Footprints of Regional Science
Great Minds in Regional Science

Peter Batey
David Plane *Editors*

Great Minds in Regional Science, Vol. 2

The Regional Science Academy

Footprints of Regional Science

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The Regional Science Academy (TRSA) is an important growth point for Regional Science. Since early 2016, a highly successful series of Academy sessions has been held at locations throughout the world, focusing on *The Voice of Regional Science* (general and strategic reflections on new topics in regional science) and *Great Minds in Regional Science* (presenting in each case a contemporaneous view on the scientific relevance of a great thinker in regional science). Both sets of mini-lectures (sometimes complemented with additional contributions) have been expanded into chapters now being published as two sub-series under the auspices of *The Regional Science Academy*, and jointly forming a book series entitled *Footprints in Regional Science*, under the general editorship of Kingsley Haynes, Karima Kourtit and Peter Nijkamp.

The book series *Great Minds in Regional Science* showcases the work of great thinkers in regional science and provides a contemporaneous perspective on their scientific achievements and relevance. This sub-series is edited by Peter Batey and David Plane.

The book series *The Voice of Regional Science* presents general and strategic reflections on new topics in regional science. This sub-series is edited by Bruce Newbold, Vicente Royuela Mora and Marie Hårsman Wahlström.

Subseries: Great Minds in Regional Science

The book series *Great Minds in Regional Science* showcases the work of great thinkers in regional science and provides a contemporary perspective on their scientific merits and relevance. Each of the volumes presents several great minds from around the world—well-known figures, as well as those whose work deserves much greater recognition—who have made valuable contributions to the theory and/or promoted the application of regional science methods and concepts in practical contexts. Each chapter examines the broader context of the work, assesses its current relevance, and discusses its standing, political and scientific impact.

The sub-series *Great Minds in Regional Science*, together with *The Voice of Regional Science*, forms a series entitled *Footprints of Regional Science.* All three present work stemming from and related to the activities of *The Regional Science Academy* (TRSA) (www.regionalscienceacademy.org).

Subseries: The Voice of Regional Science

The field of regional science continues to advance. The book series The Voice of Regional Science presents new scholarly thinking on important emerging issues and new scientific advances in the broad and multidisciplinary domain of regional science research. The contributions to the series invoke the aim of the Regional Science Academy to rethink "the spatial dynamics of people and socio-economic activities in the connected and complex spatial systems of our earth." The volumes in this series will serve the global regional science community by providing new insights on, or by calling attention to, recent developments that are rarely covered by conventional conferences, or are indicative of novel research directions.

The Voice of Regional Science welcomes both edited volumes and monographs, with works originating in the meetings of the Academy or proposed by external authors and volume editors. It features scholarly works that are retrospective only to the extent necessary to lay the groundwork for visions of future research in the area; all volumes have a forward-looking focus. Further, the series' emphasis on thematic publications is intended to promote a more future-oriented strategic focus for regional science research. Applied studies in regional science are also welcome, provided they reflect this forward-looking focus.

Peter Batey · David Plane
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Springer

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Introduction

David Plane and Peter Batey

This second volume in the book series, *Great Minds in Regional Science,* continues telling the story, begun in the first volume, of the intellectual history of regional science. The perspective provided is through the lens of the contributions made by individual scholars influential to the multidisciplinary field's establishment and development.

The *Great Minds* series is a project of The Regional Science Academy (TRSA). The contributing authors are, themselves, leading scholars in the field, many having already been elected to membership in the Academy and as Fellows of the Regional Science Association International. Each chapter gives the author's contemporaneous view on the scientific relevance of a great thinker. The sets of Great Minds featured in the specific volumes of the series have been chosen to include a blend of well-known figures and others meriting wider recognition for having advanced—in some significant way—the field's pedagogy and institutionalization.

The books in the series, *Great Minds in Regional Science,* together with those in *The Voice of Regional Science* (general and strategic reflections on new topics in regional science) currently comprise the Regional Science Academy's meta-series, *Footprints of Regional Science,* under the general editorship of Kingsley Haynes, Karima Kourtit, and Peter Nijkamp. Since early 2016, highly successful series of sessions sponsored by the Academy have been held at locations throughout the world and featuring mini-lectures on topics germane to the two constituent book series. The chapters published in this volume of *Great Minds in Regional Science* derive from these earlier presentations.

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Our intention as the editors of *Great Minds in Regional Science* is to release a new volume annually. Unfortunately, the COVID-19 pandemic, which began to sweep about the globe in early 2020, resulted in the cancellation of a number of the international conferences of the Regional Science Association International and of its member organizations. At several of those meetings, Regional Science Academy sessions would have been held but had to be canceled. As well, special, stand-alone, TRSA symposia where Great Minds presentations could have been presented were in abeyance. Volume 2 is thus being published a year later than originally planned. We would like to express our appreciation for the patience of those chapter authors whose contributions have been held longer than otherwise would have been needed to assemble a full volume.

Each volume in the Great Minds series consists of a dozen or so chapters drawing upon a dozen or so presentations. Each chapter goes beyond the presentation of facts to include an evaluation of the Great Mind's contribution to regional science and is organized with a similar format: a factual bio-sketch; a description of major contributions; an analysis of the broader context of the work; and an assessment of its present relevance, its scientific contribution, and its policy and scientific impact.

The Great Minds book series is intended to reflect regional science across the world, not just in its traditional heartlands of North America and Europe. Equally, the editors consider it important to include both prominent figures whose contributions have been to theory and those who have played major roles in promoting the application of regional science methods and concepts in practical situations.

The eleven Great Minds whose singular contributions are described in this second volume of the series have been grouped under two headings: Antecedents of Regional Science and Laying the Foundations of Regional Science.

1 Antecedents of Regional Science

The chapters in this section assess the relevance and importance to the multidisciplinary field of the work of four eminent scholars born in the eighteenth and nineteenth centuries. Their influential work was carried out before the regional science movement and the founding of the Regional Science Association in the early 1950s, but they either worked in areas that today would be recognized as regional science, or their seminal contributions to social science thought and methodology would provide important underpinnings for the subsequent corpus of scholarship coming under the regional science brand.

The four scholars spotlighted herein are:

- **Adam Smith**, the 'Father of Economics,' whose book, *The Wealth of Nations,* as well as other writings, were not only foundational to modern-day economics but also contained valuable insights into the regional and spatial dimensions of human affairs.

- **Johann Heinrich Von Thünen**, whose concepts were seminal to ongoing regional science research on the spatial patterns of land use and who provided evidence on, and innovative ideas about, the functioning of markets for goods, land, and labor.
- **Alfred Weber**, widely acclaimed for his contributions to industrial location theory, but whose lesser-known concepts and location principles form the initial basis for supply-chain design, as well as industrial and service facility location.
- **Corrado Gini**, originator of the eponymous index of inequality, who also developed methods and measures for locating centers of population, making international price comparisons, constructing indexes of agreement and classification accuracy, and measuring diversity.

Adam Smith (1723–1790): Uncovering His Legacy for Regional Science
Roberto Camagni

We lead off Volume 2 with a major piece of original scholarship by Roberto Camagni. The aim of the chapter is to justify the inclusion of Adam Smith among the Great Minds of Regional Science. This endeavor may seem curious, because Smith was never associated with regional topics, space economy, or geography, and he is rarely, if ever, explicitly referenced on particular issues in the regional science literature.

In fact, however, it is possible to find in Smith's works a clear systematization of important concepts normally used in regional science. The most significant of these concepts is that of land rent, in its twofold nature as agricultural rent and 'situation' rent. Smith analytically defines, in the latter case, the concept of bid rent, usually attributed to Von Thünen fifty years before him. Above all, to author Camagni's knowledge, Smith was the first to build a theory of urban land rent, detailing its components and sources, as well as providing justification of its 'peculiar' taxation. His theory was entirely accepted during the following one hundred years—until Marshall and Pigou—and it is still referenced today. Moreover, Smith analyzed the 'city' and the 'country' as the two archetypes of the territorial realm, interpreting the historical evolution of their relationship as the pathway of the progress of human institutions and the human mind. In his theoretical interpretation, he considered both functional complementarities and hierarchical, distributive, and power relations—concepts very instructive for the interpretation of the present role of large cities.

The importance of Smith's legacy, however, extends much beyond these direct contributions to regional science issues. His conception of economic progress as closely interwoven with political and social processes pointed to the importance of civil institutions. His analysis of individual conduct—based on self-interest and 'self-love' (not selfishness!), but also on 'sympathy' for joy or pain of others, relationality, and reciprocity—revealed the existence of a wider, individual, and social goal beyond 'opulence': that of public happiness. His philosophical equalitarianism induced him to condemn some harmful products of the invisible hand of the market when not framed by appropriate institutions and even to question the much-praised principle of the division of labor when it works against the progress and the emancipation of the lower classes, thus anticipating Marx's theory of worker alienation.

Most of these issues and fields of inquiry were advanced through new strands of economic theory starting to be developed almost one hundred and fifty years after the *Wealth of Nations* and mostly present within regional science. In this case, Camagni's intention is not to claim a historical priority for Smith's contributions, but only to signal that many theoretical developments could have been achieved earlier and more easily had Smith's legacy not been misunderstood or lost for so long.

Johann Heinrich Von Thünen (1783–1850): A Systemic View of Human Interaction Within Space
Tomás Ponce Dentinho

Following the discussion in the first chapter of Adam Smith's early systemization of concepts central to subsequent theories of land use and land rent, we feel it most appropriate for Johann Heinrich Von Thünen to be this volume's second Great Mind. Von Thünen's work predated the formalization of regional science by more than a century, yet scholars continue to refine and extend the foundational concepts he formalized.

In this chapter, Tomás Dentinho provides a rich, systematic account of Von Thünen's major research contributions: its influence in the past and its relevance today. The chapter aims to show how Von Thünen provided evidence on, and innovative ideas about, the functioning of markets for goods, land, and labor, while also contributing illuminating thoughts on economic efficiency, social equity, and sustainable land use.

The approach Dentinho takes is to analyze Von Thünen's body of published work—complemented by what was written about his theory of the 'Isolated State' over the subsequent century and a half by different scholars—from the perspective of Von Thünen in his real-life role as a wise and informed farmer and as both a manager and a landlord. On the one hand, he was interested in maximizing the value added of his farm, namely by developing the theory of land rent; on the other hand, he was concerned about the effects of urbanization and industrialization, a concern he addressed, chiefly, by creating the theory of the natural wage. Being both a farm manager and a proprietor and trying to detach himself from physiocrats, Von Thünen may have missed the multiplier effects of land rents that generate the city, while favoring the perspective of urban agglomeration economies, which are implicit in his work.

The chapter concludes by arguing that there remains much to explore in the seminal intuitions of, and the empirical evidence provided by, Johann Heinrich Von Thünen. To name just three: the spatial distribution of the multiplier effects of the rents from natural resources, the identification of policy tools for land use management, and the hierarchy of cities that develop when various cities interact with each other.

Alfred Weber (1868–1958): The Father of Industrial Location and Supply-Chain Design
Richard L. Church

In this chapter, Richard Church discusses Alfred Weber's seminal work, *The Theory of Location of Industries.* Weber published his book in the early part of his career,

and rather than attempt to describe why new industries emerge, he sought to describe why certain locations are chosen for the production of a given product. Central to his theory was the need to serve one or more places of consumption of a product with raw materials that are only found at discrete places.

Most recognize Weber for what is termed the locational triangle, a figure involving the placement of a factory between two needed, localized raw material sources and one market. He is also widely recognized for his analysis of different industrial location decisions in terms of an orientation toward a raw material source or oriented toward a market. And, in addition, he was the first to describe the notions of agglomeration and the impact of specialized labor forces. But few are familiar with his detailed discussion of complexities found in production systems, involving problems of multiple plant locations, capacitated raw material sources, raw material source allocation, and even staged production systems, where production is split among geographically separated production facilities. He was also the first to describe the impact of varying labor costs and the potential for a factory to be moved to take advantage of inexpensive labor, substitutable resources (e.g., coal vs. water power), and land prices. Many of these concepts and location principles form the initial basis for supply-chain design, as well as industrial and service facility location.

Corrado Gini (1884–1965): Versatile Originator of Measures of Variability
Peter Rogerson

Although the bulk of Corrado Gini's career predated the beginnings of the field of regional science and recent developments in spatial econometrics, his ideas and contributions have been, and continue to be, influential in past and current work carried out in many areas of regional science research. While the coefficient of inequality that bears his name is by far his most well-known contribution, his other work has also had a lasting impact and influence on the development of important measures in regional science and geography. Much of what Gini contributed was rediscovered or reintroduced many years later. For example, in a very early contribution, he discussed subjective probability, beliefs, and inductive probability. In many ways, this anticipated the seminal work on inductive logic of Carnap (1945) and Bayesian probability.

In this chapter by Peter Rogerson, the measures of variability that Gini originated are reviewed, and applications to geography and regional science are emphasized. A detailed treatment of his well-known and eponymous measure of inequality is presented, and then four other areas of measurement that have been critical for progress in a variety of research areas in geography and regional science are detailed: locating centers of population; making international price comparisons; constructing indexes of agreement and classification accuracy; and measuring diversity.

2 Laying the Foundations of Regional Science

In the second section of the volume, the spotlight turns to Great Minds whose foundational work was completed in the years since the Regional Science Association was founded in 1954. The academic fields and distinguished university positions held by this group illustrate the remarkable, fundamentally multidisciplinary nature of regional science. These seven scholars include three economists, one of whom who carried out doctoral research with well-known physicists and another who held a professorship in urban studies and planning; a geographer whose dissertation and early work was in climatology but made major contributions to economic geography and spatial statistics; an ecological scientist; and two mathematical physicists, one of whom would be appointed to a professorship in geography.

Chapters in this section examine the careers and contributions of:

- **Jan Tinbergen**, Nobel Prize winner in Economic Sciences, who trained in physics and was drawn into regional science through his interest in human and social inequity problems.
- **Albert O. Hirschman**, a product of implosion in Central Europe during the 1930s and 1940s, who migrated to the USA and contributed a number of seminal concepts, methods, and policy suggestions for regional development.
- **Leslie Curry**, whose transformative pioneering work on settlement theory and stochastic processes helped build bridges between the emerging field of regional science and human geography.
- **Crawford 'Buzz' Holling**, the first scholar to give scientific meaning to the term *resilience*, an ecological systems concept pertinent also for analyzing socioeconomic systems studied by regional scientists.
- **Karen R. Polenske**, an important and influential contributor to regional and interregional modeling in both the USA and China, who extended socioeconomic modeling to embrace environmental linkages.
- **Wolfgang Weidlich**, who founded a new field, 'sociophysics,' whose work on dynamic formalizations to represent socio-spatial transformations helped open regional science to the study of system dynamics.
- **Alan Wilson**, a scientific and intellectual giant, who began his career as a mathematician and theoretical physicist but soon realized that his ambition was to study and model people in cities rather than particles in gas chambers.

Jan Tinbergen (1903–1994): A Rational Thinker on Inequality and Distribution

Peter Nijkamp

Jan Tinbergen is generally seen as one of the greatest economists from the second part of the last century. With a background in physics, he was able to introduce a wide variety of quantitative modeling techniques in economic research. In this chapter, Peter Nijkamp describes how Tinbergen's interest in human and social inequity

problems led him also into the field of regional science, where he produced several remarkable and influential publications.

A prominent contribution to regional science can be found in the integration of his pioneering work on international (or spatial) gravity models for trade and transport with the hierarchical systems approach and central place theory paradigms developed earlier by August Lösch and Walter Christaller, respectively. Another path-breaking contribution of Jan Tinbergen can be found in his thorough quantitative analysis of income inequality and poverty in different regions of the world.

Jan Tinbergen continues to be a source of inspiration for scholars who combine a sharp analytical mind with a deep concern on wellbeing and livability issues on our planet.

Albert O. Hirschman (1915–2012): An Unorthodox Regional Scientist
Abdul Shaban

In this chapter, Abdul Shaban examines the career and unorthodox economics scholarship of Albert O. Hirschman, who was a product of implosion in Central Europe during 1930s and 1940s and who, like many other scholars, was forced to migrate to safer places. In the USA, he grew as a scholar and carried out pioneering research extending our understanding of regional and development economics. The chapter illustrates Hirschman's unique approach, detailing his contributions related to unbalanced growth strategy, the relationship between social overhead capital and directly productive activities, linkages, grassroots development, trade and regional development, non-economic factors in development, and rival interpretation of capitalism or varieties of capitalism.

Among luminary economists and regional scientists, Hirschman stands out because of his wide-ranging work on seemingly unconnected aspects of economic and social life, his unorthodox methods of investigation, and his quintessentially liberal ideological approach. Hirschman combined German idealism, English-US empiricism, and political economy and Italian liberal socialism, providing insights about the development process based on his observations rather than formal development models. He sought to turn economic theories on their heads by extending alternative explanations while always looking for endogenous social and development theory.

Leslie Curry (1923–2009): Expounder of the Random Spatial Economy and Spatial Autocorrelation
Daniel A. Griffith

Leslie Curry's scholarly contributions had significant impacts on the early formation and evolution of the multidisciplinary field of regional science, especially in terms of its quantitative theoretical geographic thinking and heritage. He made a lasting contribution to a better understanding of geospatial data through his spatial autocorrelation work (foreshadowing the emergence of the spatial statistics and spatial econometrics subdisciplines), and his revolutionary treatment of the gravity model—a key regional science instrument and one of the most popular regional science models—captures

spatial autocorrelation latent in geographic flows. His influential insights about these descriptors of georeferenced phenomena also link him to other prominent American geographers who contributed to the emergence of regional science, including the two featured in *Great Minds in Regional Science,* Volume 1: Waldo Tobler and Edward Ullman.

Curry's academic career being concomitant with the early days of regional science helped him to build bridges between this emerging multidisciplinary field and human geography. Interestingly, he proved to be a scholar before his time with regard to the quantitative revolution in geography. Although the same spatial economics pioneers inspiring Curry also later inspired Garrison's Seattle geography group, his scholarship clearly departed from their approach. Curry pursued interdisciplinary research, synergistically merging concepts from geography with those from biology, economics, physics, and mathematics. Regional science attracted Curry because of its multidisciplinary nature—one of its early-day strengths. One outcome was an allegiance to regional science that garnered him the distinction of being named (in Isserman 2004) an intellectual leader of the founding generation of regional scientists.

In this chapter, author Daniel Griffith contends that Leslie Curry left an indelible mark on regional science, one with a legacy. Going forward, Curry's bolstering of the gravity model—his uncovering of its dormant, marked, spatial autocorrelation complications—allowed a contemporary refinement of this construct's success story. He pioneered transformative work about settlement theory and stochastic processes, mostly with regard to map pattern description, and posited theories and concepts that have promoted a better understanding of the space economy. Curry's multiple-scale conceptualization of georeferenced data should continue to help regional scientists and quantitative geographers solve new problems.

Crawford 'Buzz' Holling (1930–2019): Progenitor of Resilience in Regional Science

Amitrajeet A. Batabyal

In this chapter, the career of Crawford Stanley 'Buzz' Holling, a prominent Canadian ecologist, is discussed. Holling was the first to give scientific meaning to the term *resilience* in the post-World War II era and to demonstrate its use in studying ecological systems. In the last four decades, a consensus has emerged that the notion of resilience is pertinent not only for studying ecological systems but also for analyzing socioeconomic systems studied by regional scientists.

Chapter author Batabyal details the contemporary relevance of resilience and describes five aspects of the use of resilience in regional science. This discussion includes commentary on the policy implications and the societal impacts of a resilience-based approach to regional science.

Even though Buzz Holling never worked in regional science, his interdisciplinary research and his founding of the Resilience Alliance have stimulated regional scientists to pursue research where the focus is on the development of models integrative of change that have practical value. After discussing three foundational and two policy-related issues involving the use of resilience in regional science, the chapter

concludes that additional research is necessary to: clear up some conceptual issues; more fully demonstrate that, for socioeconomic systems, resilience is not always a good thing; and focus clearly on the distinctions between resilience and sustainability when formulating regional policies.

Karen R. Polenske (1937–): A Journey from Rural Idaho to MIT
Geoffrey J. D. Hewings

Karen R. Polenske has been a very important and influential contributor to regional and interregional modeling in both the USA and China. Her work has extended to a whole range of regional growth and development issues, as well as to the extension of socioeconomic modeling to embrace environmental linkages. The latter work was heavily focused on China with the novel use of enterprise accounts for an iron and steel plant that was further elaborated to address production systems at different technological and spatial scales and to consider the health implications of these operations.

In this chapter, Geoffrey Hewings chronicles the remarkable perseverance that Polenske exhibited in launching and sustaining her career, and then becoming an internationally acclaimed intellectual leader. She had a major influence in the creation and success of the North American Regional Science Council, and she became one of the first group of scholars to be recognized as Fellows in the International Input–Output Association, for which she also served as President. Her continuing influence in the organization of science extended to the training and mentoring of hundreds of Chinese scholars at MIT. A prize in her name, funded by her alumni, bears eloquent testimony to her remarkable commitment to fostering both Chinese regional economic development and successor generations of highly skilled regional scientists.

Wolfgang Weidlich (1931–2015): A Pioneer in Sociophysics
Denise Pumain

German physicist, Wolfgang Weidlich, has been called ‘one of the great intellects of the twentieth century’ and was the founder of a new field that he termed ‘sociophysics.’ His work harkened back to an earlier body of physics research applied to social systems that was among constituent streams of thought that Walter Isard merged into his early conceptualizations of the theory and methods of regional science (Isard 1956, 1960, 1969). The theoretical approach and the models Weidlich proposed in the 1980s and 1990s—applied for instance, to human migration systems—were at that time well in line with the expectations of geographers interested in dynamic formalizations to represent socio-spatial transformations.

As described in this chapter by Denise Pumain, the work of this physicist inspired many people and marked an important moment in the opening of regional science to system dynamics. It will undoubtedly also have profound repercussions in the coming decades for advancing our understanding of the evolution of public opinions and interactions, as revealed from handling the massive data generated by various uses of mobile sensors and social networks. Those in the regional science community

with whom Weidlich came into contact were blessed by their interactions: He was a luminous speaker and a smiling, caring person, a man deeply imbued with humanism and culture. Albeit not widely known among his contemporary and current cohorts of regional scientists, Weidlich's perceptive insights into the dynamics of social systems merit his recognition and inclusion as a Great Mind.

Alan Wilson (1939–): A Renaissance Man in Regional Science
Laurie A. Schintler

Sir Alan Geoffrey Wilson is no ordinary regional scientist. Some sixty years ago, he began his career as a mathematician and theoretical physicist analyzing bubble chamber events at the Rutherford Laboratory in Harwell, England. However, he soon realized that his ambition was to study and model people in cities rather than particles in gas chambers. His move to work with a transportation planning research group in Oxford in 1963 would mark the beginning of a long, productive, and impactful career in regional science. Yet, he did not entirely abandon physics: Thermodynamics ended up being a motivation and basis for many of his ideas and innovations, including his signature entropy-based spatial interaction framework.

Over the years, Alan Wilson's 'sphere of interest' has remained relatively focused on cities and systems of cities and, particularly, the modeling of spatial interaction, location activity, and urban evolution. In these areas, he has made significant theoretical and methodological contributions. He has drawn upon and impacted various disciplines and subdisciplines, including some outside the conventional walls of regional science. What is more, Sir Alan Wilson is not just a scientific giant. He has worn many badges in his lifetime: educator, administrator, philanthropist, planner, politician, businessman, and entrepreneur, and in all these roles, he has been highly successful. But, as argued by chapter author Laurie Schintler, Alan Wilson is even more than that: He is also an artist and a philosopher, making him a Renaissance man in regional science.

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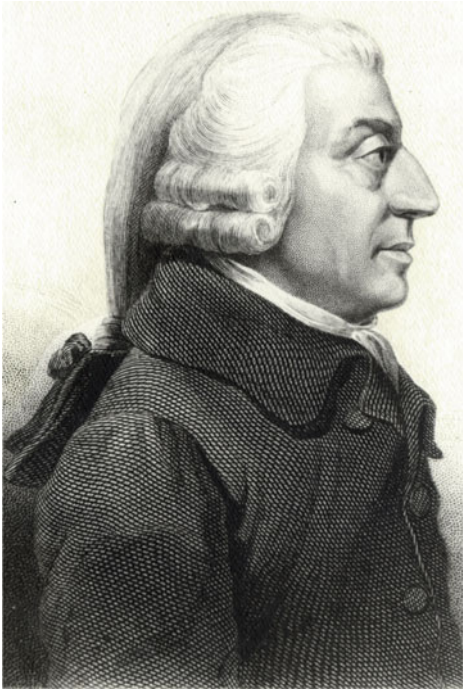
Antecedents of Regional Science

Adam Smith (1723–1790): Uncovering His Legacy for Regional Science

Roberto Camagni



Adam Smith. Etching created by Cadell and Davies (1811), John Horsburgh (1828), or R.C. Bell (1872). *Photo source* Wikimedia Commons[1]

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[1] "**Description**: Profile of Adam Smith. The original depiction of Smith was created in 1787 by James Tassie in the form of an enamel paste medallion. Smith did not usually sit for his portrait, so a considerable number of engravings and busts of Smith were made not from observation but from the same enamel medallion produced by Tassie, an artist who *could* convince Smith to sit" (emphases per

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1 Introduction

The intent of this work is to justify the inclusion of Adam Smith among the Great Minds of Regional Science. This endeavor may seem curious: Smith was never associated with regional matters, space economy, or geography (as Kant was[2]), not even as a reference on particular issues.

In fact, his monumental work embracing almost all dimensions of social life, from political economy to moral philosophy, to astronomy or history of law and social institutions, quite naturally encompassed, among others, a view on the spatial dimension of phenomena, to which he added his own capacity for abstraction and even for "model building" (Campbell and Skinner 1976, p. 4). This effort by Smith, though, is likely to have remained hidden within his huge and perhaps intimidating output. I will try to show how far he went in anticipating the conceptualization of some theoretical tools that are used in regional science and in framing some scientific issues of great importance for the society of his times, but also, as will be shown, of present ones.

While working with these goals in mind, I had a sensation of *déja vu*: all this could represent a second case of "Adam Smith's lost legacy" besides the one rightly underlined by Brown (1994) and more completely by Kennedy (2005). Their thesis, with which I agree, is that the macroscopic loss in Smith's legacy concerns the misleading view of him as the defender of selfishness in business, the progenitor of capitalism, and the supporter of *laissez-faire* policies, very common among economists and political commentators throughout the twentieth century.[3] This view is based on the false idea of a clean break between Smith's two main works, the *Theory of Moral Sentiments* (TMS),[4] allegedly theorizing human "benevolence" and "sympathy" within

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the original) https://commons.wikimedia.org/wiki/File:AdamSmith.jpg (Last accessed: September 13, 2022).

[2] Immanuel Kant was lecturing on physical geography for almost 40 years at the University of Königsberg since 1756, beginning well before his appointment as full Professor of Logics and Metaphysics in 1770. He was one of the first professors of geography in history. He thought this "science" was crucial for the development of a cosmopolitan mentality and a self-ruling, open citizenship. See Elden and Mendieta (2011).

[3] Only in the last 30 years has a growing scholarship by economists and political scientists emerged, working on primary sources and increasingly on secondary ones, reorienting the interpretation of the "true" Smith, unfortunately mainly limited, with a few exceptions, to the circle of hyper-specialists.

[4] Throughout this chapter, the abbreviations for Smith's major works and the citation system employed follow those of: *The Glasgow edition of the works and correspondence of Adam* Smith (Oxford University Press 1979). Pursuant to that style, citations to Smith's published works are given according to the original divisions, together with paragraph numbers as added in the margins of the Glasgow edition. For example: TMS, VII.ii.3.18 refers to the *Theory of Moral Sentiments,* Part VII, section ii, Chapter 3, paragraph 18; and WN, V.i.f.50, 54–55 refers to the *Wealth of Nations,* Part V, chapter i, section f, paragraphs 50 and 54–55.

society,[5] and the *Wealth of Nations* (WN), justifying individual selfishness in the economic sphere on the basis of its positive, though unintentional, outcomes.[6]

This misinterpretation of Smith's basic message shall be made clear from the outset. Besides the fact that he never used such words as "capitalism" or *"laissez-faire,"* and that he assigned the state crucial tasks in terms of direct actions and governance, it is justified neither by an analytical inspection of his work nor by the general consistency and comprehensiveness of his overall vision,[7] and it compromises the full and complex meaning of his thought.[8]

The second case of a lost legacy concerns, in my mind, Smith's importance in shaping not just concepts but entire chapters of the regional science abacus—such as for example, location rent, or, as he called it, "situation rent". To my knowledge, a reading of Smith's work under the lenses of the spatial dimension has not been undertaken up to now, with one, not recent but notable exception, covering the period from the sixteenth to the eighteenth centuries (Dockès 1969). This case is perhaps less scientifically detrimental than the former one, but it crucially requires a historical

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[5] "Sympathy," an important concept in Smith's philosophy (following Hume), is about moral judgment, not a motive for behavior (Kennedy 2005, p. 43), while "benevolence," differently from his master Francis Hutcheson's view, is according to Smith "the sole principle of action in the Deity," not in "so imperfect a creature as man" (TMS, VII.ii.3.18).

[6] This alleged theoretical turnaround (*Umschwungstheorie*) was upheld by some—inaccurate—German scholars since the mid-nineteenth century and became *Das Adam Smith Problem* ever since. See the rigorous rebuttal by the recent editors of the TMS, Raphael and Macfie (1976, pp. 20–25). Viner (1927), though sharing the idea of an "irreconcilable divergence" between the TMS and the WN (p. 207), thinks that "the significance of the natural order in Smith's economic doctrine has been grossly exaggerated" (p. 220), as demonstrated by his provision of "ammunition for several socialist orations … (against its) defects" (p. 215).

[7] The TMS (Smith 1759), his first major work, supposedly abandoned by Smith, was also his last, with its sixth corrected and integrated edition published just before his death in 1790.

[8] "It is not from the benevolence of the butcher, the brewer, or the baker, that we expect our dinner, but from their regard to their own interest. We address ourselves, not to their humanity, but to their self-love" (WN, I.ii.2). This well-known sentence by Smith has to be carefully read and referred to his entire understanding of economic actions: He speaks about "interest," normal in the exchange, and "self-love"—"the regard to our own happiness and interest", a sentiment that encompasses "very laudable principles of action (as) the habits of economy, industry, discretion, attention," and parsimony (TMS, VII.ii.3.16)—and not about selfishness. Concerning market transactions, he always had clear in his mind their nature as agreed negotiations: "mercenary exchange(s) of *good offices* according to an *agreed valuation*." (TMS, II.ii.3.2). Moreover, he was always in favor of the three impartialities: the *impartial spectator*, the internal driver of our respect and "sympathy" towards others in our moral judgment, endowing men "not only with a desire of being approved of, but with a desire of being what ought to be approved of; or of being what he himself approves of in other men" (TMS, III.2.7); *impartial justice*, the guardian of "natural" and "acquired" rights; *impartial competition*, the arbiter of fair games and prosecutor of any monopolist attitude, the crucial precondition for the "invisible hand" to drive towards public interest. More on this in Kennedy (2005), Rocha and Ghoshal (2006), and in the thorough and passionate Introduction to the TMS by Amartya Sen, who considers it "one of the truly outstanding books in the intellectual history of the world" (Sen 2009, p. vii).

and critical compensation, with two main aims: first, when consolidated theories are concerned, in order to re-establish important scientific authorships and cultural roots, enriching in many cases the conceptual and philosophical meaning of present theorizations; second, when lost scientific traditions, wider interpretive models, or methodological approaches are concerned, in order to relaunch them if any link to the interpretation of present issues is apparent.

Adam Smith is traditionally considered the Founding Father of economic science, but also one of the Great Minds of political science, after Machiavelli and Montesquieu (Weingast 2017; Schliesser 2017), thanks to his works on "the science of jurisprudence" (Smith 1763a, b), on the history of social conflicts, and on the long-term evolution of those market-supporting institutions without which "commerce" could not flourish. While these dimensions were closely interwoven with Smith's analytical economic reasoning, their long neglect by the neoclassical scientific trajectory in economics[9] has led to that evident "reductionism" and impoverishment of the interpretive capacity of economic science of which many distinguished economists have been recently harshly critical. Re-reading Adam Smith in a more appropriate and comprehensive manner would bring benefits to regional science as well, naturally affected, particularly in some regional economics traditions, by this same reductionism.

This double perspective is mirrored by the structure of the present essay. After an introductory section on Smith's biography (Sect. 2), Sect. 3 and Sect. 4 are devoted to fields in which Smith anticipated still existing models, theories, and interpretations, while Sect. 5 concerns themes and theoretical issues that were, for a long time, overlooked by the mainstream scientific tradition in regional science. In regard to the first perspective, themes such as the origin of the city and its role, the city/country economic relationship, and the consequent macroeconomic equilibrium are inspected in Sect. 3, while land rent—fertility, situation, and ground rent—are analyzed in Sect. 4. Section 5 deals with four issues: spatial monopoly and income distribution in space; the role of reciprocity sentiments in public happiness; long-term growth, innovation, institutions, and policy; social inequality and income distribution in society.

[9] Samuelson (1992) blamed the "systematic undervaluation of Adam Smith in professional circles … between 1930 and 1990" recalling their "limited interest in and knowledge of the history of economic analysis" (pp. 1–2). He attributes "major responsibility" for this undervaluation to his "old master," Joseph Schumpeter, for his judgment of "mediocrity, lack of originality and excessive imitativeness" by Smith (*ibid.*). In fact, his brusque statement that "the Wealth of Nations does not contain a single *analytic* idea, principle or method that was entirely new in 1976" (Schumpeter 1954, p. 179, italics in the text), though somehow softened elsewhere, looks rather excessive and unfair. But the undervaluation of Smith's work started at least 50 years before, in the last decades of the nineteenth century, going hand in hand with the banalization and misinterpretation of his legacy.

2 Factual Bio-Sketch

Information on Smith's life is scant, in part, because of his deep sense of privacy. His life was largely peaceful and devoid of relevant events. He was born in Kirkcaldy, Scotland, in 1723. While his father died before his birth, he always had a strong bond with his mother, a devout Christian. His likely personal, socio-psychological portrait could be the one sketched by Schumpeter:

> …first, he was a Scotsman to the core, pure and unadulterated; second, ... his immediate family background was the Scottish civil service: in order to understand his outlook on social life and economic activity (very different from what has been often imputed to him), it is important never to forget the gentility, the intellectuality, the critical attitude to business activity, the modest yet adequate means that characterized the environment which produced him; third, ... he was a professor born and bred, not only while he lectured at Edinburgh (1748–51) and Glasgow (1751–63) but always and by virtue of *character indelebilis;* fourth—a fact which I cannot help considering relevant, not for his pure economics of course, but all the more for his understanding of human nature— .... no woman, excepting his mother, ever played a role in his existence: in this as in other respects the glamours and passions of life were just literature to him." (Schumpeter 1954, pp. 176–177)

In 1737, at the early age of 14, he entered Glasgow College, where he studied moral philosophy under the supervision of Francis Hutcheson, who introduced him to liberal Christian philosophy. Glasgow and Edinburgh were the brilliant centers of the Scottish Enlightenment, in a good coexistence with Christian theology (Waterman 2004, Ch. 1 and 2) and in an acceptable relationship with the clerical establishment.[10] In 1740, he won a Snell Exhibition to Balliol College, Oxford, implying a solemn promise to be ordained into the Church of England. He moved to Oxford (on horseback), but studying there fell short of his expectations. Later, in the WN, he remarked that, due to mutual indulgence among professors, lack of incentives, or low salaries, "in the university of Oxford, the greater part of the publick professors have, for these many years, given up altogether even the pretence of teaching" (WN, V.I.f.8).

In 1744, he obtained his bachelor's degree, but subsequently he suffered a deep crisis, probably due to excessive personal study and a growing antagonism to the religious rituals of Balliol (where a copy of his friend Hume's *Treatise of Human Nature* was confiscated from him).[11] He then renounced his scholarship, breaking his engagement with the Church, and returned to Kirkcaldy in 1746. Ever thereafter,

[10] Smith was always very cautious on religious matters and wisely tried to avoid creating problems that could distract him from his work. Nevertheless, concerning his public obituary for his friend David Hume—a skeptical atheist, much less cautious than he was—Smith commented that it "brought upon me ten times more abuse than the very violent attack I had made upon the whole commercial system of Great Britain" in the WN! (Smith, "Letter to Strahan," published with Hume's autobiography, *My Own Life,* Hume 1777/1995). Nowadays, his position on religion is mostly considered closer to (French) Deism than to (Scottish) Theism of his times (Schliesser 2017, p. 334).

[11] In a letter from Oxford College to his cousin William Smith in August 1740, he wrote: "our only business here (is) to go to prayers twice a day, and to lecture twice a week" (Smith 1976, Letter n. 1, p. 36).

he was very critical of the historical role of the Roman Church and the clergy order[12] and of all forms of religious "enthusiasm and superstition" (an expression anticipated by Hume).

Two years later, he moved to Edinburgh, where he delivered public lectures on rhetoric, *belles lettres,* and "the progress of opulence," sponsored by the local Philosophical Society. During the years at Oxford, thanks to his cousin W. A. Smith, he established contact with one of the most politically powerful families in Scotland, that of the 2nd and 3rd Dukes of Argyll, whose "interest" and patronage were crucial, together with Smith's genius, in his early career (Kennedy 2005, p. 8).

In 1751, Smith was appointed to the Chair of Logic at Glasgow University, which turned into his primary interest, the Chair of Moral Philosophy in 1752. In 1759, he published *The Theory of Moral Sentiments* and, in 1762, was awarded a Doctorate in Law. In 1763, he decided to resign his professorship for a lucrative position as tutor of the young grandson of the 2nd Duke of Argyll, the Duke of Buccleuch, and with him, he made the famous tour of France and Switzerland (1764–1766). There he met Enlightenment intellectuals (like Voltaire), Encyclopedists (D'Alembert), and some representatives of the Physiocratic school whom he greatly respected (Turgot and Quesnay), introduced by David Hume, at that time secretary of the English Ambassador in Paris.[13] Free from academic duties, he turned back home and sometimes to London (where was elected Fellow of the Royal Society) to work on his masterpiece, *An Inquiry into the Nature and Causes of the Wealth of Nations*, which was published in 1776, achieving instant success.

In 1778, Smith was appointed to a post of Commissioner of Customs in Scotland and went to live in Edinburgh with his mother. From 1787 to 1789, he occupied the honorary position of Lord Rector of the University of Glasgow. He died in Edinburgh on July 17, 1790. Only in 1795 were some of his early works published posthumously, as it was his firm intention: the *Essays on Philosophical Subjects* together with his *History of Astronomy* (Smith 1795a). His *Lectures on Jurisprudence*, delivered at the University of Glasgow in 1963, were published by Professor Edwin Cannan in 1896, when *Juris Prudence or Notes from the Lectures on Justice, Police, Revenue and Arms, reported by a Student in 1763* were discovered (Smith 1763a, b/1896). They present, inter alia, Smith's main ideas on the history of jurisprudence that he had long intended to develop and to publish but never did.

A last comment may serve to highlight Smith's character and his relationship with other preceding or contemporary authors. He was deeply proud of his ideas and conscious of the logical strength of his intellectual constructs; he was ready to discuss

[12] "The clergy of every established church constitute a great incorporation. They can act in concert, and pursue their interest upon one plan and with one spirit. (…) Their interest as an incorporated body is never the same with that of the sovereign, and is sometimes directly opposite to it. Their great interest is to maintain their authority with the people; and this authority depends upon the supposed certainty and importance of the whole doctrine which they inculcate" (WN, V.i.g.17).

[13] See the *Account of the life and writings of Adam Smith* presented by his first biographer, Dugald Stewart, to the Royal Society of Edinburgh three years after his death (Stewart 1793/1980, III.9).

all matters personally with colleagues or at the club meetings which characterized the cultural climate and intellectual life in Edinburgh and Glasgow. As a professor, he was ready to deliver scientific messages and content, allowing students' notes to be taken, circulated, and even published locally. He was glad if others used and relaunched his ideas, but, of course, he expected acknowledgment of his authorship, especially in regard to leading principles and theories.

In two cases—widely debated in his scholarship—he explicitly manifested his position on this very issue with "a great deal of honest and indignant warmth." The first in 1755, when he presented a short manuscript to "a society of which he was then a member, in which paper, a pretty long enumeration is given of certain leading principles, both political and literary, to which he was anxious to establish his exclusive right; in order to prevent the possibility of some rival claims which he thought he had reason to apprehend,"[14] indicating dates of his first presentation going back to 1749. In this case, his first biographer, Dugald Stewart, justifies Smith's anxiety, in spite of the difficulty of a precise attribution of general principles or basic concepts widely discussed and often anticipated in some way by other authors: "After all, the merit of such a work as Mr. Smith's is to be estimated less from the novelty of the principles it contains, than from the reasonings employed to support these principles, and from the scientific manner in which they are unfolded in their proper order and connection." (Stewart 1793, IV.26).

The second case happened some years after, in 1767, when his colleague Adam Ferguson published the *Essay on the History of Civil Society,* and Smith accused him of plagiarism, "having borrowed some of his ideas without owning them" (quoted by Hamovy 1968, p. 249). Those were times in which acknowledgments of quotations and precedence were scanty—as they were in musical compositions as well—and Smith himself was not generous in this regard. The issue at stake concerned the theory of the division of labor. Ferguson indirectly responded that he was innocent, but maintained he had derived many notions from "a French author, and that Smith had been there before him" (*ibid.*). The author was not Montesquieu, as is sometimes hypothesized, but Alexandre Delaire, who wrote for Diderot's *Encyclopédie* the article "Epingle," published in 1755, from which Smith drew, without acknowledgment, his famous example of the pin factory—already present in his *Lectures on Jurisprudence* at the beginning of the 1760s and afterward in the first pages of the *Wealth of Nations* (WN, I.i.3).[15] Irony of fate!

[14] See: Stewart (1793, IV. 25). Stewart continues: "In questions of so complicated a nature as occur in political economy, the credit of such opinions belongs of right to the author who first established their solidity, and followed them out of their remote consequences; not to him who, by a fortunate accident, first stumbled on the truth." (ibid.). Kennedy adds the possibility that the rumors felt by Smith could have been fanned by academic jealousies concerning "his rapid progress from student to Professor" (Kennedy 2005, Appendix, p. 242).

[15] The original source of the pin factory example was revealed by Edwin Cannan, the editor of Smith's *Lectures on Justice,* more than a century later (Smith 1896, note 1, p. 164); Smith, however, added some aspects and numbers from unknown sources (Denis 1971, p. 194).

3 Theoretical Anticipations by Smith in the Fields of Regional Science

Since the beginning of its "official" life, soon after the end of World War II, regional science was built on the (right) belief and scientific evidence about the "gross inadequacy of existing economic theory: its failure to develop concepts for spatial analysis" (Isard 1951, p. 181). Instead of continuing on the previous path of a spaceless wonderland, it was necessary to acknowledge the specularity between the interest rate (in the time dimension: time-discount) and the transport rate (in a spatial dimension: space-discount) and to proceed toward a "general theory of location and space economy" (Isard 1949). Only a few authors were considered as the great fathers of the new discipline: the German geographers and economists of location theory, and then Chamberlin, Hotelling, Palander, and Zipf. The methods naturally embraced were those of the neoclassical and Keynesian schools of the twentieth century; no authors in preceding centuries were honored by a mention, with the exception of Von Thünen—and sometimes Ricardo—for their theories of land rent.

On urban economic themes, too, the condition of mainstream economic theory proved, in the middle of the last century, similarly inconsistent: space was totally absent, but no search about it was made in the literature of preceding centuries. By all accounts, the city had appeared such a normal context, or scene on which economic life performed, as to be worth just a chapter or section in the main books on principles of economics, leaving the entire field to geographers, historians, political scientists, and even philosophers (Camagni 1992, Introduction). Only some gleaning ("*spigolature*" in Italian: the picking up of single ears or seeds after the main harvest) seemed possible from the entire preceding development of economic thought in the eighteenth and nineteenth centuries.

This general neglect was not justified, though. In this section, I shall show the many fields, commonly considered to be constituent parts of regional science, to which at least Adam Smith contributed with important conceptual and analytical anticipations with respect to "official" subsequent theorizations mainly developed in the twentieth century.[16]

These fields, which will be presented hereafter, concern in order: the birth of cities and their role in the spatial context; the relationships between the city and the "country"; the theory of land rent on agricultural activities, based on both "fertility" and "situation," anticipating Ricardo and, most importantly, Von Thünen; and the theory of urban rent, distinguishing between building rent and ground or land rent.

[16] At least two other (pre-) classical economists are worth recalling and rediscovering, namely: William Petty for his indication of the similarity between the time discount (which he called "usury") and the space discount (which he called "local usury") and for the first outline of a theory of position rent (Petty 1662/1899, Ch. V); and Cantillon, for his anticipation of Quesnay's *Tableau économique* (1759/2005) and for an interesting spatial vision, as testified by his three short chapters on Villages, Market Towns (*Bourgs*), Cities and Capital Cities (Cantillon 1755). See: Schumpeter (1954, Ch. 2, Sect. 1–2) and Dockès (1971).

3.1 The Origin of Cities and Their Role

Great historians have often devoted their intellect to the explanation of the birth and the role of cities. Some of them, particularly Braudel (1977, 1979) and the French school of *Annales*, have considered cities to be the driving forces of historical development.

Within regional science (and elsewhere), an interesting debate developed in the 1970s concerning the economic conditions for the birth of cities in history. The dispute originated between the followers of the most traditional theory—locating the birth of cities in that precise historical period in which the general agricultural production exceeded the necessities of the rural workers—and the supporters of a contrary interpretation, inaugurated by Mumford (1961, Ch. 2) and shared by Jacobs (1969, Ch. 1), which considered the country as dependent upon innovations in technologies and organization of agricultural production developed by and in the city. Adam Smith was, to my knowledge, the first economist who proposed the former economic interpretation, but who, at the same time, was aware of the possibility of the opposite causal effect, with an acute and inspiring justification.

In Book III of the WN, concerning a long-term analysis of "the natural progress of opulence," we read:

> The town, in which there neither is nor can be any reproduction of substances, may very properly be said to gain its whole wealth and subsistence from the country. "It is the surplus produce of the country only, or what is over and above the maintenance of cultivators, that constitutes the subsistence of the town". (WN, III.i,1-2)[17]

"According to the natural course of things", therefore, the capital of developing societies goes first to agriculture, afterward to (urban) manufactures, and then to commerce. But soon after, Smith also affirms that, following the fall of the Roman Empire, when cities, infrastructure, and commerce were broken down and agriculture barely allowed subsistence support of country villages, around the turn of the first millennium "this natural order of things (…) has, in all the modern states of Europe, been in many respects entirely inverted. (…). Manufactures and foreign commerce (of cities) together have given birth to the principal improvements of agriculture." (WN, III.i.9).

> The increase and riches of commercial and manufacturing towns contributed to the improvement and cultivation of the countries to which they belonged, in three different ways. First by affording *a great and ready market* for the rude produce of the country (…). Secondly, the wealth acquired by the inhabitants of cities was frequently employed in *purchasing such lands as were to be sold*, and merchants are commonly ambitious of becoming country gentlemen, and when they do are generally the *best of all improvers.* (…). Thirdly, and lastly, commerce and manufactures gradually *introduced order and good government, and*

[17] Historian Lynn White, Jr. (1962), too, links the intense period of urban growth from the eleventh to the thirteenth century mainly in Central and Northern Europe to the series of crucial innovations in agrarian technologies in the previous two centuries—heavy plow, substitution of the ox by the horse, and crop rotation—generating a notable increase in agrarian productivity and "liberation" of labor force.

> *with them the liberty and security* of individuals, among the inhabitants of the country. (…). This, though it has been the least observed, is by far the most important of all their effects. Mr. Hume[18] is the only writer who, so far as I know, has hitherto taken notice of it (WN, III.iv.1-4; emphases added).

> It was thus, that, through the greater part of Europe, the *commerce and the manufactures of cities*, instead of being the effect, have been the *cause* and occasion of the *improvement and cultivation of the country*. (WN, III.iv.18)

These passages appear in a special chapter interestingly devoted to "How the commerce of towns contributed to the improvement of the country" and mention not just economic elements but also cultural and political ones, in the typical Smithian approach.[19]

3.2 The City-Country Relationship: A Spatial Archetype

The two interpretations of the birth of cities converge conceptually in a twofold manner: First, they highlight the interest of defining two archetypes of socio-economic organization, holding a deep spatial reference, the city and the country. Secondly, they lead to the conclusion of a strict complementarity of the two spaces based on a clear division of labor between them and the consequent huge volume of mutual exchange. "The gains of both are mutual and reciprocal, and the division of labour is, in this as in all other cases, advantageous to all the different persons employed in the various occupations into which it is subdivided". (WN, III.i.1)

The city-country relationship is interpreted, in this case, as a functional economic one, which drives the general society toward a condition of mutual advantage. However, Smith does not speak of "harmony," as other later classical economists did (Say, Bastiat, and, before them, Quesnay), having been always aware of the conflicting interests among social classes (Schumpeter 1968, II.3.c, p. 86), but he was very clear on the fact that this relationship implies a functional interdependence: "… the inhabitants of the town, and those of the country, are mutually the servants of one another" (WM, III.i.4).

As we shall see later in Sect. 5.1, the city-country relationship was also interpreted by Smith in a conceptually different way, when he adopted a distributive and no longer productive point of view. His distributive-hierarchical approach was shared some decades later, in a wider philosophical perspective, by the young Marx, and the complementarity in the "bourgeois" vision became a "contradiction" between city and countryside.

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[18] Hume, D. *Essays Moral, Political and Literary.*

[19] Seventy years later, a well-known representative of the Lombard Enlightenment, Cattaneo (1847/1939), was able to indicate, along the same lines, the gifts that the city makes to the countryside: *certainty* of ownership, *savings* and consequently capitals, and institutions (particularly cadaster, easement of aqueduct rights, and a tax system not penalizing improvements, which were for centuries at the basis of the success of the Lombardy region).

Continuing his reflections on this theme, in a nonsystematic way, but with a close consistency within the general interpretative framework of historical spatial development (WN, Book III), Smith obtains a further result: an abstract sketch of the early agglomeration processes taking place within the spatial division of labor:

> Without the assistance of some artificers, indeed, the cultivation of land cannot be carried on, but with great inconveniency and continual interruption. Smiths, carpenters, wheel-wrights and plough-wrights, masons, and bricklayers, tanners, shoemakers, and taylors, are people, whose service the farmer has frequent occasion for. Such artificers too *stand, occasionally, in need of the assistance of one another*; and as their residence is not, like that of the farmer, necessarily tied down to a precise spot, they (…) *naturally settle in the neighbourhood of one another, and thus form a small town* or a village. (…) The butcher, the brewer, and the baker, *soon join them*, together with many other artificers and retailers, necessary or useful for supplying their occasional wants, and who contribute still *further to augment the town.* (WN, III.i.4)

This passage anticipates Werner Sombart's distinction between "basic" activities of the city (exports, in this case oriented toward the countryside) and "complementary" or "residential" ones, and it presents in a nutshell the logic of the urban growth model *à la* Hoyt. Together with the contextual indication that "the town is a continual fair or market" (WN, III.i.4), we find here a precise definition of the original roles of the city: to be the supplier of manufactured goods and the market in the service of the country.

