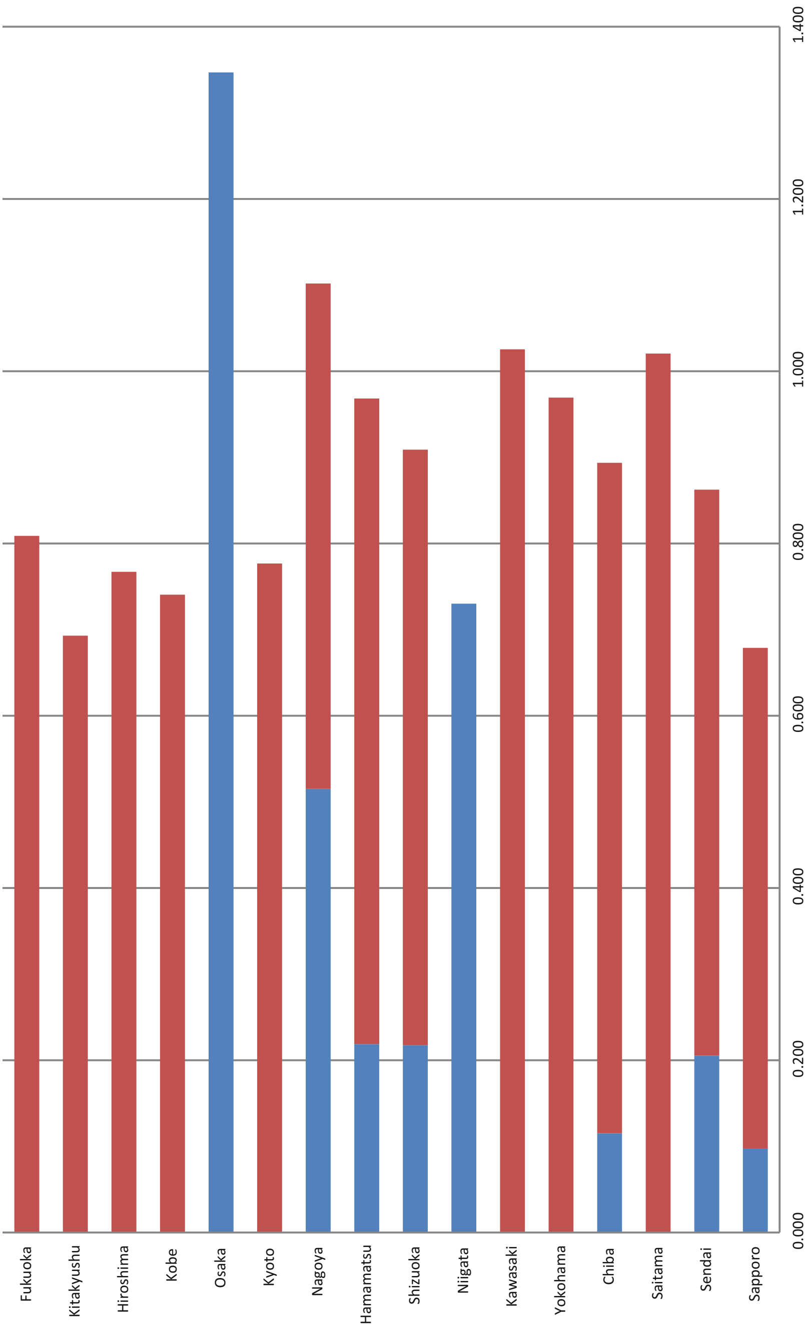
Fig. 20.10 Time-series comparison of the number of visitors in Hokkaido (Source: Report of the Tourist Bureau, Economic Department, Hokkaido Government: Report on Survey on Number of Tourists in Hokkaido, 2015)

20.4.3 Optimum Weights for Input and Output Items

We will analyse and consider optimum weights for input and output items. The optimum weight is the set of most favourable weights for each DMU, so that we can find the relative importance of each indicator with reference to the value of each input and output items for each DMU. These values show not only which items contribute to the performance of a DMU, but also to what extent they do so. The optimum weights for input and output items for each city in 2007 are presented in

	Sapporo	Sendai	Saitama	Chiba	Yokohama	Kawasaki	Niigata	Shizuoka	Hamamatsu	Nagoya	Kyoto	Osaka	Kobe	Hiroshima	Kitakyushu	Fukuoka
VX(1) Budget	0.925	1.000	1.000	0.921	0.898	0.776	1.000	1.000	1.000	0.888	0.397	0.000	0.394	0.384	0.403	0.397
VX(2) Population	0.075	0.000	0.000	0.079	0.102	0.224	0.000	0.000	0.000	0.112	0.603	1.000	0.606	0.616	0.597	0.603

Fig. 20.11 Optimum weights for input items



	Sapporo	Sendai	Saitama	Chiba	Yokohama	Kawasaki	Niigata	Shizuoka	Hamamatsu	Nagoya	Kyoto	Osaka	Kobe	Hiroshima	Kitakyushu	Fukuoka
UY(1) GDP	0.098	0.205	0.000	0.115	0.000	0.000	0.730	0.218	0.219	0.515	0.000	1.347	0.000	0.000	0.000	0.000
UY(2) Tax revenues	0.581	0.657	1.021	0.778	0.969	1.025	0.000	0.691	0.750	0.587	0.777	0.000	0.741	0.767	0.693	0.809

Fig. 20.12 Optimum weights for output items

Figs. 20.11 and 20.12. From these results, it can be seen that, for instance, Sapporo obtains a weight for Budget equal to 0.925 and for population equal to 0.075 in its inputs, while it obtains for GDP a weight of 0.098 and for Tax revenues a weight of 0.581 in its outputs. Furthermore, it can be seen that, Kawasaki obtains a weight for Budget equal to 0.776 and for population equal to 0.224 in its inputs, while it obtains for GDP a weight of 0.000 and for Tax revenues a weight of 1.025 in its output, while Yokohama obtains a weight for Budget equal to 0.898 and for population equal to 0.102 in its inputs, while it obtains for GDP a weight of 0.000 and for Tax revenues a weight of 0.969 in its output. From these findings, we notice that these cities in Kanto-region reveal features similar to optimum weights, especially since these cities have a commonality feature that have a high value for Budget in input items and for Tax revenues in output items, while they have a weakness by GDP in output items.

These results offer meaningful insights for policies on efficiency improvement of city.

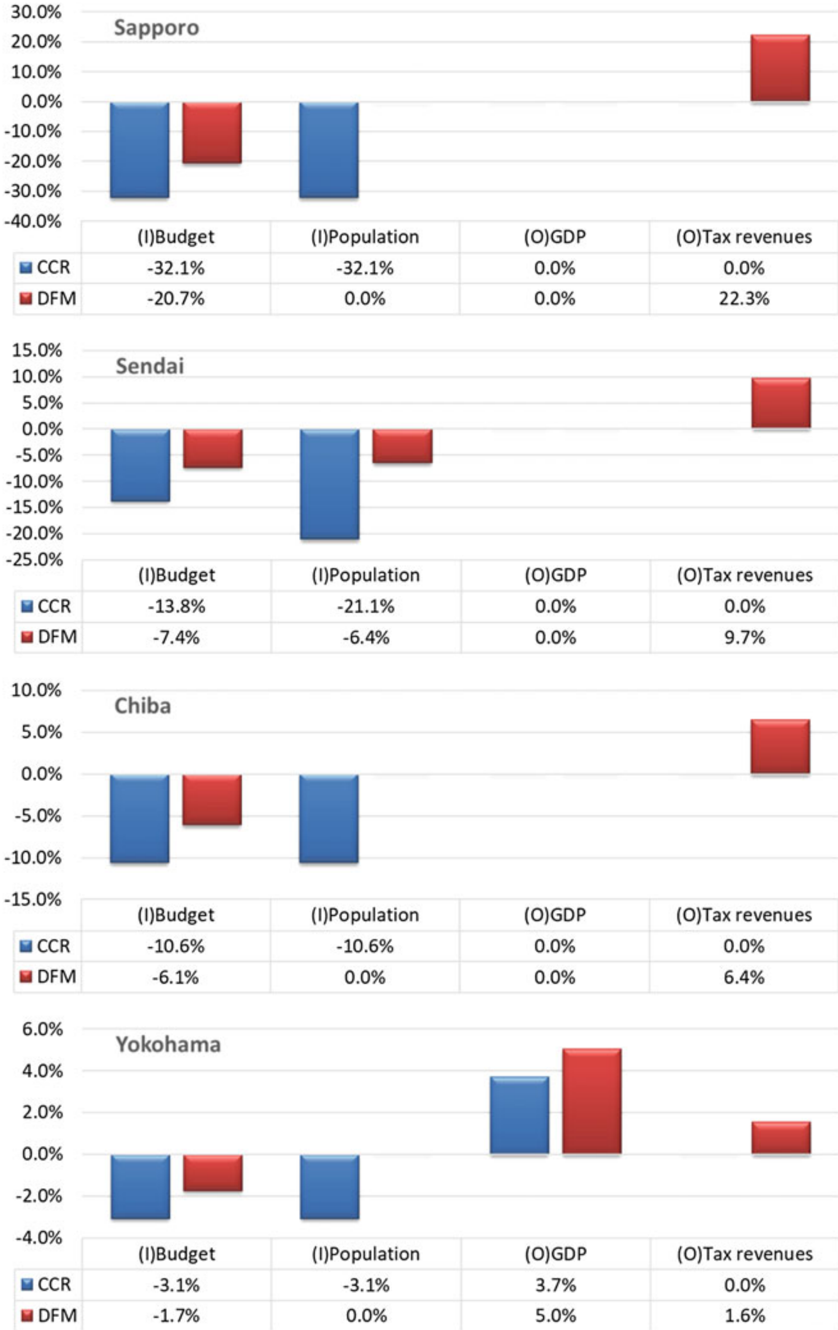
20.4.4 Efficiency-Improvement Projection Based on the CCR and DFM Models