Moreover, Smith shows that he had a precise idea about what we today call "agglomeration economies," linked to pure city size. "That industry which is carried on in towns is, everywhere in Europe, more advantageous than that which is carried on in the country, without entering into any nice computations, we may satisfy ourselves by one very simple and obvious observation" (WN, I.x.c.21). Towns and cities concentrate manufacture and most of all commerce and banking; greater and more frequent "fortunes" develop in town than in the country; entrepreneurship is mainly an urban specificity ("the merchant is commonly a bold, a country gentleman a timid undertaker," WN, III.iv.3); "greater stocks" are employed in great towns, where we find greater profits (but lower profit rates, due to competition) and higher wages, due to fast-growing demand.[20]

Concerning the advantages of an urban context beyond those due to pure agglomeration, Smith gives us a pearl of theoretical intuition (which, to my knowledge, has never been quoted in the specialized literature). He speaks in a rather modern way about the "genius or superior talent" required in some professions, which necessarily need an urban context to develop. When discussing that particular form of trade called "trade of speculation," where the merchant "enters into every trade when he foresees that it is likely to be more than commonly profitable", he affirms: "this trade can be carried nowhere but in great towns. *It is only in places of the most extensive commerce and correspondence that the intelligence requisite for it can be had"* (WN,

[20] "It generally requires a greater stock to carry on any sort of trade in a great town than in a country village. The great stocks employed in every branch of trade, and the number of rich competitors, generally reduce the rate of profit in the former below what it is in the latter. But the wages of labour are generally higher in a great town than in a country village" (WN, I.ix, 7).

I.x.b.38). The terms "commerce and correspondence" refer exactly to what nowadays are called communication networks and relational capital that mutually interact in those interconnection sites like the large or global cities, and the urban selection process, which follows, is now called sorting. The sentence in (added) italics is probably the first and only reference to the *cognitive role* of the city that one can find among the economists and "philosophers" of Smith's times and the following century.

In conceptual terms, the city-country relationship is relevant to the thesis propounded in this work, as it provides Smith with the rationale for an innovative embedding of the general laws of production, exchange, and distribution in a consistent spatial framework: an abstract, archetypical, and dichotomic framework, for sure, although it is imbued with a deep historical and factual meaning.

3.3 The City-Country Relationship and (Spatial) General Equilibrium

The two archetypes of the spatial structure of society interact with each other, giving rise to a "natural" equilibrium in terms of production, income distribution, and utilization of income between consumption and savings: an intersectoral and macroeconomic equilibrium in today's language. Smith presents his analytical view concerning general economic equilibrium in the WN, particularly Book I.vii and also Book II.i-iii; these sections would be praised by Schumpeter (1954, p. 183) as "by far the best piece of economic theory turned out by Adam Smith, that points towards Say and, through the latter work, to Walras. The purely theoretical developments of the nineteenth century consist to a considerable degree in improvements upon it." Particularly relevant is his belief concerning the necessary equilibrium between savings and investments, or, more precisely, his belief that incomes of the upper classes are always totally spent either on luxury consumption or investment ("circulating capital," namely "anticipations" on salaries and expenses for the maintenance of "fixed capital"). In fact, all this anticipated Say's law on macroeconomic equilibrium:

> What is annually saved is as regularly consumed as what is annually spent, and nearly in the same time too (…). That portion which a rich man annually saves, as for the sake of the profit it is immediately employed as a capital, is consumed in the same manner, and nearly in the same time too (WN, II.iii.18).[21]

He realized that the only problem for reaching equilibrium could arise from that portion of circulating capital represented by money, which could be maintained as a reserve of value and withdrawn from circulation. Following Quesnay, Smith maintained: "money is the only part of the circulating capital of the society, of which

[21] Moreover, savings determine accumulation and growth: "By what a frugal man annually saves, he (…) affords maintenance to an additional number of productive hands, for that or the ensuing year" (WN, II.iii.19).

the maintenance can occasion any diminution in their net revenue" (WN, II.ii.11).[22] But soon thereafter, he concluded by excluding this possibility due to the working of the financial system:

> The judicious operations of banking, by substituting paper in the room of a great part of this gold and silver, enables the country to convert a great part of this dead stock into active and productive stock; into stock which produces something to the country. (WN, II.ii.86)

The overall picture outlined here is a masterpiece of analytical representation of the static equilibrium "naturally" achieved by economic quantities.[23] Instead of presenting it in a synthetic, input–output logical format as done by Cantillon (1755) and later by Quesnay in his *Tableau Economique* (1759/2005),[24] which could have given Smith the opportunity to pursue his scrutiny of the city-country relationships, he preferred a more in-depth analytical and aggregate presentation, coining and defining new economic concepts (as for example, of all forms of capital, from human to circulating and fixed ones) and their theoretical and practical relationships.

In regard to the theoretical issue of general equilibrium, it is the merit of Thomas Malthus to have raised, almost 50 years after the *Wealth of Nations*, the question of the possibility that an equilibrium demand–supply could not be reached, in opposition to the main belief of classical economists. His merit consists, in my opinion, in having put the question no longer in static terms—as did Smith, with whom he substantially agreed on this topic—but in one that we would nowadays call intertemporal equilibrium, or dynamic equilibrium, in general.

The excess of savings generated by the virtue of frugality and parsimony—much praised by Smith—which turns into an increase in circulating capital (but also in demand for unproductive labor) is due to generate an increase of production in the subsequent year—also thanks to the increased productivity of machinery—which will require an adequate increase in demand.

> What the proportion is between the productive labourers and those engaged in personal services, which affords the greatest encouragement to the continued increase of wealth, (…) the resources of political economy are unequal to determine. It must depend upon a great variety of circumstances, particularly upon the fertility of the soil and the progress of invention in machinery." (Malthus 1820/1972, Book II.ix, 399). Therefore, "it is necessary that a country with great powers of production should possess a body of consumers who are

[22] "Money, therefore, the great wheel of circulation, the great instrument of commerce, like all other instruments of trade, though it makes a part and a very valuable part of the capital, makes no part of the revenue of the society to which it belongs" (WN, II.ii.23).

[23] The consistency of Smith's analytical picture of a static equilibrium is confirmed by Samuelson (1977), who reconstructs his general model where "axioms are those of the 1776 Adam Smith," while formal elaboration "utilizes 1976 mathematical methods, including convenient duality theory" (p. 43).

[24] Authors that he knew perfectly. In the case of Quesnay and the Physiocrats—for whom he had profound esteem—he always avoided "entering into the disagreeable discussion of the metaphysical arguments by which they support their ingenious theory" (WN, V.ii.c.7), namely about the sources of wealth, residing in their mind only in agricultural land.

not themselves engaged in production" (*ibid*.), which means the class of landowners and the class of 'unproductive' labourers ("unproductive consumers").[25]

Malthus did not respond to his own awkward question on "what proportion" would be required from time t to $t + 1$: He did not possess the necessary theoretical and mathematical tools. The historical development process of economic thought—130 years long—was due to pass through the Marxian enlarged-accumulation schemes of Book III of *Das Kapital*, Keynes' liquidity preference theory and the possibility of underemployment equilibria, and Harrod's and Domar's razor-edge model highlighting the difficulty of maintaining a dynamic equilibrium. But Malthus was (rightly) satisfied with his own intuition, much—even excessively—praised by Keynes[26] and with his demonstration of the historical necessity and merits of the landowner class: From them the necessary demand originates in terms of consumption of personal services and luxury manufactured goods.

> It is not (…) that absolutely necessary part of the general surplus produce from the land (…) without which, in fact, there would be no cities, no military or naval force, no arts, no learning, none of the finer manufactures, none of the conveniences and luxuries of foreign countries, and none of that cultivated and polished society, which not only elevates and dignifies individuals, but which extends its beneficial influence through the whole mass of the people. (Malthus 1820, Book 1, Chapter III, Section I, p. 148)

What would Smith reply, if he could, to this not untrue but emphatic sentence by Malthus? He would, of course, recognize the role of "profuse and sumptuous" consumption for his general equilibrium, distinguishing, however, between two different (historical) forms of expenditure: consumptions addressed to products of land ("the table") and personal services (menial servants, attendants to a "multitude of dogs and horses") on the one side, or addressed, on the other side, to "durable commodities" such as "adorning houses and country villas, useful or ornamental buildings, collecting books, statues, pictures, or things more frivolous as jewels" (WN, II.iii.39).

The latter form of consumption has three merits. It produces a personal pleasure in the following days or years, and therefore accumulates wealth and "magnificence of the person." It is "frequently both an ornament and honour not only to the neighbourhood but to the whole country (…). Versailles is an ornament and honour of France, Stowe and Wilton to England."[27] And lastly, "it is more *favourable to*

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[25] Malthus cleverly underlines a logical contradiction in Smith's doctrine: "It is to found a doctrine upon the *unlimited* desire of mankind to consume; then to suppose this desire *limited* in order to save capital, and thus completely alter the premises, and yet still to maintain that the doctrine is true." (Malthus 1820, II.ix. 402; italics in the original).

[26] "If only Malthus, instead of Ricardo, had been the parent stem from which nineteenth century economics proceeded, what a much wiser and richer place the world would be today!" (Keynes 1933, p. 144).

[27] Smith proceeds: "Italy still continues to command some sort of veneration, by the number of monuments of this kind which it possesses, though the wealth which produced them has decayed, and though the genius which planned them seems to be *extinguished*, perhaps for *not having the same employment*" (WN, II.iii.39). In fact, nobody these days employs a Michelangelo to design a square or a building: might Malthus be right?

private frugality, and consequently to the increase of the public capital, and it maintains productive rather than unproductive hands [driving] more than the other to the growth of public opulence" (WN, II.iii.42). The terms in added italics indicate, to my mind, that this form of consumption can be more consistent with and complementary to the frugality of the class of undertakers and manufacturers, partly overcoming Malthus' criticism (in footnote 25). In fact, Smith speaks in this paragraph of "men of fortune" and not of landowners only, as Malthus had in mind.[28] Of course, in all the present discussion, Smith maintains his static approach to general equilibrium.

The second reply by Smith would probably refer to taxation. Within the limits that he set very clearly on the responsibilities of the state, Smith was in favor of a "peculiar" taxation on rents in order to finance public investments, as will be shown later. But for Malthus, this was absolutely out of any reasonable program![29,30]

3.4 The City-Country Relation and Structural Dynamics: A Masterly Historical Picture

Having dealt with the complex relationship between city and country, implying not just economic exchange but huge social and political transformations, Smith set about writing a masterly and vivid piece of economic and social history, anticipating two broad streams of scientific literature: analyses of the "*civilization matérielle*" and common day-to-day life of our contemporary historians[31] and a

[28] On closer inspection, Malthus' solution to macroeconomic equilibrium was insufficient, because the consumption expenditure generated by landlords is limited to their rental incomes and cannot help overcome a possible overproduction crisis. A further element suggested by Smith that could be beneficial to equilibrium is an increase in salaries ("*liberal wages*") (WN, I.viii.40–44).

[29] "Taxation is a stimulus so liable in every way to abuse, and it is so absolutely necessary for the general interests of society to consider private property as sacred, that no one would think of trusting to any government the means of making a different distribution of wealth, with a view to the general good." (Malthus 1820, II, ix, p. 410). Smith would not agree with this argument, as shown later.

[30] A different modern debate on the role of Smith in theoretical economic analysis concerns his opening the way to Walras's general microeconomic equilibrium through his ideas on market prices "gravitating" towards "natural prices," and on production factors, labor, and capital, seeking their best utilization and driving towards an equalization of their rewards in different uses (WN, Book I, Ch. vii and x). Most economists would agree, following Schumpeter's above-cited favorable opinion, though underlining the "rudimentary" nature of Smith's theory (see, e.g., Robbins 1932; Stigler 1976; Samuelson 1977, 1992). Others, like Kaldor (1972), support the opposite view of the "irrelevance of equilibrium economics" started by Smith in Ch. I. iv of the WN, driving theoretical research towards the *allocative* function of market and away from its much more relevant "*creative* functions, as an instrument for transmitting impulse to economic change" (p. 1240)—also present in Smith's theory of increasing returns and innovation as effects of the division of labor. A third interesting view is that of those economists who agree with Smith's role, but claim that economic equilibrium was not his priority, being more interested in "disequilibrium" conditions, dynamics, and structural change in societies (e.g., Chandra 2003). We will return to this last theme in Sect. 5.3.

[31] See: WN, Book III, Chapters ii-iv. Schumpeter affirms that such a historical analysis had never been done until his times (mid-twentieth century) (Schumpeter 1968, Sect. 2.5).

great part of institutional economics and political science (Weingast 2017; Hill 2019, Introduction).

"In ancient times, almost all rents were *paid in kind"* (WN, I.xi.e.17). Therefore:

> in a country which has neither foreign commerce, nor any of the finer manufactures, a great proprietor, having nothing for which he can exchange the greater part of the produce of his lands which is over and above the maintenance of the cultivators, *consumes the whole in rustick hospitality* at home. (…) The great Earl of Warwick is said to have entertained every day at his different manors, thirty thousand people. (WN, III.iv.4)[32]

But the development of:

> commerce and manufactures (…) gradually furnished the great proprietors with *something for which they could exchange the whole surplus produce* of their lands, and which they could consume themselves without sharing it either with tenants or retainers ("diamonds, jewels, ..."): a method of consuming the whole value of their rents themselves. (WN, III.iv.10)

Very acutely, Smith gives great importance to this historical transformation, which he does not hesitate to call a "revolution" and that historians label as the "urban revolution" starting in the eleventh century. Even more interesting is his political interpretation of this transformation in terms of social classes:

> A *revolution* of the greatest importance to the publick happiness, was … brought about by two different orders of people, who had not the least intention to serve the publick. To gratify the most childish vanity was the sole motive of the great proprietors.[33] The merchants and artificers, much less ridiculous, acted merely from a view to their own interest, and in pursuit of their own pedlar principle of turning a penny wherever a penny was to be got. Neither of them had either knowledge or foresight of that *great revolution* which the folly of the one, and the industry of the other, was gradually bringing about. (WN, III.iv.17)

> Thus, for the gratification of the most childish, the meanest and the most sordid of all vanities, they *gradually bartered their whole power and authority.*[34] What all the violence of the feudal institutions could never have effected, the silent and insensible operation of foreign commerce and manufactures gradually brought about. (WN, III.iv.10)[35,36]

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[32] "He is at all times, therefore, surrounded with a multitude of retainers and dependants, who (…) must obey him, for the same reason that soldiers must obey the prince who pays them. (…) The hospitality of the rich and the great, from the sovereign down to the smallest baron, exceeded everything which in the present times we can easily form a notion of. Westminster-hall was the dining-room of William Rufus; (…). The great Earl of Warwick is said to have entertained every day at his different manors, thirty thousand people and though the number here may have been exaggerated, it must, however, have been very great to admit of such exaggeration." (WN, III.iv.4).

[33] "For a pair of diamond buckles perhaps, or for something as frivolous and useless, they exchanged the maintenance of a thousand men for a year" (WN, III.iv.10).

[34] They were "the judges in peace, and the leaders in war" (thanks to "armies of retainers") … and even challenged the king (WN, II.iv.7).

[35] "The power of the nobles declined in the feudal governments from the same causes as everywhere else, viz, from the introduction of arts, commerce, and luxury." (LJ (A) iv.157).

[36] I will return to this issue in Sect. 5.1, when I discuss the power relations in societies according to Smith's theory of the four "stages" of historical development.

A part of the wealth (and jobs) of the country was gradually transferred to cities: "a city might in this manner grow up to great wealth and splendor" (WN, III.iv.13). This process generated a second but not at all trivial effect.

> Inhabitants of a city, situated near either the sea-coast or the banks of a navigable river, are not necessarily confined to derive (their subsistence) from the country in their neighbourhood. They have a much wider range and may draw them from the most remote corners of the world (…). The cities of Italy seem to have been the first in Europe which were raised by commerce to any considerable degree of opulence. (WN, III.iii.13–14)

This passage well interprets a crucial possibility, which has happened in history in particular periods and is repeating itself in recent times with the development of information, communication, and transport technologies: the economic emancipation, or better the enfranchisement, of (large) cities with respect to their surroundings, their regions, and even their nation countries (Camagni 2020).

4 The Theory of Land Rent

4.1 Fertility Rent

Adam Smith was the first economist in history that clearly and analytically developed the idea—already outlined by William Petty in a sketchy way[37]—of the double source of land rent: *fertility* and *location* (or "*situation*"). His theory of land rent is, as usual, a personal, comprehensive, and consistent synthesis of the main approaches and concepts of his age, a synthesis that with small incremental improvements would persist for a century, through Ricardo and Mill to Marshall and beyond.[38] His own contribution was enriched by an original and innovative section on urban land rent, distinguishing between building rent and ground land and including an in-depth treatment of land rent taxation.

Let us first consider fertility rent and then situation and urban ground rent.

All classical economists (as Cantillon and the Physiocrats had done previously) believed that land rent derived from the original appropriation of land and of the "powers of nature."[39] According to Smith:

> As soon as the land of any country has all become private property, the landlords, like all other men, love to reap where they never sowed, and demand a rent even for its natural produce (…) which, when land was in common, cost the labourer only the trouble of gathering them (WN, I.vi.8).

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[37] Petty (1662/1899), Ch. 5, point 5, p. 48–49.

[38] Schumpeter (1968) does not agree with this judgment: He uses the subsequent Ricardian theory of land rent in order to criticize Smith, and the neoclassical theory in order to destroy Ricardo.

[39] "It does not appear that Providence has given the right of the possession of land to one man preferably to another: the most ancient titles are founded on violence and conquest" (Cantillon 1755, Ch. XI, p. 8).

Therefore, "this rent may be considered as the produce of those powers of Nature, the use of which the landlord lends to the farmers" (WN, II.v.12), what forty years later Ricardo called "the original and indestructible powers of the soil" (Ricardo 1821/1971, p. 91).[40]

The consequence that logically follows is that land rent does not enter in the price of goods, because land is a costless factor; rent appears only in the distribution phase, not in the production one. "Rent, it is to be observed, therefore, enters into the composition of the price of commodities in a different way from wages and profit. High or low wages, and profit, are the causes of high or low price; high or low rent is the effect of it." (WN, I.xi.8).[41] Turning to Smith's definition of fertility rent:

> *Rent, considered as the price paid for the use of land, is naturally the highest which the tenant can afford to pay in the actual circumstances of the land*. In adjusting the terms of the lease, the landlord endeavours to leave him no greater share of the produce than what is sufficient to keep up the stock from which he furnishes the seed, pays the labour, and purchases and maintains the cattle and other instruments of husbandry, together with the ordinary profits of farming stock in the neighbourhood. (WN, I.xi.1)

This formulation of the concept seems appropriate and ready to be directly translated into a formula: the well-known Von Thünen equilibrium equation of bid rents.[42]

> Such parts only of the produce of land can commonly be *brought to market* of which the *ordinary price* is sufficient to replace the stock which must be employed in *bringing them thither*, together with its ordinary profits. If the ordinary price is more than this, the surplus part of it will naturally go to the rent of the land. If it is not more, though the commodity

[40] There is no conceptual difference between these two definitions; Von Thünen (1826, Part I, p. 22) though, more sympathetic with Ricardo's general theory, opposes Smith's to Ricardo's definitions in favor of the latter. See footnote 42.

[41] This statement precedes by forty years the well-known sentence by Ricardo: "Corn is not high because a rent is paid, but a rent is paid because corn is high" (Ricardo 1821/1971, p. 98).

[42] Strangely enough, Von Thünen (1826) did quote Smith (he "taught me political economy": Part II, Introduction, p. 225) but only for blaming him for the "conceptual error" of including in land rents "the interests on the value of the buildings and other equipment" (Part I, Ch. 5a, 14–15, pp. 18–19). A peculiar criticism, given the extensive analysis that Smith made of "the division of stock," of the different "portions" in which fixed and circulating capital are divided (WN, II. i) and his explicit consideration of the "original expense of improvement" on land (WN, I.xi.b.24): "(t)he rent of land, it may be thought, is frequently no more than a reasonable profit or interest for the stock laid out by the landlord upon its improvement. This, no doubt, may be partly the case upon some occasions; for it can scarce ever be more than partly the case. The landlord demands a rent even for unimproved land, and the supposed interest or profit upon the expence of improvement is generally an addition to this original rent. Those improvements, besides, are not always made by the stock of the landlord, but sometimes by that of the tenant. When the lease comes to be renewed, however, the landlord commonly demands the same augmentation of rent, as if they had been all made by his own." (WN, I.xi.a.2). Von Thünen, a country gentleman and landlord, though a very industrious, well-educated and smart one, perhaps did not like the portrait of the typical landlord made by Smith; or, more probably, had the interest to undermine his role in rent theory in his own favor—given the fact that, as he affirms, "I had not read (Ricardo) when I wrote the first draft of this work" (Von Thünen 1826, p. 22). As it will be shown later, in the case of the rent of houses, Smith carefully distinguished building rent ("the interest or profit of the capital expended in building the house") and the pure "ground rent."

> may be brought to market, *it can afford no rent* to the landlord. *Whether the price is, or is not more, depends upon the demand.* (WN, I.xi.6)

This last sentence makes four important theoretical points. First, the surplus after paying all expenses, including the maintenance of fixed capital stock and the profit on the circulating capital, represents the "pure" land rent. Secondly, expenses include *transport costs* to the market. Thirdly, in the case that, on some lands, the price just covers all expenses, no rent will be paid: Rent has a *differential nature*, and, in this latter case, on that land which was later called "marginal," the least fertile among those actually utilized, no rent will appear.[43] Fourthly, in all cases, all depends on *demand*.

From the analysis that follows, which considers different "parts" or subsectors of the produce of land, we understand that, as men "naturally multiply in proportion to the means of subsistence, food is always more or less in demand, (…) and somebody can always be found who is willing to do something, in order to obtain it." Therefore "something *always* remains for a rent to the landlord" (WN, I.xi.b.1): on "marginal" land too! This rent on land that produces human food "regulates the rent of the greater part of other cultivated lands" (WN, I.xi.b.23).[44] All this means that Smith had two complementary concepts of land rent: a concept of *differential* rent, according to the different fertility of lands[45] (and to their location with respect to markets, as we will see)—a microeconomic and spatial notion—and a concept of *scarcity* rent, mainly macroeconomic, similar to the Marxian "absolute rent."[46] In fact, on this second concept, he is not very clear,[47] but in many passages, he excludes the possibility of a nil rent, in particular, as already shown, in the production of human food ("corn").[48]

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[43] Thus far, Smith's theory of land is perfectly similar to Ricardo's (1821, Ch. 2). But while Ricardo stopped at this stage, because the zero-marginal rent is totally consistent within his analytical model of income distribution, Smith, more interested in comparing theory and the real world, continued to inquire whether this critical conclusion of nil rent could be always perceived in reality, at the risk of endangering the pure perfection of the theory.

[44] Smith was perfectly aware that some types of crops generally require "greater original expenses of improvement," "greater annual expenses of cultivation," and "more attentive and skilful management" that therefore imply a superior payment to both landlords and to farmers. "This superiority, however, will seldom be found to amount to more than a reasonable interest or compensation for this superior expense" (WN, I.xi.b.24). Concerning the superior payment to landlords, Smith still called it "rent," but it is clear that it is due for the "original" expenses: "the advantage which the landlord derives from such improvements seems at no time to have been greater than what was sufficient to compensate the original expence of making them." (WN, I.xi.b.26).

[45] "The rent increases according to the goodness of the pasture" (WN, I.xi.b.3).

[46] See also, for this conclusion, Napoleoni (1970, p. 83). Marx criticized Ricardo on both theoretical and empirical grounds concerning the fact that in his model the rent on "the worst cultivated soil" is equal to zero (Marx 1894/1959, Book III, Ch. 45, p. 555), but failed to explain and justify in a consistent theoretical way his (correct) conjecture on the existence of an "absolute" rent (See: Camagni 1992, Ch. 9.4.3).

[47] In fact, Ricardo criticized Smith on this point in Ch. XXIV of his *Principles*.

[48] Before Smith, William Petty did not accept a zero rent, but did not give any justification for this rejection. Marshall did so (1890/1977, p. 351), and more recently also Sraffa (1960), when in his XI Chapter ("The Land") he wrote two equations for land rent, the first concerning the Ricardian

In regard to the economic nature of rent, an intriguing sentence by Smith generated much debate and controversy: "*The rent of land, therefore, considered as the price paid for the use of the land, is naturally a monopoly price.*" (WN, I.xi.5). As Malthus rightly affirmed (Malthus 1820, II.iii. p. 136), and later Schumpeter accepted (1968, pp. 361–362), this should not be considered an analytical sentence: The case of a monopoly price would not have been consistent with the general belief of classical economists that rent does not enter in the definition of prices (while monopoly profit does). Smith, and the many classical economists that used that expression, likely meant that the private appropriation of a costless but scarce natural resource determines effects similar to a monopoly condition.[49] This, of course, derives from the generalized idea—in those times—that land rent is an unearned income, fruit of no engagement in production by the landlord whatsoever: "They are the only one of the three orders whose revenue costs them neither labour nor care (…) independent of any plan or project of their own" (WN, I.xi.p.8).

Curiously, in the same paragraph just quoted in which Smith speaks about the "indolence," "ignorance," and lack of a veritable role within the social production process of the order of landlords, he says that the "interest" of this order "is strictly and inseparably *connected* with the general interest of society" (*ibid*.). This sentence was widely debated at the time of Malthus and Ricardo, the former using Adam Smith's authority in order to strengthen his position in favor of landlords (Malthus 1820, I.iii.viii.1) and to challenge Ricardo's opposite opinion[50]; more recently Schumpeter has referred to that sentence as "incredible" and inconsistent with respect to Smith's "ideological prejudice against landlords" (*sic*) (Schumpeter 1974, Ch. 3, ii.d., p. 153, Italian edition). It is my opinion that there is a wide misunderstanding concerning Smith's position. By "connected interests" he meant that an opulent and flourishing society *generates* major advantages for that class, through the consequent increase in employment, population, wages, and demand for food products, and not at all the

differential "extensive" rent, and the second concerning rent that emerges in the case of equal fertility of all lands (which would take differential rent to zero by definition) but of presence of aggregate scarcity. However, not all economists agree on the concept of absolute rent (in particular, the pure neoclassical school); in my opinion, the concept is particularly fruitful in urban economics, implying and encompassing the effects of agglomeration economies on the differential, at the urban border, between urban and agricultural land (Camagni 1992, Sect. 9.4.3).

[49] Marx, too, initially tried to justify his concept of absolute rent with a class monopoly, but he then changed his mind for similar reasons. J. S. Mill began his presentation of land rent theory, on Ricardian lines, with the same statement on monopoly; yet this looks only as a formal tribute to Smith, as he immediately dismissed it: "It is at once evident that rent is the effect of a monopoly. The reason why landowners are able to require rent for their land is, that it is a commodity which many want, and which no one can obtain but from them. If all the land of the country belonged to one person, he could fix the rent at his pleasure. This case, however, is nowhere known to exist; and the only remaining supposition is that of free competition; the land-owners being supposed to be, as in fact they are, too numerous to combine" (Mill 1875, II.vi.1. p. 270).

[50] "The interest of the landlord is always opposed to that of the consumer and manufacturer" (Ricardo 1821, p. 332).

other way round, so that what is good for the landlord is good for society.[51] This is the logic of the subsequent empirical examples that Smith provides to justify his sentence, and also the way in which Malthus, and Ricardo, too, read it.

In a dynamic perspective, in fact, with the growth of productivity in agriculture and greater general opulence, "every improvement in the circumstances of the society tends, either directly or indirectly, to raise the real rent of land, to increase the real wealth of the landlord, his power of purchasing the labour or the produce of the labour" (WN, I.xi.p.1) and also "the proportion of his share to the whole produce" (WN, I.xi.p.3). Almost all classical economists agreed with this argument.[52]

4.2 The Theory of Land Rent: "Situation" Rent

As said above, Smith had a perfectly clear idea about the two sources of land rent, their mutual relationships, and their appropriate analytical definitions:

> The rent of land not only varies with its *fertility*, whatever be its produce, but with its *situation*, *whatever be its fertility*. Land in the neighbourhood of a town, gives a greater rent than land equally fertile in a distant part of the country. (WN, I.xi.b.4)[53]

> The corn which grows within a mile of the town, sells there for the *same price* with that which comes from twenty miles distance. But the price of the latter must generally, not only *pay the expense of raising and bringing it to market*, but afford too the *ordinary profits* of agriculture to the farmer. The proprietors and cultivators of the town, over and above the ordinary profits of agriculture, gain, in the price of what they sell, the whole value of the carriage of the like produce that is brought from more distant parts, and they save, besides, the whole value of this carriage in the price of what they buy. (WN, III.i.1)

We find here a clear definition of situation or location rent as a saving on transport costs, together with the full Von Thünen formula of bid rent in spatial equilibrium, fifty years before him: single price for each product at the town market, whatever the fertility and location of the land producing it, single rate of profit, and all production expenses subtracted from revenues. The result is a differential rent concept, equal, in

[51] As will be shown later, this causal relationship is even more important and clear in the case of urban ground land rent.

[52] Years later, Mill was of the same opinion: "The ordinary progress of a society which increases in wealth is at all times tending to augment the incomes of landlords; to give them both a greater amount and a greater proportion of the wealth of the community" (Mill 1848, V.ii.6). Smith though, in another passage, confirms the growing real income of landlords in absolute terms but not as a share of national product (WN, II.iii.9). In this regard, the most interesting modern interpretations of Smith's general model of income production and distribution—that of Samuelson (1977) and of the Sraffian school (O'Donnell 1990)—justify the first interpretation (Freitas 2012).

[53] "Though it may cost no more labour to cultivate the one than the other, it must always cost more to bring the produce of the distant land to market. A greater quantity of labor, therefore, must be maintained out of it; and the surplus, from which are drawn both the profit of the farmer and the rent of the landlord, must be diminished. But in remote parts of the country the rate of profit, as has already been shown, is generally higher than in the neighbourhood of a large town. A smaller proportion of this (diminished) surplus, therefore, must belong to the landlord." (WN, I.xi.b.4)

this case to Von Thünen's one. Rent on the "marginal" land here follows his general law (equal in general—but not always—to zero).

One cannot find in Smith the full picture of the well-known crop rings modeled by Von Thünen according to different transport costs and accessibility needs; however, some intuitions concerning this issue, supported by empirical analysis, are present. Smith remarks that around a great city the demand for milk and forage for horses sometimes grows so high that it increases the price of grass and, given its *higher unit transport cost*, attracts its production in the vicinity of the city, crowding out the production of corn, the crucial human food, which is pushed to distant places and even imported.[54,55]

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[54] "In the neighbourhood of a great town, the demand for milk and for forage to horses, frequently contribute, together with the high price of butcher's meat, to raise the value of grass above what may be called its natural proportion to that of corn. This local advantage, it is evident, cannot be communicated to the lands at a distance. Particular circumstances have sometimes rendered some countries so populous, that the whole territory, like the lands in the neighbourhood of a great town, has not been sufficient to produce both the grass and the corn necessary for the subsistence of their inhabitants. Their lands, therefore, have been principally employed in the production of grass, the *more bulky* commodity, and which *cannot be so easily brought from a great distance*; and corn, the food of the great body of the people, has been chiefly *imported* from foreign countries." (WN, I.xi.b.11–12). In a similar way, Von Thünen finds that "near the town will be grown those products which are *heavy or bulky* in relation to their value and hence so *expensive to transport*" (Von Thünen 1826, Part I, Ch. 2, p. 2).

[55] Von Thünen developed his well-known model of "agricultural statics" and its related diagrams of successive production rings in Part I of *The Isolated State*. In the following Parts, he moved much farther along a typical Ricardian analytical program, in search of cross-effects among the income distribution variables, their endogenous determination, and on the release of the homogeneity hypothesis on fertility and *k/l* ratio throughout the plain. He considered this last hypothesis logically untenable as a consequence of the different value of grain in the different rings and consequent different incentives to increasing the k-intensity in the form of land improvements and soil enrichment. In Part II, cleverly working on the Isolated State external frontier, where rent is equal to zero (and disappears at the margin as an income distribution share) and defining capital as "accumulated labour product" or stored-up past labor, he comes to define what he calls the "natural wage": the equilibrium (and "rightful") level of real wages, independent from the interest rate, that he calculates as the geometric mean between subsistence needs and workers product (or, as Samuelson puts it, between worker's marginal and average productivity). Through differential calculus on marginal cross-productivities, he demonstrates that his "natural" wage maximizes the revenue of capital-producers and national revenue. In Part III, published after his death in 1863, he analyzed the problem of optimal rotation period of pinewood stock in forests as a capital-theoretic dynamic optimization problem, with revolutionary operational results. In both Parts II and III, he was much ahead of his times in both theory and analytical methods. Paul Samuelson, having worked on a Thünen-inspired model, was able to claim in 2009 that an answer was finally possible to Ricardo's question about distributive shares, through a production function with heterogeneous ("vectoral") capital (Samuelson 2009, p. xiii), a question that previously had triggered a harsh, highly theoretical "capital controversy among the two Cambridges" (UK and Massachusetts) following the publication of Sraffa's book (1960). Von Thünen was aware of the relevance of all these developments, beyond—but necessarily including—his early definition of crops location and distance rent: "(t)he problem touches on the relations between the various classes, on the happiness and welfare of the numerous class of labourers as much as on the obligations of the rich towards the working class; our discussion therefore reaches far beyond the first conception of the Isolated State. Here, where we come to deal with man himself, the Isolated State recedes into the background; and if our discussion

The idea of a natural organization of crops in space in successive rings around the main markets was already present in the clubs of Scottish economists. In fact, almost ten years before the publication of the Wealth of Nations, Sir James Steuart—a landed gentleman (as, later, Von Thünen), who first introduced the term "political economy"—in his *Principles of Political Oeconomy* (1767) presented the same idea of rings or "belts" in a more fully developed way than Smith's one. Locations at different distances were based on perishability (e.g., "kitchen garden products … *cannot easily be brought from a distance, in that fresh and luxuriant state which pleases the eye, and conduces to health"*), unit transport costs and volumes produced (*"bulky commodities"*) (vol. I, XX, p. 139). His full description of the rings[56] and the importance attributed to transport costs was much praised by Martin Beckmann (1981) in his tribute to Steuart as "one of the forerunners of urban economics and land use theory" (p. 1). Honestly speaking, Steuart's amazing contribution was mainly confined to a geographical location theory, but it was not complete as it left aside the dual counterpart of location, namely land rent and land rent theory—fully present in Smith as shown before.

Another reference to "circles" is made when Smith points out the crucial importance of accessibility and a good transport infrastructure, because they foster the development of more peripheral areas and of "the *most extensive circle*" of the country.[57] "They are advantageous to the town" not just because "they open many new markets to its produce" but, more importantly, because they "*break down the monopoly of the country in its neighbourhood*, (…) a great enemy to good management." (WN, I.xi.b.5). And how strong the power of this monopoly can be is revealed by the following anecdote: "It is not more than fifty years ago that some of the counties in the neighbourhood of London, petitioned the parliament *against the extension of the turnpike roads* into the remoter counties." (*ibid*.). This is indeed a clear example of the true position taken by Smith in the debate concerning interest conflicts

is still based on the concept of the Isolated State, this is because the problem seems to me to be soluble – if at all – only with the aid of the approach and the assumptions which form the basis of this hypothesis." (von Thünen 1826, Part II, Ch. 5, 24, p. 240). We see in von Thünen's work some Smithian theoretical basics and philosophical goals (as it will be shown later), a Ricardian analytical method, an anticipation of "post-1890 marginal productivity theory," and use of differential calculus (Samuelson 2009, p. xiii), a path-breaking indication of a workable general equilibrium model: not a negligible achievement indeed!

[56] "Thus we commonly find agriculture disposed in the following manner. In the center stands the city surrounded by kitchen gardens; beyond these lie a belt of fine luxuriant pasture or hay fields; stretch beyond this and you find the beginning of what I call operose farming, plowing and sowing; beyond this lie grazing farms for the fattening of cattle; and last of all come the mountainous and large extents of unimproved or ill improved grounds, where animals are bred. This seems the natural distribution, and such I have found it almost everywhere established, when particular circumstances do not invert the order." (Steuart 1767, vol. I, XX, 139).

[57] "Good roads, canals, and navigable rivers, by diminishing the expense of carriage, put the remote parts of the country more nearly upon a level with those in the neighbourhood of the town. They are upon that account the greatest of all improvements. They encourage the cultivation of the remote, which must always be *the most extensive circle of the country*". (WN, I.xi.b.5)

among classes, very similar to the subsequent position of Ricardo in his scientific and parliamentary fight against the corn laws.[58]

Another example of accessibility advantage with an interesting link with locational monopoly is provided by the islands of Shetland, where inhabitants, in order to profit from the abundance of fish—another gift of nature—generally locate on the coasts. But the landlord's rent in this case "is in proportion to what he can make both by the land and the water (…), partly paid in sea fish". (WN, I.xi.a.4)[59,60]

4.3 Urban Land Rent: Ground and Building Rent

Smith did not devote a chapter of the WN to the role of cities, the reasons for agglomeration, and the generation of an urban land rent; yet he had a clear perception and interpretation of the link among these matters, thanks to his broad historical view, his deep inductive capacity, and his mastery in the understanding of economic processes. As seen previously, a reconstruction of his view on this matter requires bringing together sentences, sudden intuitions, and profound thoughts spread throughout his entire opus. Since this reconstruction could imply some dose of subjectivity, I quote here abundantly from Smith. Interestingly enough, his analysis of urban land rent—the most innovative in his times and closest to fiscal policies—is placed in Book V, Ch. II, Part II "Of taxes" and not in Book I, Ch. XI "On the rent of land."

> The rent of a house may be distinguished into two parts, of which the one may very properly be called the building rent; the other is commonly called the ground rent. The building rent is the interest or profit of the capital expended in building the house." (WN, V.ii.e.1–2)

The ground rent is the most important concept, the only one referring properly to rent: its economic sources are the usual ones, situation and demand (under the hypothesis of some scarcity).

Here, Smith introduces a concept parallel to the one of productive and unproductive labor:

> The rent of houses, though it in some respects resembles the rent of land, is in one respect essentially different from it. The rent of land is paid for the use of a productive subject. The land which pays it produces it. The rent of houses is paid for the use of an unproductive subject. *Neither the house nor the ground* which it stands upon *produce anything*. (WN, V.ii.e.7)

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[58] "The interest of the landlord is always opposed to that of consumer and manufacturer" (Ricardo 1821/1971, p. 332).

[59] "It is one of the very few instances in which rent makes a part of the price of that commodity," i.e., fish (WN, I.xi.a.4): evidently, he considers this as a case of locational monopoly, similar to Marshall's private appropriation of "public value."

[60] The last case of situation rent refers to another natural resource, mines: "Whether a coal-mine can afford any rent, depends partly upon its fertility, and partly upon its situation." (WN, I.xi.e.10). The ability of products (coal, iron, precious metals, or diamonds) of bearing long-distance carriage depends on the possibility of separating the ore and on the intrinsic value per ton. When this value is very high, the value of the mine will almost reside in its fertility.

This "prejudice," together with the more "abstract" nature of the service of urban land, reinforced his idea of a monopolistic nature of urban rent:

> There is no city in Europe, I believe, in which house-rent is dearer than in London (…) The dearness of house-rent in London arises from those causes which render it dear in all great capitals, (…) above all the dearness of ground-rent, *every landlord acting the part of a monopolist*, and frequently exacting a higher rent for a single acre of bad land in a town, than can be had for a hundred of the best in the country. (WN, I.x.b.52)
>
> This surplus rent is the price which the inhabitant of the house pays for some *real or supposed advantage of the situation.* (…) In country villas, in the neighbourhood of some great town … the peculiar *conveniency or beauty of situation* is there frequently very well paid for. Ground rents are generally highest in the capital, and in those particular parts of it where there happens to be the *greatest demand* for houses, whatever be the reason of that demand, whether *for trade and business, for pleasure and society, or for mere vanity and fashion.* (WN, V.ii.e.3)

The usual "bid-rent" concept is perfectly focused. "Situation" encompasses not just accessibility, as in the food market, or closeness to other trade and business operators (*conveniency*), but many other subjective elements such as *beauty* of landscape, urban *amenities* and *lifestyles*—real, supposed, or imposed by *fashion.* The amount of unit rent depends on the density and wealth of local demand.[61,62] A modern theoretician of the urban location of economic and residential activities could not have put it better.

The subsequent paragraphs of the same section of the WN develop, in a normative and a political economy direction, the basic analytical concepts of the previous ones. The nature and development of a city owe nothing to the "care" or "project" of landowners but derive from the action of the State (or public administration). In fact:

> Both ground–rents and the ordinary rent of land are a species of revenue which the owner, in many cases, enjoys without any care or attention of his own. (…) Ground–rents, so far as they exceed the ordinary rent of land, are altogether *owing to the good government of the sovereign*, which, by protecting the industry either of the whole people, or of the inhabitants of some particular place, enables them to *pay so much more than its real value for the ground* which they build their houses upon; or to make to its owner so much more than compensation for the loss which he might sustain by this use of it. (WN, V.ii.e.10–11)

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[61] "In country houses, at a distance from any great town, where there is *plenty of ground* to chuse upon, the ground rent is … no more than what the ground … would pay if employed in agriculture. In country villas in the neighbourhood of some great town, it is sometimes a good deal higher; and the *peculiar conveniency or beauty of situation* is there frequently very well paid for" (WN, V.ii.e.3).

[62] "The owner of the ground-rent … acts always as a monopolist and exacts the greatest rent which can be got for the use of his ground. More or less can be got for it according as the competitors happen to be richer or poorer, or can afford to gratify their fancy for a particular spot of ground at a greater or smaller expence" (WN, V.ii.e.9).

All this theoretical elaboration on urban land rents—and the consequent suggestions on its taxation—was not present, to my knowledge, in the literature of the eighteenth century.[63] Later, it was totally absent in Ricardo[64] or Malthus, while it survived with small refinements for more than one hundred and fifty years—and under many respects up to the present day—particularly in the works of J.S. Mill, Marx (who added some specific contributions, not always acceptable), Marshall (1890), Pigou (1909), the controversial but politically effective Henry George (1879),[65] and many Italian liberal economists of the early twentieth century such as Ulisse Gobbi (1906) and Luigi Einaudi.

Marshall remained always convinced that land rent, and urban rent in particular, deserved a theoretical treatment different from the other production factors, capital, and labor, in opposition to his contemporary neoclassical economists.[66] In Chapter xi of Book V, dedicated to "Urban Values," Marshall did not mention the monopoly condition, but shared Smith's idea that urban "*situation value*" is "the indirect result of the *general progress of society* rather than the direct result of the investment of capital and labour by individuals for the sake of gain" (Marshall 1890, V.xi.1). Therefore "the greater part of situation value is '*public value*'" (V.xi.2)—as opposed to the "private value" that "can be traced to the work and outlay of its individual holders"—or, using a "precedent term," is "true rent" (V.x.5).

Smith's subsequent analysis consistently evolved in the direction of ground land rent taxation:

> Ground-rents seem, in this respect, a more proper subject of *peculiar* taxation than even the ordinary rent of land. (…) Nothing can be more reasonable than that a fund which owes its existence to the *good government* of the state, should be taxed peculiarly, or should contribute something more than the greater part of other funds, towards the support of that government. (V.ii.e.11).

And, continuing along this quite radical path, he wrote:

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[63] This is well known in the circles of land economists (see Prest 1981; Lichfield and Connellan 1997, Appendix 1.2). The "single tax" on land rents (*impôt unique*) proposed by the French Physiocrats in the same years referred to agricultural rent and derived from a completely different economic logic.

[64] Ricardo's *Principles of Political Economy and Taxation* presents a chapter (XIV) concerning "Taxes on housing," but it is as short as four pages, full of long citations from Smith and, at the end, concedes that "(i)t must be admitted that the effects of these taxes would be such as Adam Smith has described" (Ricardo 1821, p. 215).

[65] Henry George (1839–1897), American journalist and political economist, proposed a single tax on the 100% of land rents and the abolition of taxes on wages and profits. His political challenge had an important echo in the USA; in the United Kingdom his project was backed in particular by the Fabian Society and was at the basis of subsequent land-value taxation laws. His most famous self-published book, *Progress and Poverty* (1879), sold millions of copies worldwide; he died of a stroke while campaigning for Mayor of New York City.

[66] "The rent of land (…) has peculiarities of its own which are of vital importance from the point of view of theory as well as of practice" (Marshall 1890, Preface to the first edition).

> A tax upon ground–rents would not raise the rents of houses. It would fall altogether upon the owner of the ground–rent, who acts always as a monopolist (…). *No discouragement* will thereby be given *to any sort of industry.* (V.ii.e.9–10)[67]

This is a strong sentence: A tax on urban ground rent does not raise rents, and therefore, house prices and does not damage the rest of the economy. Mill, Marshall, and Samuelson, respectively seventy, one hundred, and two hundred years later, agreed with Smith on these last sentences and their underlying logics. According to Mill, "the existing land-tax (which in this country unfortunately is very small) ought not to be regarded as a tax, but as a rent-charge in favour of the public; a portion of the rent, reserved *from the beginning* by the State, which has never belonged to or formed part of the income of the landlords." (Mill 1848, V.ii.6).[68] According to Marshall, "a tax on the public value of land does not greatly diminish the inducement to cultivate the land highly, not to erect farm buildings on it. (…) It does not raise the price of produce" (Marshall 1976, V.x.4).[69] Concerning the form of taxation, Mill and Pigou (1909) preferred taxing increments of land values instead of full values.

In the case of urban ground rent, one can fully appreciate Smith's strict logic linking general principles, specific theorization, interpretation of facts, economic judgment, and consequent policy suggestions. On the strength of this general logical consistency lies the long fortune of his thought in this field.

5 Some Themes and Theoretical Issues Overlooked by Regional Science

In the two preceding sections of this work, I have shown the seminal conceptual and theoretical contributions of Adam Smith by which, in my opinion, he anticipated some of the recognized Great Minds of regional science. In this section, I shall point

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[67] This is one of Smith's intuitions praised by such a great (neoclassical) economist as Samuelson (1992): "Smith … is right to perceive that land rent is a surplus that can be taxed without affecting real price ratios" (p. 3). Von Thünen, too, agreed with this analytical proposition (Von Thünen 1826, Part I, Ch. 38).

[68] "The landlords originally held their estates subject to feudal burthens, for which the present land-tax is an exceedingly small equivalent" (Mill 1848, V.ii.6). The entire Sect. 6 in which the quoted sentence is located was eliminated from the 1885 abridged New York edition of Mill's *Principles of Political Economy,* "A Textbook for Colleges," edited by J. L. Laughlin of Harvard University, and it was substituted for by a longer note about an initiative of Mill's on land taxation.

[69] Marshall was even much stronger than that in the early editions of his *Principles of Economics:* "The sudden appropriation of [land] rents and quasi rents by the State would indeed have" huge political effects, "destroying security and shaking the foundations of society; but" in economic terms, or "if *from the first* the State had retained true rents in its own hands, the vigor of industry and accumulation need not have been impaired" (Marshall 1890, Book VI, ch. 9, Sect. 351). Strangely, in late authorized editions of *Principles* since 1900 this passage was deleted. See Camagni (1992), Ch. 9, footnote 15. As in the case of the previous footnote, the mentioned views might have seemed too "Georgist" (see footnote 65), a doctrine that was condemned by Pope Leo XIII in his Encyclical *Rerum Novarum* in 1891.

out other contributions of his, namely those pertaining to themes and issues of great importance today, which were—and still are—largely neglected in regional science. On these issues, he not only directed important attention but added striking intuitions about how to deal with them in economic terms, including, as usual, institutional and political science tools. Had regional science not been widely deaf to these issues and had it followed the pathways indicated by Smith, it would be today much better able to interpret and tackle problems that are increasingly questioning the social structure of Western countries and even challenging their political stability.

5.1 Economic Power and Spatial Income Distribution

The first and most important theme that has been overlooked and actually lost by regional scientists is, in my opinion, that of economic power and its impact on spatial income distribution (Camagni 2016a, b). Some clarifications on what I specifically mean are necessary.

Initially, the subject of income distribution and its determinants had at least an equal weight with respect to the theory of production and exchange in the treatises of classical economists; for Ricardo, it was the crucial issue of political economy. With the advent of neoclassical economic theory, the two fields were linked together by the concept of marginal productivity, i.e., by the hypothesis that the remuneration of all factors was subject to the same law, under the normal assumption of perfectly competitive markets. During the twentieth century, the interest in income distribution diminished, in parallel with the emerging belief that growth, the true economic issue, would solve any social problem.

Regional science inherited these sentiments and added a habit of measuring spatial development issues in physical units: inhabitants, jobs, and GDP (at constant prices), typical of location theory and economic geography. This functional-geographic approach proved successful and helped to explain wide interregional problems but left the pricing problem of production factors untouched: trends in remunerations with a huge spatial bias, consequent relative prices of products and terms of trade among territories, unequal exchange,[70] profits and land rents as distributive shares, spatial distribution of purchasing power. The question of the global power of large corporations and its spatial effect was left to the business administration or political science literature, while that of urban poverty and people's displacement in large cities was appropriated by planners, urban sociologists, or urban geographers. The specificity of an economic viewpoint was largely neglected.[71]

[70] These issues are present, however, in the theory of international trade, in international monetary economics, and in some economic development theories.

[71] Among economists, there are notable exceptions, of course, including Joseph Stiglitz, Angus Deaton, Amartya Sen, Daron Acemoglu, Anthony Barnes Atkinson, and Thomas Piketty. But, in spite of three Nobel Prizes between them, they remain in the minority.

The emerging issue of more recent years, what has been called the geography of "uncertainty" (Ottaviano 2019) or the "geography of discontent" (Rodriguez-Pose 2017)—affecting areas not experiencing absolute levels of poverty—was initially apparent in the new political and electoral attitudes that suddenly arose in almost all advanced countries. Then, it was sufficiently considered in geographic terms but never really explained. In my view, all this has been due to income-distribution trends in space: the explosion of land rents in large cities, the increasing control power of global finance and its headquarters, the fast divergence in the remunerations of work by tasks and professions, the increasing weakness of the traditional socio-economic role of the middle class in society (Camagni 2020).[72]

Interestingly, these processes are closely bound up with space and territories. They do not just *happen on* territory, but *in* and *by* territory, according to its specific features. More precisely, they are generated by the old, Smithian relationship between "town and country." This relationship has hugely changed since those years, but it has remained conceptually crucial: It was originally a relation of industry versus agriculture; then became a relationship between urban services and footloose industry; recently, it has turned into the relationship between *global cities and small cities,* i.e., between knowledge*,* culture, and creativity-intensive professions on the one hand, and routinized intellectual professions, at risk of automation, on the other.

As shown above, Smith thought that the relationship between town and country was largely the effect of a functional division of labor, a complementarity bringing advantages to both parties. But he was also aware of a second nature of that relationship between the two spatial archetypes, of a hierarchical and distributive nature, to which he devoted much attention in the WN: "what circumstances (…) have given the trades which are carried on in towns so great an advantage over that which is carried on in the country (…) I shall endeavour to explain at full length". (WN, II.v.37)

Firstly, Smith considered the ancient urban guilds/corporations:

> The government of towns corporate was altogether in the hands of traders and artificers; and it was the manifest interest of every particular class of them, to prevent the market from being over-stocked, as they commonly express it, with their own particular species of industry; which is in reality to keep it always under-stocked. (…) In consequence of such regulations, indeed, each class was obliged to buy the goods they had occasion for from every other within the town somewhat dearer (and …) none of them were losers by these regulations. *But in their dealings with the country they were all great gainers*; and in these latter dealings consists *the whole trade which supports and enriches every town.* (I.x.c.18)

[72] "The geography of physical assets, activities and distance should merge with a more complicated geography of control (Alderson and Beckfield, 2004), of 'command on labour' (*à la* Adam Smith), a geography of global networks of power elites at both the local and the trans-territorial levels. The traditional 'territorial capital' assets—accessibility and infrastructure, private fixed capital stock, generic human capital and social capital—should be complemented by more relevant assets such as relational capital (Camagni 2019), headquarter functions and their location, residential locations of ruling classes, nodes of global networks in the fields of information, culture, education, power, and control. Furthermore, a renewed in-depth analysis of the cumulative, *selective learning role of places* and local *milieux* becomes crucial." (Camagni 2020).