The results of an efficiency-improvement projection based on the application of CCR and DFM models for inefficient Japanese big cities in 2007 are presented in Fig. 20.13.

From Fig. 20.13, it appears that the DFM model clearly shows that a different—and likely more efficient—solutions than the standard CCR projection is available for reaching the efficiency frontier. This is particularly confirmed for Kitakyushu. For instance, the CCR projection in Fig. 20.13 show that the Kitakyushu should reduce its Budget and population by 30.7%, together with an increase in the GDP of 27.2%, in order to become efficient. On the other hand, the DFM results show that a reduction in Population by 30.4%, together with an increase in the Tax revenues of 18.1%, is required to become efficient.

20.4.5 Efficiency-Improvement Projection Based on the TS-TO-DFM Model and the Dynamic TO-DFM Model for Sapporo

Next, the above-mentioned Dynamic TO-DFM model is used to analyse realistic circumstances and to determine the requirements for an operational strategy for a feasible efficiency improvement in Sapporo city. We will use Sapporo 2007 as an illustrative case and point of reference, and present an efficiency-improvement projection result based on the TS-TO-DFM model and the Dynamic TO-DFM



Sapporo

	(I)Budget	(I)Population	(O)GDP	(O)Tax revenues
CCR	-32.1%	-32.1%	0.0%	0.0%
DFM	-20.7%	0.0%	0.0%	22.3%

Sendai

	(I)Budget	(I)Population	(O)GDP	(O)Tax revenues
CCR	-13.8%	-21.1%	0.0%	0.0%
DFM	-7.4%	-6.4%	0.0%	9.7%

Chiba

	(I)Budget	(I)Population	(O)GDP	(O)Tax revenues
CCR	-10.6%	-10.6%	0.0%	0.0%
DFM	-6.1%	0.0%	0.0%	6.4%

Yokohama

	(I)Budget	(I)Population	(O)GDP	(O)Tax revenues
CCR	-3.1%	-3.1%	3.7%	0.0%
DFM	-1.7%	0.0%	5.0%	1.6%