In fact, "(t)he inhabitants of a town, being collected into one place, can easily combine together (…). The inhabitants of the country, dispersed in distant places, cannot easily combine together. They have not only never been incorporated, but the corporation spirit never has prevailed among them." (WN, I.x.c.22–23)

Secondly, Smith referred to other regulations, concerning international trade, with a similar effect on the unequal exchange between the city and the rest of the economy:

> The superiority which the industry of the towns has everywhere in Europe over that of the country (…) is supported by many other regulations. The high duties upon foreign manufactures and upon all goods imported by alien merchants, all tend to the same purpose. Corporation laws enable the inhabitants of towns to raise their prices, without fearing to be under-sold by the free competition of their own countrymen. Those other regulations secure them equally against that of foreigners. (WN, I.x.c.25)

Lastly, Smith analyzed the "exclusive privileges" assured to specific professions and craft occupations concerning restraints in competition and regulations on access to apprenticeship in towns.[73] If we consider the tight controls on entrance and the power of such modern (urban) corporations as those of taxi-drivers, hotel and restaurant owners, and various professional activities and trades that exist in most cities today, or the resistances and difficulties surrounding the international recognition of qualifications, we can understand the continuing importance of Smith's message.

The most important point, though, is his methodological and analytical message: Monopoly powers enlarge the distributive share of the monopolists on total income, enhance the wealth of cities with respect to other territories, and reduce the economy's growth potential. This unbalanced relationship between city and country was later taken up by the young Marx in his *Economic and Philosophical Manuscripts* and in the *German Ideology* and interpreted as the historical form of a much more profound ontological "contradiction," that between intellectual and manual labor: "The greatest division of material and mental labour is the separation of town and country. This antagonism begins with the transition from barbarism to civilisation (…) and runs through the whole history of civilisation to the present day" (Marx and Engels 1970, p. 49).

The illustrated unbalanced relationship between incomes in the two spatial archetypes may also be due to a functional income distribution within the city. The advantages derived from agglomeration, initially gained as profits and remunerations of advanced services, may be partly confiscated by the rise in urban land/ground rents (Camagni 2016a, 2020).

Smith included these reflections on the power distribution in the city/country relationship, in a wider theory of the historical development "stages" of society—"hunting, pasture, agriculture, and commerce"[74]—in which he established a link

[73] The long period of apprenticeship imposed in most European countries that was used by Cantillon to justify the higher salary of the urban apprentice with respect to the rural young worker (Cantillon 1755, Ch. 7), and therefore the larger share of GDP of towns with respect to their share of population, is used by Adam Smith, together with other similar regulations, to point out an unjust condition.

[74] The third stage is divided in turn into three phases. The first coincides in Western countries with the years after the collapse of the Roman Empire, when "every great landlord was a sort of Petty

between the prevailing structure of the economy (and the modes of earning subsistence) and the nature and distribution of power, authority, and subordination among classes (Campbell and Skinner 1976, pp. 12–16). In the first stage, "universal poverty establishes universal equity," and authority is mainly based on age and personal qualities (WN, V.i.b.7). In the second, a greater inequality emerges, linked to the ownership of land. In the third stage, the power of great landlords is increasingly weakened by the emergence of urban classes and the transformation of the ways of spending and realizing land rents—as commented on earlier in Sect. 3.4. In the fourth stage, when all goods and services command a price, "tradesmen and artificers … are more or less independent of" the landlords, who lose their political power and authority. He definitely presents a philosophy of history based on the nature and distribution of property, and I agree with Mark Blaug that "it is no exaggeration to describe these men (Smith and other Scottish writers of the time, such as Adam Ferguson, John Millar, William Robertson, and even David Hume) as forerunners of the Marxist theory of historical materialism" (Blaug 1996, p. 59).

5.2 *"Sympathy" and "Reciprocity" Sentiments in Public Happiness*

In his early and fundamental work on *The Theory of Moral Sentiments*, while inquiring into the sources of moral judgments—by means of an empiricist, psychological, self-inspecting, and social investigation[75]—Smith develops an in-depth theory of human inter-personal and social relationships, which constitute the natural fabric of human societies.[76] Right from the inception, he writes:

> How selfish soever man may be supposed, there are evidently some principles in his nature, which interest him in the *fortune of others*, and render their happiness necessary to him, though he derives nothing from it except the pleasure of seeing it. Of this kind is pity or *compassion*, the *emotion* which we feel for the *misery* of others, when we either see it, or are made to conceive it in a very lively manner. That we often derive sorrow from the sorrow of others, is a matter of fact too obvious to require any instances to prove it (…). The greatest ruffian, the most hardened violator of the laws of society, is not altogether without it. (TMS, I.i.1.1)[77]

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prince" (WN, III.ii.3); the second with the emergence of a self-governing system in cities within the feudal system; the third with the development of trade and manufactures in cities.

[75] Modern psychologists praise Adam Smith highly for having carefully foreshadowed in his analysis of human judgment and preferences, "approximately 200 years before Kahneman and Tversky (1979)" themes and theories of today's behavioural economics such as loss aversion, myopic intertemporal choice, and overconfidence (Ashraf et al. 2005, p. 132).

[76] The editors of the Glasgow Edition of the TMS go as far as to affirm: "(a)ccording to Smith, conscience is a product of social relationships" (Raphael and Macfie 1976, p. 15).

[77] "It is by the imagination only that we can form any conception of what are the sensations (of our brother, or) by representing to us what would be our own, if we were in his case." (TMS, I.i.1.2).

"Sympathy" is the psychological and moral force that ties men together in society, a force that somehow, in Smith's thought, parallels the "gravity law" of Newton—the mind that he most admired.[78] Starting from this natural attitude, social relationships become founding principles of society and sources of social happiness:

> It is thus that man, who can subsist only in society, was fitted by nature to that situation for which he was made. All the members of human society stand in need of *each other's assistance*, and are likewise exposed to mutual injuries. Where the necessary assistance is *reciprocally* afforded from love, from gratitude, from friendship, and esteem, the *society flourishes and is happy*. All the different members of it are bound together by the agreeable bands of love and affection, and are, as it were, drawn to one common centre of *mutual good offices*. (TMS, II.ii.3.1; author's italics)

These statements are very important in many respects. Significant moral and social sentiments are not confined to compassion and pity or pure sociability, but expand to "fellow-feelings" with the joy and happiness of others, naturally necessary to us, and to *assistance*. These basic relational elements require a crucial condition, that of *reciprocity* in its different forms (gratitude, friendship, …), in order to generate concrete actions and make them converge on "*mutual good offices*" and "*assistance*" (what could be called "fraternity" or solidarity). The result is not just social *happiness* but also social welfare: "*society flourishes*."

This philosophical theorization was developed by Smith amid the thriving climate of the Scottish Enlightenment, which had important linkages with the French Enlightenment and the Physiocratic group and was represented by the already mentioned thinkers. They all participated in a typical "discovery" of the eighteenth century, namely that of the *civil society*, understood as a sphere of inter-individual and social relationships not controlled by political power.[79]

Smith's theorization was also developed in parallel to, but independent from, another contemporary Enlightenment tradition, the Italian "civil economics," mainly developed in Naples (Antonio Genovesi 1765; Gaetano Filangieri 1780–1788; Lodovico Bianchini 1857).[80] On the basis of relationality and reciprocity sentiments,

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[78] The young Smith wrote in his *History of Astronomy*: "Philosophy is the science of the connecting principles of nature" and "(p)hilosophers … look for a chain of invisible objects to join together two events that occur in an order familiar to all the world" (Smith 1795b, Section II, pp. 11, 49). Newton found that connection in the gravity law; according to Campbell (1975) and with some greater caution Kennedy (2005, Chap. 3), Smith tried to apply the same method in moral philosophy, following Hume, with the theory of sympathy. He wrote: "(p)ity and compassion are words appropriated to signify our fellow-feeling with the sorrow of others. Sympathy, though its meaning was, perhaps, originally the same, may now, however, without much impropriety, be made use of to denote our *fellow-feeling with any passion* whatever." (TMS, I.i.1.5).

[79] Smith uses the term "*civil society*" only three times in his two major works (TMS, I.ii.4.3; VII.iv.36; WN, V.i.g.33), and this may appear rather strange. An explanation could be that the concept was in a sense formally assigned to his colleague Ferguson, who wrote in 1767 an *Essay on the History of Civil Society*. As shown in Sect. 2, Smith had reservations in regard to this work concerning a possible plagiarism, which ended in a formal dispute around 1780 and in the breakdown of the previous friendship. See: Hamowy (1968).

[80] In a similar way to Smith, Genovesi stated: "It is a universal law that no happiness can be made except by pursuing the happiness of others" (quoted by Bruni and Zamagni 2015, p. 79, translation by this author).

Italian *Illuministi* developed an advanced theory on the generation of a *fides publica* (public trust or "confidence")—different from the simple sum of private *fides*, namely individual reputations—and put it at the basis of *public happiness*. Together with the development of trade and markets, or general economic well-being, public trust was indicated as the prime resource for achieving at the same time public happiness and a part of the wealth of a nation (Bruni and Zamagni 2015, pp. 30–33).

Smith and the Italian civil economists—all of whom owed a great deal to Francis Hutcheson, Smith's initial master in Glasgow[81]—did not subsequently obtain any recognition in this field from neoclassical mainstream economics, almost completely shaped by Bentham's utilitarianism in the interpretation of human behavior. Only two hundred years later did the work of these eighteenth-century authors regain the attention of economists, giving rise to new approaches to demand theory (the so-called relational goods that are enjoyed *and* produced only *together with* other people, as per Uhlaner 1989) and to the new "economics of happiness" (Sen 1987, 2005; Bruni and Sugden 2000; Sugden 2005; Bruni and Porta 2005; Bruni and Zamagni 2007).

With his usual pragmatism but also consistency, Smith completed his vision on assistance, confidence, and public happiness, again in the TMS, by examining the case of a *lack* of these sentiments:

> But though the necessary assistance should not be afforded from such generous and disinterested motives, though among the different members of the society there should be no mutual love and affection, the *society*, *though less happy* and agreeable, *will not necessarily be dissolved*. Society may subsist among different men, as among different merchants, from a sense of *its utility*, without any mutual love or affection; and though no man in it should owe any obligation, or be bound in gratitude to any other, it may still be upheld by a *mercenary exchange of good offices* according to an *agreed valuation.* (TMS, II.ii.3.2; author's italics)

This sentence represents the perfect bridge between the *Theory of Moral Sentiments* and *The Wealth of Nations*:[82] "beneficence" is "the ornament which embellishes, not the foundation which supports (…) the immense fabric of human society" (TMS,

[81] A thorough reading of the TMS suggests to me that Smith was ahead of both Hutcheson and the "civil economics" school for two reasons. First, because his theory no longer made reference to natural altruism or benevolence of men: Only "an independent and all-perfect Being, who stands in need of nothing external, and whose happiness is complete in himself can act from (benevolence)," but for sure not "so imperfect a creature as man, the support of whose existence requires so many things external to him." (TMS, VII.ii.3., p. 18). Secondly, thanks to that marvelous theoretical construct which is his "*impartial spectator*," that "great inmate of the breast, the great judge and arbiter of conduct": it reflects, as in a "looking glass" the judgment of other men on our sentiments and behavior, together with our own judgment on ourselves as "well-informed" imaginary spectators of our sentiments and motivations (see TMS, particularly Part III, Ch. 1 and III.2.32). This last concept was praised by Kant in his *Groundworks to a Metaphysics of Morals* (Kant 1785, first page), and many philosophers (like Rawls and Sen) still wonder how to reconcile Kant's "*categorical imperative*," born from an anti-historicist, transcendental idealism, with Smith's "*impartial spectator*," germinated from an apparently opposite empirical and psychological historicism. For an in-depth analysis and an interesting interpretation of this apparently unresolved debate, see Richardson (2017).

[82] All the previously quoted passages from Part II of the TMS were present in its early editions, well before the publication of the WN, unlike Part VI and other passages and chapters that were added

II.ii.3).[83] In its absence, society would be less happy, yet would not fall apart, and the necessary assistance to men would be provided by the market on the basis of fair negotiations and agreed valuations.[84]

There is an element worth underlining in all the previous discourse: the interest manifested by Smith in the happiness and flourishing of society, at an equal level with its progress and opulence. Society can be more or less agreeable, more or less happy: these conditions become values and goals for a "philosopher" engaged in the analysis of the nature and the causes of the wealth of nations, to be reached through civil and civic virtues, through public trust, sympathy, and reciprocity. This evidence was clear and appreciated by contemporary and following classical economists but widely forgotten thereafter and only rediscovered in recent times. The original view about Smith's message was well captured by Malthus, in a rarely quoted passage of his *Essay on the Principle of Population*:

> The professed object of Dr Adam Smith's inquiry is the nature and causes of the wealth of nations. There is another inquiry, however, perhaps still more interesting, which he occasionally mixes with it, I mean an inquiry into the causes which affect the happiness of nations or the happiness and comfort of the lower orders of society, which is the most numerous class in every nation (Malthus 1798, Ch. 16, p. 96).[85]

Smith asks himself: "What institution of government could tend so much to promote the happiness of mankind as the general prevalence of wisdom and virtue?"

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in the 6th edition of 1790, the last before Smith's death, in which he could have tried to remedy the alleged contradictions between the two books. In my opinion, this is among the most convincing evidence of the intrinsic overall consistency of Smith's work, and of the groundlessness of the so-called *Adam Smith Problem*, "a pseudo-problem based on ignorance and misunderstanding" (Raphael and Macfie 1976, p. 20). Taking this counter-interpretation to the extreme and considering the violence with which Smith depicts the political attitudes of self-interested merchants and manufacturers in the WN, one might completely reverse the traditional *AS Problem* by stating, not wrongly, that "the TMS seems to present a more positive image of self-interest than the WN" (Paganelli 2008, p. 367).

[83] On the following page, Smith illustrates what he believes to be the "main pillar" of society, namely *justice*. "If it is removed (…) a man would enter an assembly of men as he enters a den of lions" (TMS, II.ii.3.4).

[84] Smith repeatedly emphasizes the social nature of economic goals, and in particular the goal of "bettering" individual economic conditions (Campbell and Skinner 1976): "From whence, then, arises that emulation which runs through all the different ranks of men, and what are the advantages which we propose by that great purpose of human life which we call *bettering our condition*? To be observed, to be attended to, to *be taken notice of with sympathy, complacency, and approbation*, are all the advantages which we can propose to derive from it" (TMS, I.iii.2.1). "The *pleasures of wealth and greatness*, when considered in this complex view, strike the imagination as something grand and beautiful and noble, of which the attainment is well worth all the toil and anxiety which we are so apt to bestow upon it. And it is well that *nature* imposes upon us in this manner. It is this *deception* which rouses and *keeps in continual motion the industry* of mankind. It is this which first prompted them to cultivate the ground, to build houses, to found cities and commonwealths, and to invent and improve all the sciences and arts, which ennoble and embellish human life; which have entirely changed the whole face of the globe" (TMS, IV.i.1.9–10).

[85] This interesting passage is indicated by Schliesser (2017, p. 199), with an inaccurate quotation.

meaning the necessity of a condition of civil ethics. "All government is but an imperfect remedy for the deficiencies of these" (TMS, IV.ii.1). Social happiness is determined by the "proper balance" and evolution of three systems: a liberal market system leading to material progress, a non-oppressive system of justice, and a system of civil values, shared by individuals exercising the (stoic) ethics of "self-government" and "self-command" on passions.[86,87]

Coming to the present days, the importance of social relationships and sentiments like trust and social capital is well known, in economics and in regional science, at least since the works of Giacomo Becattini on industrial districts (Becattini 1979)—interpreting territory as a "choral subject" (Becattini 2015)—and the (unconventional) theories of rational trust based on reciprocity and plural or collective agents (Gilbert 1989; Sugden 1993; Hollis 1998).[88] Kenneth Arrow—the same economist who gave, with Debreu, the first mathematical proof of the Fundamental Theorem of Welfare Economics—as early as in 1971 warned that "trust, …, norms of social behaviour, including ethical and moral codes … (may be interpreted as) reactions of society to compensate for market failures" (Arrow 1971, p. 22), implicitly suggesting their crucial role even in conditions of pure competition and denying their spontaneous endogeneity created by the market.[89] Trust itself is understood today not just as individual reputation and trustworthiness built through self-interest in market exchanges (and justified by game-theoretic exercises), but also as those dispositions built through networks of civic engagements, which develop only in the presence of relationality and reciprocity (Bruni and Sugden 2000) and mutual recognition of individual identities (Akerlof and Kranton 2000). This kind of trust is nowadays recognized as a crucial device in:

- the development of collective action and cooperative agreements among private firms (Williamson 1991)
- the reduction of complexity and, consequently, of transaction costs, especially in incomplete contracts, "embedding transactions in more protecting governance structures" (Williamson 2002, p. 439)
- the reduction of dynamic uncertainty in innovation processes through local synergies and collective learning, more easily achieved in those territorial circumstances called "the innovative *milieu*" (Camagni 1991).

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[86] Self-command is "the command of the passions which subjects all the movements of our nature to what our own dignity and honour, and the propriety of our own conduct require" (TMS, I.i.5.1). In the case of civil values, "passions" involved are self-love ("the selfish passions"), justice (the "unsocial passions"), and beneficence ("the social passions") (TMS, I.ii.3–5).

[87] "If a society of free people and free markets is to avoid the Hobbesian abyss, justice must be enforced not by institutions and police but by self-government—that is, by citizens who share and adhere to a common, mature standard of civic ethics." (Evensky 2005, p. 129).

[88] What is called "we-rationality": "the possibility that collectives can be agents in a theory of rationality" (Bruni and Sugden 2000, p. 7).

[89] See also Arrow's criticism of pure methodological individualism, his belief that "social variables, not attached to particular individuals, are essential in studying the economy or any other social system" (Arrow1994) and his position about ethical norms (Cato and Lutz 2018).

Smith's message concerning reciprocal pleasure in sharing passions with others outside the family, with "colleagues and partners of trade," within "neighborhoods" or other "societies" (TMS, VI.ii.1),[90] echoes the role of sense of belonging and of sharing values and behavioral codes in territorial development[91] and is paralleled by the recent discovery of feelings of mutual "affection" linking people to places and urban landscapes, central to the hermeneutics of knowledge generation (Cusinato 2016).[92]

Another recent discovery of processes that need the crucial presence of "sympathy" among men is the wise management of (territorial) collective property goods or *commons*. As Elinor Ostrom has shown convincingly (Ostrom 1990, 1998) neither a private nor a public governance can be effective and able to avoid the well-known "tragedy of commons"; only a local community with self-organized governance can do it, on precise conditions:

- a real situation resembling that of "dynamic" or "repeated games," where *learning* can happen, and, consequently, *trust* among actors can develop[93]
- actors not deciding separately (as in the prisoner's dilemma) but discussing and *interacting "personally"*
- actors *sharing* social behavioral norms of *reciprocity*, leading to a higher probability of "conditional cooperation" (networks of civic engagement)
- clear and relatively *high social moral sanctions* (but also actual ones) for breach of cooperation
- high incentive for each actor to gain a *reputation* of reliability.

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[90] "Any state is divided into the different orders (social classes) and societies (…) and the particular distribution which has been made of their respective powers, privileges and immunities" (TMS, VI.ii.2.8). Orders and societies are independent political sub-entities or institutions according to their powers, subordinate to the state to which they owe their security and protection (Schliesser 2017, Ch. VI). In the possible conflict of interest with the state, their "partiality … may not be useless: it checks the *spirit of innovation* (and) tends to *preserve* whatever is the established balance among the different orders and societies" (TMS, VI.ii.2.10). As an economist and a philosopher of civil society, Smith was politically a moderate but always in favor of institutions promoting change.

[91] Bruni and Sugden (2000) assign Smith "a theory of rational trust which is broadly similar to the modern theory of reputation" (p. 34), where "reputation and trustworthiness are transmitted through networks of trading relationships" only originated by self-interest, "without the additional support provided by non-economic networks of civic engagement," as in Genovesi (pp. 33–34). Their analysis, brilliant and convincing in all other respects, understates Smith's contribution on social sentiments by looking mainly at the WN rather than the TMR. Of course, Genovesi presents a more consistent analysis of the social and civic roots and outcomes of trust.

[92] In all these cases where a "correspondence of sentiments" develops, as well as in the case of admiration for the merits or virtues of some men, Smith plainly accepts that there may be some underlying motive of "utility" or "conveniency of mutual accommodation," but he is sure that "the idea of the utility (…) is plainly an afterthought, and not what first recommends them to our approbation" (TMS, I.i.4). In a similar way, what we call "social capital" was indicated as "a by-product of a pre-existent fabric of social relationships, oriented towards goals other" than economic utility (Bagnasco 2002, p. 274).

[93] Games of this kind were described for the first time by Smith's best friend, David Hume, in his *Treatise* (1740/1978), a work that Smith knew very well (Bruni and Sugden 2000).

These conditions are stringent, but—according to Smith—they are not unnatural in terms of human and societal feelings, and today can be easily found in small, cohesive local societies in which these "virtues" are—rationally—praised and promoted.

The foregoing discussion should not be misunderstood. It does not mean that all these modern notions stem from Adam Smith's work, but only signal which developments could have been more easily and rapidly realized had his legacy been understood and followed properly.

5.3 Long-Term Growth: Innovation, Institutions, and Policies

a. *Law and government*

In his Advertisement for the sixth edition of the TMS published in 1790, a few months before his death, Adam Smith, looking in retrospect at his *magnum opus*, the WN, wrote that he had in mind "to give an account of the general principles of law and government, and of the different revolutions which they had undergone in the different ages and periods of society; not only in what concerns justice, but in what concerns police, revenue and arms," and that he had "partly executed this promise."

Previously, in the opening sentence of Book IV of the WN—"*Of Systems of Political Economy*"—Smith gave his definition of the goals and content of political economy as a "science":

> Political economy, considered as a branch of the science of a statesman or legislator, proposes two distinct objects; first, to provide a plentiful revenue or subsistence for the people, or more properly to enable them to provide such a revenue or subsistence for themselves; and secondly, to supply the state or commonwealth with a revenue sufficient for the publick services. It proposes to enrich both the people and the sovereign. (WN, IV.1)

No doubt, Smith was aware of the logical distinction drawn by David Hume between factual, descriptive statements and prescriptions, both normative and ethical,[94] or between "positive science" and "normative art," this latter involving extra-economic elements and value judgments. He conceived political economy as inherently concerning economic policy, "the science of the statesman." He held his normative part separated in Books IV and V of the WN, but the logical link with, and reference to, the preceding principles, and the positive, analytical part was always evident. Like all classical economists, Smith never "really questioned the validity of value judgements that were based on philosophical grounds and took proper account of noneconomic as well as the economic elements" (Schumpeter 1954, p. 451).[95]

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[94] "One cannot deduce ought from is" (Hume 1740), what was later called "Hume's guillotine" (Blaug 1980, p. 130).

[95] "To the end of the (classical) period, economists considered their recommendations concerning policies as scientific results which followed from scientific, though not purely economic, analysis" (Schumpeter 1954, p. 451). In fact, most of Smith's work is of a genuinely analytical nature, a "great analytical achievement" (*ibid.,* p. 38).

In another passage of Book IV, Smith stated his own vision of the general principles of law and government for his times—what we may call his Enlightenment project: "allowing every man to pursue *his own interest his own way*, upon the *liberal plan of equality, liberty and justice*" (WN, IV.ix.3). The former part in added italics refers to the policy style; the latter to the general preconditions for long-term growth that he envisaged in terms of appropriate institutions and common civil ethics.[96]

b. *Long-term growth*

On a purely analytical economic level, did Smith present a theory or a model of economic growth at all? This question was the focus of many studies and debates throughout the twentieth century, a debate that crossed also the problem of his vision on the "gloomy" future of "capitalism" that thrilled the entire classical political economy of the previous century. On carefully re-reading Smith's works while preparing this essay and comparing his words with some of the multiple interpretations that have been given to them over time, I reached the following conclusions.

Smith did not develop a fully dynamic model of the economy in the sense that we attach to the term today, not disposing of the necessary mathematical tools. But he did understand which were the driving forces of progress at large, their complex interactions, and their effects on the (intertemporal) equilibrium conditions of the economy. He consequently elaborated a long-run, historical vision of a developing society moving slowly from a "rude" primitive condition to agriculture, manufacturing, and trade. He did not foresee the industrial revolution, but the entire WN is a wide fresco on socio-economic transformation, moving equilibria, and long-term development. Increasing wealth and not a static condition of equilibrium was his standard object of inquiry and the desirable outcome of economic processes.[97] In his view, the best condition for society is that of progress and growth, not that of riches or opulence: "it is in *the progressive state*, while the society is *advancing* to the further acquisition, rather than when it has acquired its full complement of riches, that the condition of the labouring poor, of the great body of the people, seems to be the happiest and the most comfortable." (WN, I.viii.43).[98]

c. *Division of labor and innovation*

What is the driver of dynamism and change in Adam Smith? As is well known, it is the division of labor, to which, understood in a broad sense, he attached a central and crucial role. "Division of labor" means the break-up of complex production

[96] On Smith's "system of natural liberty," see Hill (2019, Ch. 3).

[97] See Blaug (1996): "his own faith in the benefits of the 'invisible hand' rested very little on static considerations of allocative efficiency in circumstances where competition is perfect. A decentralised price system was held to be desirable because of its dynamic effects in widening the scope of the market and extending the advantages of the division of labour—in short because it was a powerful engine for promoting the accumulation of capital and the growth of income. (…) Economic development is in fact the principal subject of his book" (p. 61).

[98] "The progressive state is, in reality, the cheerful and the hearty state to all the different orders of society; the stationary is dull; the declining melancholy" (WN, I.viii.43).

processes into a series of simple operations, leading to the invention and use of specialized machinery,[99] to automation (in a modern lexicon), and, therefore, to "the greatest improvement of the productive power of labour" (WN, I.i.1). Because all this depends on "the extent of the market," and any increase in the supply of a commodity enlarges, potentially, the market for all other commodities, we are driven—according to Allyn Young's famous article (Young 1928)—to a theorem of *endogenous* technical change and *cumulative* transformation (Kaldor 1972).

Smith describes, in very modern terms, three processes that lead to innovation—not sufficiently credited to him by the subsequent and recent literature:

- improvements in operations and in machines themselves deriving from "the invention of common workmen" and "of those who had occasion to use the machines" (what nowadays is called "learning by doing and by using")
- "improvements … made by the ingenuity of the makers of the machines, when to make them became the business of a peculiar trade" ("process innovation" *stricto* sensu)
- some improvements achieved through the ingenuity "of those who are called philosophers, or men of speculation, whose trade is not to do any thing, but to observe every thing, and who … are often capable of combining together the powers of the most distant and dissimilar objects in the progress of society." These people represent the "particular class" or the "peculiar tribe" of scientists and researchers (engaged in radical inventions/innovations). For these people, "philosophy or speculation becomes … the principal or sole trade and occupation, … subdivided into a great number of different branches". (WN, I.i.9)[100,101]

The unresolved problem remains the capacity of aggregate demand to match the growth of supply (enhanced by all "improvements") and the consequent reduction of prices (determined by competition among producers, leading in turn to an increase in real wages): the old criticism proposed but not solved by Malthus.[102] Many reconstructions of Smith's growth model converge to a steady state of no growth, where the combined effects of falling prices of commodities and falling profit rates under the

[99] All this was very clear to Smith since the times of his 1763 *Lectures*: "The division of labour no doubt first gave occasion to the invention of machines." (Smith 1763a, b, II.ii.4, p. 167). This statement is made again and enlarged in WN, I.i.5–8.

[100] In the *Early Draft* of the WN (Smith 1963/1982), probably speaking about his friend and colleague in Glasgow, James Watt, Smith affirms that "who could invent the fire engine and first form the idea of producing so great an effect by a power in nature which had never before been thought of (…) was a real philosopher," while "to apply in the most advantageous manner those powers which are already known (…) does not exceed the capacity of an ingenious artist" (ED, par. 19, p. 621). The limit is that he never conceived or foresaw something like a "radical innovation".

[101] This last sentence on the division of labor among "philosophers" was much praised by Pavitt (1998) as crucial in innovation organization.

[102] Allyn Young's answer (Young 1928) to this problem, namely the assumption of a demand with price-elasticity higher than one can potentially work for some products but not at the aggregate level. The "Smith-Young doctrine of increasing returns" cannot do without Keynesian active fiscal policies (Kaldor 1972).

average risk level drive a fall of the accumulation of capital.[103] Samuelson (1977), with his mathematical-Smithian growth model, adds some very interesting further conclusions: Smith's final "dull" stationary state is reached only maintaining the typically classical demographic hypothesis that population explodes whenever the real wage is above an unchanged subsistence level and his view about increasing land scarcity and consequent rise in land rents. With more modern demographic assumptions (including the possibility explicitly considered by Smith of a rise of monetary wages beyond subsistence level, much praised by Samuelson) and holding the hypothesis of no land scarcity or of some land-saving inventions, the model provides an endogenous long-term rate of growth, with increasing real wages and population, and a moderate growth rate of profits able to balance savings and capital accumulation.[104]

Other authors, underlining the fact that technological change was overlooked in its effects on productivity *and* profits—by Smith himself—came to partially different conclusions.[105]

Smith authorizes the emergence of a "stationary" state in a distant future. "In a country which had acquired that *full complement of riches* which the nature of its soil and climate, and its situation with respect to other countries allowed it to acquire; *which could, therefore, advance no further*, and which was not going backwards, *both the wages* of labour and the *profits* of stock would probably *be very low*." (WN, I.ix.14).[106] That sentence, though, is rather abstract and, in a sense, tautological (see added italics). Smith's immediate and final judgment is revealingly clear: "But perhaps no country has ever yet arrived at this degree of opulence." (WN, I.ix.15).

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[103] See: Adelman (1961, p. 35); Lowe (1975); Heilbroner (1975), all quoted in Kennedy (2005).

[104] "Had Smith been able to write down the full conditions" of his theoretical model, "he would have anticipated Marx's expanded-reproduction tableau of *Capital Vol. II* and would have provided Harrod and Domar with an endogenous natural rate of growth." (Samuelson 1977, p. 49). Samuelson concludes: "hats off to Adam Smith."

[105] See: Peacock (1997, pp. 48–55). In fact, Smith (and also Ricardo) understated technical change in agriculture, with respect to urban industry and commerce, mainly looking at the indolence of landowners and at the favor accorded to the sector by the English government (WN, III.iv.20). No surprise, therefore, if land scarcity and consequent rise in land rents remain, according to Samuelson, the only possible long-term cause of the fall of profits in Smith's formalized economic model (as it happens in Ricardo). This could be an important message for today, referring rents to the urban case: Important analyses have pointed out the skyrocketing increase in the share of urban ground rents on the price of houses in all advanced countries since the 1980s, a result underlying the renovated role of (large) cities in the present technological paradigm. See: Cannari et al. (2016); Knoll et al. (2018); Camagni (2020).

[106] Smith continues: "In a country fully peopled in proportion to what either its territory could maintain or its stock employ, the competition for employment would necessarily be so great as to reduce the wages of labour to what was barely sufficient to keep up the number of labourers, and, the country being already fully peopled, that number could never be augmented. In a country fully stocked in proportion to all the business it had to transact, as great a quantity of stock would be employed in every particular branch as the nature and extent of the trade would admit. The competition, therefore, would everywhere be as great, and consequently the ordinary profit as low as possible." (WN, I.ix.14).

Moreover, Smith indicates all sorts of *structural* and *institutional changes* that could push that final steady state further away: new geographical areas in which to develop foreign commerce; the conquest of new colonies; improvements in a list of "laws and institutions," ranging from those regulating monopolies, internal trade, and foreign commerce to those concerning security and justice. In the latter case, he is referring to the crucial supporting institutions and preconditions for an efficient market to exist: peace, protection of freedom in personal life and industry or commerce, protection of property rights ("natural liberty"), and enforcement of the performance of contracts (WN, I.ix.15–16).[107] In short, among classical economists, Smith was probably the one least sympathetic with a steady state forecast.[108]

In analytical terms, any dynamic model based on the pure expansion of production factors is bound to encounter some limiting elements that turn cumulative growth into decline or at least to steady state. What is needed are the incentive effects of appropriate institutions and favorable context conditions: "industrious nations and individuals" and "*thriving towns*," hosting innovations that shift labor and factor productivity upward for any given level of the K/L ratio.[109]

Up to a certain level, the fall in profit rates may not be worrying, because large capitals may aim at profits width rather than at profit rate. This is what happened in large cities with respect to smaller ones, with the advantage of consequent lower interest rates on bank loans.[110] Moreover, the lower profit rates accepted by business in advanced countries and cities as a consequence of high competition among producers can make it possible to maintain a sufficient price competitiveness: "In countries that are fast advancing in riches, the low rate of profit may, in the price of many commodities, compensate the high wages of labour, and enable those countries to sell as cheap as their less thriving neighbours, among whom the wages of labour may be lower" (WN, I.ix.23). For sure, this is an interesting, and not at all pessimistic thought on innovation (division of labor) in global competition.

In short, it is my opinion that Smith believed in the long-term possibility of social progress, taking place through a virtuous co-evolution of the economic and

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[107] Also, endogenous reactions to a potential crisis are considered by Smith: In the case that "the ordinary rate of clear profit … (and) the usual market rate of interest … would be so low as to render it impossible for any but the very wealthiest people to live upon the interest of their money, … all people of small or middling fortunes would be obliged to superintend themselves the employment of their own stocks. It would be necessary that almost every man should be a man of business, or engage in some sort of trade." (WN, I.ix.20).

[108] If read carefully, Smith's sentences concerning the final possible steady state point out, as its final cause, not really the fall of profit rates—in dealing with which the undertakers, and the legislators, have multiple options—but the lack of untapped potential business (assumed by definition).

[109] "The acquisition of new territory, or of new branches of trade, may sometimes raise the profits of stock, and with them the interest of money, even in a country which is fast advancing in the acquisition of riches," like the new American colonies (WN, I.ix.12).

[110] "Private bankers in London give no interest for the money which is deposited with them" (WN, I.ix.8).

the institutional spheres, supported by appropriate policies in both fields. The deepest meaning of the epics of mankind that he traced through "the different revolutions (which human institutions) had undergone in the different ages and periods of society" is that of a slow, difficult, but continuous "progress of human mind, unfolded over many centuries" (Rothschild and Sen 2006, p. 361).

d. *The invisible hand, policies, and institutions*

The tasks that Smith assigns to the government in the economic sphere, *stricto* sensu, are limited—and this has been widely emphasized by free marketers of all times, in spite of the fact that he *never* used the term *laissez-faire*.[111] The general political goal itself of assuring personal liberty refers also strictly to individual choices in the economic field. "The sovereign is completely discharged from a duty, in the attempting to perform which he must always be exposed to innumerable delusions …; the duty of superintending the industry of private people, and of directing it towards the employments most suitable to the interest of the society" (WN, IV.ix.51).

Smith believes in the action of the market, operating as an *"invisible hand"* in the promotion of the interest of society[112]—a market, of course, framed and supported by appropriate institutional rules, as it will be shown hereafter. I do not agree with those contemporary progressive scholars who try to undermine the metaphor of the *invisible hand*:[113] It is a flashing and brilliant interpretation of the role and logics of the market understood as an economic institution, a system of signals and incentives for the allocation of resources in a dynamic context.[114] Perhaps, when citing the

[111] See Kennedy (2005, Ch. 32). Viner (1927), though, claimed that Smith used an English equivalent for *laissez-faire*, namely "to *let (nature) alone* … in the course of her operations in human affairs … and give her fair play in the pursuit of her ends" (p. 200). But in my opinion, this phrase is more general and refers to the entire "system of natural liberty." Viner himself, positively speaking about government's direct involvement in business, when economically effective, affirms: "The modern advocate of laissez faire who objects to government participation in business on the ground that it is an encroachment upon a field reserved by nature for private enterprise cannot find support for this argument in the Wealth of Nations" (p. 227).

[112] "Every individual" employing his capital in economic activities "intends only his own security … and …. only his own gain," but, "he is in this, as in many other cases, led by an invisible hand to promote an end which was no part of his intention." (…) "By pursuing his own interest he frequently promotes that of the society more effectually than when he really intends to promote it" (WN, V.ii.9). The indication "as in many other cases" is highly relevant, in my opinion, as it widens the scope of the metaphor beyond the specific case in which it is used—the choice between investing onshore or abroad.

[113] See: Rothschild (1994), Fleischaker (2004, p. 139), Kennedy (2009), and Boucoyannis (2013), the most knowledgeable and learned in my opinion.

[114] This statement should always be accompanied with important qualifications, in particular when optimization meanings are assigned to the working of the market as resource allocator: in particular, the qualification that the market considers only effective demand, determined by the *actual* income distribution, implicitly accepted (a "strong" hypothesis, indeed). Not all neoclassical economists forget this crucial condition for speaking of an "optimal" allocation: Paul Samuelson (1977), in his formalization of Smith's static competitive equilibrium, whose outcome is interpretable in terms of "the planner's optimality," adds the condition for this optimality judgment: "there need be nothing ethically optimal about the specifications (of the different consumptions) and their allocations among the rich and poor, the healthy and the halt!" (p. 47).

invisible hand, Smith rhetorically emphasizes the paradoxical positive social outcome of private egoism (or self-love), but this irony does not limit the importance of the metaphor as explicitly argued by Emma Rothschild (1994). Nor the fact that he uses this metaphor in just three occasions in his works[115] indicates a minor interest of his on the concept, as confirmed by multiple out-of-metaphor passages of the WN.[116]

On the other hand, the relevant point concerning the role of government is that the first two main duties assigned to it—"duties of great importance, indeed"—represent to Smith's mind the crucial preconditions for any market to work properly and even to exist: defense, external and internal safety (arms and police), on the one side, and justice, respect of property rights, and enforcement of contracts on the other.[117] Considering also the other two direct duties assigned to government—public works and education[118] (respectively relevant in income production and income distribution) it is legitimate to state that in the economic sphere *lato* sensu, the duties assigned to government are relevant and strong.

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[115] Smith speaks about an invisible hand in a similar sense—promotion of unintended outcomes—in the TMS, with reference to the medieval landlord, "proud and unfeeling," "distributing" food produced in "his extensive fields" going beyond the "capacity of his stomach," to all people working for him, in nearly similar portions. "In spite of their selfishness and rapacity," landlords "are led by an invisible hand to make nearly the same distribution of the necessaries of life, which would have been made, had the earth been divided into equal portions among all its inhabitants" (TMS, IV.i.1.10). In this case, the role of the invisible hand is different from the one in the WN: not a (microeconomic) allocative role but a (macroeconomic) distributive role, leading to a kind of peculiar equilibrium of aggregate supply and demand of food (the rent of landlords—"paid in (perishable) kinds"—exchanged for the services of "an army of retainers and servants"). In the TMS case, Rothschild (1994) is right when speaking of a "sardonic" intent by Smith: The economic reasoning of the invisible hand passage seemingly anticipates Malthus's favor towards conspicuous consumption of landed orders, but taking it seriously would mean to contradict the entire message of the WN on this issue. Moreover, Smith seems to attach more sense to underlining ironically the paradox than to subscribing to a formal condition of equity and welfare determined only by the approximately similar size of human stomachs. The third time Smith speaks of an invisible hand—in his *History of Astronomy*—does not refer to economic issues but to the credulity of ancient people and to the mighty hand of Jupiter.

[116] Just as an example: "Without any intervention of law, therefore, the private interests and passions of men naturally lead them to divide and distribute the stock of every society, among all the different employments carried on in it, as nearly as possible in the proportion which is most agreeable to the interest of the whole society." (WN, IV.vii.3.88). This passage complements the one previously quoted on the duties of the sovereign (WN, IV.ix.51).

[117] "According to the system of natural liberty, the sovereign has only three duties to attend to; *three duties of great importance*, indeed, but plain and intelligible to common understandings: first, the duty of protecting the society from the violence and invasion of other independent societies; secondly, the duty of protecting, as far as possible, every member of the society from the injustice or oppression of every other member of it, or the duty of establishing an exact administration of justice; and, thirdly, the duty of erecting and maintaining certain publick works and certain publick institutions" (WN, IV.ix.51).

[118] In both cases, the private market can hardly guarantee production, operation, and maintenance of the implied assets and services, as "the profit could never repay the expence to any individual or small number of individuals, though it may frequently do much more than repay it to a great society." (WN, IV.ix.51).

Justice, the most important pillar of human society and precondition for the progress of opulence, is a virtue that has been embedded differently and imperfectly in the legal institutions throughout history (TMS, II.ii.2; WN, V.iii.7).[119] Very crudely, Smith admits that "civil government, so far as it is instituted for the security of property, is in reality instituted for the *defence of the rich against the poor*, or of those who have some property against those who have none at all" (WN, V.i.b.12),[120] and is ready to accept it for the sake of maintaining order, together with the necessary "*authority and subordination* among men." (WN, V.i.b.11). But in his view, the development of an "impartial justice" and an impartial administration of it is the difficult but possible route—whose signs were already visible in the English example—toward a "civil society" where property is protected for all, including the poor.[121,122]

As the most important institution, the market needs a precise legal framework and appropriate rules for its proper use, in the same way as other institutions of democracy like the Parliament need similar attention. Smith refers particularly to the possibility that the legislative power itself might be "captured" by the vested interests that it should regulate and control. In sharp and even violent terms—not at all usual for him—he denounces the practices of private economic interests in the legislation process (capture of the regulator).[123] An often-justified blame is extended to the entire order of merchants and master manufacturers:

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[119] "Commerce and manufactures can seldom flourish long in any state which does not enjoy a regular administration of justice, in which the people do not feel themselves secure in the possession of their property, in which the faith of contracts is not supported by law, and in which the authority of the state is not supposed to be regularly employed in enforcing the payment of debts from all those who are able to pay." (WN, V.iii.7).

[120] This sentence echoes the thought of J.-J. Rousseau, and in particular his *Discours sur l'origine et fondements de l'inégalité entre les hommes* (1754), that Smith knew, and he partly translated into English and presented in his "Letter to the Authors of the Edinburgh Review" in 1756 suggesting its circulation (Smith 1795a, p. 201). In his letter and in other letters, he shows a high appreciation of Rousseau, even if he did not follow him, as Hume and most French Enlightenment philosophers, in his late extreme political positions, exposed in *The Social Contract* and *Emile*.

[121] See Rothschild and Sen (2006, p. 350).

[122] An impartial administration of justice was giving the UK a clear advantage in trade and manufacturing over other nations: "that equal and impartial administration of justice which renders the rights of the meanest British subject respectable to the greatest, and which, by securing to every man the fruits of his own industry, gives the greatest and most effectual encouragement to every sort of industry" (WN, IV.vii.c.54).

[123] Smith does not believe "that the freedom of trade should ever be entirely restored in Great Britain": a hopeless and even "absurd" expectation as "not only the prejudices of the publick, but what is much more unconquerable, the private interests of many individuals, irresistibly oppose it. (…) The member of parliament who … opposes (these interests), …, and still more if he has authority enough to be able to thwart them, neither the most acknowledged probity, nor the highest rank, nor the greatest publick services can protect him from the most infamous abuse and detraction, from personal insults, nor sometimes from real danger, arising from the insolent outrage of furious and disappointed monopolists." (WN, IV.ii.43). This passage was added in the 1784 edition of the WN, after Smith had served for five years as Commissioner of Customs in Scotland, witnessing directly lobbying practices in commerce regulations and behavior.

> The interest of the dealers, …, in any particular branch of trade or manufactures, is always in some respects different from, and even opposite to, that of the publick." Therefore, "the proposal of any new law or regulation of commerce which comes from this order, ought always to be listened to with great *precaution*, and ought never to be adopted till after having been long and carefully examined, not only with the most scrupulous, but with the most *suspicious attention.* It comes from an order of men, whose interest is never exactly the same with that of the publick, who have generally an interest to deceive and even to oppress the publick, and who accordingly have, upon many occasions, both deceived and oppressed it. (WN, I.xi.p).[124]

5.4 Social Inequalities and Income Distribution

Adam Smith, like almost all classical economists, was deeply concerned with the issue of social inequalities and income distribution, a sphere of the social realm that was mostly abandoned with the advent of the neoclassical "revolution."

His interest was different, though, from the traditional interest of regional scientists in spatial inequalities, which he never mentioned in terms of unbalanced endogenous growth capabilities.[125] Nor was he ever attracted by the issue of whether the "invisible hand" of the market was necessarily generating spatial disparities. As said above, he was aware that the invisible hand was an abstract metaphor, and that the market which we see in practice is a complex mechanism closely interwoven with a host of political and social institutions obeying deep, space-time–specific historical evolutions.[126]

His interest was to shed light on income distribution, both personal and among social classes, as a specific economic issue and, in this regard, he indicated many conceptual pathways that prove relevant to today's scholars.

At least since the times of his *Lectures on Justice, Police, Revenue and Arms* at the University of Glasgow (LJ 1763), he was struck by the asymmetry between growing opulence and unequal distribution:

> It is the division of labour which increases the opulence of a country. In a civilized society, though there is a division of labour, there is no equal division, for there are a good many who

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[124] The consequent political conclusion, generated by the analysis of some specific cases but then generalized, follows naturally: "The government of an exclusive company of merchants is, perhaps, the worst of all governments for any country whatever" (IV.vii.11).

[125] It is a pity that Smith refused to confront himself explicitly with the Principles of Political Oeconomy by Sir James Steuart (1767). In fact, if "from the analytical point of view Smith had little to fear from the Principles, from the standpoint of policy" he would have found important material for coping with the problems of poverty, employment disparities within countries, and consequent possible "regional policies" (Skinner 1993, p. 37–38).

[126] Deborah Boucoyannis, in her article "The equalizing hand" (2013), seems to believe—more in the title than in its argument—that Smith's market is progressive and equalizing. I do not agree that this was a concern of his nor his opinion. In fact, almost all the justifications that Boucoyannis provides for her thesis refer to normative elements that Smith suggests in order to correct distortions of a political (asymmetries in power and information, exploitation of colonies), institutional (inheritance laws, anti-trade unions legislations), or economic nature (imperfect markets, monopoly practices, and privileges): distortions that a left-alone market can easily live with.

> work none at all. *The division of opulence is not according to the work*. The opulence of the merchant is greater than that of all his clerks, though he works less; and they again have six times more than an equal number of artisans, who are more employed", who work harder. "The artisan …. has far more than the poor labourer … Thus, he who as it were bears the burden of society, has the fewest advantage. (Smith 1763a, II.ii.3, pp. 162–163)[127]

This interest on income distribution stems for sure from Smith's moral egalitarianism (Fleischacker 2004, Ch. 4) or his analytical egalitarianism (Schliesser 2017, Ch. 7):

> Servants, labourers and workmen of different kinds make up the far greater part of every great political society. But what improves the circumstances of the greater part, can never be regarded as any inconveniency to the whole. No society can surely be flourishing and happy, of which the far greater part of the members are poor and miserable. It is but equity… (WN, I.viii.36).

But more than this, the philosophical source of his engagement against any social discrimination resides in what can be called his cognitive egalitarianism:

> The difference of natural talents in different men is, in reality, much less than we are aware of (…). The difference between the most dissimilar characters, between a philosopher and a common street porter, for example, seems to arise not so much from nature, as from habit, custom, and education. (WN, I.ii.4).

This explains the total absence of any racist attitude in all his works (while it can be found in Hume), his refusal of slavery, his blame on widespread exploitation of colonies in his age and by his own country,[128] his fight against rents and monopoly practices. As "a (philosophical) consequentialist in his evaluation of institutions, (the) role of reason inclines him towards accepting equal consideration of everyone as a non-negotiable rational constraint" (Schliesser 2017, p. 71).

The logical consequence of his philosophical scheme, closely linked to his long-term vision of a growing economy, is the issue of what Smith calls the "liberal reward of labour."[129] Within the dynamic pathway of the economy, "the liberal reward of

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[127] In his more mature work, the WN, Smith introduced solid justifications for "inequalities arising from the nature of the employments," determined by "five … principal circumstances. First, the agreeableness or disagreeableness of the employments themselves; secondly, the easiness and cheapness, or the difficulty and expense of learning them; thirdly, the constancy or inconstancy of the employment in them; fourthly, the small or great trust which must be reposed in those who exercise them; and fifthly, the probability or improbability of success of them" (WN, I.x.b.1). And he did not forget the "exorbitant rewards of players, opera singers, opera dancers, etc. (…. depending on) the rarity and the beauty of the talents, and the discredit of employing them in this way … considered as a sort of prostitution" (WN, I.x.b.25). He supplies similar justifications for the rewards of "different employments of stock," where "the ordinary rate of profit varies more or less with the certainty or uncertainty of the returns" (WN, I.x.b.33). Pure rents, on the other hand, do not imply any of these circumstances.

[128] Commercial policies with colonies, including American ones, and "the regulations by which each nation endeavours to secure to itself the exclusive trade of its own colonies, are frequently more hurtful to the countries in favour of which they are established than to those against which they are established" (WN, IV.vii.c.83).

[129] According to Rothschild and Sen (2006), the term "liberal" is to be understood here as "generous" or "ample." Recalling Smith's *liberal plan of equality, liberty, and justice*, I suspect he attached also a wider, moral or civic meaning to the term.

labour … is the effect of increasing wealth," its "symptom," and also "the cause of increasing population" (WN, I.viii.42). This process is continuously self-regulated ("demand of men … necessarily regulate the production of men": WN, I.viii.40) and prevents the market from being either under-stocked or over-stocked with labor. Smith explicitly wonders: "Is this improvement in the circumstances of the lower ranks of people to be regarded as an advantage, or as an inconvenience, to the society? The answer seems at first abundantly plain." (WN, I.viii.36).

Smith's opinion on this issue is, beyond any doubt, dictated by moral reasons ("it is but equity") but more importantly by economic reasons. In fact, Smith justifies the liberal reward on various grounds. Firstly, because in single cases, a liberal reward is already practiced, as shown by the fact that at the same time different levels of wages are present for the same occupations.[130] Secondly, because it "increases the industry of the common people. (…) Where wages are high, accordingly, we shall always find the workmen more active, diligent and expeditious" (WN, I.viii.44). Furthermore, contrary to the complaints of "merchants and master manufacturers (about) the bad effects of high wages," Smith recalls that "in reality high profits tend much more to raise the price of (commodities[131]) than high wages" (WN, I.ix.24).[132]

Smith would not have wanted to be seen as suggesting the need for *directly* redistributive policies by governments, that could hit particular "orders" (e.g., landlords or merchants) and benefit others (laborers)—something that he clearly condemned.[133] Nevertheless, he was in favor of *indirectly* redistributive policies, as in the case of a progressive taxation of revenues, or of specific taxations on "luxuries and vanities of life," favoring the poorer, for moral reasons.[134] And he was equally in favor of a "peculiar" taxation justified by what classical economists called an "unearned revenue": it is the case of urban ground-rent, as shown in Sect. 4.3, "a species of revenue which the owner, in many cases, enjoys without any care or attention of his own" and

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[130] "The price of labour, it must be observed, cannot be ascertained very accurately anywhere, different prices being often paid at the same place and for the same sort of labour, not only according to the different abilities of the workman, but according to the easiness or the hardness of the master." (WN, I.viii.34).

[131] In the text is written "wages," but from the context, it is clear that it is a mistake by some copier, not detected by the editors.

[132] "In raising the price of commodities, the rise of wages operates in the same manner as simple interest does in the accumulation of debt. The rise of profits operates like compound interest" (WN, I.ix.24).

[133] "To hurt in any degree the interest of any one order of citizens, *for no other purpose* but to promote that of some other, is evidently contrary to that justice and equality of treatment which the sovereign owes to all the different orders of his subjects." (WN, IV.viii.30). Boucoyannis (2013) rightly emphasizes that many purposes for redistributive public actions were otherwise accepted by Smith (p. 1057), in "an extensive view of the general good" (WN, IV.ii.44).

[134] "The necessaries of life occasion the great expence of the poor. (…) The luxuries and vanities of life occasion the principal expence of the rich; and a magnificent house" too. "A tax upon house–rents, therefore, would in general fall heaviest upon the rich; and in this sort of inequality there would not, perhaps, be any thing very unreasonable. It is not very unreasonable that the rich should contribute to the publick expence, not only in proportion to their revenue, but something more than in that proportion." (WN, V.ii.e.6).

"which owes its existence to the *good government* of the state" (WN, V.ii.e.10–11: see Sect. 4.3 before).

Smith believed, in my opinion, that a virtuous, "progressive" path toward increasing welfare for the entire society—and in particular for its poorest but largest part—was possible through the implementation of some equitable and rational policies and of the most appropriate institutional improvements; an achievement that, looking at the long-term growth of "real recompense of labour" well beyond the subsistence level, was in fact evidently taking place in the recent history of his country.[135]

In considering the social and political structure, Smith applied the same dynamic logic used in the economic analysis, implying a continuous (but not too rapid or revolutionary!) transformation in the direction of assuring less unbalanced initial conditions for everybody in terms of capabilities and opportunities. Many other passages confirm this general view of his:

- the emphasis on economic and context conditions being more important than "nature," as already shown, in determining personal status and economic success: "the very different genius which appears to distinguish men of different professions, when grown up to maturity, is not upon many occasions *so much the cause, as the effect of the division of labour.*" It "arise(s) … from *habit, custom, and education.*" (WN, I.ii.4), namely from spatial "circumstances"
- his awareness of the negative feedback effects of even his most praised driver of economic development, i.e., the division of labor, on the development of mind and personality of the workers, something that he expresses in impassioned and even violent terms (workers becoming "as stupid and ignorant as it is possible for a human creature to become"),[136] anticipating Marx's theory of workers alienation
- his consequent insistence on the role of education, a crucial task assigned to the government. He is strongly in favor of a universal schooling system, whereby the "public can facilitate, can encourage, and can even impose upon almost the whole body of the people … the essential parts of education," reading, writing, counting, and even some principles of philosophy and science (WN, V.i.f.50, 54–55; V.i.d.6). All this is crucial in order to improve the general condition of the "great body of the people" and to counter the perverse effects of the division of labor[137]

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[135] "The real recompense of labour, the real quantity of the necessaries and conveniences of life which it can procure to the labourer, has, during the course of the present century, increased perhaps in a still greater proportion than its money price" (WN, I.viii.35).

[136] "In the progress of the division of labour, (…) the man whose whole life is spent in performing a few simple operations, of which the effect too are, perhaps, always nearly the same, has no occasion to exert his understanding, or to exercise his invention in finding out expedients for removing difficulties which never occur. He naturally loses, therefore, the habit of such exertion, and generally becomes as stupid and ignorant as it is possible for a human creature to become. The torpor of his mind renders him incapable … of conceiving any *generous, noble, or tender sentiment,* and consequently of forming any *just judgment*" (WN, V.i.d.50).

[137] Rothschild and Sen (2006) rightly underline that Smith's justification for this extensive educational system has nothing to do with a goal of improving skills or diligence. Rather, its purpose is

- his concern about social inequalities, not necessarily generated by the market mechanism but by an abuse of political power[138] or of economic power,[139] by insufficient or accommodating regulations on labor market negotiations[140] or by presence of evident asymmetries in incentives and information among social "orders"[141]
- his strenuous opposition to all privileges assigned to monopolist companies in foreign and internal trade, justified on economic grounds (see his criticism of the entire mercantilist ideology on which these privileges were built, in Book IV of WN) but also on political grounds, in terms of excessive power in society.

When discussing wages, kept at the subsistence level by the higher bargaining power of masters and land tenants, and consequently defining "necessaries" (and deprivation of necessaries, as a condition of poverty), Smith gives a last sign of his sophisticated analytical capacity. "By necessaries I understand, not only the commodities which are indispensably necessary for the support of life, but whatever the custom of the country renders it indecent for creditable people, even of the lowest order, to be without." And linking his fine socio-psychological analysis to political economy reasoning, he continues with a famous passage: "a creditable day-labourer would be ashamed to appear in publick without a linen shirt" or "leather shoes" (WN, V.ii.k.3).

Necessaries, poverty, and economic deprivation are not defined in absolute terms but in relative ones with respect to the minimum standards of consumption in society. This intuition, according to Amartya Sen, has proved to be "extremely rewarding" in its implications for present socio-economic analyses and crucial for his own concept of capabilities.[142] Furthermore, it bridges the gap between a concept of (absolute)

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to increase dispositions to "make disinterested and reflective judgements about the government's own conduct" (p. 352), that is, in order for people to become better citizens. This interpretation is corroborated by the following passage of Smith's at the end of Book I: The "condition (of the labourer) leaves him no time to receive the necessary information, and his education and habits are commonly such as to render him *unfit to judge*, even though he was fully informed. In the public deliberations therefore his voice is little heard" (WN, I.xi.9).

[138] "All for ourselves and nothing to other people, seems, in every age of the world, to have been the vile maxim of the masters of mankind" (WN, III.iv.10).

[139] "In every different branch, the oppression of the poor must establish the monopoly of the rich, who, by engrossing the whole trade to themselves, will be able to make very large profits" (WN, I.ix.15). "In all other countries (different from the new American colonies), rent and profit eat up wages, and the two superior orders of people oppress the inferior one" (WN, IV.vii.b.3).

[140] "The masters, being fewer in number, can combine much more easily; and the law, besides, authorises, or at least does not prohibit their combinations, while it prohibits those of the workmen" (WN, I.viii.12).

[141] See Boucoyannis (2013), a paper particularly effective on the subject of asymmetries. Smith concludes: "When the regulation (…) is in favour of the workmen, it is always *just and equitable*; but it is sometimes otherwise when in favour of the masters." (I.x.c.61). Any asymmetry generates a rent and consequently rent-seeking behavior; Paganelli (2011, Sect. 3.1) reminds us that "Smith spends most of Book IV (of the WN) explaining the damages of rent-seeking."

[142] See: Rothschild and Sen (2006, p. 359).

poverty and of (relative) inequality, dear to regional scientists. The current debate on the disease of the middle class in Europe owes a great deal to this approach.

At this stage, given all this evidence of the complexity but also the transparency of Adam Smith's political vision, the question naturally arises about how that vision could have been interpreted in such a misleading way for so long, and not just in the common view but also in knowledgeable circles. Emma Rothschild (1992) provided an interesting historical reconstruction on how Smith's complex vision could have been condensed into a simple lesson—"all trade should be free"—and his portrait become that of a "hero of commerce" and capitalism. His ideas on the *"liberal plan of equality, liberty and justice"* were well known in his country and were associated with those of the *French Enlightenment.* He died when the French Revolution had just started, but when it entered its more sanguinary phase, a strong reaction against progressive ideas spread through Great Britain. In fact, his biographer, Dugald Stewart (1793), in his writings and presentations of Smith's legacy, blurred his more radical views and delivered a truncated message on economic freedom that could be acceptable by authorities and the general public. This treatment opened the way to a "right" and a "left" Smithian perspective. Most classical economists mainly followed the latter one, but everything changed with the advent of a new approach to economic theory in the late nineteenth century.

6 Conclusions

My direct encounter with the work of Smith happened while I was looking for possible theoretical intuitions on spatial matters in classical political economy during the drafting of the introduction to my textbook on urban economics (Camagni 1992). In that case, I discovered how important, to Smith's mind, was the relationship between the urban and the rural realms, or between the "town" and the "country," in the interpretation of crucial economic structures and historical transitions: the economic conditions for the birth of the city (when an agricultural surplus emerged due to "the improvements of the productive power of labour") and the advantages that the country received from the city in terms not only of technologies but also of "order and good government" and "liberty and security."

I was particularly struck by Smith's analytical intuition that this relationship between town and country does not only concern a *functional* dimension, deriving from a natural complementarity in the respective specializations; it also involves a *hierarchical* and *distributive* dimension, firstly because of the greater capacity to "combine together" typical of urban lobbies of master manufacturers and tradesmen, resolving in a monopoly pricing in the exchanges between the town and the country; and secondly because of the brilliant perception of the spatial monopoly of the city in those high-level "trades" for which the "intelligence requisite can be had … only in places of the most extensive commerce and correspondence," namely, in today's lexicon, in the presence of communication networks and relational capital.

"These trades can be carried nowhere but in great towns": This was probably the first reference to the cognitive role of large cities in the history of spatial thought.

My second discovery at that time concerned Smith's perfect awareness and theorization of a "situation rent" linked to distance from markets, besides the traditional "fertility rent." What I could not realize then—and what I have discovered during my current further, deeper, and more complete reading of all Smith's works—was his analytical and even modeling capacity. *Inter alia,* he demonstrated this in dictating the formula of locational bid rent *à la* Von Thünen, and in his analysis of urban building and ground rents (for the first time in history, to my knowledge), detached from any reference to agricultural production. Ground rent derives from a demand for "some real or supposed advantage of the situation (…) whatever the reason for that demand, whether for trade and business, for pleasure and society, or for mere vanity and fashion."

In regard to the first theme, the town-country relationship, I have realized how crucial this relationship was for Smith's interpretation of the structure and, most of all, of the evolution of human society, to the point of making it the evolving spatial archetype of the sequence of economic and institutional "revolutions" which took place in the different ages and periods of society after the fall of the Roman Empire. The evolution of material conditions (like the transition from rents-paid-in-kind to rents accumulated in gold and jewels) merges with the evolution of production systems, of governance institutions, and also of power relationships among social classes ("orders") in a masterly picture of historical transformations, highly praised by today's political scientists.

Besides the possible discovery of analytical anticipations by Smith, an expectation that I had when engaged in this work concerned the superior complexity and consistency of the approach and the vision of a classical political economist with respect to that of a modern neoclassical economist. This expectation was widely confirmed, in many cases, and particularly in the treatment of land rent. The presence of some interpretive principles on the sources of rent, such as the exploitation of "the powers of nature" or, in the case of urban rent, the exploitation of locational advantages generated by the "good government of the sovereign"; the importance of the institution of private ownership of land; the analysis of the interest conflict between landlords and the rest of society; the consequent normative indications—taken separately from the analytical part, but totally consistent with it—such as that land rent is naturally liable to a "peculiar taxation": all this converged in a consistent vision in which value judgments based on philosophical grounds were never questioned. The general normative conclusions of Smith were followed by classical economists for more than a century, particularly by J.S. Mill, and later until Alfred Marshall, Arthur Pigou, and some highly respected economists of the present times like Paul Samuelson.

For a widely normative discipline like regional economics (and regional science) deeply involved in the themes of spatial inequalities in development potential and consequent policies, the greatest appreciation of the grandeur of Smith's vision should be given to his interpretation of the respective roles of the state and the market. Far from relying on the virtues of the "invisible hand" of the market—his own

perceptive but abstract metaphor of the "invisible hand" which drives the decisions of the individual pursuing his own interest toward that of the society, "an end which was no part of his intention" (WN, IV.ii.9)—Smith's main concern was with real and factual "market imperfections" and with the institutional and political conditions by which the market could properly function. Fulfillment of these conditions, assigned as duties to the state (limited but "very important duties, indeed") consists in individual and social security and liberty; in the impartiality of justice, and, in particular, the autonomy of judges; in impartial competition, freed from the presence of institutional monopolies and from the overwhelming power of vested interests, naturally able to force the hand of the political and legislative *milieu*; in public education in order to guarantee not just a relative equality in abilities and an appropriate and efficient human capital, but also a civic capacity to judge the actions of "the sovereign" and the public administration; in the supply by the state of appropriate public works and services due to an evident market failure but also avoiding likely government failures through the partial financing by users.[143]

The richness and depth of Smith's thought, arising from a political economy approach, strongly contrasts with the "reductionist" character of much of the modern analytical work in economics and space economy, developed amid the host of limiting conditions for its validity—made explicit but often only implicit. Moreover, it seems less ideological than the truncated analytical and stylized synthesis of the invisible hand in Walras's general equilibrium model.

As regards long-term perspectives, Smith identifies the main driver of the production system in the enlargement of markets which allows the widening of the division of labor and the consequent increase of productivity. The sources of these increases consist of both microeconomic and macro-territorial processes: on the one hand, of new operational and technical arrangements through "the invention of common workers", improvements introduced by "the ingenuity of the makers of the machines", and inventions of "philosophers or men of speculation …. combining together the powers of the most distant and dissimilar objects"; on the other hand, of such favorable context conditions as "industrious nations and individuals" and "thriving towns" (once again!). The modernity of this vision is clear and so, too, is the role of education and good institutions. The only missing element was consciousness of the potential of new "technological paradigms", like the one which at the turn of the century was about to generate the industrial revolution that Smith, and also the early classical economists in general, were unable to anticipate.

The beneficial effects of technical innovations, together with the potential innovations in socio-economic institutions, were so clear to Smith that they induced him—this is my firm opinion—to adopt an optimistic view of future prospects. In fact, despite a well-known phrase on a possible future dismal or "dull" steady state of low wages and profits once "the full complement of riches" has been acquired by

[143] In modern "governance" terms: "(t)he hallmark of an 'advanced' developed society is a government that exhibits the attributes of good governance: transparency, effectiveness, rule of law, lack of corruption, voice and participation. From Adam Smith on down, economists have recognized the importance of these attributes." (Rodrik 2008, p. 17).

countries "which could therefore advance no further"—an evident tautology, which Smith himself immediately discarded—his enlightenment spirit suggested to him the possibility of society evolving, albeit slowly and with difficulty, upon what he calls "the liberal plan of equality, liberty and justice."

Returning to Smith's analytical and modeling capacity—a talent much praised by modern scientific style and taste—I wish here to underline again the clarity and precision of his masterly reflection on the complex interaction among economic, socio-psychological, and institutional variables in a long-term perspective, and how it was able, once expressed in modern mathematical terms by a master of today's economic theory, Paul Samuelson, to generate a consistent system of dynamic equilibrium conditions, anticipating "Marx's expanded-reproduction model and (providing) Harrod and Domar with an endogenous natural rate of growth." Interestingly, the results show that the only potential threat to growth could come from a rise of rents, i.e., from an income-distribution dimension, a theme rather neglected by today's economic literature in spite of its manifest factual significance.

Equity was the principle that prompted him to approve a trend of—carefully—increasing real wages (a "*liberal reward of labour*"), a trigger to push manufacturers toward increasing productivity; to underline some significant negative effects of (his beloved) division of labor, namely a crystallization of the unequal distribution of abilities among classes and the risk of workers' alienation due to the repetitiveness of operations, anticipating Marx; and to strongly oppose any sort of privilege. Interestingly, in regard to poverty and deprivation, Smith introduced a definition in relative terms, with respect to the standards of society, and not in absolute ones, an intuition "extremely rewarding" in scientific analysis according to Amartya Sen.

Finally, let me recall the theory about human nature and social relationships that Smith developed in his first (and also last) opus, the *Theory of Moral Sentiments*, which warranted a better reading and a better understanding during the following two centuries, particularly by economists. Far from being totally separate from, and even antithetical to, the WN, it furnishes an empiricist psychological analysis of the natural sentiment of "sympathy" and "fellow-feeling" of men with any passion of others, both happiness and sorrow, generating, when reciprocated, social cohesion and happiness. "It is thus that man, who can subsist only in society, was fitted by nature to that situation for which he was made. All the members of human society stand in need of each other's *assistance*, and are likewise exposed to mutual injuries. Where the necessary assistance is *reciprocally* afforded from love, from gratitude, from friendship, and esteem, the *society flourishes and is happy*." (TMS, III.ii.3.1).

By saying this, I do not wish to imply that Smith anticipated modern theories on inter-personal trust, cooperation, public happiness, or on collective action in the maintenance of *commons*. I only suggest that his personal interpretation of *homo socialis* could have been inspirational for an earlier development of these theories, in the same way as Smith's entire work could have been for the recent developments of the new institutional economics.

Regional science, too, due to its interdisciplinarity in the sphere of society and territory and its attention to institutions, would draw important suggestions and deep inspiration from a more profound understanding of Smith's work, which could prove crucial for its further development and renewal.

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Johann Heinrich Von Thünen (1783–1850): A Systemic View of Human Interaction Within Space

Tomás Ponce Dentinho

Johann Heinrich Von Thünen. *Photo source* Alchetron.com

We must always have the strength to forget what we know, in order to better understand and assimilate a truth contrary to our personal prejudices (Von Thünen 1826)

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1 Introduction

Johann Heinrich Von Thünen is a Great Mind of regional science for three main reasons. First, because he was one of the pioneers who explicitly considered space in the study of human interaction, secondly because the Von Thünen general equilibrium model of urban rings is still used and useful to understand how land use depends on land suitability, technology, land property rights, and the size and distance to the market, and finally, because his book, *The Isolated State*, has still many ideas to explore, such as the fair rent complementing the fair wage; the productive space, beyond space as distance; and the income multiplier effects of the value of natural resources expressed on land rents.

2 A Consistent Thinker in a Changing Germany

Johann Heinrich Von Thünen was born in 1783 in Kanarienhaussen, in the parish of Waddewarden, in the Jeverland district close to the German North Sea, eighty kilometers from The Netherlands and eighty kilometers from Bremen Haven (Hall 1966). He began an apprenticeship in agriculture in Gerrietshausen, Jeverland, in 1799, where he observed the agricultural conditions of the time. In 1802, he went to an agriculture school near Hamburg, where he came under the influence of the Baron Von Voght on social issues and, in a Summer Course in Celle, he was introduced to the thinking of Albrecht Von Thaer (1752–1828) on agriculture systems. The seminal ideas of his future research were already vivid by then when he wrote:

> When one assumes a land of 40 miles diameter with a large city in the center; and assumes that this land could sell its products only to this central city; and that the agriculture of the area had the highest development. Then one could expect that the economic system around this city would divide itself into different agricultural systems. (as quoted in Schumacher-Zarchlin 1868; Schneider 1934; and Peterson 1944)

This perspective was contrary to Albrecht Von Thaer's thesis that the condition of each soil determined the respective suitability. Baumont and Huriot (1996) noted that Von Thünen demonstrates a real scientific spirit: intuitive, abstract, and deductive.

In 1803, he registered at the University of Gottingen for a year's study that allowed him to reinforce his liberal and social ideas without losing his roots in agricultural science. In a study visit to Mecklenburg, he got to know one of the sisters of a colleague and married two years later. In 1810, he bought an estate in Tellow, in Mecklenburg-Schwerin, forty kilometers from Rostock and two hundred from Berlin, where he devoted most of his time to developing his farm and his research (see Fig. 1).

Von Thünen did not have a university career. Instead, his preference was to manage a farm that also served his innovative applied research. Nevertheless, due to the success of the first version of *The Isolated State* (Von Thünen 1826), the philosophical faculty of the University of Rostock conferred on him an honorary doctorate in 1830, and the city of Teterow, near his farm in Tellow, declared him a freeman of the city.

Fig. 1 Places where Von Thünen lived during his life *Photo source* Google Maps

During the period of the unification process of Germany, in 1848, he declined a seat in the National Assembly of Frankfurt am Main due to health problems. He died in 1850 (Frambach 2012).

The various versions of *The Isolated State* include most of his scientific work. The first edition (Von Thünen 1826) contains Part I: "*Derisolierte Statt in Belziehung auf Landwirtschaft und National ökonomie*" (The isolated place in dependence on agriculture and national economy). The second partial and revised edition appeared in 1842 (Von Thünen 1842). The last edition still supervised by the author was published in 1850, and included Sect. 1 of Part II, titled "*Der naturgemäbe Arbeitslohn und dessen Verhältnis zum Zinsfubund zur Landrente*" (The natural wage and its relation to the interest base to the land rent) (Von Thünen 1850a). Section 2 of Part II and Part III were published after his death, with Part III bearing the title, "*Grundsätze zur Bestimmung der Bodenrente, der vorteilhaftesten Umtriebszeit und des Wertes de Holzbestände von verschiedenem Alter für kieferwaldungen*" (Principles for determining the land rent, the most advantageous rotation time and the value of wood stocks of different ages for pine groves) (Von Thünen 1863).

2.1 Major Contributions

Johann Heinrich Von Thünen created a formidable knowledge of agronomy reinforced by rigorous farm accounts, and, synthesized in the three parts of his formulation of the "Isolated State," he built up a critical scientific approach to economics, creating a systemic perspective of human interaction within space, that is akin to what we now refer to as regional science (Kourtit et al. 2016). The French edition of his book (Von Thünen 1850b) extends to more than 100,000 words, organized into

38 topics and 3 sections. The first section, with 26 topics, develops the creation of the "Isolated State" with a description and explanation of six circles of land use that surround the state's main city. In the second section, with seven topics, the author confronts the conceptual framework with reality. The third section of the book focuses on the impact of taxes on agriculture.

Beyond the modeling of land use and land value, the final edition of *The Isolated State* (Von Thünen 1863) also includes an analysis of the natural wage. And, as reported by Fujita (2000), Von Thünen sets out the fundamental principles of spatial agglomeration. Von Thünen's ideas were a precursor to marginal analysis, providing a scientific background to the principles of *kameralism* (Justi 1764), a mercantilist doctrine focused on the efficiency of public expenditures that argued that the expected tax revenue should finance the expenditure generating it. Furthermore, the framework of the "Isolated State" highlights the constraints of space and time on land use, wages, and property values, which were very much disturbed by the process of economic development in the nineteenth century in Germany, where traditional self-sufficient farms and market-oriented farms nearby major towns were becoming in conflict (Ponsard 1983; Albergaria 2009).

2.2 Land Use

2.2.1 The Isolated State—Hypothesis and Research Problem

Regarding land use, the research question put forward by Von Thünen (1826) is the following:

> Imagine a very large city in the middle of a plain susceptible to cultivation, which is not crossed by any navigable channel or river. Let this plain be formed by an identical terrain everywhere in nature. That this plain is finally, at a great distance from the city, limited by an arid desert that separates it entirely from the rest of the living world. There is no other city beyond this one. With these conditions in place, we can infer that the central city must supply the countryside with all the manufactured products it needs, whereas, on the other hand, it is obliged to obtain from these same fields all its food products and all essential materials. Suppose, furthermore, that the mines and salt plants responsible for delivering the necessary metals and salt to the city center are in its vicinity. This city, being the one and only in the middle of the supposed plain, will be called simply: The City of the Isolated State. What has just been said naturally leads to the following question: How will agriculture behave in these circumstances? In what and how this agriculture, rationally realized, will change with the greater or lesser distance from the City?

To analyze this question in Sect. 1 of his book, Von Thünen selects two farms—one in Tellow five miles from the market and the other close to the market—both selling rye to the city. The cost of producing rye is the same on both farms; land costs are proportional to the extent of the land; and capital costs are in relation to the amount of production. Thus, the only factor that differentiates the production conditions of the two farms and affects the cost proportional to land is the cost of transporting rye to the city, which is higher the greater the distance to the market.

Therefore, the farm near the city has a higher rent per area than the farm located farther away. Based on those two observation points, Von Thünen derives the value of land rent for any distance from the city center until land rent becomes zero and there is no agricultural land use 50 miles from the city center.

Von Thünen demonstrates that land use results from the confrontation between the proprietor, who supplies land to whomever offers the highest value, and the farmer, who demands the land and has the possibility to choose the land use that maximizes land rent. Then, the farmer that offers the higher rent uses the proprietor's land and gets a good income for his labor and capital. In farms close to the market, the option of intensifying the crop is advantageous even with decreasing marginal productivity of labor because the production costs of these farms, added to the transport costs to the market, will, up to a certain limit of production, be lower than the product's selling price in the city. Farms far away from the city adopt extensive farming systems because the advantage of intensification is very small.

According to Von Thünen, and in line with Ricardo (1817), land rent is not what is left after the costs of capital and labor, as assumed by Adam Smith (1776) and Say (1803), nor is it the only source of value, as assumed by Quesnay (1766). Land rent is the income from the natural resource of land and its respective location, separable from labor and capital income, and very much influenced by distance to the market. Also, contrary to what his contemporary agronomists thought (Von Thaer 1809–1812), Von Thünen demonstrates that rotation of land uses, linked to labor and capital intensity, is not defined for each type of soil but depends strongly on the distance to the market.

2.2.2 The Model

Based on the model of the "Isolated State" and on agronomic knowledge that assumes complementary connections—learned from agricultural statistics—within each agricultural system, including soil depreciation, fertilization, climate, and livestock, Von Thünen derives the influence of exogenous variables on a set of endogenous variables. Exogenous are: the price of grains, associated with the price of livestock and influenced by the size of the market; soil fertility; the transport cost to the market, influenced by the type of transportation; taxes; and distance to the farmhouse, dependent on the form of the farm and on the initial location of the farmhouse close to water and to roads. Endogenous are: labor distribution, land use, land rent, and land value. In other words, grain prices, defined by demand and supply in the market; transport costs of products and factors; environmental conditions; and technological complementarities of agricultural systems among crops, livestock, and soil features together define land use, land rent, land value, and the spatial distribution labor (Fig. 2).

Land rent per unit of land (Rdi) of land use (i), located at a distance (d) from the city center, depends on the weighted price of the products of each land use (i) converted into the price of grain in the city center (U_i*) that changes with the market

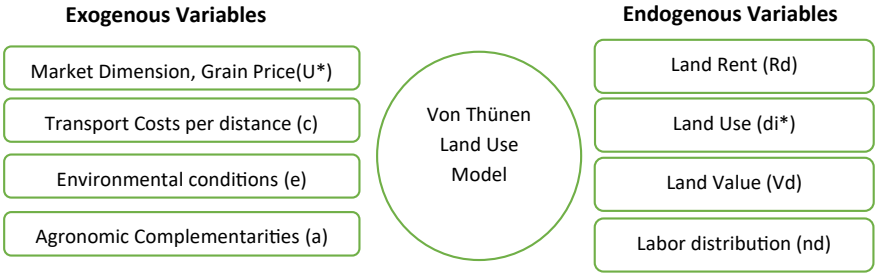

Fig. 2 Von Thünen's land use model

dimension. Land rent per unit of land (Rd*i*) of land use (*i*) depends also on the cost of production (C_i), the productivity per unit of land per environmental conditions (Qei), and the cost of transportation per unit of distance to the city center (t_i):

$$\text{Rdi} = [U_i^* - C_i - t_i(d)]\ \text{Qei}$$

Each land use (*i*) involves all of the complementary products associated with it (including firewood, hunting, fruits, and mushrooms from the forest; beef from pasture and forages) and with all its crop rotations (identified in Holstein: fallow, barley, oat, pasture, pasture, pasture; in Mecklenburg: fallow, rye, barley, oat, pasture, pasture, pasture; and in Marche: potatoes, rye, oat, pasture, pasture, pasture, fallow). All these complementary products are technologically and economically linked to the rye and its price in the city center. Land use (*i*) at distance (*d*), (*id*), is selected to maximize the land rent (Rdi) {di^* = Max [Rdi] for all possible land uses (*i*) at distance *d*}.

Finally, linked to the theory of natural wage explained below, land value equals the maximum land rent (Rd) divided by the interest rate (*z*), and labor distribution at distance *d* (nd) depends on the number of workers (*n*) per land use (*i*).

2.2.3 The Six Land Use Circles

The maximization of land rent associated with the distance to the main city defines six land use rings of agricultural systems.

The first ring is for labor-intensive crops, without fallow: crops that do not support long-distance transportation, such as fresh vegetables based on fertilizers bought in the city center or produced within the farm, and fresh milk coming from cows fed by forages brought from far away. It extends 4 miles from the city center, where land rent is high. The same applies to land value, but it is potentially capable of expanding with economic development.

Forestry for energy occupies the second ring, providing wood for combustion, construction, and coal production. According to Von Thünen, this ring extends out to 8 miles from the city center because, beyond there, the cost of transportation

of wood does not compensate the price paid in the city center. Forestry competes with potatoes that are viable up to 9.3 miles from the city center, according to the estimates and evidence revealed by Von Thünen. Interestingly, his idea that a forest, very much along the lines explained two centuries later in forest economics (Pearse 1990), is like a long-term bank deposit, the management costs of which involve not only the plantation, maintenance, and recollection cost, but also the opportunity cost of capital.

Along the third, fourth, and fifth rings, from 9.3 to 31.5 miles from the city center, the choice is between two alternative rotation systems. On the one hand, there is pastoral rotation with oats, fallow, barley, cereals, and five years of pasture. On the other hand, there is a three-year rotation system with rye, barley, and fallow combined with manure. The choice between one and the other depends only on the price of grain, with high grain prices inducing pastoral rotation and low grain prices stimulating the adoption of a three-year rotation. In the third ring, the choice is between rotations; in the fourth ring, pastoral rotation is predominant; and in the fifth ring, the three-year rotation becomes the main agricultural system. Changes in rotational agricultural systems not only occur in space, but also take place in time, with the appearance of more intensive systems in more developed regions.

Livestock production is very sparse on the outskirts of the city but increases in direct proportion to distance, reaching its maximum at 31.5 miles. From that point on, the land rent falls, but by so little that it still remains high at 50 miles. Since livestock has so many advantages 50 miles from the city, it is not at that distance that it will reach its limits; in fact, it can expand even more into nomadic land uses.[1]

The presentation made by Von Thünen follows the framework of an integer linear programming model[2] with n (land uses) $\times$ m (rings) variables, with an objective function equal to the sum of the gross margins per land use/ring that decrease with the transport costs from the city center for each specific land use/ring. It is an integer model, because each variable takes only the value of 1, if the surface unit in that ring (j from m) is occupied by land use (i from n) or 0 otherwise. There is a deterministic process for rings 1, 2, 6, and beyond, but it is foreseeably a stochastic process in rings 3, 4, and 5 where different types of rotations can occur. Von Thünen does not describe all the integer linear programming model, but highlights its implicit structure in the choices of land uses between consecutive rings with a careful estimation of the gross margins associated to the complementary products linked to each land use.

[1] Huriot (1989) argues that none of Von Thünen's rent functions are linear, and, therefore, the original model is unable to assure that rents are decreasing with distance to the center. Nevertheless, Von Thünen focuses on the changes between rings and assumes the freedom of places through farmers to maximize the rent of the place even if the profile of the rent is not linear in all the rent functions and only along the border of the various rings.

[2] As detailed in, e.g., Hillier and Lieberman (2014).

2.2.4 Confronting Reality and the Impact of Taxes on Land Use

Von Thünen also explains how prices in small cities relate to prices in the main central city, and he shows how different agro-industrial products like cognac, wool, rapeseed; tobacco chicory; clover for seeds; and linen also fit into the Isolated State. Finally, he demonstrates that all taxes reflect on land rents that generate inefficiencies. It is difficult to estimate because small price changes in the city center can have major impacts on land use, land rents, and land values.

2.3 Natural Wage

2.3.1 Income Distribution between Labor and Capital and Migration

Classical economists regarded labor as a commodity—with wages necessary to enable workers to subsist and perpetuate—and not dependent on productivity (Ricardo 1817). Von Thünen assumed that workers have freedom to establish themselves as producers; that all laborers are of the same class and equal in strength, skills, and intelligence; and that wages depend on productivity, divided into means of subsistence (a) and surplus above the means of subsistence (y) (Von Thünen 1863).

According to Moore (1895), the Von Thünen Natural Wage Theory explains the interest rate (z), the surplus above the means of subsistence (y), and the optimal natural wage [$(a + y) = \sqrt{}$ap] as a function of the product of labor (p), the units of capital per labor (q), and the subsistence income of labor (a) (Fig. 3).

The land use model (Fig. 2) fixes land rent, but the connection with the wage model occurs in the periphery of the Isolated State where the rent is zero. In the periphery, wages cannot grow because land rent would be negative, production would be abandoned, and workers would migrate to the center, thereby lowering the wages there. Therefore, in the periphery, wages ($a + y$) can grow only if the interest on capital decreases.

The amount of capital, Q, divided by the year's wage, $a + y$, leads to the number of units of capital, nq, where n is the number of workers and q the unit of capital per worker. On the other hand, n laborers that generate np product receive $n(a + y)$ in

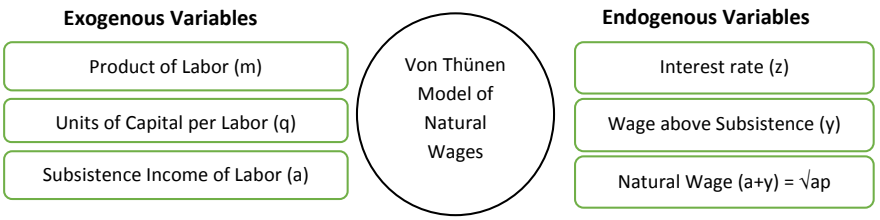

Fig. 3 Von Thünen model of natural wages

wages and generate a margin for the capitalist of $p - (a + y)$. This margin divided by the capital employed, $Q = np(a + y)]$, results in the rate of interest of capital, z, that is a function of the product of labor, m, the units of capital per labor, q, and the subsistence income of labor, a, as shown in Eq. 1[3]:

$$z = [p - (a + y)]/[q(a + y)] \tag{1}$$

2.3.2 Marginal Freedom and Optimal Income Distribution

Equation 1 has three exogenous variables (a, p, and q) and two endogenous variables (y and z). To solve the problem, Von Thünen had to assume that producers in the periphery choose between being autonomous farmers receiving their margin or workers receiving the interest of the wage surplus. Therefore, the income generated by an autonomous entrepreneur in relation to the capital employed, $[p - (a + y)]/[q(a + y)]y$, has to be equal to the interest received from the surplus income, $T = yz$. So long as there is freedom to invest and to move, "the wage of farmers at each distance from the Town is to be endogenously determined such that the utility of farmers, who consume crops grown in the field, as well as goods manufactured at the Town, is the same everywhere" (Fujita 2000).

The maximization of this interest of the surplus income, $T = [p - (a + y)]/[q(a + y)]y$, on the total wage, $a + y$, leads to the formula that Von Thünen asked to put in his graveyard, $a + y = \sqrt{ap}$, which is equivalent to:

$$y = \sqrt{ap} - a$$

This also allows estimation not only of the outcome of increased productivity on the wage surplus but also the rise in profits linked to a productivity increase:

$$r = p - (y + a)$$

Figure 4 shows that if labor productivity is lower than the wage subsistence level, both the wage surplus and profit are negative, and there is no activity. On the other hand, there is a productivity premium for both the worker and the investor.

[3] This is only possible if labor, n, does not depend on the interest, z, on capital, q, and the only adjustment is for capital, q, which can be secured with a Cobb–Douglas Production Function with constant increases on scale, fixed subsistence wage, a, fixed labor, $n = 1$, and an adjustable interest rate, z, per unit of capital, q.

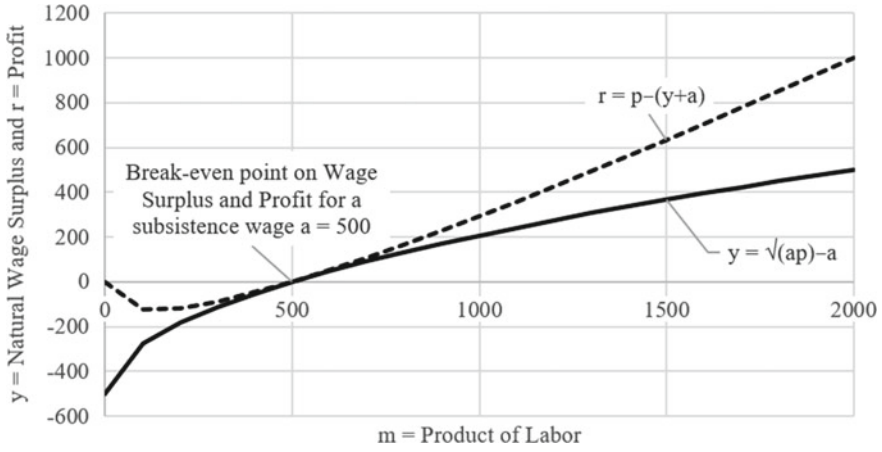

Fig. 4 Von Thünen's natural wage surplus, $y = \sqrt{(ap)} - a$, and profit, $r = P - (y + a)$, as a function of labor productivity for any location and land rent within the Isolated State

3 Quesnaysian Multipliers in Von Thünen's Model: The Path to a General Theory of Location

Assume that the entire agriculture production concentrates on grain, as used by Von Thünen to establish the technological and economic connections with all the land uses. The rent profile, *Rd,* maximizes all possible land uses for each distance from the center, *d,* according to the transport costs, *t*, the productivity of land, *Q,* and the price of territorial products, *U,* net of production costs, *C*: Rd $= [U - C - t(d)]Q$. $Rd = 0$, when $(U - C)/t = dl$, where *dl* is the radius of the isolated city area, and the total rent, *TR*, comes to $TR = (1/3)[\pi(U - C)^3]/t^2$.

If territorial owners are located in the city center, the amount of production and consumption from the territory would be given by $Dl = \pi\,[(U - C)/t)^2 Q]$. On the other hand, through a Quesnaysian multiplier effect, *m*, of the land rent, *TR*, it is possible to generate the total product of the isolated city, *Y*. Using a base-model framework, the multiplier effect, *m,* varies with the inverse of the activity rate, Ω, the proportion, ρ, of territorial production, *Dl*, in the total product, *Y*, a constant, *k*, of other services related to product and $m = \Omega/[1 - \Omega(\rho + k)]$, the multiplier effect of the land rent, TR. Therefore, product, *Y*, comes to:

$$Y = \Omega/[1 - \Omega(\rho + k)][(1/3)\pi(U - C)^3/t^2]$$

The territorial production, D*l*, will be:

$$\begin{aligned} \mathrm{D}l &= \rho Y = \pi[(U - C)/t]^2 Q \\ &= \rho\Omega/[1 - \Omega(\rho + k)][(1/3)\pi(U - C)^3/t^2] \end{aligned}$$

The margin, U–C, will increase with production per unit of land, Q:

$$U - C = 3Q/\{\rho\Omega/[1 - \Omega(\rho + k)]\}$$

The same happens with the dimension of the city, dl, that increases with the production per unit of land but restrained by the transport costs, t:

$$\mathrm{d}l = 3Q/\{\rho[\Omega/[1 - \Omega(\rho + k)]\}t$$

The way to safeguard and reward land is through the payment of land rents to owners. Yet, the spatial distribution of those rents influences the spatial profile of economic performance influenced by land productivity, Q, the multiplier effect, m, with all its components—Ω, the inverse of the activity rate; ρ, demand for land products; and k, demand for non-land goods—and the restraining cost of distance, t.

This is the link to Quesnay, avoided by Von Thünen, but implicit in his Isolated State, where land rents that capture the value of land, sun, and rain in the production process should go somewhere. From this perspective and following François Quesnay's thoughts, land rents go to the city center, generating demand for land and non-land products through multiplier effects, and increased land productivity leads to the expansion of the city.

The relevance of this relates to the missing links of Von Thünen's thinking, the ones that could explain the initial location of the city center. It is clear that the places surrounded by more productive areas and lower transport costs would be larger, with higher centripetal forces and lower centrifugal forces.

4 Scientific Recognition in the Literature

Among the personages included in Fig. 5, François Quesnay (1694–1774) was a medical doctor able to understand the working of the human body and capable of devising a revealing analogy with the functioning of the economy. Von Thünen was eventually the first and the last territorial 'doctor,' capable of understanding human interaction within space and with sufficient proximity not only to comprehend land use but also to promote land use management. There is no great use of the work of François Quesnay in the works of Von Thünen. Nevertheless, the idea of an isolated city, where the proprietor receives and spends the rent of the farm with implicit multiplier effects that, in their turn, feed the demand for agricultural, commercial, and industrial goods and services, accords very well with the reasoning of François Quesnay's (1766) Economic Table.

Another author who influenced Von Thünen is Johann Justi (1717–1771) and the *kameralist* accounting system (Justi 1764; Backhaus 2009) taught at the University of Gottingen, the marginal principle of which is that "those who receive the benefit

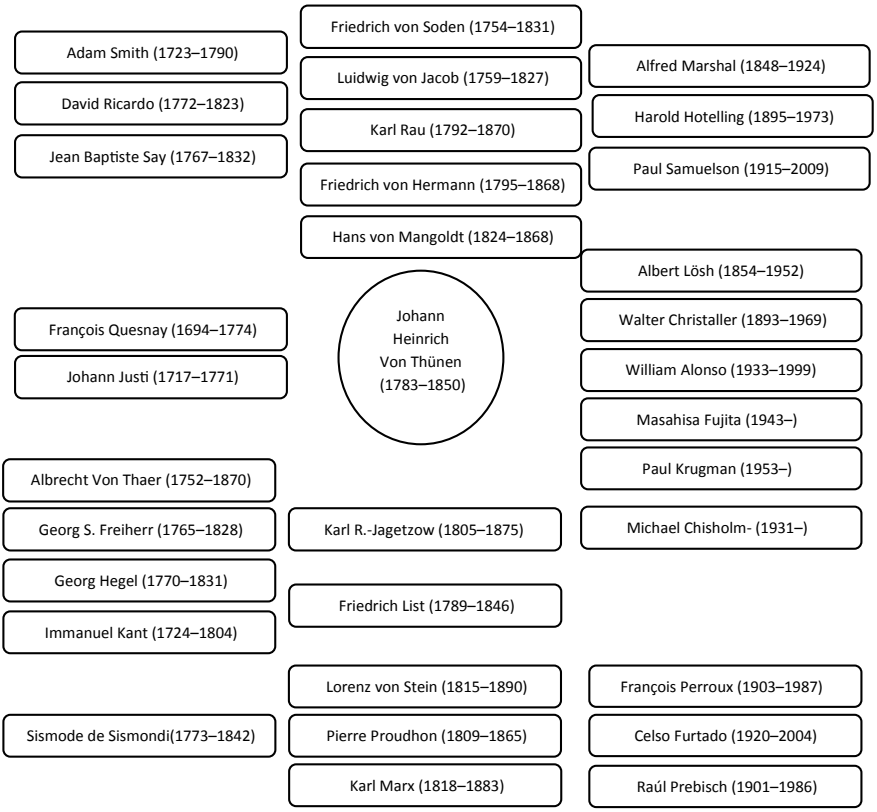

Fig. 5 Von Thünen in the literature of philosophers, sociologists, economists, agronomists, and regional scientists

from each extra public infrastructure must pay its costs." This fits quite well with the marginal concepts of economics and the decaying profile of land rents.

Related to agriculture or land use, the influence of Professor Albrecht Von Thaer (1752–1870) was relevant to the understanding and critical analysis of agricultural systems and land use (see Von Thaer 1809–1812). We might even think that it was Von Thaer's aim to educate capable directors for large estates who could enhance the value of the land entrusted to them according to the circumstances. It was thus that Von Thünen justified his main activity throughout his life as a farm manager.

Georg Sartorious Freiherr (1765–1828),[4] professor at the University of Gottingen, introduced Von Thünen to the works of the classics. The works of Adam Smith (1723–1790), David Ricardo (1772–1823), and Jean Baptist Say (1767–1832) all contributed

[4] Georg Freiherr was a translator and popularizer of Adam Smith's *Wealth of Nations*; his major work is *Geschichte des Hanseatischen Bundes*. (*History of the Hanseatic League*) published in three volumes 1802–1808.

importantly to Von Thünen's theoretical framing of the Isolated State, where, respectively, the role of the market, the understanding of rents, and the importance of production margin in the generation of demand play a crucial role.

The work of Johann Heinrich Von Thünen compiled by Schumacher-Zarchlin in his (1875) bibliography represents a systemic view on human interaction within space involving not only an environmental perspective represented by land use and an economic view shown in the rents, but also a social consideration in the analysis of the natural wage. This social perspective is rooted in the works of romantic thinkers represented by Immanuel Kant (1724–1804) who, beyond his moral and epistemologist thoughts, also wrote textbook notes on geography, highlighting the role of the discipline in the understanding of phenomena, and Georg Hegel (1770–1831), with his mature statements of legal, moral, social, and political philosophy. Unavoidably, some socialist writers also had a strong influence on Von Thünen, such as Simonde de Sismondi (1773–1842), who, similarly to the natural wages of Von Thünen, presents the seminal idea that all value comes from labor because it adds value to a product.

Nevertheless, neither was Von Thünen a rationalist in the tradition of Smith, Ricardo, and Say, and as followed by such contemporary classic German thinkers as Friedrich Von Soden (1754–1831), Luidwig Von Jacob (1759–1827), Karl Rau (1792–1870),[5] and Friedrich von Hermann (1795–1868), nor was he a romantic protectionist like Friedrich List (1789–1846), or the social-anarchist represented by Pierre Proudhon (1809–1865). His stated positioning is "the interest of the individual associated with the welfare of the whole" (Von Thünen 1966): owing much to the precepts of Kant to "behave in a way, which will be of benefit for you if all the others that were to behave in exactly the same way, and be willing to sacrifice the performance of this principle when others disobey."

Von Thünen's rediscovery is mainly due to Lösch (1954), and after him to Alonso (1964), even if other authors, including Paul Samuelson (1983), went some way toward recognizing his seminal works on marginalism and general equilibrium, the twin bedrocks of neoclassical economics, or Masahisa Fujita (2000), who gives credit to Von Thünen for the concepts of comparative advantage and the Leontief input–output model. According to Robert Walker (2022), Von Thünen's ideas also serve historians like William Cronon (2009) to help explain the centrality of Chicago in US westward expansion.

Masahisa Fujita (2000) analyzes Von Thünen's thinking on urban networks and agglomeration economies. His argument is that the work of Von Thünen already took into consideration the existence of various urban locations in space, anticipating the model of Walter Christaller (1933). The central city produces backwash net effects in the peripheral ones due to centripetal and centrifugal forces, and the development of transport networks, such as railways, reinforce that process, in line with the New Economic Geography (Krugman 1991; Parr et al. 2002).

The Von Thünen centrifugal forces are the high prices of agricultural products and land rents in more central places. Centripetal forces involve: (1) the costs of

[5] See Rau (1823).

machinery and the minimal number of costumers to allow the dimension break-even; (2) people skills, which require a minimum market dimension to promote specialization according to their skills; (3) the better adjustment between demand and supply, with the reduction of transaction costs in cities; (4) the technological links between sectors; and (5) technical innovation. Fujita remarks that Von Thünen makes no reference to knowledge spillovers associated with agglomeration economies, as referred to in the concept of industrial districts of Alfred Marshall (1892), but they are not explicit in the work of Paul Krugman.

Beyond the great initial disagreement with Von Thünen's theory of natural wage, Komorzynski (1894), quoted by Moore (1895), acknowledges Von Thünen's thoughts on 'Dependency Theory.' The works from François Perroux (1950), on underdevelopment by Furtado (1962), and unequal trade by Raúl Prebisch (1949) are interesting cases of Von Thünen's impact on the dependency school.

There are many works that cite the Isolated State of Von Thünen, but there are many more citations of the books of Adam Smith, David Ricardo, or even Jean Baptiste Say. What is comparable is the rate of change (see Fig. 6). Regarding this indicator, the recent growth of citations of Von Thünen's thoughts is interesting. Examining articles published in 2020 and 2021 that cite the work of Von Thünen, more than 27% are in German, 60% are on agro-environmental issues, and very few are concerned with urban and regional economic issues. Interestingly, there is one that refers to urban sustainability, raising questions about urban scaling and the benefits of living in cities (Sugara and Kennedy 2021).

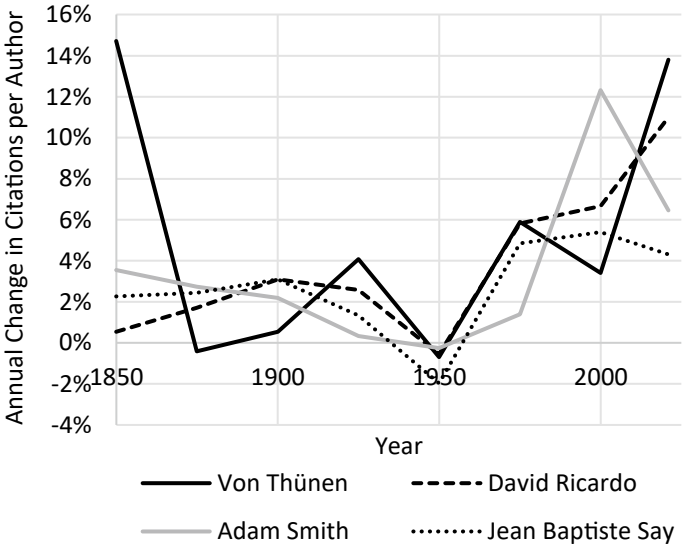

Fig. 6 Change in Google Scholar citations per year

5 Policy and Societal Impact of Von Thünen's Studies

Economists, geographers, agronomists, and regional scientists mainly recall Von Thünen from a historical perspective, with much of that body of literature consisting of academic explanation of the Von Thünen rings, as presented in the first part of his book. Nevertheless, there are not many works that treat space neither as a continuum nor as a productive space as Von Thünen did.

On the other hand, the operational treatment of complementarities within the rotation system analysis emerged a long time before the work on input–output tables proposed by Wassily Leontief (1986) and his followers, including Walter Isard and Thomas Langford (1971).

Regarding agglomeration economies, it is clear that the ideas of Von Thünen clarified how cities grow, but there was no development of the question of where cities grow, why some cities grow more than others, and why diversity is more absent in peripheral areas than in central ones, this last, a matter confirmed by Paul Krugman (1991) and others, although using a discrete space of two cities.

Even in the field of spatial justice, the arguments of Von Thünen were mainly used to associate spatial justice with social justice (Harvey 1992), rather than to explore the seminal separation of spatial justice (not analyzed by Von Thünen) from matters of social justice carefully analyzed in his works on the natural wage.

Summing up, Von Thünen was ignored by many and simplistically destroyed by others; he seemed to have unfinished work, and the formula of the natural wage in his tomb may be an indication of that. Most probably, the assumption that land rent will not affect the trade-off between wages and profits could be relaxed to open the analysis of the optimal distribution of land rent, taking into account its multiplier effects in the central city or in the peripheral cities. One may only agree with Masahisa Fujita (2000) that there is much still to explore in Von Thünen's thoughts.

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Alfred Weber (1868–1958): The Father of Industrial Location Theory and Supply-Chain Design

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Alfred Weber. *Photo source* Heidelberg University

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1 Introduction

In 1909, Weber published his classic book, *Über den standort der Industrien*, a book that describes many first principles of economic production and location (Weber 1909). This book is his only major work in the field of economic geography. Most textbooks in location science, economic geography, and regional science describe his theory as a simple triangular construct of three points in geographical space, two that represent needed localized raw materials and one that represents a market. The central problem is that of locating the most efficient point of production of a good, using the raw materials that are transported to the factory, and shipping the product to the market. Weber suggests that all else held constant, the optimal location of the factory would be the location at which the sum of the three transport costs is a minimum.