Fig. 20.13 Efficiency-improvement projection results of CCR and DFM model

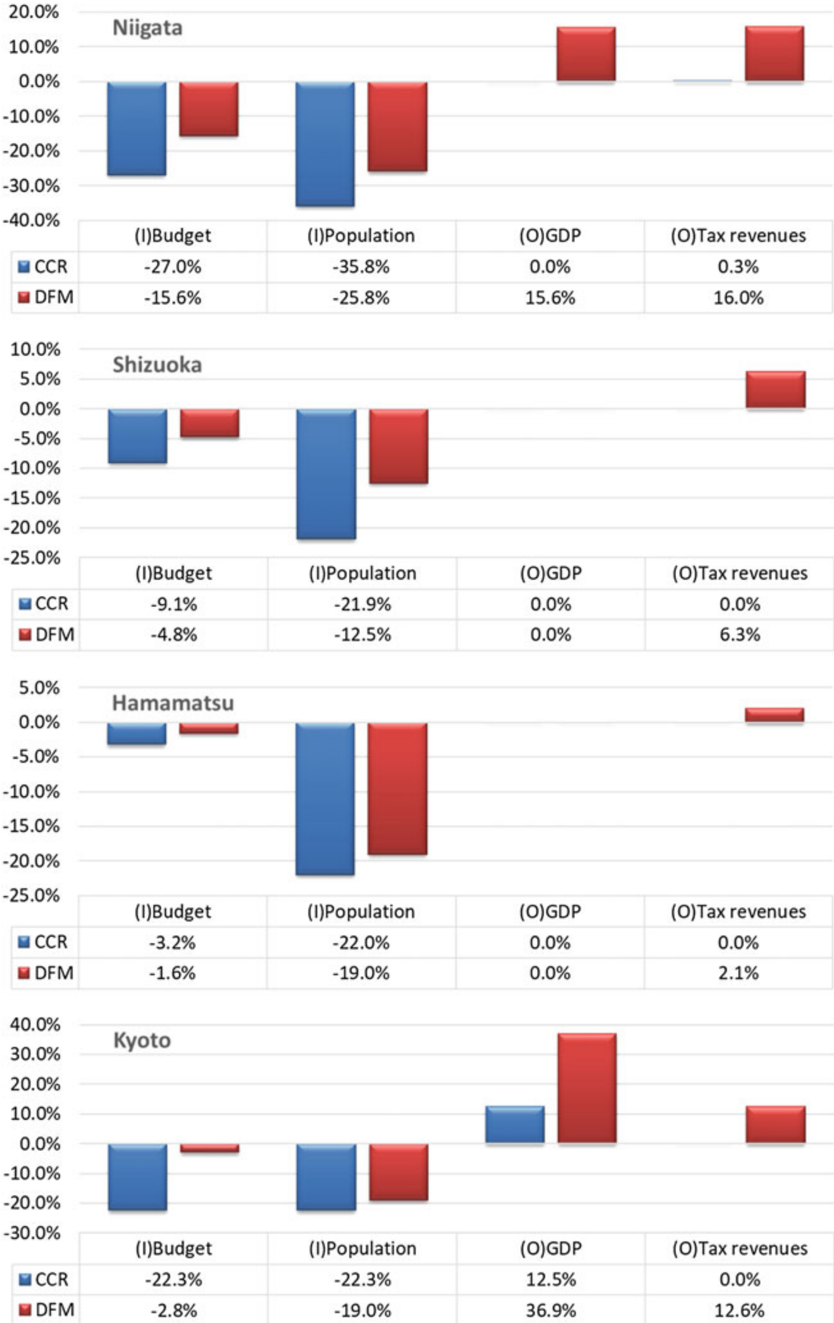


Fig. 20.13 (continued)

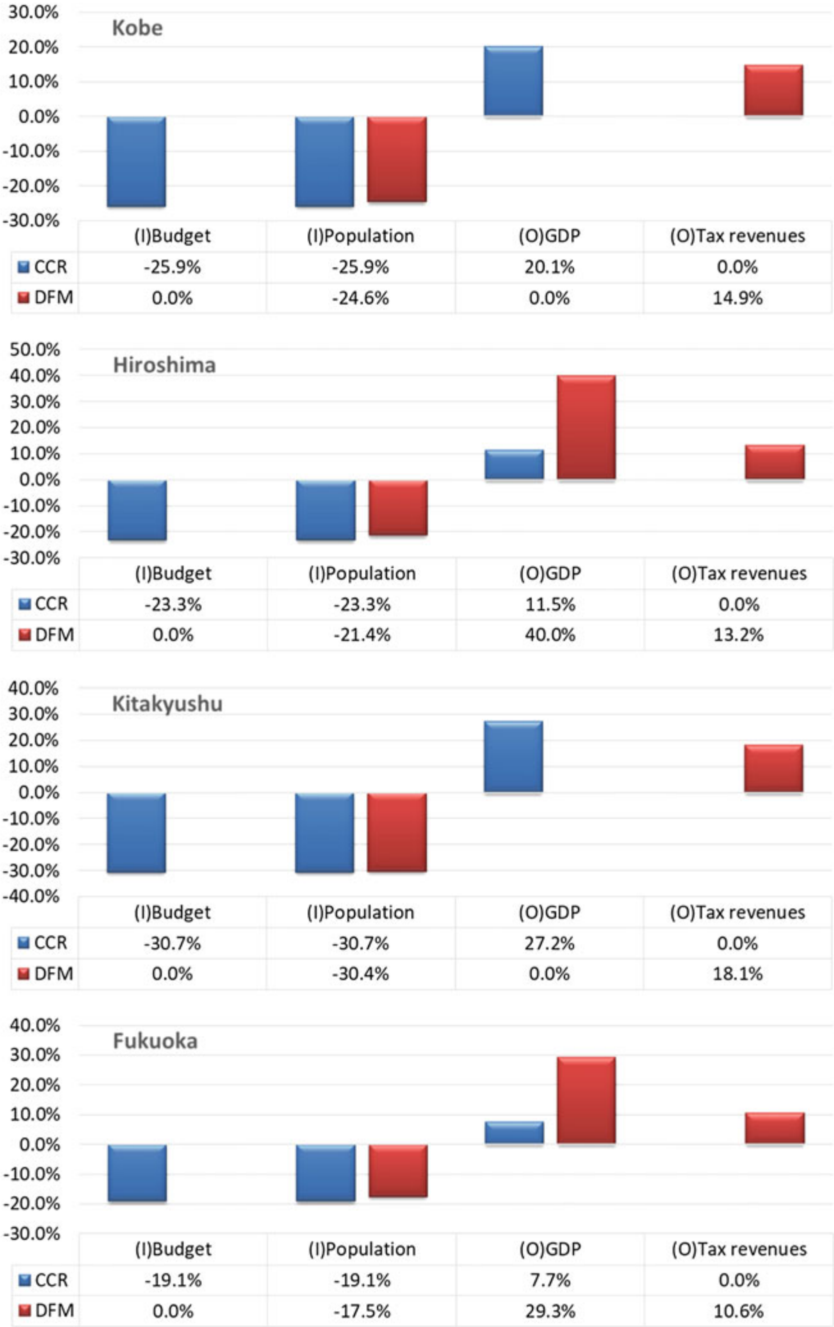
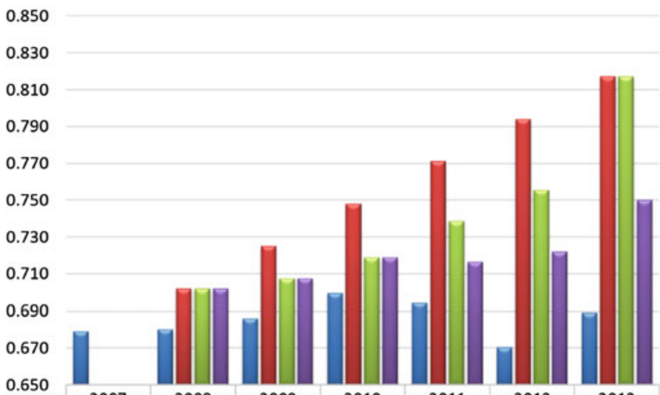