This problem representation was also described in earlier work by Launhardt (1872). A geometrically derived solution to this problem is often attributed to Georg Pick, which is given in an appendix of Weber's book, even though Launhardt and others (e.g., Simpson 1750) had developed methods for determining the optimal solution many years and even centuries before Weber. Because of more recent recognition of Launhardt and, perhaps, a more appropriate attribution to some of these earlier developments, the importance of Weber's construct seems to have diminished, and many have stated that Weber has been given undue prominence for his classic work.

The goal of this chapter is to set the record straight. Simply put, Weber was, and should be considered, henceforth, an early giant in the field of regional science, primarily due to the more nuanced constructs that are described in his seminal book, but which have, for the most part, been overlooked. It will be shown that his location theory was extensive, reaching far beyond a simple "triangular figure," and relevant to many of the problems faced by industries today, including the design of supply chains.

This chapter is organized as follows. Section 2 provides a short biography of Alfred Weber. Section 3 presents the emerging consensus of Weber's contributions with respect to location theory. Section 4 discusses, in detail, the locational triangle with its relationship to the emerging location literature. Section 5 returns the focus to specific elements of Weber's paradigm that have been overlooked and are even more relevant today to regional scientists, industrial engineers, and economic geographers. Section 6 presents a final appraisal, along with a summary of some of the impacts of Weber's work.

2 Short Biography

Alfred Weber was born in 1868 in Prussia. His father, Max Weber, Sr., was quite educated and held a doctorate of law. Max, Sr., served in a number of positions that included governmental posts and leadership in political groups. Among these was a

stint as a city magistrate in Berlin. He also served as a leader in the National Liberal Party. During much of Alfred's formative years, his father served in the Prussian House of Representatives and was a member of the German Empire Reichstag. Many notable scholars and politicians were regular visitors at Alfred's family home due to the prominence of his father. This certainly was a fertile environment for a young budding scholar in the late 1800s. Alfred was one of eight children, although two died at an early age. His older brother, Maximillian (Max), also became a notable scholar.

To understand Alfred fully, one also has to understand Max. Max started his studies at the University of Heidelberg and eventually moved to the University of Berlin. He worked as a junior lawyer, passed an examination to practice law, and, as well, earned a doctorate of laws. This was followed by the completion of a *habilitationsschrift* on Roman agrarian history and its significance to the law. Shortly after, Max joined the faculty of the University of Berlin. Max is considered to be one of the founders of modern sociology. His early writings had a profound effect on this field, and they no doubt had a significant influence on Alfred. Alfred followed Max into an academic career as well. He started his university studies at the University of Berlin, where Max had finished his studies, completed a doctorate in 1895, and, in 1899, started teaching there, just as his brother Max had. Alfred left Berlin in 1904 for a short stint at the University of Prague. In 1907, he joined the faculty at the University of Heidelberg, just as Max had done in 1896. Alfred remained at Heidelberg for the rest of his academic career. Two years after he joined the University of Heidelberg, he published his classic book on the *Theory of the Location of Industries.* Although he retired in 1933, he remained active in his writings until he died, at the age of 90, in 1958.

Alfred Weber is known both as an economist and a sociologist. His main contribution to economics is *Theory of the Location of Industries*, which was published in German in 1909. Carl Friedrich translated Weber's book into English in 1929, which was published by the University of Chicago. It is this English version of Weber's work that brought his work to prominence. But Alfred was highly influenced by his brother's work in sociology, as well as by his father's political perspective. Alfred is best known in the field of sociology for his work *Kulturgeschichte als Kultursoziologie*, published in 1935, which explores the relationship between knowledge and culture. From the 1920s on, Weber was so enmeshed in the studies of history, philosophy, and culture that his early work in economics appears to be but a footnote in his academic career. However, his book on the theory of industrial location was an early view on industrial development and clearly influenced regional scientists and economists, including Palander (1935), Hoover (1937), Isard (1949), and Moses (1958). It is interesting to note that scholars either know about Alfred Weber for his location book or for his works on culture and history, but not for both. From what I know from discussions I had with Walter Isard, I suspect he was quite aware of Alfred's accomplishments in cultural sociology. But Isard was definitely influenced by Weber's industrial location book and covered elements of this work in his book, *Location and Space-Economy,* as well as in many papers.

3 An Emerging Perspective on Weber's Work on Industrial Location

It seems that every regional scientist knows something about Alfred Weber and his industrial location model that involves the optimal location of a factory that produces a product, requires two localized raw materials, and serves one market center, where the objective is to minimize the costs of transportation of the raw materials and the finished product. If you hold demand, prices, and labor costs to be constants, then it is an easy task to design a production plant to efficiently produce enough product to meet demand. Weber divides raw materials into two classes: ubiquitous and localized. If all materials are ubiquitous, then it would make sense to locate the factory at the place of consumption or market. But, if some of the raw materials are localized, then they must be transported to the place of production. What is left is to locate the facility in such a manner that the sum of all transportation costs is minimized.

The problem is typically depicted as a location triangle, as given in Fig. 1a. All diagrams in this chapter that represent some form of a Weber problem involve triangles to represent localized raw material sources, circles to represent demand/markets, and squares to represent the factory location. The fact that this locational triangle is

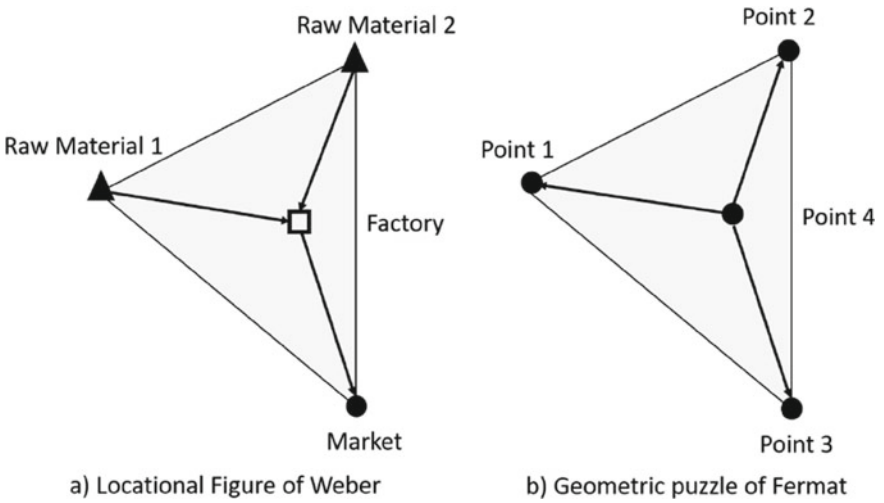

Fig. 1 Depiction of the classical locational figure of Weber showing its similarity to the triangular problem of Fermat to find the interior point minimizing the sum of the distance to the vertices. Weber's figure is usually called the "locational triangle," but Weber viewed this as a simple form of a more complex diagram, simple enough to convey that the industrial activity will be placed somewhere within the region of points defining the geography of the problem. Here, in Weber's figure and in subsequent diagrams, circles represent points of demand, triangles represent raw material locations, and squares represent factory location(s). *Source* Drawn by the author

a universally understood view among geographers, economists, and regional scientists is due to widescale coverage of this model in introductory courses in economic geography, location science, industrial engineering, and production and operations management.

Weber in his classic book also made several important observations about production orientation and agglomeration. Depending upon the product being made and the relative amounts of raw materials being used, Weber described the pull in locating a plant toward a resource or close to a market: toward a resource when most of the weight of the resource is being consumed in the production of the product and close to the market when the weights of ubiquitous materials make up a considerable portion of the final product. In fact, Weber goes into great detail about the role of relative weights of materials in factory location. He also suggested that certain elements of the landscape fabric would evolve with the introduction of an industry. This includes the rise of a specialized labor force, and even infrastructure that would support certain types of industries. Such an emerging infrastructure may include specialized educational programs, transportation elements like rail sidings, and supporting industries (making the screws and other products that may be needed in an assembled product of some other firm). Weber stated that these evolving elements supported an agglomeration of associated functions. That said, is this the total sum of Weber's book? Do we need to look any further than what we have read in introductory texts on Weber, or did Weber actually create a much richer theory of industrial location? That is, have most of us overlooked something in his book or maybe never read it? Besides, today, many have changed their focus to understanding the factors and policies which give rise to an industry in a region rather than the process of location selection.

Before digging deeper into Weber's classic, I would be completely remiss if I did not recognize the discussions of Weber by Pinto (1977) and Perreur (1998). Pinto (1977) was the first to raise questions concerning the importance of Weber when he stated that the industrial location triangle was actually proposed by Launhardt in the 1870s, nearly forty years before Weber's book. In fact, Launhardt's construct was more nuanced than Weber's, as Launhardt was interested in the construction of the underlying transport infrastructure as well. This lack of long overdue attribution is due to the fact that Launhardt's work was never translated from German and, for the most part, remained in relatively obscure manuscripts. Perreur (1998) also discussed Weber in light of Launhardt and even asked the question: "Should we forget about Weber?" To be accurate here, it should be noted that Perreur answered this question by stating that Weber's discussion of specialized labor and agglomeration tendencies were, in fact, groundbreaking critical observations, but, like Pinto, he credited the location triangle to Launhardt (1872). Others (e.g., Laporte et al. 2015) have since followed this line of criticism and have begun to give principal credit to Launhardt and not to Weber.

Another undercurrent in the discussion of the location triangle is that the "triangle problem" arose in the mathematical literature several hundred years earlier (see for a detailed explanation Wesolowsky 1993). It is stated that Fermat posed the following mathematical puzzle: Given three points, what is the location of a fourth point that minimizes the distances to the other three points? Note that this puzzle was a purely

geometrical one and was not related to anything that was economic or practical for that matter (it is depicted in Fig. 1b). Wesolowsky was not acquainted with Launhardt, but he was with the developments of Calverli, Torricelli, Steiner, and Simpson. He concluded in his review of the Weber problem that the naming of this problem was due to the "imperialistic control of the economists." To be perfectly clear, the problem posed by Fermat was purely a puzzle, whereas the one proposed by Launhardt and Weber described a problem that deals with the efficient location of an economic activity. Furthermore, the problem proposed by Fermat was but a special case of what was described by Launhardt and Weber. This is because Launhardt and Weber required hauling various weights of materials to the factory as well as hauling the finished product to the market. Even though the costs of shipping were a function of distance, they varied depending upon the amounts needed from a given source, amounts of product supplied to the demand, the attributes of the materials and products (bulky, dense, breakable, etc.), and the transport mode. The assumption in the Fermat problem is that the distances to the three points are just distances alone, making it an unweighted sum of distances problem. Since Fermat's problem is just a special case of Launhardt's and Weber's, it is quite presumptuous of Wesolowsky to call the naming an imperialistic move on the part of economists!

Altogether, past reviews and discussion in the regional science literature (e.g., Pinto 1977; Perreur 1998) and location science literature (Laporte et al. 2015; Wesolowsky 1993) have intimated or even outright suggested that Launhardt be credited with this problem. Such conclusions reflect a lack of understanding of what Weber proposed. I hold the view that this is probably due to the fact that most if not all of the current researchers in our field have not read Weber's book but only derivative works in textbooks and review papers. Without a full understanding of Weber, beyond the aspect of agglomeration and deagglomeration, one could easily ask the same question that Perreur (1998) did: Should we forget Weber? The main goal of this chapter is to put Weber's work into perspective, describe the richness of Weber's paradigm, and demonstrate without a doubt that Weber was way beyond his time, contributed a fundamental understanding to efficient resource allocation and industrial location, and belongs among the group of luminaries such as Koopmans, Beckmann,[1] and Kantorovich (Koopmans 1951; Koopmans and Beckmann 1957; Kantorovich 1939).

4 Understanding the Details and History of the Locational Triangle

To fully understand how recent scholars have touted the work of Launhardt over Weber, it is first instructive to present Launhardt's model. The problem is basically the same as what is depicted in Fig. 1a, except there is an additional element: The

[1] For a discussion of Martin Beckmann's contributions, which place him in the pantheon of *Great Minds in Regional Science,* see Mulligan (2020).

costs of developing the transport links are also included rather than just the haulage costs. For the sake of brevity, consider that the raw material sources are numbered and indexed by i, the markets or demands are indexed by j, and let the location of the factory be defined as point (x, y). Consider the following notation:

V: the annual interest and principal cost and the yearly cost of maintenance cost per kilometer, associated with the building of a conveyance system (road or rail)
C: the transportation cost per ton per kilometer
t_i: the distance from point i to location at (x, y) where i represents a raw material location.
d_j: the distance from the location at (x, y) to point j where j represents the location of market $j = 1$
w_i^R: the volume (tons) of annual traffic needed to be hauled from source where $i = 1$ or 2.
w_j^M: the volume (tons) of annual traffic needed in supplying the market $j = 1$.

Using this notation, we can pose the following transportation investment and location problem: Find the point (x, y) which minimizes Z, where:

$$Z = \left(V + cw_1^S\right)t_1 + \left(V + cw_2^S\right)t_2 + \left(V + cw_1^M\right)d_1 \tag{1}$$

Equation (1) represents the essence of Launhardt's model. It involves locating the factory in order to minimize the sum of transport costs as well as the investment costs of the underlying infrastructure needed to convey the raw materials to the factory and the finished product to the market. Launhardt assumed that all distances were calculated as Euclidean, as did Weber and Fermat. If we let $V = 0$ (no infrastructure investment), then the model is that of Weber. If we let $V = 0$ and all of the cw terms $= 1$ (nothing is transported, only distances count), then we have essentially the Fermat problem. Thus, the Fermat problem is a special case of the Weber problem, and the Weber problem is a special case of the Launhardt problem. So, if this is all there is, one can easily view Launhardt's model as being superior to that of Weber. But, to hold this view, one needs to ignore most of Weber's book.

It is worth noting that Simpson (1750) proposed a weighted version of the Fermat problem and developed a method to optimally solve it. So, technically, Simpson had developed a solution method for Weber's construct of three points more than 150 years before Weber's book. I am unaware of any early literature that suggests a practical application to this problem until Launhardt (1872). Launhardt also developed a solution method for Problem (1), which has since been used in forestry (Greulich 1995) and recently described in Laporte et al. (2015) as an overlooked development. Consequently, the method developed by Pick to solve the three-point problem of Weber (given in the appendix of Weber's book) was not really necessary as it had been formally solved twice before.

Given the emerging view that Weber's construct was not new and that there already existed methods for its solution, you can perhaps understand how Weber's work has

been discounted today. But before I attempt to set the record straight, let me quickly review a few key model and solution developments that followed the work of Weber. Later, it will be clear that these developments have tended to nibble at the edges of Weber's paradigm rather than tackle the key problems described by Weber.

Andres Vasonyi, working under the pseudonym of Weiszfeld, published an article in a Japanese journal that was written in French (Weiszfeld 1937). This article presented an algorithm for solving an *n*-point Weber problem. That is, he solved a weighted *n*-point problem involving Euclidean distance. Some refer to this as a minisum problem on a plane, where the term "minisum" represents minimizing the sum of weighted distances to a number of points. Although there is one issue of convergence that was neglected by Vasonyi, this article went unnoticed in the English literature until many years later. In the 1960s, Cooper (1963), Kuhn and Kuenne (1962), and Vergin and Rogers (1967) each independently developed a Weisfeld style of algorithm for the weighted *n*-point problem. Vergin and Rogers (1967) also proposed a simple procedure for solving this problem optimally when using a Manhattan or grid metric. Wersan et al. (1962) proposed a liner programming model for this same problem for Manhattan or grid distances as an approach for locating an incinerator within a city. Kuhn and Kuenne and Cooper called their problem an extension of the Weber problem, that is, a generalized Weber problem due to that fact that their problems involved more than three points.

Within the regional science literature, Isard (1956) described several location problems and used isocost contour lines (isodapanes) to describe the composite costs across a landscape for the location of a facility. He correctly attributed this approach to Weber, who first suggested the construction of isotims and isodapanes. Such cost terrains are easily calculated today using tools such as MATLAB, which did not exist a century ago. That is, Weber proposed a solution/visualization methodology that can be used to identify the optimal (lowest cost) point as well as easily find all solutions which are within a given percentage of optimality. Cooper (1964) also proposed a multi-facility form of the Euclidean minisum problem, where the objective is to find the optimal location of *p* facilities, where each of the *n* points is assigned to their closest located facility, and where the total weighted distance of all *n* assignments is minimized. Cooper (1964) considered this problem a generalization of Weber's because he addressed a multi-facility location problem and assumed that Weber did not. This research work is followed by a number of articles that improve on the basic solution algorithm, propose methods to handle cases of negative weights (Drezner and Wesolowsky 1991), address problems where distances are asymmetric (Drezner and Wesolowsky 1989), deal with the existence of linear or polygonal barriers (Katz and Cooper 1981; Klamroth 2001), as well as other elements. But these developments never really address the central problems raised by Weber, because Weber is viewed through the lens of a location triangle and not his complete paradigm.

In the next section, I describe a number of major issues that most of the research literature has pretty much ignored, and that are why, in my opinion, these developments have tended to nibble at the edges of Weber's paradigm rather than to tackle the key problems described by Weber.

5 Back to Weber: A More Complete Picture of His Paradigm

I use the term paradigm here to suggest a larger and more complete framework of location problems instead of the term location triangle, a terminology never used by Weber: He called it a "locational figure." That is, Weber has been pigeonholed with a problem consisting of three points, whereas his book describes a richer and far more complex view of factory location. This will quickly be apparent in this section.

Weber used a three-point construct to convey the spatial properties of the location problem, but he never stated that the key problem was relegated to three points. His view was that the central problem could involve a number of different raw materials that were sourced locally and possibly many markets. When Kuhn and Kuenne (1962) suggested a solution method for an *n*-point location problem, they called it the generalized Weber problem because they erroneously viewed Weber's construct as consisting of three points only. Figure 2a depicts the problem viewed by Kuhn and Kuenne as a generalized Weber problem, which is comprised of a number of points all being served by a central facility. The problem as described by Kuhn and Kuenne is to minimize the total weighted distance of serving all demand. Figure 2b depicts a slightly more complex version of the classic form of Weber's locational figure. The depiction in Fig. 2b is based on text given in the English translation of Weber (1929). Figure 2b contains a simple location problem where there are more than three localized raw materials (see Weber 1929, p. 64) and more than one market where the product may be distributed "*for all other places of consumption for which it gives better transportation costs…*" in all directions (Weber 1929, p. 71). The major distinction between Fig. 2a, b is not in the number of points, but in recognizing that there is a difference in the direction of raw materials and product flows, where raw materials are brought to the facility and products are taken to market areas. At first, one might consider this to be such a slight distinction, and that it is hardly worth mentioning. However, this distinction is a key to understanding Weber's paradigm.

When locating one facility where there is a set of fixed and limited raw material location sources (one source for each needed raw material) and one or more markets, the transportation costs are not dependent on the direction of the material and product transport. Consequently, such a simple construct can be solved by the methodology proposed by Weiszfeld (1937) or any of the later developments. This approach does not handle all of the components of the problem described by Weber when stating that the locational figure represents the closest sources of each needed raw material. This means that, as a factory position is moved across a landscape, its sources of allocated raw materials will change. Thus, the location of the factory will, in part, be determined by which given raw material source is closer or has least overall cost, as well as by which markets are to be served. When there is more than one source of a given raw material, then the optimal factory location will be controlled, in part, by raw material resource allocations.

Looking beyond a locational figure that is distilled to three points, the actual problem landscape envisioned by Weber is more like that given in Fig. 3 (see Weber

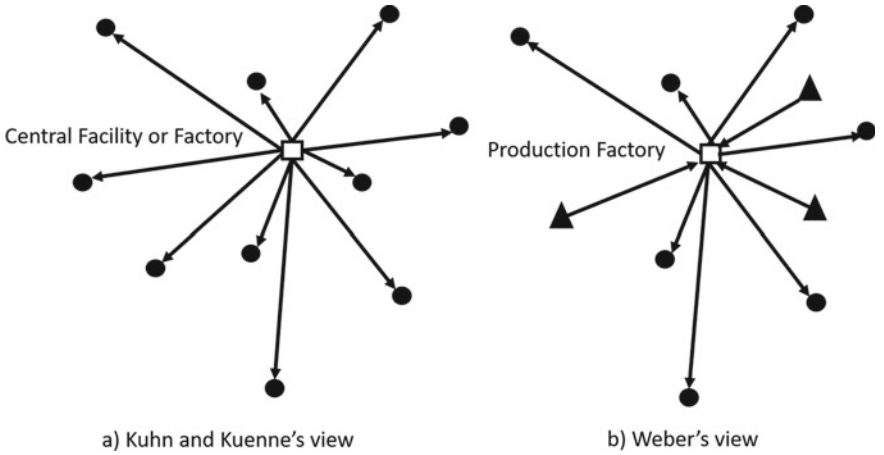

Fig. 2 Depiction of Kuhn and Kuenne's problem along with a depiction of one form of Weber' paradigm. Kuhn and Kuenne (1962) locate a facility to serve a number of demands, while Weber locates a facility that considers supply flows (from needed localized raw material sources) and product flows (to demands) simultaneously. *Source* Drawn by the author

1929, p. 68, where he describes competing locations of the same type of raw material). Figure 3 depicts several options for sourcing two different raw materials, while serving one market. (Fig. 3a depicts a possible location at position A, and Fig. 3b depicts a possible factory location at position B.) The closest sources of raw material 2 change depending upon the factory location. Weber summarized this by stating: "Naturally that deposit will be chosen whose use entails the smallest transportation

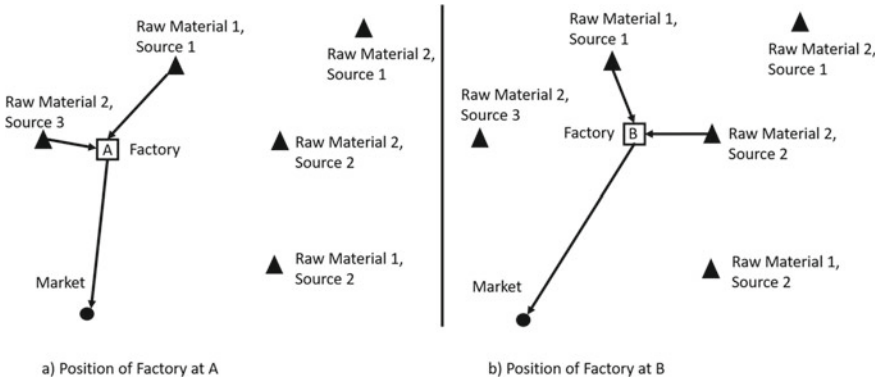

Fig. 3 Depiction of a problem described by Weber in which multiple sources of a given type of localized raw material exist. **a** Depicts the raw material allocations made when factory is positioned at location A, and **b** depicts the allocations made when the factory is positioned at location B. Thus, the mathematical formulation of this problem must contain allocation variables. *Source* Drawn by the author

costs" (Weber 1929, p. 70). He even demonstrated that the closest source of a raw material to a given market may not be the one used in the product that is shipped to that market (Weber 1929, p. 68). To model this, we need to introduce allocation variables for each of the raw materials and their sources, a fact that has been overlooked for over 100 years. A formulation of this problem, which involves alternate sources for each needed raw material along with source allocation variables, has recently appeared in Church (2019), and details for solving this problem can be found in Murray et al. (2020).

Weber stated:

> …it can and will happen that the normal output of the natural deposits of the most favorable [raw material] may not be sufficient to supply the demand of the place of consumption. In this case, less favorable … material deposits will come into play. (Weber 1929, p. 70)

Technically speaking, Weber is describing the case where several sources of a given raw material may need to be used.

Taking the same example presented in Fig. 3, Fig. 4 depicts the case where two sources of raw material 2 need to be used in order to meet the requirements for making enough product to meet the demand for the market.

If all raw material sources are large enough to satisfy all demand for each needed material at a given factory, then there is no need to go beyond the closest raw material source for a specific factory location. But, if sources do not have the capacity to fully satisfy the needs of a factory, then the issue is to purchase from multiple sources the needs while minimizing transport costs. Weber in his construct clearly assumed that the market price for a given raw material was the same at every location and was based upon taking ownership at the location of the source. To include this in a

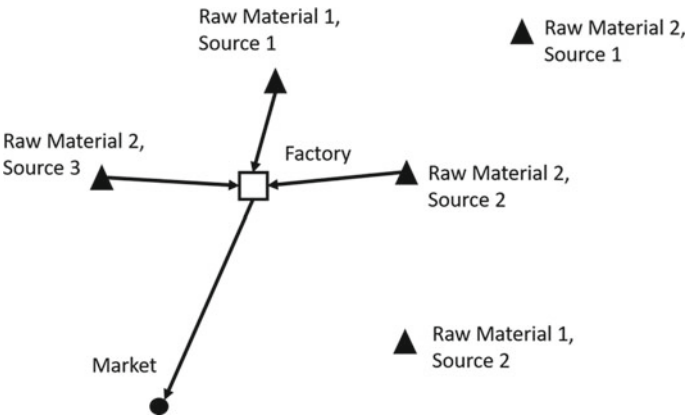

Fig. 4 Weber's envisioned case where raw material sources may have a maximum capacity to provide a given material, and additional sources of the same raw material may need to be used. Here, the factory requires raw material 2 from source 2 and source 3. The allocations and factory placement represent that point at which the sum of all weighted distances is minimized. *Source* Drawn by the author

model, one needs to introduce variables that represent the amounts of material that are acquired at each raw material source. In addition, constraints must be included to ensure that the right amount of each raw material is shipped to the factory and ensure that raw material allocations do not exceed the capacity of any source (see Church 2019).

One of the issues that I believe is misunderstood is the definition of what a raw material represents. Although many texts describe the locational figure using primary materials like iron ore and coal, Weber's view of needed materials included products from other factories. That is, most texts suggest that the factory produced a product from primary materials, whereas Weber clearly states that this is not necessarily the case. For example, if a company makes a product that requires sheet metal, screws, and paint, then either the company considers these components to be raw materials, or it makes these materials as well from primary sourced materials. Weber stated that some of these needed materials might be produced by the same firm in a system of supply that may easily involve multiple locations. He described this in the following excerpt:

> Let us suppose that an industry is influenced only by the cost of transportation, and let us neglect all of the deviating influence of labor and agglomeration. What, given such assumptions, does it mean that the production process does need to be entirely performed at one location, but split into a number of parts which may be completed at different locations? The only cause which could lead to a resultant transfer of the parts to different locations would obviously be that some ton-miles would be saved in the process… (Weber 1929, p. 174)

What Weber described is a somewhat complex industrial system, where some components may be produced at a given location and then be shipped to a second factory where other items may be fabricated and assembled, including the items produced at the first factory (see Fig. 5 as an example). That is, such systems involved staged production, where several stages of production are to be located. Suggesting such a problem clearly places Weber as having not only an understanding of a possible

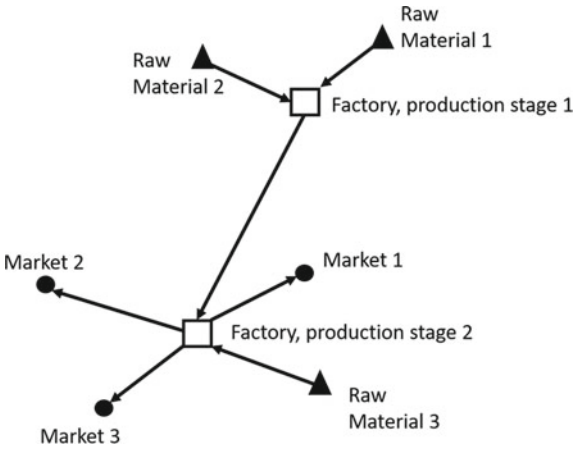

Fig. 5 Depiction of a two-stage production system, with different resources/materials needed at each stage. *Source* Drawn by the author

supply chain, but as having proposed a problem of locating a set of coordinated facilities that at the final stage results in a finished product that is shipped to market centers.

Such systems are not relegated to complex production systems, but even simple ones as well. For example, Church (2019) discusses coffee production as a staged system that fits exactly the issues raised by Weber in staged production. Coffee is usually grown on small farms, picked as coffee cherries, and is brought to local buying centers, where the crop is partially dried. The process of drying reduces the weight as well as the costs of transport to a central production facility. At the plant, the beans are extracted from the cherries and dried again. Then, the remaining beans are graded and shipped for export. The major goal in accomplishing these processes as close to the farm areas as possible is to minimize shipping costs, for the bean itself is only 20% of the weight of the cherry. The beans are then exported, and final processing, like roasting, grinding, and packaging, takes place near the final market. Thus, this is a split production system: one, which takes place near the farms, and a second, which takes place near the markets. Weber summarized his comments on split production systems by stating: "single location of production will be the exception and a split of production into several locations will be the rule for productive processes which can be technically split" (Weber 1929, p. 178).

One of the least understood elements in Weber's text is his perspective on several industrial plants that make the same product. The answer to this is a bit hidden and scattered among several sections of his book. But, this is unquestionably within the scope of Weber's original work, as he broached the issue of multiple facilities when describing that the "locational figures will always be individual or specific for a particular plant. These weight figures are general, applying to all plants of the same kind of production" (Weber 1929, p. 55). His vision appears to be that of a landscape with a number of industrial plants of the same type. Each plant would require resources for the production of the product, and each plant would serve a set of markets (see Fig. 6 for an example). For each production plant, one can draw a locational figure, which includes raw material sources supplying the plant and markets served by the plant. A simple locational figure would involve a market and one or more material sources. More complex ones would involve a host of material sources and markets. Figure 6 depicts two production plants, along with what we might call their unique resource and service sheds (analogous to watersheds). Each resource and service shed represents a locational figure and represents a locational problem.

From Weber's perspective, each factory needs to be optimally placed within its given resource and service shed, a strategy taken by Maranzana (1964) and Schultz (1969) in early examples of solving a multiple facility location problem. Clearly, Weber was interested in the placement of each factory at the optimal position within its resource and service shed, but what Weber didn't discuss was how the landscape of service regions would be defined. He also didn't state that this was the result of one company making multiple location decisions or the result of the decisions of a number of independent companies. Whatever the case, we shouldn't view this as a shortcoming, but rather a formalism that was emerging long before the techniques

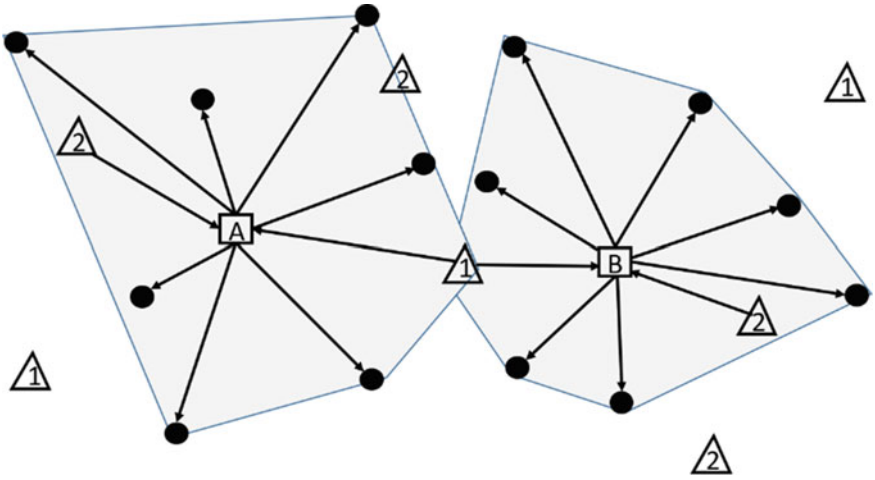

Fig. 6 Depiction of a multiple facility location problem. The numbers in the triangles signify the type of raw material available at that location. Note that all demand is served by the two facilities, and the raw material source 1 in the center of the diagram is shared by both production facilities. *Source* Drawn by the author

of optimal resource allocation and mathematical programming had been formally proposed. That is, before the Nobel Prize-winning work of Koopmans (1951) and Kantorovich (1939).

There probably is a lingering question that you might have: Does this paradigm actually fit the types of conditions that we see today? For example, China became a powerhouse in manufacturing because of its cheap labor as compared to Europe and North America. This was aided, of course, by significant government investment and lax environmental policies. It would seem that a focus entirely on transport costs would entirely miss moving production to such a distant location from the USA or Europe to take advantage of low-cost labor and reduced costs of environmental control. Before the era of containerized cargo, ships were loaded and unloaded by longshoremen. This was a time-consuming and costly process, and ships often spent more time in a port than at sea (a truly inefficient use of a transport vehicle). With the exception of bulk cargo such as grain, coal, and iron ore, transport costs at sea were high enough to hinder global trade except for products that were not manufactured everywhere. In the late 1950s, Malcolm McLean experimented with shipping loaded truck trailers between ports in the Gulf of Mexico and the east coast of the USA in order to reduce trucking costs. This was so successful that he started to experiment with using containers instead of trailers, which were easier to load on a ship and could be stacked efficiently. By the mid-1960s, a great transition was made from relying on costly hand loading of ships to using cargo containers. This led to a substantial decrease in the per mile shipping costs for ocean transport. Weber stated that different modes of transport could come into play, but his main focus in his book was to describe those industries where transport costs played a major role in

deciding where a factory would be located. So, in this instance, how would China be competitive as a manufacturing location when transport costs would be increased substantially by moving a plant to China? That is, it seems that a global search for cheap labor doesn't fit into Weber's paradigm. But, just like a number of complexities, including split production, Weber raises what he calls "realities." Cheap labor is such a reality! Weber describes this issue in the following way:

> Every change of location away from the point of minimum transportation costs to a favorable labor location means, in terms of transportation, a "deviation," which lengthens the transportation routes and raises transportation costs above those prevailing under the most advantageous conditions. The changes of location can therefore take place only if the rise in cost per ton of product which it causes is compensated, or more than compensated, by savings of labor costs. (Weber 1929, p. 103)

Weber summarizes this reality issue in saying:

> …a location can be moved from a point of minimum transportation costs…. only if the savings in the cost of labor which this new place makes possible are larger than the additional costs of transportation which it involves. (Weber 1929, p. 103)

Thus, Weber's paradigm addresses this reality of today.

It is important to briefly discuss the notions of agglomeration and deagglomeration in Weber's theory. Weber raises the notion of agglomeration when discussing an evolving industry or sector of industry. As an example, a specialized labor force may emerge with the location of a factory. This could include workers that operate equipment in a factory or even those who are trained to repair the equipment. Other companies may want to take advantage of this trained labor force in locating a nearby plant. Other forces of agglomeration, like an improved transport system, a water system, streets, gasworks, etc., may also attract new unrelated industries. Industries also might locate close to other companies when those companies produce products that are required as raw materials in their products. Altogether, Weber describes a number of issues associated with agglomeration and what he terms the accumulation or distribution of industry. Weber notes that agglomeration may result in increased expenses. For example, agglomeration will increase the demand for land, which will result in a rise of land values. A rise in land values in one location will make other locations more attractive (by comparison), which will lead to a deagglomeration or the location of production at other locations. Weber states that: "all deagglomeration tendencies start from the increase in economic rent (ground rent)" (Weber 1929, p. 132). This leads to a weakening of agglomerative forces.

Finally, Weber discusses the notion of industrial strata, the links between industries, and the impacts that they have on location. Industries may be linked by their use of materials, products, and labor. For example, one industry may need the products of another industry to assemble their product. A specific case of this would be a company that may not make screws, sheet metal, and paint, but may need all these products to make bread boxes. That is, their manufacture is related to other companies' products and where those companies' production takes place. Consequently, there is a whole fabric of production that evolves, and each new entrant is, in part, controlled by previous developments on the landscape.

6 Concluding Comments

Weber was instrumental in describing a theory of industrial location that has, for the most part, been underappreciated. Although best known for his locational figure in the simple form of a triangle and his theory of agglomeration, the key elements of his locational construct have remained hidden in his text as most have relied on derivative works for discussion of his work. It is clear that Launhardt developed a location triangle before Weber, which was more complete in that it dealt with both the transport of the materials and product, but also the investment in the mode of transport. Launhardt's construct clearly represented his engineering interests in transport infrastructure investment. When removing the elements of the infrastructure investment from Launhardt's model, the three-point problem of Launhardt is equivalent to Weber's three-point locational figure. However, Weber's construct was not really a three-point figure as it could involve many points of localized raw materials and market locations. Further, Weber envisioned a landscape where specific raw materials did not exist at unique locations but were possibly quite numerous. This factor requires the notion of resource allocation, a formalism beyond that of Launhardt. Further, Weber clearly understood that production could be split into stages at a series of production facilities, each located so as to minimize total transport costs, where each facility is supplied by its nearest and least cost sources of needed raw materials. This problem element alone places Weber as one of the originators of supply-chain design. Finally, Weber's perspective was not constrained to the location of a single production plant for a given product, rather he conceived of a landscape of plants, each serving their own set of nearby markets. If such a production system is not reliant on localized raw materials, then this multi-plant location problem is equivalent to the *p*-median problem, that is, a model designed to minimize transport costs of weighted distances of serving all demand, where each demand or market is served by its closest facility. Without a doubt, the details in Weber's book describe a set of problems which form the basis for, e.g., the *p*-median problem, supply-chain design, and efficient resource allocation. Although Launhardt's theory was a breakthrough, Weber's was a complex paradigm on a higher level.

While many texts in production and operations management describe the Weber model as useful in factory location (or assign a Weber problem in homework exercises), it is usually described as locating a factory to serve a set of customers. This literature simply ignores the shipment of needed raw materials when describing the Weber model. Geography and regional science texts present only the simplest of depictions—that of the location triangle—when Weber himself described a rich and complex set of problems. Although research dealing with the Weber problem has addressed interesting facets of Weber's original work, most nibble at the underlying assumptions, rather than tackling the hard and complex problems that he posed. Such works include solving a problem on a planar surface with polygonal barriers to travel, linear barriers to travel, optimal placement of bridges across barriers, and distance metrics other than Euclidean, but they have not addressed key issues such

as resources that are capacitated, staged production, and the inherent differences between raw material resources and demand.

Most today would think that the level of production is not fixed to meet a specific level of demand, but rather demand itself is a function of price, where price is dictated by production, profit margins, inventory and sales costs, land costs, and delivery costs. Therefore, the Weber paradigm is simple compared to what might be viewed as a complete production and location problem. In addition, Weber did not consider possible competition with other companies, or even the influence of product differentiation. It took nearly fifty years for many of these factors to be addressed in detail (see, for example, Isard 1956; Moses 1958; Koopmans and Beckmann 1957; Alonso 1960).

It is my opinion that Weber was constrained by what was known in the mathematical sciences of the day. Sure, the elements of calculus and classical constrained optimization were known by the time Weber wrote his book. This even included the concept of a Lagrangian function that was developed in the 1780s. But Karush–Kuhn–Tucker conditions had not yet appeared (Karush 1939; Kuhn and Tucker 1951), nor had the works of Kantorovich (1939), Koopmans (1951), and Koopmans and Beckmann (1957). These notable developments, along with the development of linear and integer programming algorithms by Dantzig beginning in the late 1940s, helped form a new field now called operations research (OR). The tools of OR have been instrumental in the formulation of many factory location and transport-flow problems that have had wide application in industrial development (see, for example, Breitman and Lucas 1987). My point is that Weber lacked the developments of OR, which could have allowed him to translate his verbal statements of problem issues into formal models.

Ackoff (1956) describes operations research as a science. He describes the process of OR in six steps: (1) describing the problem, (2) constructing a mathematical formulation of the problem, (3) deriving a solution for the model, (4) testing the model and the solution derived from it, (5) determining the conditions under which the solution may need to be modified, and (6) implementing the solution. In most OR applications, many people may be involved: some describing the essence of a problem, others formulating the appropriate mathematical model, and even others solving the model and implementing the solution. In a more recent work, I have argued that Weber had defined many different problems of industrial location and resource allocation that clearly fit within the scope of step 1 of Ackoff's description of OR (Church 2019). What Weber couldn't do was to use the tools that we have at our fingertips today to formulate and solve such problems. That is, Weber knew the essence of many problems faced by industry, described these functions, and looked closely at specific instances when land costs, labor costs, and prices were held fixed. With such a set of assumptions, he distilled the essence down to that of location based upon minimizing transportation costs (raw materials and products). He recognized that labor specialties may not be available everywhere and that other costs (e.g., land) may not be constant, but the modeling tools of the day constrained him in bringing such problems to subsequent stages, like model formulation and solution. Today, many of the problems suggested by Weber exist in network-based facility

location models. However, with the notable exception of the recent work of Murray et al. (2020), most of his problem constructs have not been solved with respect to a continuous space domain.

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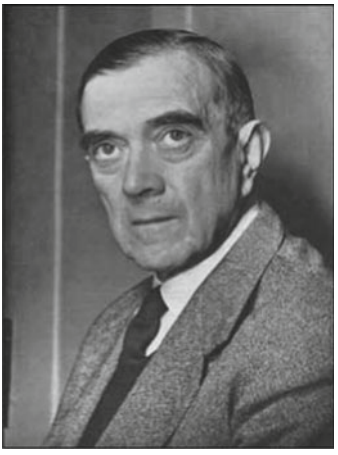
Corrado Gini (1884–1965): Versatile Originator of Measures of Variability

Peter Rogerson



Corrado Gini. *Photo source* https://commons.wikimedia.org/wiki/File:Corrado_Gini.jpg (last accessed October, 2022) and *Metron*

1 Introduction

Although the bulk of Corrado Gini's career predated the beginnings of the field of regional science, his ideas and contributions have been, and continue to be, influential

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in the past and current work carried out in many areas of regional science research. While the coefficient of inequality that bears his name is certainly his most well-known contribution, his other work has also had a lasting impact and influence on the development of important measures in geography and regional science.

After reviewing some of the highlights and pertinent aspects of Corrado Gini's life in the second section, the third section focuses on his well-known and eponymous measure of inequality. The following four sections review his contributions to other areas of measurement that have been critical for progress in a variety of research areas in geography and regional science. These include: locating centers of population; making international price comparisons; constructing indexes of agreement and classification accuracy; and measuring diversity. The final section provides a short discussion and conclusion.

2 Biography and Life

Corrado Gini (1884–1965) was born the son of wealthy landowners in Motta di Livenza, in the province of Treviso, about 60 km northeast of Venice. He studied law, mathematics, economics, and biology at the University of Bologna. He went on to become well known in the fields of statistics, sociology, economics, and demography, and his work has had a tremendous impact on many other fields, including geography and regional science.

Gini's first paper was published in 1908; in it, he provided evidence to support the theory that the tendency to produce children of a given sex was an inheritable trait.[1]

Two years later, at the age of 26, he became Chair of Statistics at the University of Cagliari; three years after that, he accepted the same position at Padua. He started the journal *Metron* in 1920; the journal publishes papers on statistical methodology and applications, and, at the time of writing this chapter, it was celebrating its centennial.

Gini was Chairman of the Central Institute of Statistics from 1926 to 1932.

He founded the Italian Committee for the Study of Population Problems in 1929, and in 1931 this Committee organized its first Population Congress. In 1934, he was responsible for the beginning of *Genus,* that committee's journal of population sciences that has continued until the present day. Later on, the Committee was responsible for leading several international population congresses that were supported by the United Nations and the International Union for the Scientific Study of Population. The Committee also became widely known for its expeditions aimed at better understanding isolated populations.

Gini's honorary degrees include those awarded in economics, by the Catholic University of the Sacred Heart in Milan (1932); sociology, by the University of Geneva (1934); sciences, by Harvard University (1936), during the celebration of the

[1] A recent study provides strong support for this hypothesis (Gellatly 2009). In particular, men who have many brothers are more likely to father sons; men with many sisters are more likely to father daughters.

300th anniversary of its founding; and social sciences, by the University of Cordoba, Argentine (1963).

Extremely active in scientific societies, Gini was an Honorary Fellow of the Royal Statistical Society, President of the Italian Genetics and Eugenics Society (1934), President of the Italian Sociological Society (1937), and President of the Italian Statistical Society (1941).

Although he could at times appear sociable and extroverted, these traits were not those of his inner nature; more often, he came off as quiet and withdrawn. He was married and had two daughters—and it does not appear that, with his professional duties, he spent a great deal of time with his family. Giorgi (2001) writes: "As far as human relationships were concerned, for Gini they were reduced to a minimum and compliments were almost non-existent." But Benedetti (1965), who knew Gini well, tempers this (a bit) and says that this was only Gini's way of progressing with his work, and once he saw his way through on an issue or problem, he was very adept at adjusting his intellect and needs to those of others. Benedetti also mentions that he gave few lectures, instead spending time on conferences, scientific expeditions, and writing what turned out to be over 800 papers! He relates that "Gini's assistants and some other professors used to work in small glass boxes, fitted with a microphone which Gini could use to listen and talk, but the occupier of the box could only reply if spoken to… as for the university students, Gini was practically unapproachable" (Benedetti 1965, pp. 9–10).

There has also been some discussion regarding Gini's relationship with Mussolini and fascism. While Macuglia (2014) argues that his interest in eugenics and early connections with Mussolini were associated with the rise of fascism, Castellano (1965) argues that Gini's "independent and impatient spirit" led him to resign his position as President of the Central Institute of Statistics in 1932, following interference of Mussolini, the rise of fascism, and the related desire for strong centralization and control.

Although Corrado Gini worked primarily before the field of regional science started, his ideas and contributions have been instrumental in the past and current work carried out in many areas of regional science research. Indeed, a Google search of "Gini" + "regional science" yields over 50,000 hits. Among his broad-ranging works on statistical measurement that would serve as important antecedents to research in regional science were: (a) the Gini coefficient, (b) median centers of population, (c) the EKS index and international price comparisons, (d) indexes of agreement and classification accuracy, and (e) measures of diversity.

3 The Gini Coefficient

Corrado Gini is most widely known of course for the coefficient of inequality that bears his name. Shortly after Lorenz (1905) developed his curve to depict inequality by plotting the relationship between two cumulative distributions, Gini (1912, 1921)

developed a numerical measure to accompany the curve. The Gini coefficient (sometimes referred to as the Gini index or the Gini ratio) is equal to the ratio of the area lying between the 45-degree line and the Lorenz curve, to the full triangular area beneath the 45-degree line. It is most often used to describe income inequality, but it has also been widely used to describe variability in population density over a region that has been divided into subregions and in many other contexts as well.

The Gini index may be expressed as a fraction or a percentage, and higher values indicate more inequality. One interpretation in the context of income is that it represents the average amount that would have to be paid from one randomly chosen individual to another (relative to the mean income), in order to equalize their incomes. Accordingly, the Gini coefficient may be expressed as one-half of the relative mean absolute difference between all pairs of incomes:

$$G = \frac{\sum_{i=1}^{n} \sum_{j=1}^{n} |x_i - x_j|}{2n^2 \overline{x}} \tag{1}$$

The quantity $2G\,\overline{x}$ is the sample estimate of Gini's mean difference (GMD), defined as the expected absolute value of the difference between two random observations—that is, $\text{GMD} = E[|X_1 - X_2|]$, where X_1 and X_2 are independent observations from the distribution of X. This is an alternative way of measuring variability (for instance, the variance is $E[(X_1 - X_2)^2]/2$). Several properties of Gini's mean difference as a measure of variability make it more attractive than the variance for the case of non-normal distributions, and these have been touted by Yitzhaki (2003).

3.1 Regional Aspects of Inequality Measures

Bickenbach and Bode (2008) note that measures of inequality have the property of "anonymity"; like Rey and Janikas (2005), they point out that different spatial patterns of income can yield identical measures of inequality. In studies of residential segregation, this is known as the "checkerboard problem" (White 1983). To address the issue, Rey and Smith (2012) decompose the Gini coefficient into pairwise contributions between observations that are close, and those that are not close. This allows spatial autocorrelation to be detected in addition to inequality. Rey and Smith also trace the history of efforts to include space in measures of inequality and segregation, citing the work of Arbia (2001), Dawkins (2004), and Wong (1993, 2003). A spatial version of the Gini index has been suggested by Dawkins (2004), and another generalized spatial version has been set forth by Folch (2012) (see also Folch and Rey 2016).

Panzera and Postiglione (2020) develop methods for assessing the effect of spatial dependence on measures of regional inequality. They, and Dawkins (2007), base their measures on Schechtman and Yitzhaki's (1987) Gini correlation, which in turn is based on the covariance of a variable X and the cumulative distribution of

another variable Y (in their case, Y, is defined as a weighted sum of the nearby X's), standardized by Gini's mean difference of X.

In addition to its use in the regional analysis of income inequality, locational Gini coefficients were introduced by Krugman (1991). These he defined using Eq. 1, and then dividing by 2, where x_i is defined as the location quotient for an industry (say k) in region i. In turn, the location quotient is simply region i's share of employment in sector k, divided by region i's share of total employment. This locational Gini ranges from a minimum of zero (when sector employment is spread out across regions in proportion to total employment) to a maximum of 0.5 (when the sector's employment is concentrated in one region). This has been applied by regional scientists in, e.g., a widely cited study of production in the UK (Devereux et al. 2004) and in the study of economic activity in the European Union (Combes and Overman 2003).

An alternative spatial Gini coefficient was developed by Ellison and Glaeser (1997), and this version has been used in numerous regional studies. For example, Guimaraes et al. (2009) note that within the Ellison-Glaeser framework, the location quotient can be viewed as an estimator; they thus provide the basis for a statistical framework for what previously had been a purely descriptive measure. Another example of the Ellison-Glaeser approach is in the work of Alkay and Hewings (2012), who use it to study the agglomeration of manufacturing in Istanbul.

There has also been a fairly lively debate regarding whether regional measures of inequality such as the Gini index should be weighted by population. Gluschenko (2018) summarizes this debate and argues that weighting inequality measures by regional population gives a poor estimate of overall interpersonal inequality. Furthermore, many authors misinterpret such a measure as an estimate of *regional* inequality.

Other measures of concentration used in geography and regional science are based conceptually in Gini's contributions. Folch's (2012) centralization index, which has applications to the measurement of segregation and is used to measure the relative concentration of groups around a center, has its foundations in the Gini index. It is further developed by Folch and Rey (2016).

Gini's contributions to other measures of concentration and dissimilarity should also be recognized. The Hoover index of population concentration (Hoover 1941) and the Duncan index of dissimilarity (Duncan and Duncan 1955)—both well known and widely used within geography and regional science—have their roots in Gini's (1912) original study of variability. The Hoover index of population concentration is:

$$H = \frac{1}{2}\sum_{i=1}^{r}|p_i - a_i|$$

where p_i and a_i are the shares of total population and total area that are in region i. The Duncan index of similarity is:

$$D = \frac{1}{2}\sum_{i=1}^{r}\left|\frac{P_{ig}}{P_g} - \frac{P_{ih}}{P_h}\right|$$

where there are r regions, g and h are two subgroups of the population, and P represents population. These indexes may be interpreted as the fraction of population that would have to move to equalize either population density or subgroup representation across regions.

Both the Hoover and Duncan measures rely on a sum of the absolute values of differences, which is precisely what is also used in Eq. 1. Goodman and Kruskal (1959) thus, rightly, give credit to Gini (1914–15a, 1914–15b, 1937) for suggesting measures of variability that led to these applications. Duncan (1957) gives credit to Hoover (1941) for being the first to make use of this measure in applications to population concentration.

The Hoover index is also known as the Pietra index. Pietra (1915; translated in 2014) discusses it explicitly and cites one of Gini's measures of variability as forming the conceptual core of the index. In fact, in his early work, Gini (1912) set out 13 different measures of inequality! These have been nicely summarized by Ceriani and Verme (2012).