Fig. 20.13 (continued)



	2007	2008	2009	2010	2011	2012	2013
real efficiency Score	0.679	0.680	0.686	0.699	0.694	0.670	0.689
TES for each year by TS-DFM for 2013		0.702	0.725	0.748	0.771	0.794	0.817
TES for each year by Dynamic-DFM for 2013		0.702	0.707	0.719	0.739	0.756	0.817
TES(revised in 2011) for each year by Dynamic-DFM for 2013		0.702	0.707	0.719	0.716	0.722	0.750

Fig. 20.14 Efficiency score and Target Efficiency Score (TES) for each year in Sapporo

model as shown in Fig. 20.14. The 2007 DEA efficiency value for Sapporo is 0.679, and we set the origin period $p = 0$ at the year 2007.

We now consider a target achievement time P of 6 (i.e., 2013), while the steps necessary to improve efficiency are given by the time series $t = 1, 2, 3, 4, 5$, and 6 (i.e., 2008, 2009, 2010, 2011, 2012, and 2013).

In generally, the final TES may be set by a policy- or decision-maker based on public promises or the actual economic situation. Our new model maintains flexibility of the value setting by such changing situations. However, if the final TES may require a new value setting in an objective way, we may propose a one-objective rule as follows:

Rule 1 If an efficiency score of target DMU in origin period $p = 0$ falls below an average efficiency score of inefficient DMUs at the origin period $p = 0$, then FTES is set as this average efficiency score of inefficient DMUs considering attainable and realistic goals.

Rule 2 If an efficiency score of target DMU in origin period $p = 0$ is reached above an average efficiency score of inefficient DMUs and below an average efficiency score of all DMUs (i.e., including efficient DMUs) in the origin period $p = 0$, then FTES is set at this average efficiency score of all DMUs considering attainable and realistic policy goals.

Rule 3 If an efficiency score of target DMU in origin period $p = 0$ exceeds the average efficiency score of all DMUs (i.e., including efficient DMUs) in origin period $p = 0$, then FTES is set at 1.000 (i.e., a completely achieved efficiency frontier).

Table 20.3 Average score for each rule in $p = 0$ (2007)

	Average efficiency score of inefficient DMUs	Average efficiency score of all DMUs
Sapporo	0.679	0.679
Sendai	0.862	0.862
Saitama	Efficient DMU	1.021
Chiba	0.894	0.894
Yokohama	0.969	0.969
Kawasaki	Efficient DMU	1.025
Niigata	0.730	0.730
Shizuoka	0.909	0.909
Hamamatsu	0.968	0.968
Nagoya	Efficient DMU	1.102
Kyoto	0.777	0.777
Osaka	Efficient DMU	1.347
Kobe	0.741	0.741
Hiroshima	0.767	0.767
Kitakyushu	0.693	0.693
Fukuoka	0.809	0.809
Ave.	0.817	0.893

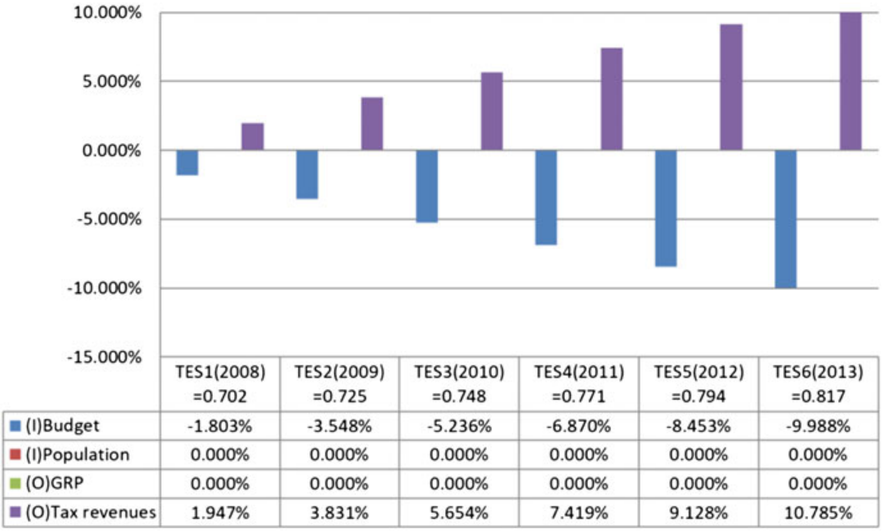
Based on above-mentioned rules, we present now each target score of Rule 1–3 in the final TES for Sapporo 2013, as shown in Table 20.3.

In this case, the efficiency score for Sapporo at $p = 0$ (2007) is 0.679, while the average efficiency score of inefficient DMUs is equal to 0.817. This case becomes an adapted Rule 1, when final TES is set 0.817.

Based on this final TES, each TES for each year calculated by the TS-TO-DFM model and the Dynamic TO-DFM model is shown in Fig. 20.14. Especially the TES for each year calculated by the Dynamic TO-DFM model represents a frontier-shift effect, as shown in Fig. 20.7. The resulting input reduction values and the output increase values for Sapporo city, based on the TS-TO-DFM model and the Dynamic TO-DFM model, are presented in Figs. 20.15 and 20.16.

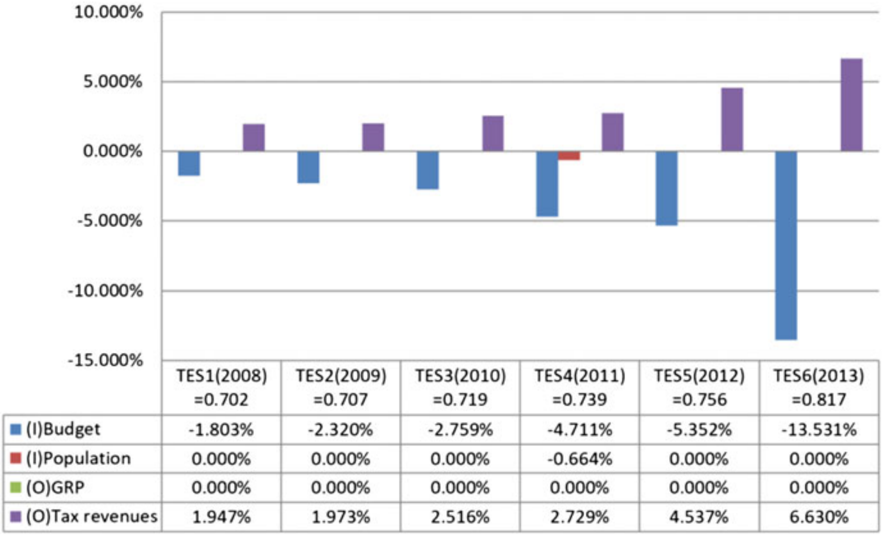
From Fig. 20.15, we notice that the projection results of the TS-TO-DFM model seem to be linearly increasing values in a rather simplistic form year by year.

In contrast, from Fig. 20.16 we notice that the projection results of the Dynamic TO-DFM model seem to reflect a frontier-shift effect for each year, so as to reach a score of 0.817 in 2013. We also notice that the TES from 2011 to 2013 might represent an unrealistic situation, as it does not incorporate the influence of the Great East Japan Earthquake in 2011. In fact, the efficiency score of Sapporo from 2011 to 2013 appears to clearly drop to a lower value, as shown in Fig. 20.8. In this regard, the Dynamic TO-DFM model can incorporate an adjusted FTES as Step 9 in Sect. 20.3, based on these facts and real-world conditions. In the present chapter, we assume a $\mathrm{FTES}^{2013}_{\mathrm{Adjustment}}$ set at 0.750, while each target score is set for each year from 2011 to 2013 in Fig. 20.14. The result of this revised Dynamic target TO-DFM model is presented in Fig. 20.17.