Finally, the Gini index itself has been used in areas where these other measures are used. Plane and Mulligan (1997), for example, use different Gini indexes in the context of migration, measuring the degree of focusing (analogous to inequality) that was observed in sets of in- and out-migration streams. Duncan and Duncan (1955), James and Taeuber (1985), and Plane and Rogerson (1994), among others, give an alternate version of Eq. 1 for determining the Gini coefficient in the context of residential segregation.

Absolute differences between pairs of observations have also been used in other important contexts. For example, the absolute difference between pairs of residuals has been the basis for a robust form of regression that is not sensitive to outliers (Olkin and Yitzhaki 1987).

In addition to the inequality coefficient that bears his name, Gini made many other lasting contributions—both to his primary fields of statistics and population studies, and to ancillary fields and topics. A large number of these have had—or could potentially have—significant impacts on geography and regional science. In the sections that follow, I describe the most relevant and most interesting of these contributions.

4 Median Centers of Population

Sviatlovsky and Eells (1937) begin their paper on "The centrographical method and regional analysis" with a statement on the importance of the study of center points:

> The development of a fully adequate theory of regional analysis by statistical means is one of the outstanding problems of geography today. The map alone is not enough, nor are statistical data alone. They must be brought together. This is the aim of centrography. (p. 240)

They go on to discuss the history of center points and note the US Bureau of the Census's error in equating the mean center of population with the point of minimum aggregate travel.[2] They relate how it was Gini and Galvani (1929) who were the first to point out the error and also the first to suggest the now-accepted term "median center" for the point of minimum aggregate travel. In their paper, Gini and Galvani also developed a more general approach to finding a type of mean for nominal data, basing it upon a measure of deviation between classes of the distribution. The two combined with Berardinis to write on the means of bivariate distributions (Gini et al. 1933), and there they applied their methods to geographical problems. The contributions of this Italian-language paper may be under-recognized, since Weiszfeld's iterative solution, now widely cited, was not published until 1937.

The location of the median center is identical to the solution to the "1-median problem," which is a specific case of the *p*-median problem (where *p* facilities are to be located) that has a long and rich tradition within regional science and geography. ReVelle and Swain (1970) formulated the problem as an integer programming problem and thus began what is now a fifty-year period of activity in the form of research, collaboration, papers, and special sessions at regional science meetings that has immeasurably increased the visibility and importance of the field of regional science. Reviews of location science include Hale and Moberg (2003), Daskin and Maass (2015), and ReVelle et al. (2008).

5 The EKS Index and International Price Comparisons

There are several alternative ways real gross domestic product (GDP) may be compared across countries. Similarly, there are different ways the purchasing power associated with the currencies of different countries may be compared. An important and widely used index is the EKS volume and price index. It was developed simultaneously by Eltetö and Köves (1964) and by Szulc (1964). It has its antecedents in the work of Drechsler (1962), where an appendix written by Elteto contains the index itself, and, more importantly, in the antecedent work of Fisher (1922) and Gini (1924, 1931).

Aten and Heston (2009) describe the contributions of Gini to this area, noting: (a) The EKS index is the most widely used measure of international purchasing power and real product; (b) Gini was the first to suggest the approach; and (c) as Gini noted,

[2] Eells (1930) independently made the same point regarding the Census error in his own paper that appeared the next year. The Census error is discussed in an editor's note in the *Journal of the American Statistical Association* that appeared later in 1930. The US Census Bureau continues to calculate the center of population incorrectly. Correct calculations that account for the proper map projection and great circle distances are described in Plane and Rogerson (2015).

it is constructed from the pairwise comparisons described by Fisher (1922) and the solution to a least squares problem.

Gini's circular test requires the product of successive indices over a period to be equal to the product of the first and last indices. If, for example, there is a 5% increase in the index in period 1, and a 6% increase in the index in period 2, the index when calculated for the combined period should increase by $(1.05)(1.06) = 1.113$ or 11.3% (Donaldson and Pendakur 2010). Applications by regional scientists include Rokicki and Hewings (2016) and Aten (1996, 1997).

6 Indexes of Agreement and Classification Accuracy

Classification analysis has been used in many areas of geography and regional science, and indexes of agreement constitute another area where Gini's work is antecedent to today's practice in these fields.

Hand (2012) reviews and compares measures of classification accuracy. He makes the important points that different indexes measure different things, and hence, the measure chosen should match the study's objectives (in much the same way that different statistics have differing statistical powers against different types of alternative hypotheses), and, consequently, empirical comparisons of measures have limited value.

Regarding classification, Hand (2012) also makes the distinction between cases where the success of a single classification table is to be measured and cases where a threshold is specified to yield a classification. With regard to the latter, in epidemiology and other fields, including geography and regional science, continuous variables are often dichotomized using some threshold to provide, e.g., maximally discriminated relative risk ratios above and below the threshold.

Perhaps, the most common measure used to evaluate the success of a single classification in this setting is Cohen's (1960) Kappa index. The Kappa index is a chance-standardized version of the probability of correct classification, equal to $(C - E)/(1 - E)$, where C is the actual proportion correct (or, in the case of raters, in agreement), and E is the expected proportion correct (or in agreement), based upon the marginals of the 2×2 table of predicted and true values.

The Kappa index is used both in the setting described here, where classification success is measured (and classification is either right or wrong), and also in settings where two raters are placing objects into categories, and a measure of agreement is desired for the table cross-classifying the ratings of rater 1 with those of rater 2. The Kappa Index is the most widely used measure for comparing the agreement among two people who rate N subjects and place them into C mutually exclusive categories; it provides a numerical measure of agreement.

Although the Kappa index now has Cohen's name attached to it, Warrens (2015) gives credit to Gini for developing and studying measures of agreement on nominal scales at a much earlier date. Warrens (2013) compared Kappa with three separate coefficients of agreement suggested by Gini. The story here is similar to Gini's

development of thirteen measures of inequality and variability mentioned earlier. When he worked on these measures, he didn't just develop one: he developed several.

In geography and regional science, the Kappa statistic is found in classifying trip activities from GPS data (Feng and Timmermans 2017). Another common application area is in the study of land use analysis; Lu et al. (2020), for example, make use of the Kappa statistic in this context. The results of Warrens (2013) suggest that these applications could just as easily have used one of Gini's measures of agreement/classification accuracy. In any case, Gini's work serves as the antecedents for this common measure.

In many applications, thresholds of a variable are selected to maximize classification accuracy. These thresholds may be chosen by maximizing a measure of classification accuracy. Gini's index, the Kappa index, and the odds ratio can all be used for selecting a threshold. Nelson et al. (2017) compare many methods aimed at threshold determination using simulation, and they find that the Gini index, like several other measures, estimates the true threshold well.

When a threshold is to be specified in the classification exercise, relations between sensitivity and the false positive rate (and hence classification tables) are examined for a range of thresholds. The Gini coefficient is also used in this context, and it is directly related to measures of classification accuracy. Hand (2012) also demonstrates that this Gini coefficient used for classification is precisely the same as the Gini coefficient of inequality.

Regarding spatial perspectives, the Kappa statistic has been extended to a regional setting by Hagen-Zanker (2009). In particular, a fuzzy Kappa statistic gives weight to cells or regions on one map that are in agreement not only with those same cells or region on another map, but also to a region that is in agreement with a nearby region. This suggests that Gini's alternatives could also be extended to spatial problems in a similar manner.

7 Gini and Measures of Diversity

Gini is also well known for his measure of entropy; it has seen widespread application in many areas, including classification and decision trees, and in the measurement of species diversity. His measure of entropy is:

$$G_e = 1 - \sum_{i=1}^{n} p_i^2$$

where p_i is the probability that an object belongs to class i and there are n classes. The measure is interpreted as the probability that two elements chosen at random do not come from the same class.

Simpson's index is a widely used measure of diversity; it was suggested by Simpson (1949) and is equal to $1 - G_e$. It is interpreted as the probability that

two random elements come from the same class. In ecology, G_e has also been called the Gini-Simpson index (Jost 2006) and the probability of interspecific encounter (Hurlbert 1971).

In economics, Simpson's index is known as the Hirschman-Herfindahl index, where p_i is the market share of firm i. A maximum index value of 1 indicates concentration in one firm, whereas a minimum value of $1/n$ occurs if each firm were to have an identical market share. Its pedigree under that name has an interesting history of its own. In a note in the *American Economic Review,* Hirschman (1964) points out that a number of articles (Massell 1964; Kindleberger 1962; Michaely 1958; Tinbergen 1962) refer to it as the Gini index or the Gini coefficient. Hirschman claimed that his index (which was originally suggested in 1945 as the square root of $1 - G_e$) was original; he was, of course, aware of the Gini coefficient for income inequality but was seemingly unaware of Gini's G_e. He also noted the work of Herfindahl (1950; Herfindahl used $1 - G_e$ without taking the square root) and was frustrated by the fact that the index had then come to be known as the Herfindahl index—principally in measuring industrial concentration—due in part to Rosenbluth's (1955) use of it. At least now both economists receive credit for the Hirschman-Herfindahl index in economics, notwithstanding the fact that it was Gini who originally developed the measure.

Gini's measure is also used in other disciplines. It is the Gibbs-Martin index (Gibbs and Martin 1962) in psychology, sociology, and management. In sociology, it's known as the Blau index (Blau 1977), where it is used to measure racial and ethnic diversity. It is also used in population genetics to measure expected heterozygosity.

The Gini-Simpson index has seen application in a variety of areas of regional science. It has, for example, been used to measure land use diversity (see, e.g., Saksena et al. 2014). Fassio et al. (2015) use the index to measure the diversity of migrants in different occupational sectors. Nijkamp and Poot (2015) refer to it in their study of measures of cultural diversity.

Another name for the measure under discussion here, as used in classification, is "Gini impurity." It is the probability of an incorrect classification of a new observation when it is randomly chosen according to the probabilities associated with each class. Gini impurity (GI) is equal to:

$$\text{GI} = \sum_{i=1}^{k} p_i(1 - p_i) = \sum_{i=1}^{k} p_i - p_i^2 = 1 - \sum_{i=1}^{k} p_i^2$$

where there are k classes and p_i is the probability that an observation belongs to class i. If the proportion of sunny days is 5/8 and the probability of cloudy days is 3/8, the probability that a new observation (which is classified randomly, according to the probabilities above) will be misclassified is $(5/8)(3/8) + (3/8)(5/8) = 30/64 = 15/32 = 0.4688$. GI has a minimum value of zero, when there is only one category. The Gini impurity measure is used in the construction of decision trees; features with low measures are chosen first, because they have lower probabilities of misclassification. An example of its use in geography and regional science is in decision tree approaches

to house-price determination as an alternative to hedonic regression models (see Fan et al. 2006).

Ellerman (2017) applied the logic of partitions to information theory. Whereas Boole developed logical probability as a normalized counting measure on subsets in his study of the logic of subsets, Ellerman does the same for partitions. That is, he develops a normalized counting measure on partitions in a logic of partitions. All this is to say that in so doing, Ellerman provides a logical derivation of Gini's (1912) measure of diversity; he terms this measure *logical entropy*.

In physics, Gini's measure of diversity has been generalized and is known as Tsallis entropy (1988); the latter is also a generalization of the widely known Boltzmann–Gibbs entropy. Tsallis entropy was also suggested earlier within the literature on information theory (Havrda and Charvat 1967). For a discrete set of probabilities, it is equal to:

$$S_q = \frac{k}{q-1}\{1 - \sum_{i=1}^{n} p_i^q\}$$

where Gini's index of diversity is obtained for $q = 2$ and the Boltzmann–Gibbs entropy is obtained in the limit as q approaches one. While this is an interesting example of Gini's impact in its own right, it is also important to recognize that information theory and entropy maximization have been important in model development in geography and regional science (Wilson 1970, and, for an overview of more recent works, see, e.g., Wilson 2010).

Light and Margolin (1971) relate how the form of the familiar Gini coefficient as used in economics can be related to the entropy version for categorical data, by looking at the sum of pairwise products, instead of the absolute value of pairwise differences:

$$\frac{1}{2n}\sum_{i \neq j} n_i n_j = \frac{n}{2}\left(1 - \sum_i \frac{n_i^2}{n^2}\right)$$

where there are n_i responses in category i.

To understand the connection between this measure and Gini's mean difference, one needs to investigate the extension of the mean difference to the case of qualitative variables—say, where there are K classes. Let n_i be the number of observations in class i, and set the diversity between any two classes equal to one. The mean difference between observations is then equal to $\sum_j p_j(1 - p_j)$. See, e.g., Light and Margolin (1971) who also point out that Gini's index of diversity may also be viewed as the sum of variances across the K categories, where the variance for each category is found by assigning one to each observation in the category and zero to all other observations.

8 Discussion and Conclusions

One of the difficulties in assessing the entirety of Gini's contributions to statistics and social science is that many of his works have remained untranslated. This, of course, has limited their impact, but summaries of these untranslated works show both the scope of his mind and the potential for placing other areas of study in historical perspective. The entry on Gini in the *International Encyclopedia of the Social Sciences* (Salvemini 1968) summarizes and provides assessments of a number of these works. The present chapter, while attempting to give an account of Gini's scholarly life in typical fashion, recognizes that many developments in both statistics and social science have been followed up by others recognizing antecedents in Gini's work.

Much of what Gini contributed was rediscovered or reintroduced many years later. For example, in a very early contribution, he discussed subjective probability, beliefs, and inductive probability (Gini 1911, 2001). In many ways, this anticipated the seminal work of Carnap (1945) and Bayesian probability.

Like many areas of science, it turns out that one of Gini's important concepts, now known as Gini's mean difference, had actually been examined earlier. David, in his historical reviews of measures of sample variability (1968, 1998), found that Jordan (1869), von Andrae (1869, 1872), and Helmert (1876) had previously studied properties of the Gini mean difference. Gini himself became aware of these only after his own work had been published.

Today, most every economist, quantitatively oriented geographer, and regional scientist is familiar with the Gini index now widely employed for measuring income distribution inequality. In addition to his coefficient of inequality, however, his antecedent work in many other areas has had a lasting impact and influence in the fields of geography and regional science. As the versatile originator of so many of the fundamental concepts now used in our statistically oriented research, Corrado Gini merits inclusion among the Great Minds in regional science.

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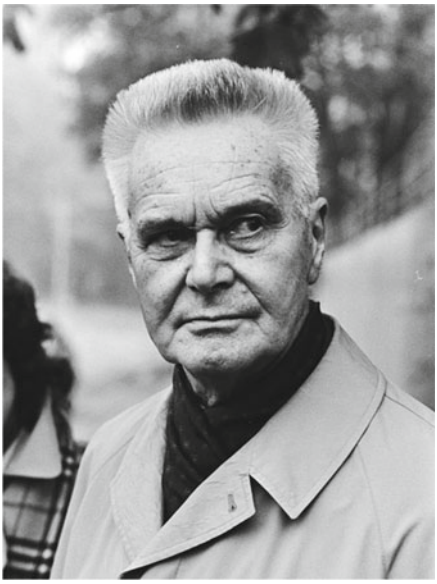
Laying the Foundations of Regional Science

Jan Tinbergen (1903–1994): A Rational Thinker on Inequality and Distribution

Peter Nijkamp



Jan Tinbergen. *Photo source* https://commons.wikimedia.org/wiki/File:Jan_Tinbergen_1982.jpg (last accessed September, 2022)

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1 Jan Tinbergen: A Life Sketch

Regional science started to flourish as of the 1950s. It should be noted, however, that the beginning of the twentieth century was already a fruitful vintage period for the subsequent rise of regional science in the post-WWII years. Several scientific giants who have generated lasting imprints in the history of regional science later on in the second half of the twentieth century were born in the period 1900–1920: Francois Perroux (in 1903), Wassily Leontief (1905), Jan Tinbergen (1903), August Lösch (1906), Richard Stone (1913), Torsten Hägerstrand (1916), and Walter Isard (1919). Clearly, Walter Isard—the founding father of regional science—found later on a fertile cradle in the achievements of his earlier predecessors. One of them was Jan Tinbergen, who also met with Isard during the early regional science conferences in Europe held in The Hague, The Netherlands, in the 1960s.

Jan Tinbergen (April 19, 1903–June 9, 1994) was born in The Hague, The Netherlands. He was the eldest child in a middle-class family with five children, who were raised in an atmosphere of scientific education and societal responsibility.

Tinbergen studied mathematics and physics (1921–1925) at the famous University of Leiden, at a distance of only 20 kms from The Hague. His doctoral supervisor was the world-known physicist Paul Ehrenfest, who brought him also in contact with other great scholars, such as Heike Kamerlingh Onnes, Hendrik Lorentz, Pieter Zeeman, and Albert Einstein, who were all featured Nobel laureates. Clearly, Tinbergen grew up in an intellectual and international climate of theoretical physicists in an epoch where major path-breaking discoveries in physics were made. Nevertheless, Tinbergen's interest shifted gradually toward societal problems of economic growth and welfare distribution. He had a strong social-political orientation, which explains his interest in growth and inequality in society, in particular, in the years before the Great Depression. His Ph.D. subject provides witness to the gradual turn in his life; the title of his Ph.D. dissertation signaled already his change in interest: 'Minimisation Problems in Physics and Economics.' This original study provided an interface between mathematics, theoretical physics, macro-economics, and policy analysis. He demonstrated that the mathematical formulation of economic processes may be identical to the equations describing physical processes, for instance, in mechanics. This study showed Tinbergen's great potential to model complex processes in various disciplines.

Meanwhile, as a substitute for compulsory military service in the country, he was forced to provide community and social service, first in the administration of a prison and later on at the Central Bureau of Statistics (CBS) in The Hague. He continued to work there for a long time, even until the end of WWII. The wealth of empirical data at the CBS allowed him to develop and test operational macro-economic models for the Dutch economy, in particular on business cycles and economic dynamics. He also started publishing on his findings. His great scientific skills did not remain unobserved in Dutch academic circles. By the time he was thirty, he had been appointed as part-time (associate) professor at the University of Amsterdam and the Netherlands School of Economics (at present, Erasmus University) in Rotterdam. He was the first

economist who developed a full macro-economic model for a national economy, with an application to The Netherlands. This type of macro-economic modeling was soon followed in many other countries.

Tinbergen lived most of his life in The Netherlands, although he worked in the pre-WWII time also as an advisor to the League of Nations (later on, United Nations) and traveled extensively after the war to numerous countries all over the world, as well as spending one year (1955–1956) as a visiting professor at Harvard University.

After the end of WWII, he was appointed as the first director of the newly founded Central Planning Bureau (CPB) in The Netherlands so as to provide independent evidence-based economic advice on the reconstruction of the Dutch economy after WWII. This position also allowed him to develop evidence-based macro-models (including, for instance, distributed lag models), which later became the international trademark of the CPB. In this period, he also laid the practical foundation for the new discipline of econometrics, mainly from a macro-economic applied angle. From 1955 onward, his interest shifted also to education, scientific guidance, and service provision to less privileged academics and countries, not only for students but also for scholars from developing countries (e.g., India, Pakistan, Indonesia, and Venezuela). He founded the Econometric Institute in Rotterdam (1956), in cooperation with another founding father of econometrics, Henri Theil. His interest shifted increasingly toward global issues of unequal development and later on toward the global governance of resources and wealth from a macro-normative distributional perspective. Notwithstanding his deeply rooted social-political belief, he never became a political figure; he remained a rational evidence-based thinker, despite his deep social-democratic engagement in poverty and income-distribution issues. He had a wide-ranging interest in issues like economic growth, international trade, theory and models of economic policy, welfare and income distribution, development economics, international economic order, global governance institutions, and also spatial economics.

Jan Tinbergen became—together with Ragnar Frisch—the first Nobel laureate in economics (1969). They received the Nobel Prize for their seminal work on the development and application of dynamic growth models for depicting complex economic processes. Interestingly, Tinbergen's emerging interest in regional issues was not mentioned during the Nobel Prize Award ceremony in 1969 in Stockholm, as this interest had not yet crystallized in a consistent conceptual and analytical framework of interconnected regional economies. Tinbergen, though, referred explicitly to August Lösch in his Nobel lecture. It is—in passing—noteworthy that also for many other Nobel Prize winners, who exerted a thorough influence on regional science thinking and application, their regional economic interest—or spatial-economic relevance—was never explicitly mentioned or hardly recognized in their official Nobel Prize motivations. Examples are: Paul Samuelson, Simon Kuznets, Kenneth Arrow, Lawrence Klein, Wassily Leontief, Gunnar Myrdal, Bertil Ohlin, Herbert Simon, Richard Stone, Gary Becker, William Vickrey, Amartya Sen, Daniel McFadden, Joseph Stiglitz, Daniel Kahneman, Thomas Schelling, Paul Krugman, William Nordhaus, and Paul Romer. It is interesting that especially the first generation of Nobel Prize awardees appeared to be well connected with regional economists and regional

scientists, although—to the best of my knowledge—the term regional science was never referred to in any of the Nobel Prize laudations.

Jan Tinbergen continued to be involved in scientific reflection and macro-analysis till his death in 1994. He kept his broad interest in macro-economic issues, not only inside the country, but increasingly at a worldwide scale. Despite his deeply rooted social-democratic conviction, he was first of all the cool rational scholar who wanted to understand societal and economic complexities before suggesting solutions. He enjoyed a simple and sober lifestyle and was by no means interested in luxury. A visit to his home—at a close distance from the Peace Palace in The Hague—was always an unforgettable human and intellectual experience: As a real gentleman, he always asked about your wellbeing while offering a cup of tea; then he started to raise thought-provoking questions. He was a careful listener and a deep analytical thinker; his answers and thoughts were logically grounded; his suggestions were based on rational arguments; and his solutions took for granted that, in a rational world, far-reaching improvements were—and should be—possible. He believed in rational knowledge-based solutions for distributional questions in a heterogeneous and often conflictful society.

2 Jan Tinbergen: The Scientist

Tinbergen's core contribution to economics can mainly be found in the quantitative modeling of interdependent macro-economic phenomena. He started his economic research in the pre-WWII period mainly from the statistical analysis of business cycles and international trade. He published seminal articles on these topics, for instance, in *Econometrica* (Tinbergen 1938), in the *Review of Economic Studies* (Tinbergen 1940), and in *Weltwirtschaftliches Archiv* (Tinbergen 1942). In particular after WWII, he got involved in questions on how to control the economy in order to provide a better wellbeing for mankind. As director of the Dutch Central Plan Bureau, he got involved in questions on the controllability of the economy, in line with his social-democratic ideas. He published a first article on his views on government planning in the *Review of Economic Studies* (Tinbergen 1947).

In his analytical contribution to economic policy analysis, he made a distinction between quantitative policy (i.e., a quantitative flexible adjustment of existing policy measures), qualitative policy (i.e., a change in the nature and composition of policy intervention measures), and structural policy (i.e., a change in institutional competences and governance structures).

His major contribution on the foundations of macro-economic policy can be found in two seminal studies, viz., *On the theory of economic policy* (Tinbergen 1952) and *Economic policy: Principles and design* (1956). The latter core publication of Tinbergen's came out in the same year as Walter Isard's main conceptual and seminal opus, *Location and space-economy* (Isard 1956). In his latter two publications, Tinbergen made a successful attempt to define economic policy as a rational

process in a search for appropriate policy measures so as to achieve a set of pre-defined goals (the so-called Tinbergen rule of 'fixed targets'). Tinbergen was able to mathematically show that an overambitious list of pre-specified policy goals will lead to inconsistent outcomes, unless the policy intervention measures would also increase with the same intensity (leading almost to a centralized regime). In his view, a model should at least depict past realities in order to assess the intensity of policy measures for achieving pre-specified goals. A necessary condition for balanced and realistic economic policy is to bring the number of quantitative policy goals (e.g., balance of payment, inflation rate, employment, etc.) in balance with the number of feasible and available policy instruments (e.g., taxation measures, public investments, etc.). Thus, given a set of prior quantitative policy targets, economic policy is a rational process of finding a match between goals and tools by reversing the causality chain: from instruments → targets, into: targets → instruments. This approach was inspired by his belief in the makeable nature of an economic system, under the supervision of a central coordinating authority. From 1965 to 1969, he even held a chair position at the Erasmus University in Rotterdam on the theory of centrally planned economies.

Clearly, this approach also provoked criticism, as it has some serious limitations; it presupposes a flexible adjustment capacity in an economic system by quantitatively skilled rational policymakers, based on prior specified goals. Tinbergen was aware of this restrictive element in his approach and also addressed explicitly a more general method, called the 'flexible target approach.' In this case, the economic system is supposed to be driven by an overarching social welfare function, which ought to be maximized by a rational policy authority, subject to economic constraints incorporated in an operational empirical model. This approach is still nowadays used in welfare economics and also in regional science (see, e.g., the concept of a 'social planner' or 'central authority,' inter alia, deployed more recently by Batabyal 2017 and Batabyal and Nijkamp 2010). The shadow side of the latter approach, however, is that for practical policy purposes, the social welfare function ought to be estimated and known before the actual optimization process can be carried out. It is even possible that the social welfare function might be influenced by the actual outcomes of the economic process itself. It is clear that such real-world limitations have meant a major hurdle to the theoretically more elegant operational social welfare approach as compared to the straightforward fixed target approach.

A seemingly elegant way out of this dilemma was provided some years later by Tinbergen's closest colleague, Henri Theil, who was by origin, like Tinbergen, also a physicist. He published in 1964 a path-breaking book on *Optimal decision rules for government and industry* (Theil 1964). In his approach, Theil introduced a social welfare function in the form of a so-called quadratic penalty function for the discrepancy between pre-specified and actual target values for policy objectives. This 'compromise' social welfare approach had a major analytical advantage, viz., the first-order (necessary) conditions from the minimization of a quadratic penalty function subject to a linear model describing the economy concerned. This approach led to an analytically tractable linear solution system for policy instruments, with unambiguous outcomes for policy-making bodies. The use of quadratic penalty functions

in programming analysis has ever since been a common approach in programming theory (e.g., in goals-achievement models).

However, the Theil approach also has—despite its elegant character—a serious limitation, viz., the lack of empirical insight—or of empirically estimated values—concerning the weights attached to the successive policy goals in the quadratic penalty function. Using certainty equivalence and smoothing amendment procedures, Theil made an attempt to address these issues, but they remained mainly at a conceptual-technical level of economic policy analysis. A first successful attempt to solve the latter 'Maxwell's demon' problem was made by Nijkamp and Somermeijer (1971), who introduced an operational econometric model to estimate so-called 'implicit social welfare functions.' The pivotal idea of this approach is the assumption that any policy realization—wanted or unwanted—is the empirical outcome of a complex but implicitly socially optimal multidimensional evaluation process in a heterogeneous democratic economy. Examining then the first- and second-order conditions for welfare optimization of an economic system, the policy-preference parameters can be estimated ex-post, while also intertemporal robustness analyses concerning shifting policy parameters over time can be carried out. This approach bears some resemblance to what is nowadays known as revealed preference estimation of individual behavior, e.g., in discrete choice modeling (see McFadden 1974) or environmental policy analysis (see Nijkamp and Paelinck 1973).

In this period, Tinbergen also got involved in three new complementary analytical departures in his scientific work. In the first place, he extended his interest in international trade analysis toward an operational modeling framework of world trade flows. In this context, he developed the first full-fledged gravity model for trade flows (Tinbergen 1962b), an undertaking which was not a surprise given his background in theoretical physics. From this perspective, he may be seen as the founding father of operational gravity models in regional science. It is noteworthy that this original contribution to spatial interaction modeling did not only find its origin in his ambition to technically solve the specification and estimation of interdependent global trade models from a gravitational angle, but also from his already mentioned normative consideration that socio-economic inequality in the world, production specialization, and trade flows were intricately interwoven phenomena which had to be thoroughly understood in order to shape a more equitable world. A visit to India in 1951 had once more convinced Tinbergen that the current economic power positions in the world needed a change, based on rational economic arguments.

In addition to dealing with spatial inequalities, he also looked for fundamental mechanisms to shape more analytical order in the capricious space economy. Central place theory (as developed by Christaller 1933) was for him a structured, economically grounded theory based on logical principles that provided a logical hierarchical constellation of the space economy. Although he did not develop new hexagonal spatial systems, he believed that product specialization, scale advantages, distance frictions, and effective market demand in a complex space economy were the basic ingredients of a logical spatial-economic order. It is noteworthy that his paper on 'Spatial distribution of industry' (Tinbergen and Bos 1961) was presented in 1961 at the first European regional science conference in The Hague in the presence of

Walter Christaller. Tinbergen's intelligent combination of central place theory and gravity analysis may be seen as another pioneering contribution of this great thinker to regional science. This systemic methodology on hierarchical patterns in space also encouraged him to later write a study (in 1965) on the principles of regional planning, in which logical considerations on the spatial-economic architecture played a basic role.

And, finally, he also laid the systematic foundation for social cost–benefit analysis following a cascadic approach from macro-policy analysis, via sectoral and regional model application, to project planning. This new approach was inspired by the urgent need for spatial reconstruction policy in the Western part of the country after the devastating flood disaster ('Watersnood') of January 30–31, 1953. He was responsible for the economic calculation of the most far-reaching water-management plan in Dutch history (the so-called Delta Works), which was only in recent years—after more than 50 years—completed. Nowadays, this plan is often also referred to in The Netherlands against the background of emerging sea-level rise threats and river floods. Tinbergen not only prepared a comprehensive, spatially differentiated cost calculation, but he tried to estimate also all direct and indirect costs and benefits of all public intervention schemes (dikes, dams, etc.) by means of input–output analysis (Tinbergen 1954a, b). This led, later on, to the design and application of the so-called semi-input–output model including trade in open national or regional economies, an approach which was—given the usual situation of restricted data—also applied in various developing countries (e.g., Pakistan; see Tinbergen 1961a).

By the mid-1960s, Tinbergen had developed an increasingly thorough interest in the global division of welfare. His systemic views on the world economy, as reflected in his gravity-inspired trade interest and his hierarchical decomposition of interacting economies, were helpful instruments in developing new structures for economic order in the global space economy. He got increasingly involved in ambitious initiatives to lay the foundations for a new economic world order. This is clearly mirrored in the title of his article on 'Wanted: A world development plan' (Tinbergen 1965b). His science-inspired ideas on a balanced division of welfare not only can be found in his seminal book (Tinbergen 1978) on income distribution, which was preceded by another study on income distribution written in collaboration with his colleague Jan Pen, but also in his visionary—original but still realistic—study on the 'New economic order' (Tinbergen 1974, 1987). His cool and modest, almost anti-emotional and seemingly apolitical, analysis of complex distributional problems in the world made him a respected advisor to many governments and international bodies. In the last part of his life, he also got deeply involved in the global sustainability debate—in the spirit of the Brundtland Report (1987)—which stimulated him to link his views on a more satisfactory world economy (one with less painful inequality characteristics) to the global division of wealth and resources and to the need for more equitable environmental quality. A good illustration of his systematic analytical thinking can be found in his publication on 'Warfare and welfare' (Tinbergen and Fischer 1987). He remained until his death in 1994 involved in issues of global and environmental justice.

During his extraordinarily productive and influential scientific career, Tinbergen developed many contacts with the great economists from his time, for instance, Keynes, Haberler, Rosenstein-Rodan, Kaldor, Schumpeter, Ohlin, Koopmans, Kalecki, Chenery, Myrdal, Stone, Leontief, Frisch, Goldberger, Klein, Rothenberg, Samuelson, Jorgenson, and Isard (several of them would later become Nobel laureates themselves). Through this communication with so many other Great Minds, he was able to work at the forefront of new views on human capital, talents, and education; on combined supply and demand impacts on inequality; on the economic importance of good and solid institutions; on the benefits of decentralized and coordinated centralization of socio-economic policy; and on the cornerstones of an optimal international economic order. He left behind an impressive volume of scientific contributions, sometimes published in prestigious journals (e.g., *Econometrica*, the *Review of Economics and Statistics*, the *Review of Economic Studies*, and the *American Economic Review*), sometimes in local outlets in order to reach out to a broader public.

3 Jan Tinbergen: A Panoramic Overview

The broad spectrum of Tinbergen's work on economics (including economic policy) is amazing. The synergy of his physics-inspired thinking and his socio-economic engagement with distributional inequality made him, over a period of several decades, a real pioneer in new economic approaches and original perspectives. In the context of a concise overview of the contribution of this great scholar, I will limit myself here to a few prominent areas which characterize his scientific contributions, viz., econometrics, development economics, and regional science.

3.1 Econometrics

Tinbergen was convinced that—in contrast to qualitative logical policy arguments (as advocated by respected colleagues, e.g., John Keynes)—economic theory and policy needed to be substantiated by quantitative, testable, and evidence-based underpinnings. In this respect, he was in complete agreement with his co–Nobel laureate, Ragnar Frisch. From a systemic perspective, he addressed problems like: How to estimate a system of simultaneous equations, without the use of any computer power? How to collect and develop reliable databases that are a solid foundation for economic policy analysis? How to estimate a macro-economic production function with heterogeneous human-capital components? How to design a consistent global world trade model, incorporating different countries and industrial sectors, using adjusted gravitational principles? How to estimate a multi-country input–output model, with input substitution in an open world economy?

From his early scientific work in the 1930s onward, Tinbergen worked relentlessly on the solution of such questions, with a view to the development of testable econometric macro-models. His influence on the macro-economic modeling exercises of his American colleague, Lawrence Klein, (also a later Nobel laureate) is undeniable. Reading Tinbergen's work—or, better, his struggle—to find an evidence-based pathway to the treatment of such complicated issues, in a period where computers did not exist, is very insightful, since only intelligent analytical power was able to come up with satisfactory solutions. His close colleague, Henri Theil, wrote later on an extensive book on the principles of econometrics (Theil 1971), a work that culminated later on in novel research on the two-stage least squares estimation method (when error terms are correlated with independent variables) by their colleague, Arnold Zellner (again with a background in physics), who later on pioneered the field of Bayesian econometrics (see Zellner 1999).[1] Tinbergen—and, in his footsteps, Theil—may be seen as among the founding fathers of modern applied econometrics, with a worldwide impact.

3.2 Development Economics

After Tinbergen's first visit to India in 1951, he was shocked not only by the bitter poverty situation in that country, but also by the rigid structural societal causes of that phenomenon. He even wrote later on an article on 'Myrdal's Asian drama' (Tinbergen 1968a). He made an analytical attempt to understand and map out the fundamental causes of poverty from the prevailing institutional-economic structures in that country, while he also tried to articulate—and also criticized—the lack of development cooperation of the wealthy nations.

In 1956, Tinbergen was also appointed as a professor in development economics in Rotterdam; in this way, he was able to educate young people from abroad and to lay the foundation for the Dutch school of development economics, which arose later on (and could count among its members, e.g., Henk Bos, Loet Mennes, George Waardenburg, and Hans Linnemann). In his structuralist view on the economy, planning and governance systems around the world had to be drastically changed and improved so as to create a better—i.e., more equitable—world.

Tinbergen's interest was less in microeconomic or personal motives of people to achieve a higher position on the welfare ladder. Nevertheless, his interest in income distribution brought him also into the domain of labor markets and, partly, microeconomics. An interesting contribution of Tinbergen can be found in his view on optimal income distribution: that there might be a logical empirical boundary to differences in income in a given country. This is often referred to as the Tinbergen norm: The difference between the lowest and highest income in an organization should not exceed the ratio of 1:5, since otherwise productivity or efficiency will no longer be

[1] I refer the interested reader to Zellner's obituary published in the *University of Chicago News* (2010) for more details.

favored. This empirical rule, however, is hard to trace in Tinbergen's writings (see Akkerboom 2015). But in general, his work focused more on an aggregate level. In his macro-view, educational quality was a critical component to cope with poverty and inequality. He emphasized, in particular, equal access conditions for all people to educational systems. Despite the fact that he saw little progress, and despite many disappointing outcomes, he believed, on rational grounds, that the world has the potential to improve its fortune and that a change in organizations governing the world economy is necessary and realistic.

3.3 Regional Science

Jan Tinbergen was never trained as a regional scientist. His spatial interest started from analyzing welfare disparities in a macro-economic system, but in so doing, he became increasingly aware of the role of space (in particular, regions) in economic modeling and socio-economic policy. And, therefore, in Sect. 4, a more detailed presentation of Tinbergen's influence in regional science will be given.

4 Jan Tinbergen: The Regional Scientist

The origin of Tinbergen's interest in regional science has to be found in his macro-economic international trade modeling research, which had started already in the 1950s. In his view, the use of gravitation analysis offered an applicable quantitative methodology for investigating and explaining international trade flows, in which distance frictions and economic heartland power played important roles. The gravitational principle implied a logical, universally valid structure of spatial interactions between countries of different size, location, and economic power. Any change in a country's welfare position would also imply a change in the country's gravitational power, which may be measured by the use of a multi-country gravitational flow model.

One of the important conceptual problems to be solved by Tinbergen in his attempts to specify a full-fledged gravitation model for international trade flows was the question of dimensionality. Trade flows were usually physical in nature, but of totally different dimensions, and, consequently, such heterogeneous trade flows had to be homogenized by translating them into a monetary value, which was—given the limited statistical data—a major analytical challenge needing to be addressed within the standard framework of physically inspired gravitation theory.

Tinbergen's rising interest in inequalities brought him not only into the realm of economic welfare disparities, but also into that of international and regional economic disparities. A region was essentially a vehicle for welfare creation and distribution, and that idea stimulated him to write in 1958 an article on the economic principles for the optimal use of space (Tinbergen 1958), followed in 1961 by a seminal article on

the spatial dispersion of production (Tinbergen 1961b). This article formed also the basis for his European Regional Science Association conference paper on 'Spatial distribution of industry' (Tinbergen and Bos 1961), which he presented in 1961 in The Hague in the presence of Walter Christaller and Walter Isard.

The global gravitational force field reflected in industry-specific and in sector-specific trade flows offered an operational and logical constellation to better understand uneven economic development from a structuralist perspective. In this context, his attention was drawn to hierarchical spatial systems' architecture as incorporated in decomposition principles of the Christaller-Lösch type (see, for an overview, Nijkamp 2020). The first European Regional Science Association conference in The Hague not only brought Tinbergen, Christaller, and Isard together, but also stimulated a vivid debate. Apparently, Tinbergen was impressed by systemic thinking in regional science and participated also in the seventh European Regional Science Association conference in 1967 in The Hague, where he again met many well-known regional scientists.

After his recognition of the great merits of hierarchical spatial systems—as a result of Christaller's central place theory—he continued his work on the organization of the space economy with another seminal article, this one on 'The hierarchy model of the size distribution of centers,' presented at the European Congress of the Regional Science Association in 1967 in The Hague (Tinbergen 1967). He continued to publish on regional matters in subsequent years, but less in regional science journals.

The 'hierarchical systems' approach was also used by Tinbergen as the cornerstone of his conceptualization of the new world economy (Tinbergen 1962a, 1974). This idea was later on (in 1969) operationalized in a really original, model-based study on spatial structures in development planning, together with others (see Mennes et al. 1969; Zimmerman 1964). Economic order was for him the anchor point for policy intervention.

In a period when computing power hardly existed, Tinbergen was able to develop not only the first macro-econometric model for The Netherlands, but also the first full-fledged global gravity model for international trade. This tool is now a standard vehicle in quantitative regional science. An elegant model-based illustration of the hierarchical structure of the space economy can be found in a modeling study by Bos (1984). Tinbergen's multi-layer, multi-sectoral model for interdependent hierarchical spatial systems in the Christaller-Lösch tradition has found many followers (see Paelinck and Nijkamp 1976; Paelinck 1959; Nijkamp and Ratacjzak 2021), sometimes under the overarching umbrella of so-called Tinbergen-Bos systems (see Tinbergen and Bos 1965). Even though Tinbergen never called himself a regional scientist, he may be seen as one of the founding fathers of quantitative regional science (see Nijkamp 2020).

4.1 Realistic Ideals

Tinbergen during his entire life made an uninterrupted effort to create a better world (as can also be witnessed from the memorial statement read for his funeral: "his effort to create a better world remains an example for us all"). A comprehensive overview of his work, his personal views, his national and international impacts, and his driving forces can be found in a long historical biography by Dekker (2021). He was not a utopian dreamer, but a realistic idealist who sought to lay the scientific foundation for the structure of new economic systems that would be more equitable. Despite his sometimes 'centralistic' views, he believed in democratic centralism. A significant part of his work on controlled systems was more focused on the questions of economic convergence between different political-economic systems, rather than on political claims about the desirability of centralized versus decentralized governance structures. He became ultimately also increasingly skeptical about the centrally governed economies in Central and Eastern Europe, as, in his social-democratic view on society and economy, a democracy was a basic prerequisite. His work on the New International Order (NIO), addressing issues like environmental quality, fair access to resources, and socio-economic equity, was a predecessor to the subsequent Brundtland Report in 1987. His economic views on a new world order, in which wealthier countries would be charged with financial transfers to the poorer countries, was based on the logic of a win–win situation for both parties. His institutional proposal to turn the IMF into a Global Ministry of Finance and the World Bank into a Global Central Bank was sometimes seen as unrealistic ideas. However, Tinbergen's argumentation was not based on political feasibility, but on the necessity to change the world in the interest of us all. All such new institutions should serve a livable earth, including a redistribution of resources.

Tinbergen's personal views are best articulated in his manifesto on 'The liveable Earth' (1974), which offers a concise and systematic record of his realistic ideals on poverty in the world, environmental and climatological concerns, industrial capital and technology development, and, of course, the new international economic order. A good illustration of his broad, but also modest, view on the need for alternative and novel economic approaches to pressing world problems can be found in his missionary message written as a foreword to Nijkamp's (1980) book *Environmental policy analysis:* "Recent information on environmental and energy supply limitations have necessitated the introduction of the corresponding variables into models. Similar enrichments may be obtained by the introduction of a number of social indicators (on family life, work environment, position in a hierarchy) into our models which increasingly require such an interdisciplinary approach." And: "Among the future activities a systematic collection of verifications of the strategies hypothesized with the aid of observed behaviour may rank high" (Tinbergen 1980, pp. x–xiii). Despite his great ambitions, Tinbergen would never impose his views on others; he always sought a collegial and rational debate, far from political emotions.

5 Epilogue

Jan Tinbergen has undoubtedly been one of the greatest economists of the twentieth century. Despite international conflicts and turmoil, he offered an organized perspective by presenting a structuralist contribution to the achievement of a better earth, in particular, by suggesting an applicable global governance structure for socio-economic and environmental issues in a complex space economy. His interest in market structures and labor division, public investments, and scale advantages in a world with heterogeneous product specialization in different regions or centers make him also one of the early predecessors, '*avant la lettre,*' of the New Economic Geography.

Despite many tragedies in his personal life (among others, the early decease of his younger brother, the sad loss of his daughter), Tinbergen remained an indestructible rational optimist, who believed that logical arguments and empirical evidence were needed to convince others (Tinbergen 1984). In a way, his world views may sometimes be seen as somewhat naïve, as is witnessed in his attempts to rationally understand national-socialism and communism. But his ideals were never dreams; he started from current structures and built on top of these his ideal–typical but logically based construction. His influence on Dutch economists has been great; an informed overview on the 'descendants of Tinbergen' can be found in a book by van Dalen and Klamer (1996, 1997), which shows the scientific footprints of Tinbergen all over the country.

In another publication (Nijkamp 2020), the author has highlighted the influence of Jan Tinbergen on the early development of regional science in The Netherlands. Clear traces can be found back in the seminal works of another great Dutch regional scientist, Leo Klaassen (see Klaassen et al. 1959). For an earlier overview from a European perspective, the reader is referred to Van Geenhuizen and Nijkamp (1996).

Tinbergen's path-breaking work in economics cannot only be traced in his numerous publications (more than 900; see, for a sample, Dekker 2021), but also in the Tinbergen Institute, a post-graduate research and education center based in both Amsterdam and Rotterdam, which carries his name. And as one of the founding fathers of the Tinbergen Institute, I was extremely fortunate to organize, beginning in 1995, an annual Tinbergen workshop on regional science, which over the course of years attracted hundreds of regional science colleagues from all over the world. For more information on Tinbergen's work, I refer the interested reader to de Wolff (1994), Derksen (1959), Hansen (1969), Heckman (2018), Kol and de Wolff (1993), Pen and Tinbergen (1977), Pronk (1970), Tinbergen (1956, 1963, 1965a, b, 1966, 1968b, 1981a, b), Tinbergen and Bos (1965).

Tinbergen himself remained a modest gentleman in all the economic turbulence he studied and wished to improve. He was also very modest about his contribution to spatial dispersion issues and models in regional science, as witnessed by the following text of an interview with him:

> For some time I have been interested in the distribution of a population over cities and villages, in short, over centres of different size, and I tried to develop a theory, but that

> theory was either incomplete or too simple. It was mainly based, I think, on the demand side. So what I wrote about it was unfinished and I think that the subject, although it's terribly interesting, is very difficult, too difficult for me. Perhaps Jean Paelinck will be able to solve that problem. But this is an area in which I would have liked to make more progress than I did. (Tinbergen 1987, p. 138)

Tinbergen was fully aware of the limitations in his thinking, but at the same time, he always raised the bar very high. Nevertheless, he has always kept his solid belief in evidence-based and quantitative research for the improvement of our world, as is witnessed in the following quotation: "For some queer and deplorable reason most human beings are more impressed by words than by figures, to the great disadvantage of mankind" (Tinbergen 1987, p. 141). His ideas on new world constellations are still vivid and seem to get rejuvenation in the recent debates on global climate change. Regional and global issues will ultimately appear to be connected phenomena on our earth.

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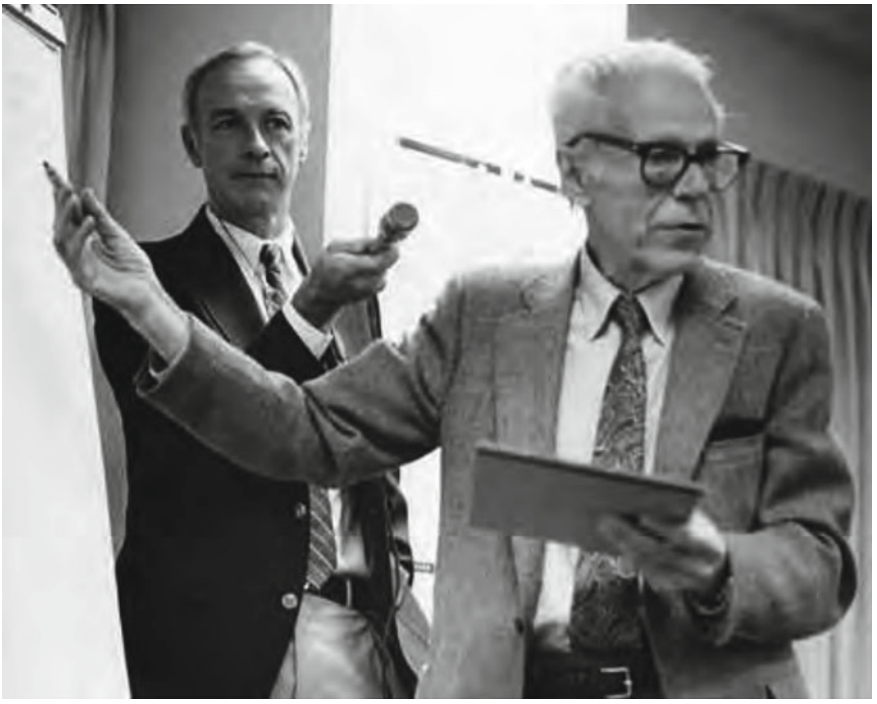
Albert O. Hirschman (1915–2012): An Unorthodox Regional Scientist

Abdul Shaban



Albert O. Hirschman, right, with Inter-American Foundation vice president Charles Reilly. *Photo source* IAF

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1 Introduction

Albert O. Hirschman was a product of one of the most difficult times in human history of the first half of the twentieth century. This was the time when wars ravaged Europe and so many other continents, causing human miseries, migration, holocaust, and destruction of material wealth. From these ruins and implosion in central Europe, the best brains of the world (Albert Einstein, Hannah Arendt, Hans Krebs, Fritz Haber, James Franck, Fritz London, to name a few) also emerged helping the humanities to write the stories of successes in many fields—physics, biology, medical sciences to social sciences. Hirschman was one of those who contributed by extending our understanding of regional and development economics, and in building cross-cultural solidarity to stop violence and human rights violations, which Hirschman himself witnessed and was subjected to. In his more than seven decades of academic life, he would help regional scholars, planners, and practitioners to transform their understanding of the (regional) development processes from his experience and intellectualism based on a cross-cultural life experience and from cross-disciplinary academics in Europe and the Americas. His method of inquiry, analysis, theories, and developmental policies emerged from different contexts and was rooted in cross-disciplinary paradigms, though economics, as a discipline, dominated his approach. He lived two parallel lives: an inner life, humanitarian at core that was wounded by Hitler's fascist violence, while an outer life, related to academics and regional science, was calm and serene. He never revealed any of the miseries that he went through in Germany, France, Spain, and Italy, where he fought the wars against the fascism during his early youth. In the early days of his youth, he learned German idealism and Marxism and was a radical member of the Social Democratic Party in Germany. He was a prodigious concept builder and a cosmopolitan thinker.

Among luminaries in economics and regional science, Hirschman stands out because (a) his wide range of essays related to many unconnected aspects of economic and social life; (b) his methods of investigation were unorthodox and differed as per the context and problems; and (c) he remained quintessentially a liberal in his ideological approach, a nonconformist and 'possibilist' (Lepenies 2008) with respect to theorization and abstraction. Hirschman's arduous life journey, especially when he was young, may have shaped his orientation toward unorthodoxy and his tendency to search for endless possibilities to understand, address, and resolve development problems. His curious inquiries as a child from his father (Hirschman 1995), the holocaust, association with radical socialist groups, wars between countries, exposure to a multiplicity of ideologies as he grew up, life as a refugee, fear of discrimination and of violence as a Jew in Europe and America, his wife Sarah, reading of Hayek's 'Road to Serfdom,' and his employment and research-related visits to various regions all left indelible imprints on his thinking process and leave us amazed as they get contextualized, abstracted, and theorized in an unorthodox manner in his writings and everyday life. From these also stems his ability to contribute to regional science, where (a) regional problems emerge in their own contexts and peculiarities with their unique possible solutions, (b) the seed of solutions was, for him, embedded within the

regions, and (c) there is no unique formal theory which can help in understanding the grand phenomena. He worked in an interdisciplinary field and contributed through his writing to all the social sciences and made a synthesizing discipline like regional science richer. Hirschman also displayed a 'propensity to self-subversion' by re-examining his own theories and arguments. Most relevant to regional scientists, the concept of 'unbalanced growth' (besides the role of asymmetry in international relations propounded in the 1940s and 'exit and voice' contributed in the 1970s) presented in 1958 was also subject to his re-examination.

In this chapter, I attempt to take an overview of Hirschman's biography and then swiftly move to examine his major contributions to regional science. It is not that all his contributions are related to spatial and regional questions, but they do have significant potential to be further implicated into the regional science inquiry. The rest of this chapter is divided into the following major sections. Section 2 presents a short biography of Hirschman. Section 3 examines his major academic contributions to regional science and is organized in several sub-sections. These consist of an examination of his contributions to:

- unbalanced growth strategy
- the relationship between social overhead capital (SOC) and directly productive activities (DPA)
- linkages
- grassroots development
- trade and regional development
- the non-economic factors in development
- rival interpretation of capitalism.

Section 4 discusses the limitations of his work, while Sect. 5 presents conclusions and the legacy of his work for future generations.

2 A Short Biography

Albert O. Hirschman was born on April 7, 1915, in Berlin, Germany, into a Jewish family. He went to Friedrich-Wilhelms-Universität, Berlin, for his law degree in 1932, but the anti-Semitist policy of Hitler, the consequent social upheaval in Germany, and the death of his father led to his emigration to France in April 1933 (Adelman 2013). In Paris, he studied at the École des Hautes Études Commerciales (HEC), and it is said that economic geography courses at the École had a lasting impact upon his academic career (Lepenies 2008). He assimilated in his development thinking the role of regional and geographical features, like topography, climate, and social characteristics, which is why he never became an orthodox economist for the rest of his life. Unlike orthodox economists, he was not solely concerned with economic variables, like investment, saving, interest rate, capital-output ratio, etc., while nevertheless understanding the development processes and outcomes (Lepenies 2008, p. 441; Hirschman 1995, p. 116). He did not shy away from stating, "it was a great relief

to realize that one could do tolerably competent work in economics without having to resolve whether Keynes…had all the right answers" (Hirschman 1995, p. 118). From Paris, he also went to the London School of Economics as a research fellow for a short period of time in 1935–1936.

It is amazing to see Hirschman fighting wars as well as continuing his studies during those difficult times. In 1936, he participated in the Spanish civil war, while at the same time continuing to work on his Ph.D. He received his Ph.D. in economics from the University of Trieste in 1938. That was the time when Keynesianism dominated macro-economic theory. Away from those, he published his first academic paper on the Italian economy. He joined the French army against German aggression in 1940, and once it was no longer possible to resist the Germans, he changed his identity and left for the USA in December 1940.

In the USA, Hirschman received a scholarship from the Rockefeller Foundation, which helped him to work as a researcher at Berkeley. He contributed to statistical analyses of several reports on trade (Alacevich 2021) and, subsequently in 1945, published his first book: *National power and the structure of foreign trade* (Hirschman 1945). He served in the United States Army (1943–1946) and became a US citizen. After that, he worked from 1946 to 1952 with the Federal Reserve Board in Washington on the Marshall Plan for the reconstruction of Western Europe. Later, he became an advisor to the National Planning Board of Colombia (1952–1954). He held various academic appointments related to economics in several American universities, among them: Yale (1956–1958), Columbia (1958–1964), Harvard (1964–1974), and Princeton, in the Institute for Advanced Study (1974–2012).

The turbulence Hirschman had experienced as a young man may well have affected his thinking process when he began his academic career (Lepenies 2008; Grant 2018). In 1932, he was forced to leave Berlin, which, with the rise of Hitler's fascism, becomes a hotspot of polarization against Jews. As a consequence, he lived two lives: "one as an anti-fascist and refugee, the other as a renowned economist" (Lepenies 2008, p. 440).

With rising McCarthyism in the USA in the early 1950s, and given his left-wing sympathies, he moved to Colombia in 1952. Hirschman stayed there with his family for almost four and a half years. He succeeded in reinventing himself as a regional and development economist. Based on what he observed in Colombia, he turned the then in vogue economic development theories on their heads. In 1958, he published his famous book, *The strategy of economic development* (Hirschman 1958), and many other important contributions followed subsequently.

3 Major Contributions

Hirschman wrote on several themes with multiple perspectives. He did not believe that one model or universal economic theory could explain and help design strategies of development everywhere. Rather, he was a pragmatist, who believed that there

are endogenous forces within regional economies which need to be understood and mobilized for the development of regions. In this context, Bray (2009) argues:

> Hirschman was a prolific generator of theories and is associated with the idea that no universal economic development template exists. Strategies had to be designed for the circumstances of a particular country, he maintained, because, contrary to the prevailing belief, there was no single correct sequence of interventions. (Bray 2009, p. 5)

His contribution extended to development economics, the understanding of regional development, political economy, and social psychology. The major books by Hirschman are:

- *National power and the structure of foreign trade* (1945)
- *Colombia: Highlights of a developing economy* (1955)
- *The strategy of economic development* (1958)
- *Latin American issues: Essays and comments* (1961)
- *Journeys toward progress: Studies of economic policymaking in Latin America* (1963)
- *Development projects observed* (1967b)
- *Exit, voice, and loyalty: Responses to decline in firms, organizations, and states* (1970)
- *A bias for hope: Essays on development and Latin America* (1971)
- *The passions and the interests: Political arguments for capitalism before its triumph* (1977)
- *Essays in trespassing: Economics to politics and beyond* (1981c)
- *Shifting involvements: Private interest and public action* (1982)
- *Getting ahead collectively: Grassroots experiences in Latin America* (1984)
- *Rival views of market society* (1986)
- *The rhetoric of reaction* (1991).

Hirschman developed several important concepts and ideas that are helping us to understand development processes and design strategies. These are listed in Table 1 with citations to the works in which Hirschman proposed or developed the respective concepts. Given the limitation of space and scope of this paper, I have only discussed some of these concepts while focusing on his major contributions in regional science.

Hirschman also received several awards. He received the Frank E. Seidman Distinguished Award in Political Economy in 1980, and the American Political Science Association honored him in 2003 with the Benjamin E. Lippincott Award for his exceptional contribution through his book, *The passions and the interests: Political arguments for capitalism before its triumph* (Hirschman 1977).

3.1 Regional Economic Growth and Development

As I have noted already, one of Hirschman's major contributions on regional development is his book, *The strategy of economic development* (Hirschman 1958). Unlike

Table 1 Important ideas and concepts about development processes and design strategies proposed or developed by Albert O. Hirschman

Idea or concept	Work(s) where he originated or elaborated upon the idea
'Trade and political dependence'	Hirschman (1945)
'The Herfindahl–Hirschman Index'	Hirschman (1945, 1964)
'Unbalanced growth strategy'	Hirschman (1958)
'Chain of disequilibria'	Hirschman (1958)
'Growth pole'	Hirschman (1958)
'Trickle down'	Hirschman (1958)
'Linkages'	Hirschman (1958, 1992a, 1992b)
'Hidden rationalities'	Hirschman (1958, 1968, 1992b)
'Blessings in disguise'	Hirschman (1963a)
'Fracasomania' (failure complex)	Hirschman (1963b, 1975)
'Reform mongering'	Hirschman (1963c, 1963d)
'Visiting-economist syndrome'	Hirschman (1963e, 1992b)
'Principle of the hiding hand'	Hirschman (1967a)
'Exit and voice'	Hirschman (1970)
'Bias for hope'	Hirschman (1971a)
'Possibilism'	Hirschman (1971b, 1992c)
'The right to a non-projected future'	Hirschman (1971a)
'Obituary improving activities'	Hirschman (1973a)
'The tunnel effect'	Hirschman (1973b)
'Passions versus interests'	Hirschman (1977, 1992d)
'Trespassing'	Hirschman (1981b)
'Mono-economics'	Hirschman (1981a)
'Rival views of market society'	Hirschman (1982a, 1992e)
'Happiness of pursuit versus free riding in public life'	Hirschman (1982b)
'Shifting involvements'	Hirschman (1982b)
'Getting ahead collectively'	Hirschman (1984)
'Rhetoric of reaction'	Hirschman (1991)
'Propensity to self-subversion'	Hirschman (1995); see also Özçelik (2014, pp. 115–116)

many other economists and idealists of his time, he argued in favor of 'unbalanced' regional and sectoral growth. His major argument in defense of an unbalanced development strategy was, "development depends not so much on finding optimal combinations for given resources and factors of production, as on calling forth and enlisting for development purposes, resources and abilities that are hidden, scattered or badly utilized" (Hirschman 1958, p. 5). This was an attack on the 'balanced growth' strategies, advocated by Rosentein-Rodan (1943) and Nurkse (1953), which required a 'big push' for development of underdeveloped countries. These theories were influenced by Keynesianism, which required active investment by the State. However, for Hirschman, the need for development of underdeveloped regions was just the opposite: *unbalanced* sectoral and regional growth. According to him, this will create regional economic disequilibria and tension for propelling economic growth. This was in fact easier to implement and was pragmatic for countries and regions, as they could prioritize the sectors where the investment can be made first based on the limited resources at their disposal. Balanced growth was the end result for him, which would emerge from the unbalanced growth processes.

Hirschman further summarized the main argument of this book in his co-authored paper with Lindblom:

> At any one point of time, an economy's resources are not to be considered as rigidly fixed in amount, and more resources or factors of production will come into play if development is marked by sectoral imbalances that galvanize private entrepreneurs or public authorities into action … The crucial, but plausible, assumption here is that there is some "slack" in the economy; and that additional investment, hours of work, productivity, and decision making can be squeezed out of it by pressure mechanisms. (Hirschman and Lindblom 1962, pp. 211–212)

In the book, Hirschman argued that the best course of action for regional planning was to identify and invest initially only in strategic sectors/regions, and, because of the interlinkages, all the sectors/regions will grow. He argued that development occurs through "growth being communicated from the leading sector of the economy to the followers, from one industry to another, from one firm to another" (Hirschman 1958, p. 63). Like Perroux (1950), he argues that:

> The process of development is better conceived as 'a chain of disequilibria' in which investment in particular industries raises profit and induces investment in other industries, which in turn promotes further rounds of investment and increased profits in other parts of the economy. (Hirschman 1958, pp. 65–66)

To maintain a chain of disequilibria in the development process, he asserted:

> Our aim must be to *keep alive* rather than to eliminate the disequilibria of which profits and losses are symptoms in a competitive economy. If the economy is to be kept moving ahead, the task of development policy is to maintain tensions, disproportions, and disequilibria. (Emphasis in the original text, Hirschman 1958, p. 66)

Hirschman believed that the key economic problem facing developing countries did not arise because of scarcity of resources, but rather from the fact that factors of production and 'abilities' were 'hidden,' scattered, and badly utilized (Hirschman

1958, p. 5). For him, due to this, "the best development strategy is one which sets up 'pressure', 'tensions', which elicit and mobilise the largest amount of resources, in effect inducing development." (Gore 2013/1995, p. 95)

The unbalanced growth path proposed by Hirschman assumes that an economy is balancing between two sectors—industrial and agricultural—and if the target of the economy is to move forward and grow, the economy can follow either a balanced growth path where both the sectors grow proportionately, called the balanced growth, or the unbalanced growth path where the economy first strides out in one direction (industry or agriculture) and then (as shortages emerge in other sector due to demand generated in the developed sector) the developed sector pulls up the lagging one. He states this as:

> Unbalanced growth means to strike out first in one direction and then, impelled by resulting shortages, balance-of-payments pressures, and other assorted troubles, in the other. …traveling along this circuitous route, which is likely to be more costly because of the accompanying shortages and excess capacities, the economy may get faster to its goal. (Hirschman and Lindblom 1962, p. 213)

3.2 Unbalanced DPA and SOC

Hirschman provided special emphasis on regional development led by Social Overhead Capital rather than its shortages (Friedmann and Alonso 1964). He defined SOC as:

> SOC is usually defined as comprising those basic services without which primary, secondary, and tertiary productive activities cannot function. In its wider sense, it includes all public services from law and order through education and public health to transportation, communications, power and water supply, as well as such agricultural overhead capital as irrigation and drainage systems. (Hirschman 1958, p. 83)

To him, the role of SOC is crucial for further expanding the Directly Productive Activities (consumer goods), which it "permits and, in fact, invites …to come in" (Hirschman 1958, p. 84). He was in favor of SOC-supported unbalanced growth of regional economies. He argued, "Development via shortage is an instance of the 'disorderly,' 'compulsive' sequence" (Hirschman 1958, p. 89), while the "excess SOC capacity is essentially permissive" (p. 93). He favored this zig-zag manner of growth of the economy. In his view "*it is the experience of unbalanced growth in the past that produces, at an advanced stage of economic development, the possibility of balanced growth*" (Emphasis in the original text, Hirschman 1958, p. 93).

3.3 Linkages in the Unbalanced Growth Process

Hirschman also propounded concepts of 'linkages' in the development process. These concepts can be mobilized to understand the regional and sectoral evolutions of economies.

To him, strategizing of investments is needed with regard to whether they will push the backward (linkages) or forward (linkages) production process (Lepenies 2008):

> First, an existing industrial operation, relying initially on imports not only for its equipment and machinery, but also for many of its material inputs, would make pressures towards the domestic manufacture of these inputs and eventually towards a domestic capital goods industry. This dynamic was called *backward linkages,* since the direction of the stimulus towards further investment flows from the finished article back towards the semi-processed or raw material from which it is made or towards the machines which help make it. Another stimulus towards additional investment points in the other direction and is therefore called *forward linkages:* the existence of a given product line A, which is a final good or is used as in input in line B, acts as a stimulant to the establishment of another line C which can also use A as in input. (Emphasis in the original text, Hirschman 1989, pp. 210–211)

The investment in one sector will generate demand from another sector, which, in turn, will lead to investment in that sector. This complementarity effect of investment is the main process through which one can break the vicious circle of underdevelopment. Therefore, to give maximum play to this complementarity process, the last industry in the chain can be located first. Following this analogy, in a spatial context, industries first can be located in big cities.

3.4 Polarization and Trickle-Down Effects

Polarization and trickle-down effects are two other concepts that have often been used in the regional development literature. To explain the regional growth process and its consequences for both the developed and developing regions, Hirschman argued that there is no balanced growth process in regional development:

> Economic progress does not appear everywhere at the same time and that once it has appeared, powerful forces make for a spatial concentration of economic growth around the initial starting points… the emergence of "growing points" or "growth poles" in the course of the development process means that international and interregional inequality of growth is an inevitable concomitant and condition of growth itself. (Hirschman 1958, pp. 183–184)

He recognized the Marshallian economies (Marshall 1961/1890) of scale and the argument by Perroux (1950) about the 'growth pole.' For him, the economic advantage that agglomeration provides is crucial in location decision making by entrepreneurs and helps in creating a growth atmosphere within the region or city. However, this localized growth will not proceed indefinitely. For "once growth takes a firm hold in one part of the national territory, it obviously sets in motion certain forces that act on the remaining parts" (Hirschman 1958, p. 87). This creates a countervailing tendency against polarization. This is what is popularly known as diseconomies of scale. He labels the growing region as 'North' and the lagging region as 'South.'

Hirschman argues that the growth of the North "will have a number of direct economic repercussions—some favourable while others adverse" (Hirschman 1958,

p. 187). The favorable effect he calls 'trickle down,' which occurs through Northern purchases and investments in the South. This helps in raising the factor income, consumption, and labor productivity in the South. The migration of labor from the South to the North and their remittances play an important role in this process of income transfer from North to South. The demand for labor in the North also helps in overcoming unemployment in the South.

Hirschman also recognizes the adverse impact on the South of polarization. The efficient production in the North can depress the economic activities, and the migration can denude the human resources and enterprising men in the South (Hirschman 1958, p. 188). This may lead initially to increase the regional imbalance, but, like Kuznets (1955) and Williamson (1965), he argues that in the long run, the geographical trickle-down effect will be sufficient to reduce such disparities. However, his optimistic conclusions ultimately rest on the theory of state intervention, which is an integral part of Hirschman's unbalanced growth strategy. For him, the State is taken as an equilibrating mechanism—a new kind of invisible hand—and thus:

> If the market forces that express themselves through the trickling-down and polarization effects result in a temporary victory of the latter, deliberate economic policy will come into play to correct the situation. Actually, of course, economic policy will be an important influence throughout the process. (Hirschman 1958, p. 190)

Overall, in the context of regional planning, Hirschman's argument leads to the conclusion that an urban industrial growth pole strategy offers the best way to achieve national growth objectives.

Hirschman, being the kind of self-subversive and reflective regional scientist and economist that he was, realized the limitation of his unbalanced growth model. In the 1988 edition of *The strategy of economic development,* he subverted his own idea and wrote that the sector and regions which may have initial advantage may gain at the expense of the lagging region in the unbalanced growth process, and there may be political consequences of the same (Hirschman 1988, pp. 28, 32). However, he argued that rising inequalities in the development process are tolerated—at least for some time—by those left out because of certain psychological reasons, which he called the 'tunnel effect.' He explains this as follows:

> Suppose that I drive through a two-lane tunnel, both lanes going in the same direction, and run into a serious traffic jam. No car moves in either lane as far as I can see (which is not very far). I am in the left lane and feel dejected. After a while the cars in the right lane begin to move. Naturally, my spirits lift considerably, for I know the jam has been broken and that my lane's turn to move will surely come any moment now. Even though I sit still, I feel much better off than before because of the expectation that I shall soon be on the move. But suppose that the expectation is disappointed and only the right lane keeps moving: in that case I, along with my left lane co-sufferers shall suspect foul play, and many of us will at some point become quite furious and ready to correct manifest injustice by taking direct actions (such as illegally crossing the double line separating the two lanes). (Hirschman 1981a, p. 41)

This explanation of the 'tunnel effect' is very realistic and is derived from his own experiences and observations. This is a powerful explanation of toleration of inequality by those left out rather than only the simple explanation, as by Kuznets

(1955), that inequality rises at the initial state of development only to decline later on as development proceeds.

3.5 *Fieldwork, 'Social Energy,' and Grassroots Development*

Fieldwork and observations constituted the central data collection process for Hirschman. He wrote based on his own observations rather than drawing data from grand, central sources. Starting from his observations, he proceeded to provide abstractions and theorization. Among others, two of his books, *Exit, voice and loyalty* (1970) and *Getting ahead collectively* (1984), are fine examples of this.

In 1983, Hirschman spent fourteen weeks in Latin American countries—The Dominican Republic, Colombia, Peru, Chile, Argentina, and Uruguay—to study, with support from the Inter-America Foundation, 'grassroots development' and 'collective actions.' He drew enormous insight from these field investigations. He used them to explain the 'working' of (regional) development and relations among rulers, the ruled, and social movements. This also highlights the importance of fieldwork in academic inquiry, grassroots organizations and collective actions in people's development, and their relations with national development and political regimes.

Hirschman does not emphasize the grand framework of 'gross' and 'total' but argues that fragmented and particular activities specific to their context do add significantly to the welfare of local communities. These grassroots activities, which can be captured mainly from fieldwork, are important in 'saving souls' and vital for the 'solidarity and hope' of communities, and one does not need to do the 'impossible' task of aggregating them and comparing the resulting 'total' to 'some equally nebulous concept such as General Economic Welfare.' (Hirschman 1984, p. 95)

Grassroots development remained very important to him. Grassroots initiatives and their interactions shape regional economies. However, Hirschman did not want to conflate the contribution of grassroots initiatives to the overall economic development frame. In this regard, he further argues:

> The whole venture of grassroots development has arisen in good measure from a revulsion against the worship of the "gross national product" and of the "rate of growth" as unique arbiters of economic and human progress. Grassroots development refuses to be judged by these standards. (Hirschman 1984, p. 95)

Another important finding from Hirschman's fieldwork in Latin America on grassroots initiatives is that grand political change need not be the first condition of people-centered development. In fact, his findings are consistent with those of Francois Furet, who argued that a change of central power is not a precondition for 'social change' (Scott 1991). In this connection, Hirschman argues that this need for a change in central power is:

> … also being questioned in Latin America, precisely by the grassroots movement. The decision of many middle class professionals to work for the social activist groups is a case in point… Latin America's restless middle-class youth: becoming a *promoter social* whose task

> it is to build self-help communities at the grassroots and thus to achieve human betterment and social change in a less spectacular, but perhaps more fundamental manner. (Emphasis in the original text, Hirschman 1984, p. 96)

His fieldwork in Latin America contributed significantly to understanding of the relationship between 'grassroots' movements and 'centralized' authoritarian regimes. In this context, he argues:

> A dense network of such movements, jointly with a large number of social activist organizations, is bound to change the traditional character of Latin American society in several ways, most of which are not yet well understood. But it seems safe to assert that, with such a network, social relations become *more caring* and *less private*. …. In principle, the formation of cooperatives and other forms of collective action at the grassroots should therefore be incompatible with the very structural requirements of those authoritarian regimes. Perhaps these movements can then claim some credit for the recent weakening and retreats of these regimes which, with all the might and frightfulness at their command, and with their pretensions to introduce a stable new order, seem to have a lifespan of at most ten years? (Emphasis in the original text, Hirschman 1984, pp. 97–98)

In the book, *Getting ahead collectively* (Hirschman 1984), he argued that, as opposed to popular belief in economics, poor people were working together to resolve their hardship and to get ahead collectively, "…that collective action, arguably undertaken because of immediate benefits to each individual, could broaden into public advocacy with less clearly personal benefits" (Bray 2009, p. 5). To Hirschman, these collective actions emerged, because of: (a) the aggression of poor people against powerful individuals, society, and the State responsible for their sufferings, and, more importantly, (b) because of the 'principle of conservation and mutation of social energy.' His important concept of 'social energy' became very popular in 'grassroots' and 'community' development literature (e.g., Lepenies 2008; Dhesi 2000; Adelman 2013). However, he did not develop that further. Bray argues:

> It is a useful concept that exists somewhere between that of "human capital," meaning knowledge, and that of "social capital," personal networks that can be used for economic advancement. He used the term "social energy" in his observation that failure did not always lead to abandonment of collective action. Instead, participants often learned from the failure and tried again later, their social energy in "storage" in the meantime. (Bray 2009, p. 6)

3.6 Trade and Regional Development

Hirschman recognized both beneficial and adverse effect of the trade on regions in his book published in 1945, *National power and the structure of foreign trade* (Hirschman 1945). To him, trade has possibilities to enhance peace; it can alter citizens' behavior from a feudalistic outlook to gentility, and it can promote order. As trade often expands the interest of regions and countries, it has a civilizing effect since the economic interest is more likely to be advanced through peace.

However, unequal trade power can turn dominant countries into monsters. The classic example was Hitler's Germany context, where Nazis attempted to expand

trade through many means. In fact, through this economic means, economic relations were created between countries that made "the pursuit of power a relatively easy task" (Hirschman 1978, p. 46). Nazis capitalized on the side effects or disequilibria, which are otherwise considered harmless trade relations, for exercising power on other countries. Using the example of Hitler's Germany, he argued:

> …sheer economic weight enabled the German empire to exert a considerable political influence on a number of smaller East-European countries. The description of these negative political effects of trade, and of the political dependencies resulting from international economic inequalities, anticipated many arguments employed by the Dependency theory of the 1960s, whose proponents readily claimed Hirschman as one of their own. (Lepenies 2008, p. 443)

It was not Germany alone which exercised the power through trade but, as Hirschman pointed out later, "side effects of foreign trade and investment are still very much with us—two obvious examples are the relations of the United States with Latin America and of the Soviet Union with Eastern Europe" (Hirschman 1978, p. 46).

This is why, in 1945, he differed from other neoclassical economists who claimed that trade could be beneficial to all the trading partners. He argued that trade gains are asymmetrical between countries, and this asymmetry cost is higher for the poor and small countries that engage in trade with large and richer countries. Thus, though he agreed with the usual assumption of beneficial effects of the trade for trade partners, he also highlighted the adverse effect as 'Dependency' theories did.

However, Hirschman was not in complete agreement with the Dependency theorists who were only concerned with demonstrating the structure of relations between unequal economic powers. "They hardly ever explore whether the system might contain the 'seeds of its own destruction' or might otherwise be subject to some changes" (Hirschman 1978, p. 47). In other words, one needs to explore whether in such trading systems there are some endogenous forces which counteract against the continuation and sustaining of dependencies (Lepenies 2008). Using this thought, Hirschman in 1978 argued that the smaller country which pays more attention to its trade relations with a bigger country, and the bigger country which gives less attention to the smaller country as the volume of trade may be small from the smaller countries, may develop a "dialectical movement which would transform an asymmetrical relation, not into its opposite à la Hegel, but at least into a relation of considerably reduced asymmetry" (Hirschman 1978, p. 49). Through these arguments, he countered the doomsdays presented by Dependency theorists while explaining the asymmetry of trade power relations between the USA and Latin American countries.

3.7 Attention to the Non-economic Factors in Economic Theory

Hirschman can be considered an 'interdisciplinary essentialist' in his approach to understanding socio-economic phenomena. He successfully blended the roles of sociology, psychology, geography, and political science in this regard. Besides this,

for him, fusion of these disciplines with economics helps in (a) transcending the artificial barriers erected by a disciplinary essentialist position, which is indispensable for behavioral sciences, and (b) overcoming the feeling of superiority or limitations which one develops while working mainly within a disciplinary confine. I provide a few examples of his arguments below while discussing his other major contribution to economic theory on "repairable lapses of economic actors" (Hirschman 1970, p. 1) in his book, *Exit, voice and loyalty: Response to decline in firms, organizations and states.*

Until the1970s, little attention was paid in formal economic theories to what Hirschman calls 'repairable lapses' of economic actors, but, rather, the 'exit' of consumers was considered as the only solution for correcting the firms' behavior, which Hirschman extended to other organizations including states and political parties. With his interdisciplinary approach, he used the option 'voice' of consumers/stakeholders as another major mechanism for correction of repairable lapses of a 'slack' economy, which he technically defines as the gap between the potential and actual output or quality of a good of a firm or political and organizational leadership. He borrows from the literature on animal (baboon) behavior and beautifully fuses the same into the economic and political behavior of humans to explain why under the surplus production condition, firms/human/state leaders may err and lapses may happen. In this context, he argues:

> The reason for which humans have failed to develop a finely built social process assuring continuity and steady quality in leadership is probably that they did not have to. Most human societies are marked by the existence of a surplus above subsistence. The counterpart of this surplus is society's ability to take considerable deterioration in its stride. A lower level of performance, which would mean disaster for baboons, merely causes discomfort, at least initially, to humans. (Hirschman 1970, p. 6)

Though breached in history many times, like John Stuart Mill's 1848 inquiry into the *Principles of political economy* (1965), Hirschman also considers economic institutions exercising strong barriers to violence and instability, and he extends his purview to authoritarianism and totalitarianism. He, thus, also contributes immensely to criminology and political science. He argues, summing up from other studies:

> While technical progress increases society's surplus above subsistence it also introduces a mechanism of the utmost complexity and delicacy, so that certain types of social misbehavior which previously had unfortunate but tolerable consequences would now be so clearly disastrous that they will be more securely barred than before. (Hirschman 1970, 8–9)

Another of Hirschman's important contributions was on the perpetual nature of slackers being born in the economy. In fact, his book, *Exit, voice and loyalty,* takes a "more radical step in recognizing the importance and pervasiveness of slack" and argues that "it is continuously being generated as a result of some sort of entropy characteristic of human, surplus-producing societies. There's a slacker born every minute…" (Hirschman 1970, pp. 14–15). To overcome the slack, countervailing forces appear, and he argues "decay as an ever-present force constantly on the attack, generates its own cure: … it is likely that the very process of decline activates certain counterforces" (p. 15). Thus, to him, slack is countered by "endogenous forces for

recovery" (p. 15) which are led by the "customer's decision to shift" either through 'exit,' as empathized by Friedman (1962), or 'voice,' which is the opposite of 'exit.' Hirschman's contribution here lies in the recognition of 'voice,' a messy concept; it can be in the form of "critical opinion" inclusive of "faint grumbling to violent protest," is "direct" rather than "roundabout," and "is a political action par excellence" (Hirschman 1970, p. 16), but this was conceived as "cumbersome" by Friedman (1962, p. 91).

Hirschman criticized Friedman's bias against 'voice' and favoring of 'exit.' Hirschman added the importance of voice in the formal theory of 'exit,' which was largely advocated by the economists. This also assured engagement and possibilities of recuperating regional firms and organizations. For him, it was not the cumbersome political channel as expressed by Friedman. He called this the economist's 'Blind Spot,' or as Veblen (1999/1914) referred to it, "Trained incapacity." For Hirschman, exit can be criminal, and it results in desertion, defection, and treason. Thus, he introduces the importance of both the market (demand/exit) and nonmarket (political/voice) working together for the efficiency and sustainability of regional economies. This idea was also introduced in his book, *The strategy of economic development* (Hirschman 1958), where he had argued that "nonmarket forces are not necessarily less 'automatic' than market forces" (p. 63). By introducing the interplays between the 'slack,' 'exit,' and 'voice,' he essentially brought the interdisciplinary approach to the fore. In fact, he argued,

> In developing my play on that basis I hope to demonstrate to political scientists the usefulness of economic concepts *and to economists the usefulness of political concepts*. This reciprocity has been lacking in recent interdisciplinary work… (Emphasis in the original text, Hirschman 1970, p. 19)

3.8 On Varieties of Capitalism

A further important contribution of Hirschman was his recognition of four interpretations of capitalism, which can be called varieties of capitalism, in his book, *Rival views of market society and other recent essays* (1986). These different varieties have implications for the regional development strategies one can adopt as they each in their own way can be said to be contributing to the evolution of spatial economies. He identifies these four rival interpretations of capitalism through concepts like the 'sweet business' (Silk 1988), the 'self-destructive,' the 'feudal shackles,' and the 'feudal blessings.'

These four varieties of capitalism contributed to social development in their own ways, but one common impact has been that they made humans gentler. The sweet business is the early phase of mercantile…

> capitalism, which … led a rather shaky existence, having to contend with a host of precapitalist mentalities left behind by the feudal and other "rude and barbarous" epochs, will create, in the course of time and through the very practice of trade and industry, a set of compatible psychological attitudes and moral dispositions, that are both desirable in themselves and conducive to the further expansion of the system. (Hirschman 1986, p. 109)

According to the self-destructive thesis, which combines thoughts of Marxists and conservative thinkers, such as Hirsch (1977), "…capitalist society, far from fostering *douceur* and other fine attitudes, exhibits a pronounced proclivity to undermining the moral foundations on which any society, including its own, must rest" (Hirschman 1986, p. 110). In this regard, he further argues:

> The advance of capitalism requires, so this story begins, that capitalists save and lead a frugal life so that accumulation can proceed apace. However, at some ill-defined point, increases in wealth resulting from successful accumulation will tend to enervate the spirit of frugality. Demands will be made for dolce vita, that is, for instant, rather than delayed, gratification, and when that happens capitalist progress will grind to a halt. (Hirschman 1986, p. 113)

On the feudal-shackle thesis, he argues:

> …a number of societies that have been penetrated by capitalism are criticized and considered to be in trouble because this penetration has been too partial, timid, and half-hearted, with substantial elements of the previous social order being left intact. These elements are referred to variously as feudal overhang, shackles, remnants, residues, ballast, or relics and they turn out to retain considerable influence and power. (Hirschman 1986, p. 125)

Given the presence of feudal shackles as we see in many countries of Asia, Africa, and Latin America, the bourgeois revolution gets obstructed. As such, capitalism is not able to freely work to transform the society and space economy completely.

To Hirschman, as the USA has no feudal past, it also lacks ideological diversity:

> …the lack of ideological diversity in America has meant the absence of an authentic conservative tradition, is responsible for the often noted weaknesses of socialist movements, and has even made for the protracted sterility of liberal political thought itself. (Hirschman 1986, p. 134)

In this way, he combines from history several thoughts on market and society. Each of the thoughts or perspectives can shape regional policy and may have their own implications for regional development.

4 Limitations and Pragmatism

Hirschman's contribution did not emerge as an integrated perspective toward development, like we see from Sachs (2005) for reduction of regional poverty through a 'big push' in development assistance or a strategy of 'one step at a time,' as propounded by Easterly (2007).

However, Hirschman was skeptical of one solution working for all, which many development institutions followed. Rodrik (2006, p. 986) has appreciated the World Bank's recent advocacy for the 'case by case' solution approach 'rather than top-down model.' Easterly (2006a, 2006b) has also cautioned planners against the 'blue print' approach. In fact, this has been the approach of Hirschman. For him, the solution of the development problems lies in the regional and social context. Hirschman has been critical of grand theories and 'one-size-fits-all' approaches, without naming the

propounders of the grand models like Escobar (1995), Chambers (1996), and Sachs (1991). He himself acknowledged his approach in *Shifting involvements : Private interests and public action* (Hirschman 1982b), advocating that real life is much too complex to be captured through an all-encompassing theory or paradigm (Lepenies 2008).

Hirschman was a reflexive social scientist who was even critical of his own approaches through what he called 'self-subversion' (Hirschman 1995). He denied that there was 'one best way' (Lepenies 2008, p. 447) to development (Hirschman 1963a, 1971a, b). He believed in 'endogenous' development potentials and "calling forth and enlisting for development purposes resources and abilities of the countries and regions that are hidden, scattered or badly utilized" (Hirschman 1988, p. 5). He was annoyed with the approach of some of the elite-led governments of Latin American countries that often changed their development strategies based on the advice of 'visiting economists' (Lepenies 2008) without giving due consideration to the potential of past policies in shaping development. To describe the tendency of new governments to engage in denial or indulge in a failure complex about previous strategies, he coined the term 'fracasomania.' He thus contributed to the alternative philosophy of development (Ellerman 2005), which he called 'possibilism' (Lepenies 2008, p. 448), a concept he mobilized from the discipline of geography and used as an antithesis of 'fracasomania.' He described possibilism as:

> …an approach to the social world that would stress the unique rather than the general, the unexpected rather than the expected, and the possible rather than the probable. For the fundamental bent of my writings has been to widen the limits of what is or what is perceived to be possible, be it at the cost of lowering our ability, real or imaginary, to discern the probable. (Hirschman 1971a, p. 28)

Based on his observations of World Bank projects, Hirschman gave us the 'Principle of the Hiding Hand' (Hirschman 1967a) to describe the unexpected problems that may emerge in executing a development project where the solution of the same can be hidden in the local capacities and resources (Lepenies 2008). He valued local knowledge and traits for success of development. He distinguished two types of projects on the 'knowledge' base: (a) the 'trait-taking' type, based on local knowledge and practices, and (b) the 'trait-making' type, based on non-local knowledge and practices, which require prior training of people for successful execution of the project. However, to succeed, the projects of the latter category would need to adapt to the local settings. This regional contextual approach of Hirschman was also the antithesis of the 'one-size fits all' approach quite common in the donors and practitioners' approach. This academic and practice philosophy of Hirschman explains why he was more fluid rather than rigid in his ideological approach and wanted to 'cross boundaries' of disciplines and thoughts. In fact, he wrote one of his essays with the title 'Crossing boundaries' to explain why he preferred to do this (Hirschman 1998).

5 Conclusions and Hirschman's Legacy for Future Generations

Hirschman made significant contributions to advancing our knowledge and understanding of the processes of regional economic development. His early life was full of difficulties, as he had to escape from, and fight against, fascism in Europe in the 1930s and 1940s. He moved from one place to another and joined armies to fight wars, and yet he was able to direct efforts to carry on his academic pursuits. He led two parallel lives: one that was very personal in Germany, France, Spain, and Italy where he fought the wars; and the other the life of an academic in the USA. However, we find that the academic understanding he evolved was based on an intermingling of these two—the personal and the academic—spheres of his life. His context-based, region-based, unbalanced, collective-action-led, moving together approaches; his view of international trade as the exercising power; and his synthesis of disciplines in understanding development emerged from his own personal experience in the places he fought wars, sought refuge, or traveled as an academic expert or tourist. He was a great synthesizer of ideologies, disciplines, cultures, and languages, and he was, at his core, anti-fascist. As a regional economist, he believed in local development and 'endogeneity.'

He was a reflexive social scientist who questioned his own ideas and their applicability with time. He termed this as 'self-subversion.' However, his 'uncertainty' is not chaotic but paves the way for possibilities of, and optimisms for, local development through utilization of local resources "that are hidden, scattered, or badly utilized" (Hirschman 1988, p. 5). Thus, his approach to development is more pragmatic, context-based, and inclusive in every respect and has enormous potential for sustainable social, economic, and regional development. He did not attempt to provide grand ideas and theories, rather "he favoured 'small ideas' and 'lesser thoughts' that have the potential to generate 'great insights' of practical value" (Özçelik 2014, p. 1115). In fact, we find today that many of his ideas are reflected in the United Nations' Sustainable Development Goals (SDGs), particularly in SDG-8 (Decent Work and Economic Growth, especially Economic Growth), SGD-9 (Industry, Innovation and Infrastructure), SDG-11 (Sustainable Cities and Communities, especially, Sustainable Communities), SDG-16 (Peace, Justice and Strong Institutions), and SDG-17 (Partnerships for the Goals).

Not only did he frame and guide the policies of development (and their implementation) of international organizations like the World Bank, but subsequently many of his ideas also left a deep imprint on these institutions and helped shift their policies beyond revolution and reforms to more pragmatic and realistic approaches.

As a scholar, he combined German idealism, English-US empiricism and political economy, and Italian liberal socialism. He provided very interesting insights on development processes based on his observations rather than concentrating on formal development models. He turned economic theories on their heads as he provided alternative explanations and integrated the different streams of thought in the social sciences without any grand theories. He preferred complexity over certainty. He can

be called a pragmatic idealist. He wanted observation-driven social science, which can offer clues about how to get out of problems and traps. He was always looking for endogenous social theory. He never believed in the shock therapy for development that many mainstream theorists in economics articulate.

Albert O. Hirschman left behind a great fund of ideas for future generations of regional scientists and development economists. He was inherently liberal and influenced by Friedrich Hayek. He was an advocate for the idea that 'nothing goes as planned' in real life, but he also recommended the 'unbalanced growth' strategy for regional development. He was a possibilist and did not adhere to any orthodox theoretical perspectives. He argued that today's developed countries developed without any orthodox planning (Özçelik 2014) through trial and error and mostly led by unbalanced growth. This path can also guide developing regions rather than a prescribed 'balanced development' approach. He used many concepts, including 'chains of disequilibria,' 'unbalanced growth,' 'linkages,' 'hidden rationalities,' 'blessings in disguise,' '*fracasomania,*' 'the hiding hand,' 'the tunnel effect,' the 'last industry first,' and regional 'endogeneity,' to explain his unorthodox understanding of development processes. He was an optimistic regional scientist. His ideas and methods will continue to serve and guide future generations of planners and regional scientists.

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Leslie Curry (1923–2009): Expounder of the Random Spatial Economy and Spatial Autocorrelation

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Leslie Curry, lecturing in New Zealand early in his career. *Photo source* Caryl Curry

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1 Introduction

Leslie Curry (nickname: Les) ranks among the Great Minds in regional science, with his scholarly contributions having significant impacts on the early formation and evolution of this interdisciplinary field, especially in terms of its quantitative theoretical geographic thinking and heritage. Several of his papers appear as special anthology reprints in, among others, Leahy et al. (1970) *Urban Economics* reader, English and Mayfield's (1972) famous compendium, and Noma's (1977) Japanese translated compilation. He made a lasting contribution to a better understanding of geospatial data through his spatial autocorrelation work (foreshadowing the emergence of the spatial statistics and spatial econometrics subdisciplines), and his revolutionary treatment of the gravity model captures spatial autocorrelation latent in geographic flows: a conceptualization Nijkamp and Ratajczak (2021) praise as a key regional science instrument and as undoubtedly one of the most popular regional science models. His influential insights about these descriptors of georeferenced phenomena also link him to other Great Minds, such as Tobler and Ullman. Curry was active in various regional science associations from their early onsets, further contributing to the intellectual development of the discipline through his many conference presentations. His scholarship embraced, as well, transformative pioneering work about settlement theory and stochastic processes, mostly with regard to map pattern description.

2 Biographical Sketch

Leslie Curry was born November 22, 1922, in Gosforth, a suburb of the Northeastern England city of Newcastle upon Tyne, to parents John—a gardener employed by a municipal park—and Sarah (Hedley) Curry. He had one older brother (by four years), Frank. Toward the end of his primary education, he earned a local scholarship for his secondary education, going on to become a star athlete (cross-country and track; see Fig. 1) and soccer player while completing his grammar school education. His running continued as one of his personal hallmarks throughout his career.

Curry was a young man when World War II (WWII) began, and at age 18 he voluntarily joined the British Royal Navy (Fig. 1) on February 24, 1941 (his service commenced on August 6, 1941). He served for five years as a 14th Destroyer Flotilla radar mechanic. This happenchance helped motivate his later academic interest in spatial autocorrelation. He not only served in the Mediterranean, but also participated in the June 1944 Normandy invasion. By the end of WWII, he was training to be a crew member on a submarine destined for deployment to the western Pacific Ocean.

Upon leaving the military, Curry went to university for undergraduate education (with funding from the British government), then on to graduate studies. After graduating with his master's degree, Curry worked for six months as an economic affairs officer at the United Nations (UN), during which time he met and began dating Jean

Fig. 1 Photo montage of Leslie Curry through the years. Top left: competing in a race. Top right: in his WWII Royal Navy uniform. Bottom left: at age 59, Central Park Zoo. Bottom right: in Paris (the early 1980s). *Photo sources* Caryl Curry

Blick, a UN bilingual secretary originally from New York City, who became his first wife. They were married in the Bronx on September 18, 1952, and together had twins (a boy and a girl) and then another daughter. In 1981, Jean died. That same year, Curry was named Connaught Senior Fellow in the Social Sciences and awarded a residency at the Rockefeller Foundation's Study Center on Lake Como at Bellagio, Italy. There, at age 59 (Fig. 1), he met Caryl Pines, who became his second wife nearly a decade later; they were married in September of 1989. They lived in Annapolis, MD, until Curry's death on January 12, 2009 (Sullivan 2009). During his retirement years, Curry returned to the sea by owning a boat, at least to the point of passing the required Coast Guard safety test (apparently skills gained during his days in the Royal Navy were waning).

2.1 Academic Career

Curry's intellectual interests started coming into focus as his university career began in Durham University's King's College—created by the 1937 amalgamation of Durham University's Armstrong College and the College of Medicine in Newcastle, becoming the independent University of Newcastle in 1963—where he studied and then received a joint bachelor of arts (AB) degree in geography and economics (with honors) in 1949. This training was a motivator of his later space economy and quantitative economic geography interests.

Two years later, with Fulbright and Isaiah Bowman School of Geography scholarship funding, he received a Master of Arts (M.A.) degree in geography from the Johns Hopkins University, where, among other things, his coursework introduced him to probabilistic models of queuing and storage theory. His thesis, titled *The use of the regional concept in economic studies,* built upon the works of Ohlin, von Thünen, Christaller, Lösch, Koopmans, and other pioneers of spatial economics, a number of years before geography underwent its quantitative revolution; he was a geographic scholar before his time!

Curry next spent a short time, in 1952 (after his stint at the UN), as Bill Garrison's temporary replacement at the University of Washington. Next, he became a doctoral student in the Department of Geography at the University of Auckland. His position was that of both a member of the teaching staff (an instructor) and a doctoral student in geography, being on staff there for seven years (with responsibilities for climatology courses), specializing in climatology and then graduating with his Ph.D. degree awarded on May 8, 1959; his doctoral dissertation was titled *Climate and livestock in New Zealand: A functional geography.* This research endeavor examined relationships between livestock farming and climate across New Zealand, building upon earlier knowledge he gained while at Thornthwaite's Johns Hopkins University Laboratory of Climatology (Seabrook, New Jersey) for nine months. Curry's New Zealand tenure established his academic interests in probability theory as well as the treatment of storage operations (Curry 2002, p. 87). In 1957, he returned to the University of Washington for three months to teach quantitative methods to its Geography Department's graduate school program.

Curry left New Zealand in 1960, going from there to the University of Maryland, and then to Arizona State University (where his interest in spatial autocorrelation solidified; Curry 2002, p. 88), before settling at the University of Toronto (UofT) for the remainder of his academic career. He arrived in Toronto in 1964 and retired as an emeritus professor in 1985. Curry and his family lived in Rosedale, a rather upscale residential neighborhood in which such world renowned UofT faculty as the non-Euclidean geometrist Coxeter and the urban geographer James Simmons lived.

Table 1 Curry's major/legacy contributions by thematic area

Journal articles	Book chapters
Those writings blended together for his book	
Curry (1967b, 1972a, 1976a, 1976b, 1978b, 1979, 1981a), Curry and Sheppard (1982), Curry (1982b, 1984a, 1984b, 1984c, 1985a, 1985b, 1985c, 1986a, 1989)	Curry (1966c, 1971b, 1977, 1981b, 1983b, 1986b)
Other writings that, along with some of the works chosen for the book, established his enduring legacy as a Great Mind in regional science	
Curry (1952, 1955, 1959, 1960a, 1962a, 1962b, 1963, 1964, 1965, 1970, Curry et al. (1975, 1976)	Curry (1962c, 1966a, 1967a, 1971a)
A remaining assortment of his individual writings on especially quantitative and economic geography topics	
Curry (1960b, 1966b, 1967c, 1969, 1972b, 1982a, 1983a, 1991, 1998a)	Curry (1960c), Curry and Bannister (1974), Curry (1978a, 1987, 1993)

3 Major Intellectual Contributions

Toward the end of his career, while in retirement, Curry published his sole book, titled *The Random Spatial Economy and Its Evolution* (1998b). It represents a lifetime of research and publishing work and essentially is a loose integration of 23 of his published pieces (see Table 1). Collectively, these articles place Curry in the general category of theoretical geographer, a scholar who scrutinizes the generation, differentiation, and change through time of patterns, structures, and systems that can be represented on a map, as well as how individuals' behaviors connect to them, seeking explanations that furnish predictions of these map patterns, structures, and systems. He self-described his scholastic ilk and curiosities as follows:

> Geography studies spatial arrangements and resulting flows over the Earth's surface. Economic geography addresses the areal commercial structures and processes by which the world works and evolves. These are usually much too complex to be understood directly so that simplified models of them are abstracted in attempts to see the logic involved. Hence theory! Imaginary worlds are created in hopes of providing insights about the real world. We theoretical economic geographers are distinct from economists in that our concern is with areas and spatial processes, theirs with value theory.[1]

This statement sets the stage for at least one of Curry's legacies: his extremely insightful and novel contribution to gravity model specifications describing geographic flows.

[1] From personal written archival materials provided by Curry's widow, Caryl.

3.1 Contributions to Climatology: Early Career Years

The middle panel of Table 1 shows the major journal articles and book chapters by Curry, including those appearing in the climatology literature. Curry (2002, p. 87) eventually characterizes his work during this period as "two lifelong interests emerged…; probability theory … and the treatment of storage operations." Curry (2002, p. 88) describes the context of his first *Annals of the Association of American Geographers* (1962a) paper as follows: "I started taking stochastic processes seriously as a way of life: this was the way the world worked. As I saw it, climatic change as a random series again involved storage." Curry's future Toronto colleague, distinguished climatologist Kenneth Hare, later commented that this specific paper contributed a significant intellectual breakthrough to the climatology field (Johnston 2010, p. 390). King (2009, p. 156) writes about papers Curry (1962b, 1963) derived from his doctoral dissertation that "[t]heir analysis of pastoral farming, 'a commonplace picture' in which 'one may discern the poetry of finely modulated, integrated systems, the drama of risks taken, the statement and the solution of problems of baffling complexity', was brilliant, elegant and novel in the economic geography literature." Johnston (2010, p. 390) further writes that these two papers "… brought climatology and economic geography together in novel ways, treating climate as varying both temporally and spatially but having to be addressed as 'not a fact but a theory … because each investigator [has] to provide an ordering of the weather experience appropriate to his own purposes' (Curry 1963, p. 95)." Notable is that Curry unsuccessfully "… tried to develop an analytic queuing model rather than simulating to obtain actual evapotranspiration …" (Curry 2002, p. 87), a disappointment helping to usher out his climatology era, which essentially ended with the publication of his 1965 journal paper about the topic, but not before publishing a book chapter now considered a "… pioneering application of Bayesian statistics, suggesting that farmers use their appreciations of the experienced recent past as the basis for their decisions: 'Given the range of possibilities, utilities can be assigned and decisions taken: without them decisions become gambles' (Curry 1966a, b, c, pp. 136–37)" (Johnston 2010, p. 390).

The closure of this period in Curry's academic life coincided with the beginning of one concentrating on economic geography. Curry abandoned climatology, declaring "Nothing interesting there" (Johnston 2010, p. 390). He already had begun transferring his skills to economic geographic analysis with the publication of his 1960 *Lund Studies* paper, followed by his famous 1964 *Annals of the AAG* paper on the random spatial economy (Table 1).

3.2 *Selected Quantitative Economic Geography Contributions: Mid- and Late-Career Years*

Curry's quantitative and economic geography publications cluster into three groupings: (1) those he blended for his book, *Random Spatial Economy and Its Evolution* (1998b); (2) others that, along with some of the works chosen for the book, established his enduring legacy as a Great Mind in regional science to be discussed in detail in this chapter; and (3) a remaining assortment of his individual writings on quantitative and economic geography topics. Table 1 enumerates the various works included in these clusters. The first group constitutes the topic of Sect. 3.3, and the non-climatological pieces in the second group constitute a foundation for the subsequent Sect. 4.

Curry's publications in the third category here are classified as "other" works solely because of the focus of this chapter; they are somewhat reflective of his 19 H-index value (calculated with Google Scholar data as of May 8, 2021). His most cited composition (Curry 1972a) currently has 276 overall citations and is the fundamental essay for his gravity model legacy. His two most cited entries in category (3) presently have 69 (a book chapter) and 53 (a journal article) citations. The former, "The geography of service centres within towns; the elements of an operational approach" (Curry 1960c), is considered a classic by many senior urban economic geographers and regional scientists. It enjoys a long life, having been cited as recently as (2018) by van Meeteren and Poorthuis. His other reasonably well-cited miscellaneous publication, "A note on spatial association" (Curry 1966b), has fared almost equally as well, being cited by Jacobs-Crisioni et al. (2014) in a journal article, and by a book chapter author in Yagamata and Seya's (2018) edited collection.

Because this subsection devotes attention to depicting Curry's overall non-climatological publishing history, it seems the suitable place to present some context for his three North Atlantic Treaty Organization (NATO) Advanced Studies Institute (ASI) book chapters. These pieces symbolize his tradition of writing his research papers while summering in Europe. The NATO Scientific Affairs Division, in Brussels, Belgium, sponsored a civilian research program that funded specialized conferences (up to three with related themes) at designated (usually renovated historical sites) facilities across Western Europe; the former Eastern Europe now enjoys an expansion of this program. The geostatistics community had an extremely successful outcome with this research support mechanism (even today, histories of geostatistics continue to mention its formative ASIs), which motivated me to seek funding for quantitative space–time themed conferences. During my doctoral program of study at the UofT, Curry had encouraged my desire and then efforts to organize a mathematical spatial theory titled special session at the 1975 Milwaukee annual AAG meeting. We were taking advantage of the program openness Curry achieved with his 1973 Atlanta business meeting public remarks. He helped me obtain participation commitments from such regional science luminaries as Ben Stevens, as well as other prominent regional scientists. Later, *Environment and Planning A* published some of the final papers generated by this session that were at the frontiers of our research

interests. This experience was both rewarding and a primary motivator of my NATO ASI pursuits.

I secured the first ASI funding and co-convened it with Ross MacKinnon. As already noted, Curry liked to spend summers in Europe, particularly in Greece; he comments in his *Geographic Voices* chapter that "[Jean and I] tried a different island or group of islands each year, Naxos, Samos, Paros, Rhodes, Corfu, Cos, and others" (Curry 2002, p. 92). MacKinnon and I met Curry in Paris (see Fig. 1) in July of 1980, and the three of us drove to Chateau de Bonas, in Southern France (near Auch, of Tour de France fame). This two-week sojourn resulted in Curry's (1981b) book chapter. Curry did a long run each day, sometimes in the afternoon and sometimes in the evening, depending upon breakout session scheduling; lecturers delivered their presentations to participants in the mornings. The second ASI, co-convened in July 1982 with Tony Lea at Centro studi <i Cappuccini>, was held in San Miniato, Italy. This two-week sojourn resulted in another of Curry's (1983b) book chapters. Again, he ran each day, with the timing of his runs based upon scheduled ASI events. The third, and final, ASI of this series, co-convened with Bob Haining, took place in Hanstholm, Denmark, in August 1985, and resulted in yet another of Curry's (1986b) book chapters: a foundational penning for his subsequent book. Once more, when time permitted, Curry did his daily run. All three of these book chapters became integral parts of the anthology-style book Curry produced in retirement. Their intellectual content is a topic of the next subsection.