	TES1(2008) =0.702	TES2(2009) =0.725	TES3(2010) =0.748	TES4(2011) =0.771	TES5(2012) =0.794	TES6(2013) =0.817
(I)Budget	-1.803%	-3.548%	-5.236%	-6.870%	-8.453%	-9.988%
(I)Population	0.000%	0.000%	0.000%	0.000%	0.000%	0.000%
(O)GRP	0.000%	0.000%	0.000%	0.000%	0.000%	0.000%
(O)Tax revenues	1.947%	3.831%	5.654%	7.419%	9.128%	10.785%

Fig. 20.15 Efficiency-improvement projection results based on the TS-TO-DFM model (Sapporo)

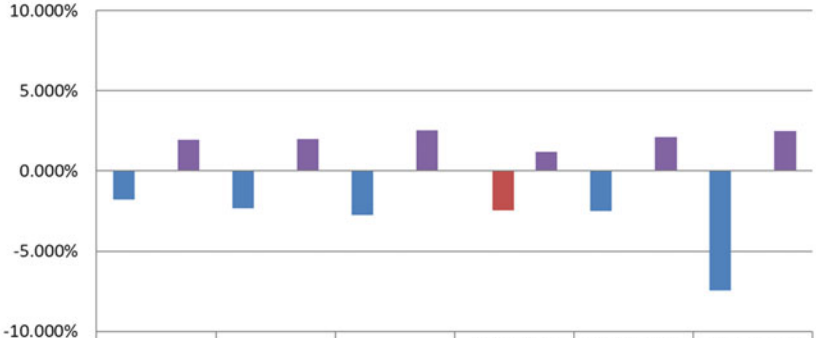


	TES1(2008) =0.702	TES2(2009) =0.707	TES3(2010) =0.719	TES4(2011) =0.739	TES5(2012) =0.756	TES6(2013) =0.817
(I)Budget	-1.803%	-2.320%	-2.759%	-4.711%	-5.352%	-13.531%
(I)Population	0.000%	0.000%	0.000%	-0.664%	0.000%	0.000%
(O)GRP	0.000%	0.000%	0.000%	0.000%	0.000%	0.000%
(O)Tax revenues	1.947%	1.973%	2.516%	2.729%	4.537%	6.630%

Fig. 20.16 Efficiency-improvement projection results based on the Dynamic-TO-DFM model (Sapporo, Rule 1 representative, FTES = 0.817)

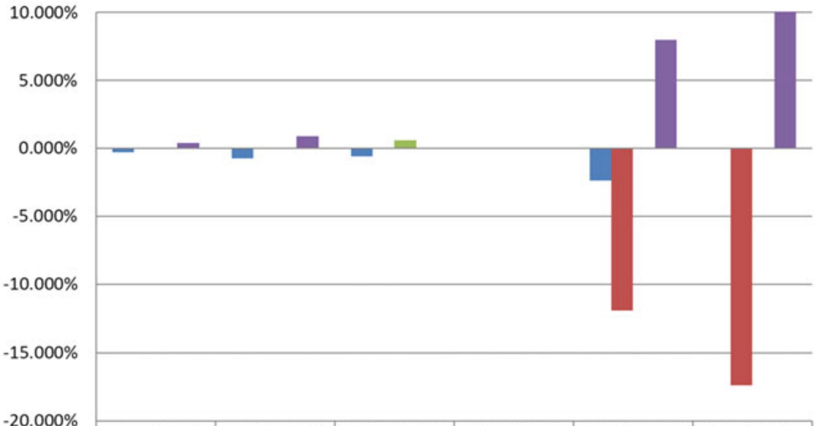
From Fig. 20.17, it is noteworthy that the Dynamic TO-DFM model shows the characteristics of flexibility and implementability in urban policy programmes.

In this chapter, some other cases corresponding to Rule 2 and 3 are set, namely Sendai (Score 0.862) and Chiba (Score 0.894), respectively. The resulting input reduction values and the output increase values for Sendai and Chiba city based on the Dynamic TO-DFM model are presented in Figs. 20.18 and 20.19.



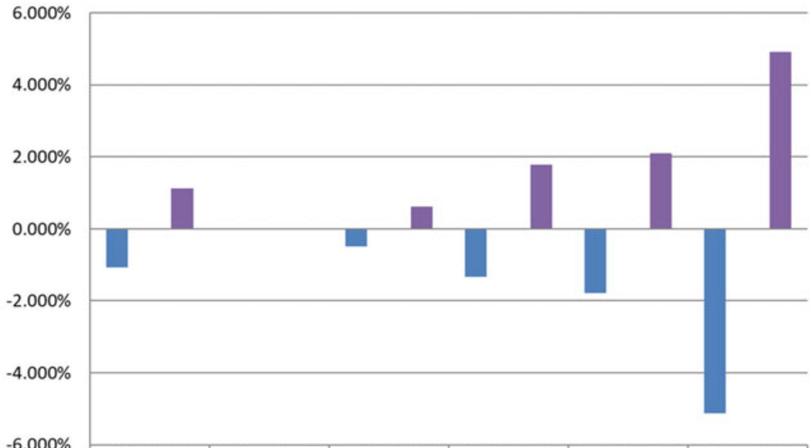
	TES1(2008) =0.702	TES2(2009) =0.707	TES3(2010) =0.719	Revised TES for 2011 =0.716	Revised TES for 2012 =0.722	Revised TES for 2013 =0.750
(I)Budget	-1.803%	-2.320%	-2.759%	0.000%	-2.490%	-7.468%
(I)Population	0.000%	0.000%	0.000%	-2.440%	0.000%	0.000%
(O)GRP	0.000%	0.000%	0.000%	0.000%	0.000%	0.000%
(O)Tax revenues	1.947%	1.973%	2.516%	1.194%	2.111%	2.504%

Fig. 20.17 Efficiency-improvement projection results based on the revised target Dynamic TO-DFM model (Sapporo, Rule 1 representative, Revised FTES = 0.750)



	TES1(2008) =0.868	TES2(2009) =0.843	TES3(2010) =0.862	TES4(2011) =0.926	TES5(2012) =0.778	TES6(2013) =0.893
(I)Budget	-0.294%	-0.746%	-0.598%	0.000%	-2.378%	0.000%
(I)Population	0.000%	0.000%	0.000%	0.000%	-11.914%	-17.416%
(O)GRP	0.000%	0.000%	0.598%	0.000%	0.000%	0.000%
(O)Tax revenues	0.386%	0.881%	0.000%	0.000%	7.958%	11.647%

Fig. 20.18 Efficiency-improvement projection results based on the Dynamic-TO-DFM model (Sendai, Rule 2 representative, FTES = 0.893)



	TES1(2008) =0.911	TES2(2009) =0.9995	TES3(2010) =0.972	TES4(2011) =0.950	TES5(2012) =0.966	TES6(2013) =1.000
(I)Budget	-1.067%	-0.006%	-0.487%	-1.339%	-1.778%	-5.132%
(I)Population	0.000%	0.000%	0.000%	0.000%	0.000%	0.000%
(O)GRP	0.000%	0.000%	0.000%	0.000%	0.000%	0.000%
(O)Tax revenues	1.127%	0.007%	0.621%	1.775%	2.105%	4.917%

Fig. 20.19 Efficiency-improvement projection results based on the Dynamic-TO-DFM model (Chiba, Rule 3 representative, FTES = 1.000)

20.5 Conclusion

In this chapter, we have presented an empirical assessment framework and applied findings on economic efficiency of Japanese big cities. From these results, it is clear that Osaka, Nagoya, Kawasaki, and Saitama may be regarded as super-efficient cities. These cities have a characteristic that is essential for the vitality of the regional economy and the manufacturing hub in Japan, situated in the Tokyo metropolitan area. These facts highlight the impact of spatial attributes to improving a city performance.

Furthermore, this chapter has demonstrated the statistical significance between city performance and population density. Based on these facts, it supports a policy of population concentration in urban areas, which can improve city performance, even in a depopulating nation like Japan. It is noteworthy that Korea, Thailand, and China will also become depopulating nations in the period 2020 to 2040, and then a policy of population concentration in urban areas may be possible to sustain their economic performance in a future and mature society.

We have here presented a new DEA methodology, the Dynamic TO-DFM model. Its feasibility was tested for improving the economic efficiency of Japanese big cities; the new model was examined on the basis of real-world information on relevant indicators. From the above findings, we note that the Dynamic TO-DFM model is able to present a realistic efficiency-improvement programme which incorporates a stepwise target score in a time-series perspective, frontier-shift effects, and real-world conditions so as to achieve a target efficiency score.

In conclusion, our Dynamic TO-DFM model is able to programme a rather realistic efficiency-improvement urban development plan, and may thus provide a meaningful contribution to decision making and planning for efficiency improvement of big cities in Japan, but also for other cities in mature or emerging economies.

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