3.3 Curry's Book: Retirement Years

Curry selected 17 journal articles and 6 book chapters from 15 publishers as his most influential pieces, securing copyright permission to weave them together into his single book comprising 7 sections. Curry's assessment of his most important works agrees to some degree with recently compiled citation counts.

Curry writes the following essay in his Prologue (Curry 1998a, b, p. xi) to his book:

> … this is a theoretical study, representing a lifetime's pursuit of understanding how the economy works geographically. Unfortunately, our discipline does not have a tradition of theory; even Immanuel Kant reads like the worst form of "capes and bays" gazet[t]eer. But nowadays no one with any curiosity about the surface of the earth and its myriad places can avoid coming to grips with theorizing—attempting to generalize, looking for processes. … The "Random Spatial Economy" (RSE) was a term that I dreamed up on a whim in 1964. It had no past and was to have no future. I little thought that I would be spending a quarter of a century working away at it.

This statement underlines a catch-phrase for Curry: the random spatial economy. It also underlines the previously declared classification of him as a theoretical geographer.[2]

[2] As an aside, Bannister coined the eponymous phrase "the Curry effect," referring to spatial auto-correlation effects in spatial interaction data in terms of the convolution of distance with human

Paraphrasing Curry (1998a, b, pp. x–xvii), this volume constituted a highly innovative first attempt at a consistent theoretical framework capturing the elements, structures, and dynamics of the geography of economic agents, human settlements, and trade flows. Curry drafted narratives asserting abstraction from the particular, with a fairly general conceptualization that sought to explain articulation of the preceding concepts. His objective was to establish a simplified model that provides insights into a hopelessly complex reality. Constrained chance replaces determinism, aggregate populations replace hypothetical representative individuals, variability replaces uniformity, and stochastic processes replace unique history. Ignorance is a major factor in these inter-personal and inter-locational commercial relations (e.g., spatial autocorrelation in spatial interaction effects), shifting focus to flows of information and their effects on the efficiency of the space economy, or, alternatively, on changes in its information content. The narrow set of economic geography themes addressed includes: organization of, geographic variation in, and linkages among places housing the work of the world, the use of land and its resources, usage constraints arising from the motivation and practices of various cultural groups, direct interactions between economies and their immediate physical environments, and the nature and degree of geographic interactions among neighboring economies (i.e., spatial autocorrelation). Accordingly, the communicated concern is with spatial interaction of both inter-personal and inter-regional commerce; the substantive focus is on the existence of and processes generating evolving geographical structures.

Methodologically focused, this book integrates recent work at its time of publication about the role of spatial arrangement in many physical and social sciences, assembling and then translating this cognate subject matter into an overriding geographical viewpoint. Key concepts include: location potential, distance friction, mobility, diffusion, spatial pattern and texture, adaptability, efficiency, and spatial interaction and dependence. Analytic methods include: autocovariance (re spatial autocorrelation) and transfer functions and areal spectral densities and entropy. Examinations extend to various forms of the self-organization of economic spatial patterns.

Kanaroglou (2003, p. 256) evaluates this book by saying "Overall, although hard to penetrate at times, this volume is full of great ideas and belongs on the shelves of all researchers in spatial analysis and economic geography." He comments that Curry's highlighting of the elements that one must account for when studying economic geography phenomena is particularly effective, providing ideas about the necessary tools for doing so, a contribution that quantitative economic geographers should not underestimate. Kanaroglou further notes that because one aim of the models appearing in this book is to understand economic processes across space, Curry appropriately incorporates the term "spatial economy" in its title. MacKinnon (2004, p. 113) echoes Kanaroglou's sentiments, stating that "The articles included here are formidable in terms of their scope and difficulty" and noting "… passages that are difficult to appreciate, either because they are technically demanding, unclear in

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behavior and map pattern. This term appears in Gould (2000, p. 65), referencing Curry's 1972a highly cited *Regional Studies* article, but its use never became fashionable; in addition, Curry did not like it.

exposition, or obscure in their empirical referents," while also expressing that this compendium builds upon at least two of Curry's seminal papers. In addition, MacKinnon agrees that a geographic viewpoint guides all of Curry's scholarship, emphasizing that Curry frequently borrows theories and models from disparate disciplinary sources (e.g., economics, biology, physics, operations research, climatology, engineering, statistics, and mathematics). MacKinnon (2004, p. 114) assesses this book as follows: "… this is an amazing body of work—grand theorizing that is unique in geography. Curry is clearly a deep thinker with a span of knowledge and insight that is astounding. Geography is much richer for his presence and dedication to our discipline."

4 A Broader Context for Curry's Work

This section spotlights the broader quantitative economic geography context of Curry's work encompassing the substance of both his book and his contributions to regional science; this restriction in no way dismisses or diminishes his climatology contributions. His beyond-climatology interest dates back to his master's program of study, in which, as already mentioned, he explored works by the great location theorists and other pioneers of spatial economics (e.g., he presented Hotelling's spatial competition geographic landscape in some of his UofT courses). Contextualizing his contributions and positioning them in a broader paradigm also situates them within the writings of Beckmann, Eigen, Ising, Lotka-Volterra, Lowry, Nijkamp, Paelinck, Prigogine, Weber, and Wilson. The intellectual background was one in which regional science à la Isard, urban economics à la Mills (1997) [O'Sullivan (2019) adding a contemporary version], and regional economics à la Richardson were emerging. The *Journal of Urban Economics* appeared in 1974, as did *Regional and Urban Economics* earlier, in 1971 (which became *Regional Science and Urban Economics* in 1975). Dean et al. (1970) and Leahy et al. (1970) supply useful anthologies, whereas Richardson (1969) supplies a comprehensive survey, for this backdrop. Meanwhile, Ponsard (1983) provides an informative historical synopsis of this literature. The more contemporary Urban Economics Association hosted its first meetings in 2006. In other words, Curry formulated his work within this developmental trajectory, also resorting to the nascent scholarship about complex dynamical systems, foreshadowing developments to come in the profession.

In the mid-1970s, Curry began thoroughly educating himself about classical physics potential theory, which developed from the theories of gravitation and of electrostatics. Familiar for decades with an analogous form of gravitational analysis that had been a key instrument in analyzing geographic flows (e.g., Nijkamp and Ratajczak 2021), Curry shifted his attention to physics potential fields to describe not only geographical variability in price, but also price gradients that drive economic commodity flows. Sheppard (1979) further pursued this new variant of research, resulting in their 1981 collaboration (entry #16 for his book), examining the notion of spatial price equilibrium from a potential theory standpoint, and rendering an actual

Table 2 Brief history of the Ising model in geographical analysis

Year	Event
1925	The one-dimensional Ising model derived (from Ising's 1924 doctoral dissertation)
1944	Onsager's extension of the Ising model to two dimensions
1972	Besag coins the term "auto-logistic"
1975	Bartlett links the Ising and auto-logistic models
1985	Haining applies the Ising model–based auto-logistic model to spatial price competition
1985	Curry applies the Ising model to geographic labor markets
1998	Huffer and Wu derive Markov chain Monte Carlo maximum likelihood estimates (MCMC-MLEs) for the auto-logistic model
2004	Griffith devises the Moran eigenvector spatial filtering (MESF) auto-logistic alternative specification

market situation solution with it. Curry exploited the two-dimensional Ising model (re spatial autocorrelation) to capture inefficiencies in the geographical operation of labor markets (entry #21 for his book) in terms of phase transitions, demonstrating a mechanism that could fragment a coherent geographic labor market into separate stable zones of employment and unemployment. The Ising model involves a Bernoulli random variable and hence relates to an auto-logistic model specification. Table 2 summarizes its history.

In addition, Curry (entry #2 for his book) describes macroscopic occupational competition in a spatially structured labor market with the Lotka-Volterra predator–prey model, rewriting it to establish a microscopic foundation. He argues that the Lotka-Volterra equations are not inherently biological; rather, they represent an interaction matrix, one having negative coefficients for geographic labor markets. Occupations compete for recruits, do not struggle for existence and may grow or decline: "survival of the fittest" translates into an ability of an occupation to reproduce itself through recruiting. Manfred Eigen introduced the hypercycle (a natural self-organizing principle embodying a cycle of connected, self-replicating very large molecules composed of thousands of covalently bonded atoms) in 1971. This was another conceptualization Curry found insightful and useful, and he introduced (in entry #24 for his book) this construct as a formal mathematical structure of general villages and settlements. However, he ignores its biochemical origins and treats it as though it was devised to investigate the evolution of settlements. He uses this notion to denote a primitive economic organization, analogous to either medieval European village organization or contemporary India with internal commerce based upon direct contact between occupations. The first requirement for any type of phenomenon to evolve is reasonably accurate self-reproduction: A geographic labor market occupation is only viable if it can recruit successors to replace those who retire or die. A necessary condition is that not only a single occupation must reproduce itself, but also an entire set of coupled occupations must do so. To achieve this end requires three occupational properties: (1) correct roles populate a geographic labor market;

(2) information flow works in the space economy to ensure that these roles reproduce; and (3) scope for change exists, such that better roles are allowed without unduly affecting the entire set of occupations. The hypercycle embraces these characteristics, allowing it to serve as a mechanism in urban economies.

Finally, Curry (entry #18 for his book) proposes to overcome the naive morphological studies of commercial geography and the spaceless structural ideas of economics by employing Prigogine's Brusselator, a theoretical model for a genre of spatial economic reactions concerning trade and its geographic arrangement foundation that also serve as a catalyst for the same or coupled reactions, with the possibility of a set of such reactions collectively becoming self-sustaining; spatial autocorrelation plays a crucial role here.

Sheppard (2010, p. 397) interprets the preceding natural science sourced depictions as "utilizing emergent scholarship on complex dynamical systems almost two decades before it became popular in geography," which furnishes a bridge between previous and contemporaneous contributions by his colleagues and others. Today, the Ising model continues to be utilized to describe geographic variation (e.g., Schawe et al. 2017). The Lotka-Volterra model supports diffusion of disease investigations (e.g., Sarkar and Pal. 2020). Eigen's hypercycle informs an understanding of nonlinear urban system characteristics (e.g., Dongchen et al. 2014). And, Prigogine's Brusselator relates to, for example, spatial analysis through spatial pattern generation (e.g., Ekaterinchuk and Ryashko 2016). Interestingly, spinoffs from Curry's adaption of potential theory remain absent. The discipline of geography and the field of regional science have come a long way since a launching of the new urban economics by Curry and some of his contemporaries.

5 The Present Relevance of Curry's Work: Whither a Research Legacy?

Haining (2010, p. 393) delivers suitable remarks about what has become at least part of Curry's research legacy, namely a set of unanswered questions posed by him that guide some present-day spatial analysts. Haining categorizes two of these as Curry's "most important contributions to [the spatial analysis] literature"; Table 1 enumerates affiliated publications. The first theme arises from Curry (1970, 1971a, b) wherein:

> ... he proposed decomposing maps into different scales of variation which could be used as the building blocks for forecasting. His method was based on a form of spatial averaging that identified local departures from averages calculated at different map scales.

The other concerns the spatial analysis of gravity model descriptions of geographic flows:

> Curry (1972a) published a significant paper that continues to make an impact in the field of spatial interaction modelling … Among other problems, he considered those associated with estimating the parameters of the unconstrained gravity model. … his view, that friction

of distance effects and the map structure of the origins and destinations were confounded making it difficult (indeed impossible) to determine the true distance exponent in empirical fits of the gravity model.

This second theme garnered Curry a large share of his total citations: 276 for the original paper and 102 and 53, respectively, for his exchanges with Cliff and Ord that were co-authored by Sheppard and me. Efficiently, effectively, and comprehensively addressing this particular research question had to wait decades for appropriate computer technology to evolve.

5.1 Geographic Data Cascading

Curry argued that spatial analysis needs specialized methods, acknowledging that this condition is attributable in part to spatial variation existing at different scales. Accordingly, he devised a scale decomposition data cascading technique. When designing this procedure, one goal was that computational requirements should not be too onerous. The resulting data organization resembles the quad tree structure of geographic information systems databases (Fig. 2a): It organizes a large spatial tessellation into a multi-level hierarchical structure with multiple segmentations at each level, and, for a regular square tessellation (e.g., a remotely sensed image), it is similar to an image pyramid in remote sensing.

Research dating back to my doctoral dissertation, supervised by Curry, eventually spawned Moran eigenvector spatial filtering (MESF; see Table 2) to account for spatial autocorrelation in geographic regression model specifications (Griffith

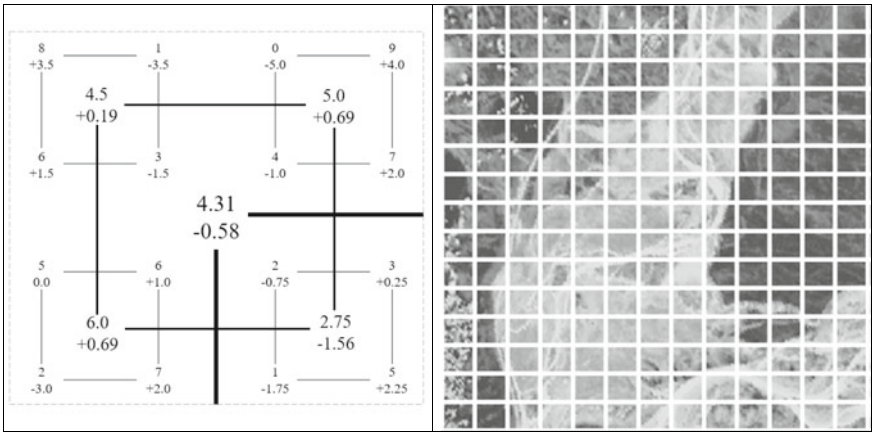

Fig. 2 Left **a**: a graphical illustration of Curry's geographic data cascading technique (adapted from Curry 1971a, b, p. 12; see Table 1); right **b**: a remotely sensed image subregion segmentation (demarcated by white boundaries) of part of Yellowstone National Park with a superimposed mesh of subregions to support a cascading scheme. *Source* Created by the author

2003). This methodology constructs n synthetic variates from an n-by-n spatial weights matrix, where n denotes the number of locations; functioning as covariates, a subset of these accounts for spatial autocorrelation in data geographically distributed across the arrangement of locations designated by the given spatial weights matrix. The methodological challenge arises from extending this data analytic approach to remotely sensed datasets, whose pixels number from the hundreds of thousands through the tens of millions. Curry's cascading procedure furnishes a convenient and effective way to handle this challenge. A three-level structure example implementation for a Landsat 7 remotely sensed image is as follows: A regular square tessellation of pixels is divided into multiple segments at the first (or finest resolution) level, with an aggregation of these segments comprising subregions at the second level; the third (coarsest resolution) level tessellation is constructed by aggregating the second level segments. Figure 2b portrays these first and second levels; partitioning this image further by constructing 5-by-5 square collections of white subregions forms the third level. This local regionalization allows estimation of an eigenvector spatial filter (ESF) for each of the subregions by level; concatenating these ESFs yields an almost perfect composite global ESF. This strategy converts a single n-variate regression analysis into K smaller n_L (the number of pixels in each region for a specific level; e.g., Fig. 2b) regression analyses, where $n = Kn_L$; expediency necessitates trimming an image's edges to ensure that n/K is an integer. Chun and Griffith (2019) successfully adapt this version of Curry's cascading scheme to analyze massively large remotely sensed images, deciding from their summarized empirical and simulation analyses that a square, 25-by-25 subregion seemingly is an ideal size.

5.2 The Curry Effect

Consider the following doubly constrained gravity model description of spatial interaction flows (see Sen and Smith 1995):

$$F_{\mathrm{ij}} \approx \kappa e^{\mathrm{SF}_{O_i \times D_j}} A_i O_i B_j D_j \mathrm{e}^{-\gamma d_{\mathrm{ij}}},$$

where F_{ij} denotes the flow between origin areal unit i and destination areal unit j, A_i and B_j respectively denote the origin and destination balancing factors (ensuring that total predicted and observed in/out flows are equal), O_i and D_j respectively denote the observed in/out flows, d_{ij} denotes the distance separating origin i and destination j, γ denotes a distance decay parameter to be estimated, and κ denotes a constant of proportionality that often is set to 1 because it is absorbed by $\mathrm{A_i}$ and/or $\mathrm{B_j}$. Curry accepted Wilson's negative exponential distance decay derivation appearing here. Parameter estimation is by Poisson regression when F_{ij} are counts, with log-F_{ij} utilized for normal approximation-based parameter estimation. The term $\mathrm{e}^{\mathrm{SF}_{O_i \times D_j}}$ integrates into this specification a certain source of spatial autocorrelation latent in

geographic flows data. Prior to Curry's 1972a paper, $e^{SF_{O_i \times D_j}} \equiv 1$; thereafter, it gained wide recognition as being variable.

In 1972, with co-authored follow-ups in 1975 and 1976 (see Table 1), exploiting the way Lowry used a gravity model describing spatial interaction, Curry (1972a, p. 137) theorized that.

> ... allocating [a] "pure" gravity number to a particular destination, the pure gravity total may be greater or less than the known total for that destination. This means that each origin will send some of its people greater distances or lesser distances than pure gravity on various legs of the total distance.

This proposition declares that the term $e^{SF_{O_i \times D_j}} \not\equiv 1$; rather, the geographic arrangements of flow origins and destinations influence nearby flows between locations (i.e., spatial autocorrelation at work; Fig. 3). The geographic distributions of A_i and B_j offered some, but only a partial, accounting of spatial autocorrelation in spatial interaction data. The continued presence of this dependency in georeferenced flows data also transfers to and corrupts the estimation of γ.

Figure 3a illustrates Curry's contention. The principal areal unit flow is between the two black transportation zones (denoted by a heavy arrowed solid black line showing the direction of the flow). Spatial autocorrelation enters this geographic landscape by this principal flow being correlated with flows from the origin (i.e., the City of Toronto) to the gray zones surrounding the principal destination (denoted by an intermediate width arrowed solid black line): The probability of these flows

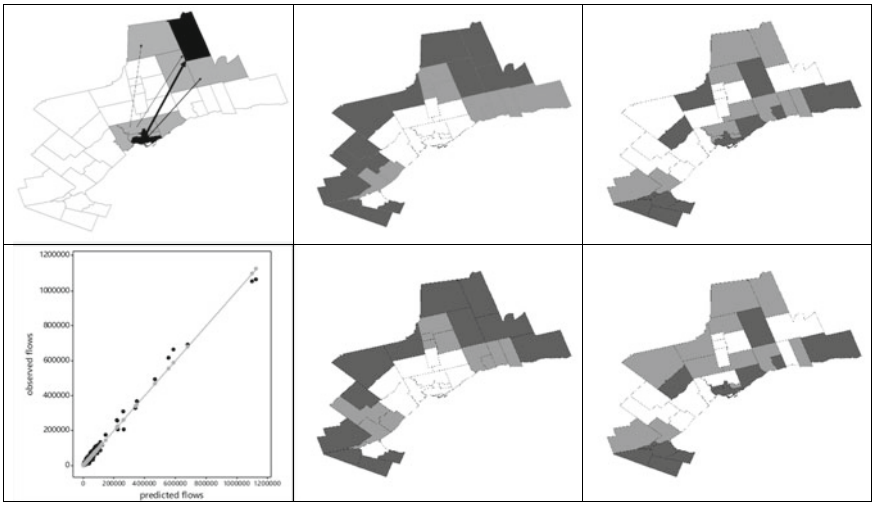

Fig. 3 ESF-DCGM results for the 2011 Toronto transportation survey; for maps (b), (c), (e), and (f), white denotes low, gray denotes intermediate, and black denotes high values. Top left **a**: illustrative spatial dependence sources and materialization. Top middle **b**: LN(A_i); MC = 0.57, GR = 0.42. Top right **c**: origin flows ESF; MC = 0.41, GR = 0.50. Bottom left **d**: scatterplot of predicted and observed flows. Bottom middle **e**: LN(B_j); MC = 0.57, GR = 0.42. Bottom right **f**: destination flows ESF; MC = 0.41, GR = 0.49. *Source* Created by the author

occurring is in/deflated simply by their origin/destination locational relationships with the principal flow. Flows from gray origins to the principal destination (denoted by a narrow width arrowed solid black line) also endure this effect, as do the flows between gray origins and gray destinations (denoted by a narrow width arrowed dotted black line). The $e^{SF_{O_i \times D_j}}$ term creates this in/deflation: Because ESFs have means of zero, a negative ESF value yields a multiplicative factor between 0 and 1, deflating what otherwise would be the predicted independent flow; an approximately zero ESF value essentially yields a multiplicative factor of 1, leaving the predicted independent flow unaltered; and a positive ESF value yields a multiplicative factor greater then 1, inflating what otherwise would be the predicted independent flow. This is spatial autocorrelation at work!

Table 3 summarizes estimation results for three specimen journey-to-work flows datasets, with this particular type of flow being selected because Curry comments about commuting in his 1972a article. In all three cases, the simple gravity model specification furnishes a respectable description of flows, although one with an incorrect distance decay parameter estimate, exactly as Curry claimed. Capturing some of the spatial autocorrelation in these data (Fig. 3b, e) buried in the geographic distribution of workers and of jobs improves model performance (e.g., reduced extra-Poisson variation and an increased pseudo-R^2) and slightly alters the distance decay parameter estimate. Capturing the remaining spatial autocorrelation (Fig. 3c, f), that portrayed in Fig. 3a, further improves model performance (the V-shaped increasing dispersion affiliated with a Poisson random variable gives way to a much better alignment between the predicted and observed flows; see Fig. 3d) and dramatically reduces the distance decay parameter estimate. This is the "Curry effect" established in Curry's 1972a article.

5.3 Present Relevance of Curry's Work

Although this section restricts attention to two specific studies, it exemplifies that Curry's publications have had major impacts, have been followed up by others, and are of a trend-setting nature. For example, Griffith and Jones (1980) documented the presence of one reservoir of spatial autocorrelation, that in the A_i and B_j balancing factors of a double-constrained gravity model, within a decade of Curry's 1972a article appearing. The other reservoir, which scholars label network spatial autocorrelation and which relates to the three arrow links in Fig. 3a other than the thick black one, has been far more difficult to quantify. Bolduc et al. (1992) achieved this end with a computationally intensive procedure that discouraged, and in some case prevented, other spatial analysts from implementing it. With the advent of computer RAM, ROM, chip clock speed, and multiple processor design advances, numerical constraints dramatically diminished. Consequently, LeSage and Pace (2008) formulated a modified gravity model that employed the log-normal approximation and a standard spatial autoregressive specification. Chun and Griffith (2011) formulated a MESF-modified gravity model, with their specification including ESF terms (e.g.,

Table 3 Poisson regression estimation results for selected gravity model specifications

Specification	$\hat{\gamma}$	Over-dispersion	Pseudo-R^2	Bivariate regression		Spatial autocorrelation		
				a	b	Normalizing factor	MC	GR
Toronto journey-to-work ($n = 36$)								
GM	10.06	79	0.844	3056	0.703			
DCGM	11.03	41	0.981	−250	1.024	A_i	0.57	0.42
						B_j	0.57	0.42
ESF-DCGM	8.86	31	0.989	47	0.995	A_i	0.41	0.50
						B_j	0.41	0.49
Seoul journey-to-work ($n = 77$)								
GM	14.17	3257	0.645	−1309	1.336			
DCGM	13.84	1992	0.783	−114	1.029	A_i	0.41	0.12
						B_j	0.59	0.18
ESF-DCGM	10.32	1291	0.890	−224	1.058	A_i	0.17	0.94
						B_j	0.21	0.82
Germany journey-to-work ($n = 439$)								
GM	5.57	201	0.919	−41.2	1.289			
DCGM	5.64	166	0.933	−5.5	1.039	A_i	0.94	0.03
						B_j	0.94	0.02
ESF-DCGM	3.14	69	0.974	−4.2	1.030	A_i	0.86	0.34
						B_j	0.80	0.33

MC denotes the Moran coefficient spatial autocorrelation index
GR denotes the Geary ratio spatial autocorrelation index
GM denotes the simple unconstrained gravity model equation
DCGM denotes the doubly constrained gravity model equation
ESF-DCGM denotes the doubly constrained gravity model equation explicitly containing the term $e^{SF_{O_i \times D_j}}$

Fig. 3c, f). Griffith et al. (2017) compare these two alternatives. Meanwhile, Metulini et al. (2018) extend this analysis to one that accounts for the excessive number of zeroes that frequently appears in origin–destination (O-D) tables.

6 Policy and Societal Impact of Curry's Work

Curry crafted little applied or policy-relevant work. Two exceptions were his pair of jointly authored reports, one to the US Geological Survey (Curry and McDougall 1972) and the other for UofT's Centre for Urban and Community Studies (Curry and MacKinnon 1974).

Curry cited the first, co-authored in 1972 with E. Bruce McDougall, entitled "Statistical Spatial Analysis and Remotely Sensed Imagery," in his co-authored book chapter with Bannister, his *Geographica Polonica* article, and his *Man, Culture and Settlement* book entry. Gould (1975, pp. 310, 218) comments on the ingenious use of optical computers for spatial forecasting reported in this document.

"Aggregate dynamic urban models oriented towards policy," co-authored by Ross D. MacKinnon, with contributions by Eric Sheppard, Russell Lee, and John Miron, is a 1974 report submitted to the Canadian Ministry of State for Urban Affairs. Its overall goal was to attempt to demonstrate the policy relevance of the scrutinized models, all of which exhibit potential relevance to policy related matters, have formulations that assume a willingness and capability to control urban development by the Canadian government, and encourage initiation of a discussion with policy makers to determine whether or not these models are relevant, as well as how they could be made more relevant to policy questions.

7 Scientific Recognitions

As a prominent scholar, Curry was the recipient of a number of honors/awards/recognitions. During his long and distinguished career, and without discernible mathematical spatial theory precedent beyond some piecemeal spatial economics literature, the preceding sections underscore that his scholarship developed innovative, transformative, and highly mathematical approaches to locational analysis based upon stochastic variation—drawing upon probability theory mathematics and physical systems analysis concepts—and promoted the perspective that the importance of economic geography depends upon a healthy suspicion of neoclassical economic theory. His contributions to spatial analytic economic geography brought into question the highly problematic Walrasian assumptions that rational individuals in a free market would construct a socially rational geographic landscape. By doing so, his work challenged established lines of thinking and provided valuable new insights into the ways human behavior shapes the world in which we live. Gould (1985, p. 99) characterizes him as "one of geography's major and most imaginative theoreticians," also noting (p. 115) that one novel and monumental outcome of Curry's work has been a serious questioning of the role played by distance in many quantitative spatial models: What is the effect of distance on human behavior, and how is it convoluted with map pattern (geographic arrangement)? This question rests upon one of Curry's legacies.

Maclaren and Johnston (2009) inventory academic acknowledgments and recognitions of Curry's outstanding contributions to theoretical economic geography. During his university career, Curry had a Visiting Commonwealth Professorship to the University of Reading while a US resident, a three-month fellowship in the School of Pacific Studies at Australian National University—a higher education institution established in 1946 within a climate of post-WWII optimism—and, as already mentioned, a residency at the Rockefeller Foundation's Bellagio Study Center. Curry

received an inaugural UofT Connaught Senior Fellowship in the Social Sciences that funded his Bellagio residency. In 1969, Curry received American Association of Geographers Honors—an accolade established in 1951. Curry was named John Simon Guggenheim Fellow in 1976, which supported a visit to Cambridge University. The Canadian Association of Geographers (CAG) conferred their Award for Scholarly Distinction upon Curry in 1977. In 2000, Curry received his most prestigious award, the Lauréat d'Honneur from the International Geographical Union (IGU; see Fig. 4), an award established in 1976 to recognize individuals who have achieved particular distinction in international geography. The IGU bestows only three or four of these tributes quadrennially at its world congress, and Curry became its first Canadian recipient. His reads: "…a scholar who by way of his contributions in climatology, economic geography and spatial analysis has challenged established lines of thinking and provided valuable new insights into the ways whereby human behavior shapes the world we live in" (King 2009, p. 156). Curry's ultimate standing in geography and regional science mostly reflects his theoretical treatises about economic geography and about settlement patterns, almost all work undertaken and completed while he was at the University of Toronto.

8 Curry's Legacy

Curry made a variety of transformative contributions to the discipline of geography. One was to the sociology and leadership service of the now American Association of Geographers (AAG) organization: He stood up during the 1973 AAG business meeting, in Atlanta, GA, and admonished the leadership for operating a too exclusive and inadequately inclusive and diverse program of paper presentations. One outcome was a radical opening of the annual AAG program; its net effect was that, within only a very few years, annual meeting attendance grew from a roughly stable 20% to a sizeable 75% of the Association's membership, a percentage that continues through today. Curry also was instrumental in establishing an AAG quantitative geography specialty group (SG)—first named the Mathematical Models and Quantitative Methods SG, and then around 2000 renamed the Spatial Analysis and Modeling (SAM) SG. This effort dovetailed with his serving as chairperson of the IGU's Working Group on Systems Analysis and Mathematical Models in Geography (1976–1984).

In the classroom, Curry was never considered to be an engaging or charismatic instructor, punctuating every one of his lectures with one or more extended pregnant pauses (Johnston 2010, p. 391); his professional presentations, too, often incorporated this same quirky silence. Nevertheless, his second major contribution was his ability to organize outstanding graduate education opportunities for his students, as well as attract—unfortunately just a relatively few—advisees who eventually would help make a real difference in the geography discipline. With regard to the former, at one point in time, Curry co-organized a weekly informal exchange seminar between the UofT and McMaster University quantitative geography graduate programs focusing

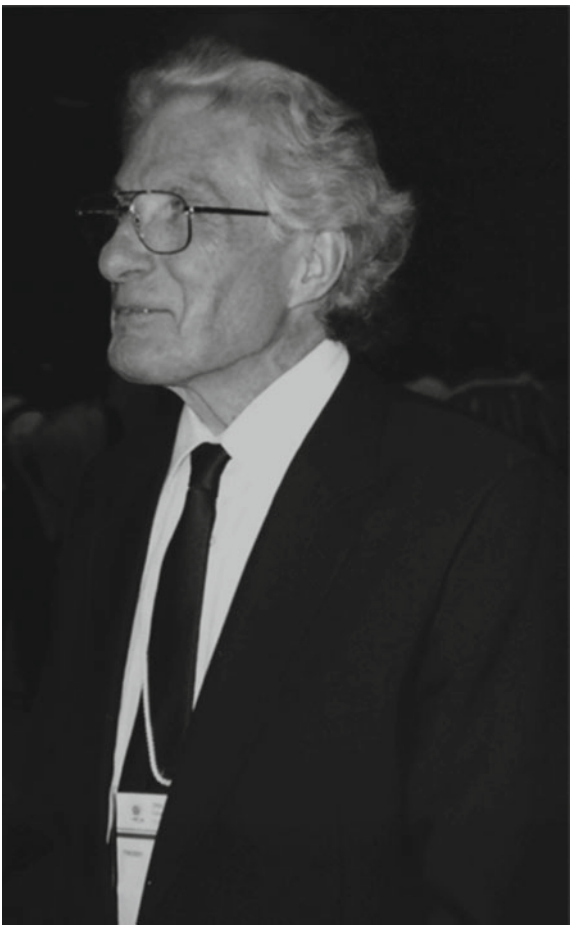

Fig. 4 Leslie Curry at his IGU award ceremony in Seoul, Republic of Korea, 2000. *Photo source* Caryl Curry

on mathematical spatial theory; trips between campuses rotated. Faculty participating in this educational venture also included Ross MacKinnon, Leslie King, Yorgo Papageorgiou, and Michael Webber; doctoral students participating in it included Geoffrey Bannister (former Butler University President, Schiller International University President, and Hawai'i Pacific University President), Anthony C. Lea (2001 Geography in the Service of Government and Business Award recipient, the CAG), Eric Sheppard [University of California, Los Angeles (UCLA) Alexander von Humboldt Chair in Geography], and me (foreign fellow, Royal Society of Canada) from UofT, and A. Stewart Fotheringham [GWR and United States (US) National Academy of Science], Morton O'Kelly (Edward L. Ullman Award, AAG Transportation Geography SG), and Russell Lee [Distinguished R&D Staff Member, Oak Ridge National Laboratory (ORNL), prior to his demise] from McMaster. Bannister, Sheppard, and I were Curry's doctoral advisees, and Lee was his master's advisee; Curry was on Lea's

doctoral committee. Curry's third, and perhaps most influential academic contribution, was his set of scholarly publications, virtually all being journal articles and book chapters.[3] While not especially large in number by today's standards, his publications certainly were of exceptionally high quality.

Curry's major contributions to the regional science literature were noted in Isserman's 2005 North American Regional Science Council presidential address that highlighted, among others, Curry's significant contributions to the regional science literature (also see Isserman 2004) and mentioning that Curry's (1967b) "Central places in the random spatial economy" had the most citations over the longest period of time (17 years) during 1955–2001 of any article in the field's flagship outlet, the *Journal of Regional Science*. Whitehead (1985, p. 228) corroborates this stature, noting that Curry was one of the small group of 32 most cited geographers during 1966 to 1982. Sheppard (2010, p. 395) labels him "the Frank Knight, John Maynard Keynes or Friedrich von Hayek of late twentieth-century Anglophone economic geography." Curry's publications also generated occasional disciplinary controversy, such as pushback from the emerging feminist geography community of that time because of an included cartoon in his 1967c article showing a naked quantifactus kidnapping a near naked geographia, taking her across the fluvius calculus, away from distraught qualifactus (the Latin usage reflecting his grammar school education).

9 Concluding Comments

Curry's academic career was concomitant with the early days of regional science, before excessive publish-or-perish pressures became the norm; regardless, his final articles-plus-book-chapters-plus-book publication record numbers are quite respectable, being catapulted into the impressive realm by their quality. Curry's UofT fonds reveals an additional six unpublished manuscripts to add to this body of literature.

In some ways, Curry was a scholar before his time with regard to the quantitative revolution in geography, which helped build bridges between human geography and regional science; Johnston (2010, p. 388) points out that the same previously mentioned spatial economics pioneers inspiring Curry also later inspired Garrison's Seattle group (e.g., Berry, Bunge, Dacey, Getis, Marble, Morrill, Nystuen, and Tobler). "Yet [Curry's] scholarship departed from the approach associated with the urban and economic geography forged by Bill Garrison and his students at the University of Washington" (Sheppard 2010, p. 395). This was a time when universities organized themselves according to traditional academic disciplines; in contrast, Curry pursued interdisciplinary research, merging concepts from geography with those from biology, economics, physics, and mathematics (e.g., probability theory). One outcome was an allegiance to regional science; Curry attended and presented

[3] See, e.g., https://discoverarchives.library.utoronto.ca/index.php/leslie-curry-fondsforagrosslyincompletelisting.

a paper at most North American meetings, first publishing in the regional science literature proper in the early 1980s (see Table 1, and entry #7 for his book), and is classified by Isserman (2004) as an intellectual leader of the founding generation of regional science. Curry was instrumental in inviting leading regional scientists to give UofT colloquia, including: Isard, Paelinck, Tietz, and Richardson.

Although Curry conversed with non-quantitative geographers (e.g., he had interesting discussions with historical geographer Don Meinig when I hosted him at Syracuse University), Curry was frustrated by the qualitative nature of human geography theory formulations before he pursued his economic geography interests, as well as by its return to this mode after his retirement. Nevertheless, he was not uniformly appreciated by quantitative economic geographers, either; Sheppard comments (2010, p. 396):

> Writing at a time when quantitative human geography prided itself in developing law-like deterministic explanations of the space economy, rooted in rational behavior, Curry's epistemology was neither popular nor particularly influential. Yet he was one of twentieth-century economic geography's most original thinkers …

Sheppard (2009, p. 377) expounds as follows:

> His strategy of theory construction was orthogonal to that favoured by his fellow quantitative revolutionaries, who prioritized a deterministic deductive approach, deriving spatial economic patterns from individuals' rational economic choices. Notwithstanding a shared faith in science, mathematics and logical empiricism, Curry's contribution to the first generation of theoretical human geography avoided such rootedness in neoclassical economic analysis. He argued that deterministic theories are not necessary to make sense of the world, and that careful consideration of the spatiality of economic activities profoundly disrupts economists' theorizations of production and exchange. His approach to theory construction often eschewed logical rigor for intuitive leaps of faith.

Moreover, although somewhat out of step with many of his peers, "The importance [Curry] attached to geographical theory reflected the geographer in him, certainly, but a geographer of the Quantitative Revolution for whom theory was everything" (Haining 2010, p. 393).

In conclusion, regional science attracted Curry because of its multidisciplinary nature, one of its early-day strengths. It benefited greatly from contributions by geographers like Curry, who were the best and brightest minds in that discipline. Going forward, Curry's bolstering of the gravity model success story by uncovering its dormant, marked, spatial autocorrelation complications, allowing a contemporary refinement of this construct, and his then-fresh, multiple-scale conceptualization of georeferenced data should continue to help quantitative geographers solve new problems. Leslie Curry left an indelible mark on regional science, one with a legacy. He posited theories and concepts that have promoted a better understanding of the space economy. However, comprehending his work comes with a cost. Haining (2010, p. 394) summarizes Curry's accomplishments as follows:

> Curry's intuition inspired many of his colleagues, while his inattention to, or disregard for, detail frustrated others. His papers were never easy to read but they engaged with important topics and he left the literature richer and more interesting for his contribution.

MacKinnon (2009, p. 114) concurs:

> [Curry's] results often were bewildering, even for, perhaps especially for, the quantitatively sophisticated audience; there was something of the poet or impressionistic artist in Curry—huge leaps of logic, matters to take on faith; gaps, details that could be filled in later, perhaps by others; many got stuck in those gaps and never fully appreciated Curry's contributions to the field.

But familiarity confirms that the cost involved is worth incurring for the insights gained; certainly many, if not most, newly trained regional scientists should make this expenditure.

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Crawford "Buzz" Holling (1930–2019): Progenitor of Resilience in Regional Science

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1 Introduction

Canadian ecologist Crawford Stanley "Buzz" Holling was the first to give scientific meaning to the term *resilience* in the post-World War II era and to demonstrate its use in studying ecological systems. In the last four decades, a consensus has emerged that the notion of resilience is pertinent not only for studying ecological systems but also for analyzing socioeconomic systems studied by regional scientists. As such, after briefly discussing two of Buzz Holling's other major research contributions, in this chapter, I comment on the contemporary relevance of resilience—the most widely used concept in regional science attributable to Holling. Several aspects of the use of resilience in regional science are discussed, including commentary on the policy implications and the societal impacts of a resilience-based approach to regional science. Even though Buzz Holling himself never worked in regional science, his interdisciplinary research and his founding of the Resilience Alliance have stimulated regional scientists to pursue research where the focus is on the development of integrative theories of change that have practical value.

Crawford Stanley "Buzz" Holling was born on December 6, 1930, in Elmira, New York, in the USA to Canadian parents.[1] The name "Buzz" was given to him by his older sister because she thought it suited his personality, a point on which there was agreement between brother and sister.[2] Holling grew up in the boreal forests of Northern Ontario in Canada and, from a very early age, developed an interest in nature in general and in insects in particular. Given this interest, he realized very early in his life that "an education in science and ecology would be the only way to appease [his] thirst for knowledge" (Holling 2017, p. 10).

Holling completed his B.A. and M.Sc. degrees in 1952 from the University of Toronto and then proceeded to work for the Forest Research Laboratory in Sault Ste. Marie, Ontario. This experience introduced him to a number of competent scientists, gave him a feel for interdisciplinary research, and instilled in him a desire to "produce excellent work" (Holling 2017, p. 15). After spending some time at this laboratory, Holling proceeded to the University of British Columbia (UBC) for doctoral research and obtained his Ph.D. in 1957. In his doctoral dissertation, Holling developed the first mathematical theory of predation. This theory and Holling's related ideas are still widely used to analyze predator–prey interactions.[3]

After completing his Ph.D., in the 1960s and 1970s Holling extended his previous work by using systems analysis to understand different kinds of interactions between humans and nature. Professionally, Holling served as Professor and Director of the Institute of Animal Resource Ecology at the University of British Columbia and then as a visiting researcher at the International Institute for Applied Systems Analysis

[1] Go to https://www.resalliance.org/news/51 for more details. (Last accessed 30 June 2021).

[2] Go to https://www.stockholmresilience.org/research/research-news/2019-08-23-pioneering-the-science-of-surprise-.html for more details on this point. (Last accessed 30 June 2021).

[3] See Carpenter and Peterson (2019) and https://www.stockholmresilience.org/research/research-news/2019-08-23-pioneering-the-science-of-surprise-.html for more on this point. (Last accessed 30 June 2021).

(IIASA) in Laxenburg, Austria. He later returned to IIASA as its Director from1981 to 1984. During his tenure at IIASA, Holling collaborated with researchers both inside and outside universities to better comprehend issues in land development, forest management, and pest management.[4]

After the completion of his tenure as IIASA Director in 1984, Holling returned briefly to his old faculty position at the University of British Columbia. However, he "opposed the changes that had occurred while [he] was at IIASA…" (Holling 2017, p. 64), and he found the Dean at UBC to be "rigid and opposed to change" (Holling 2017, p. 64). Therefore, he soon left UBC and in 1988 moved to the University of Florida in Gainesville, where he became the Arthur R. Marshall, Jr. Professor, and Eminent Scholar in the zoology department. Holling retired from the University of Florida in 1999, but remained on the faculty as Emeritus Eminent Scholar.

During his decade-long stay at the University of Florida, Holling began a long-term collaboration with a group of researchers based in Stockholm, initially through the Beijier Institute of Ecological Economics at the Royal Swedish Academy of Sciences, and then with researchers at Stockholm University. These collaborations were organized into the Resilience Network that was initially funded by the MacArthur Foundation. The success of the Resilience Network projects led Holling to create the Resilience Alliance in 1997.[5] The Resilience Alliance was created to foster the research activities of an international group of interdisciplinary researchers interested in studying transformations in human and natural systems.

Carpenter and Peterson (2019) note that, as one of the world's most eminent ecologists in the last five decades, Holling received a variety of prestigious awards from professional and scholarly organizations. He received two significant awards from the Ecological Society of America.[6] The first, the Mercer Award, was given to Holling in 1966 in recognition of an outstanding paper by a young scientist in that year. The second, the Eminent Ecologist Award, was given to him in 1999 for outstanding contributions to the science of ecology. Outside the field of ecology, Holling received the Kenneth Boulding Memorial Award in 2000,[7] the Volvo Environment Prize in 2008,[8] and honorary doctoral degrees from the University of Guelph in 1998 and from Simon Fraser University in 2011. Finally, he was a Fellow of the Royal Society of Canada and Foreign Fellow of the Royal Swedish Academy of Sciences; he was awarded the Austrian Cross of Honour for Science and Art; and, in 2009, he was made an officer of the Order of Canada for his significant contributions to the field of ecology, particularly for his work on ecosystem dynamics, resilience theory, and the emergent field of ecological economics.

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[4] Buzz Holling's time at IIASA overlapped with the time spent there by some prominent regional scientists such as Peter Nijkamp (per personal e-mail correspondence) and Andrei Rogers; see Rogers (2018). Even so, somewhat surprisingly, Holling appears not to have worked either with Nijkamp or with Rogers on research projects.

[5] See https://resalliance.org/. (Last accessed 30 June 2021).

[6] Go to https://www.esa.org/about/awards/ for more details. (Last accessed 30 June 2021).

[7] See http://www.isecoeco.org/boulding-award/. (Last accessed 30 June 2021).

[8] See http://www.environment-prize.com/. (Last accessed 30 June 2021).

Accounts by contemporaries—see Carpenter and Peterson (2019)—tell us that in addition to being an amiable person, Holling had a knack for getting people from different disciplines to work together, often in congenial settings. As a result, his interdisciplinary planning sessions led to many friendships and productive collaborations both across and within disciplines. A key point about Holling is the importance he placed on mentoring young scholars, and prominent ecologists such as Eric Charnov have acknowledged the positive impacts on their careers from Holling's mentorship.[9] His support of young scholars led to the creation of the Resilience Alliance Young Scholars (RAYS) network which provided plenty of networking opportunities for junior researchers. Aside from his research activities, Holling loved nature, loved creating sculptures inspired by his fondness for nature, and loved being physically close to his family.

After a sterling career that produced disciplinary and interdisciplinary research of the highest quality, Holling died at the age of 88 on August 16, 2019, in Nanaimo, BC, Canada. In his research, Holling routinely combined systems theory and ecology with simulation modeling and policy analysis to develop integrative theories of change that have practical value. Three key ideas that he introduced into the ecology literature and the literature on environmental management more broadly are: (i) adaptive management, (ii) panarchy, and (iii) resilience. In Sect. 2, I briefly discuss the first and the second ideas and then begin a systematic discussion of resilience, placing particular emphasis on definitional issues. Sections 3–6 first point to a specific aspect of the use of resilience in contemporary regional science research and then discuss research and policy issues that arise from this particular manner of usage. Section 7 concludes the chapter with a prospective look at how researchers might enhance the way in which they conceptualize and study resilience in regional science.[10]

2 Three Key Interdisciplinary Ideas

2.1 Adaptive Management and Panarchy

In the late 1970s, Holling (1978) described an approach to management that he called *adaptive*. In this kind of management, when confronted with uncertainty, a decision-maker utilizes an iterative and structured approach along with system monitoring to attenuate the uncertainty over time. By acting in this way, a decision-maker can not only accomplish one or more resource management objectives, but can also gather information that is needed to improve management in the future. Put differently, adaptive management can be thought of as a tool to not only alter a system, but also to learn about this same system. A key point to grasp here is that because adaptive

[9] Go to https://oceans.ubc.ca/2019/09/13/in-memoriam-buzz-holling/ for additional details on this point. (Last accessed 30 June 2021).

[10] This discussion borrows, in part, from Batabyal and Kourtit (2021).

management is based on a *learning* process, the incorporation of this learning in decision-making can improve the outcomes of management in the long run.[11]

There is no dispute on the point that a system—ecological or socioeconomic—cannot be understood or managed by observing it at a single scale. This is because all systems exist and function at multiple scales of space, time, and social organization. Therefore, the interactions across scales are critically important in ascertaining the dynamics of the system at any particular observational scale. This interacting set of hierarchically structured scales is what Gunderson and Holling (2002) call a *panarchy*. Looked at a little differently, because the central focus of panarchy is to rationalize the interplay between change and persistence, on the one hand, and between the predictable and the unpredictable, on the other, Gunderson and Holling (2002) contend it is possible to draw on the concept of hierarchies of influences between embedded scales or panarchies to denote structures that support experiments, test their results, and permit adaptive evolution.[12]

Even though the concept of panarchy originated in ecology, we are now beginning to see some applications of panarchy theory in other disciplines. For instance, Garmestani et al. (2006, 2009) point out that the panarchy concept permits one to examine the size of companies and thereby shed light more generally on governance systems. In addition, Wieland (2021) discusses how the idea of a panarchy can be used to analyze the management of supply chains. Regional scientists have devoted scant attention to panarchy, and to the best of my knowledge, there are only two studies in regional science that have worked with the notion. Specifically, Simmie and Martin (2010) discuss the extent to which panarchy theory can be used to generate testable hypotheses about urban and regional resilience. Eason and Garmestani (2012) use panarchy theory and point out that urban systems are scale-dependent. Even so, they note that it is important to comprehend that city growth is typically not random but correlated with other salient variables such as mean household income and the percentage of the population with a college degree. So, it is fair to say that of the three key ideas put forth by Holling in the ecology and environmental management literatures (see Sect. 1), resilience is the concept that has, by far, had the greatest impact on research in regional science.

2.2 *Two Interpretations of Resilience*

In order to use the concept of resilience meaningfully in regional science, one needs to first understand that, even though this concept was introduced into the ecology literature in the post-World War II era by Holling (1973), the concept now has two interpretations in ecology. First, we have *engineering* resilience, or resilience of the first kind. Even though Holling (1996) came up with the term engineering resilience, resilience in this specific sense originates in the main from the research of Pimm (1984). Other

[11] Go to https://www.resalliance.org/adaptive-mgmt for more details. (Last accessed 30 June 2021).

[12] Also see https://www.resalliance.org/panarchy. (Last accessed 30 June 2021).

scholars who have contributed notably to the development of engineering resilience include O'Neill et al. (1986), and Tilman and Downing (1994).

Second, we have *ecological* resilience or resilience of the second kind. This second sense in which the notion of resilience is used in ecology is due to Holling (1973). It is important to recognize that engineering resilience and ecological resilience are *dissimilar* concepts, and therefore, in general, one does not expect there to be any discernable relationship between these two disparate ideas.

To see the difference between these two notions of resilience, let us reflect on the prevailing definitions of these two concepts. Engineering resilience "concentrates on stability near an equilibrium steady state, where resistance to disturbance and speed of return to the equilibrium are used to measure the property…" (Holling 1996, p. 33).[13] In contrast, ecological resilience "emphasizes conditions far from any equilibrium steady state, where instabilities can flip a system into another regime of behavior—that is, to another stability domain" (Holling 1996, p. 33).[14] From these two definitions, it should be obvious to the reader that engineering resilience is an "equilibrium-centered" view of an ecological system and that ecological resilience is a "far-from-equilibrium" view of an ecological system.

The research of Pimm (1991) and Perrings et al. (1995) indicates that both these notions of resilience are germane when studying the responses of ecological systems to shocks. In addition, the research of Perrings (1987, 1991) and Batabyal (1998; 1999a, b; 2001) indicates that these two concepts are also pertinent when studying jointly determined ecological-economic systems such as fisheries, forests, and rangelands.[15] That said, a central question now is the following: Are these two notions of resilience useful as organizing concepts for *socioeconomic systems,* which are the systems that regional scientists standardly work with? Research by Levin et al. (1998), Batabyal (1998), and Walker (1998) indicates that the answer to the preceding question is "yes."

Given this "yes" answer, we must next decide whether to use the definition of engineering or ecological resilience when studying socioeconomic systems. Regrettably, the literature in regional science does not provide an unambiguous answer. On the one hand, Stanickova and Melecky (2017, p. 233) contend that for regional economic analysis, "the most natural conceptual meaning of economic resilience is the ability of a regional economy to maintain or return to a pre-existing state (typically assumed to be an equilibrium state) in the presence of some type of exogenous shock." The suggestion here is that engineering resilience is the apposite notion to concentrate on. In contrast, in their commentary on how regional social-ecological systems ought to be managed, Lebel et al. (2006, p. 3) observe that "[t]he alternative to trying to maintain, or transform to, a system configuration that is very narrowly defined is to manage resilience. Resilience is a measure of the amount of change a system can undergo and still retain the same controls on structure and function or

[13] Also see Pimm (1984), O'Neill et al. (1986), and Tilman and Downing (1994).

[14] Also see Holling (1973) and Holling et al. (1995).

[15] Such systems are said to be jointly determined because their evolution over time and space is overseen by forces that are partly ecological and partly economic in nature.

remain in the same domain of attraction…" These researchers are obviously speaking about ecological resilience.

Regional scientists ought not to be bothered by the fact that there is no one answer to the query concerning which definition of resilience to use when studying socioeconomic systems. That said, regional scientists do need to understand the *yardsticks* that will help them determine whether their attention in any given scenario ought to be on engineering or on ecological resilience. I maintain that there are four yardsticks that *together* will help a researcher ascertain whether the focus ought to be on engineering or on ecological resilience.

2.3 Engineering or Ecological Resilience?

The first yardstick asks a regional scientist to focus on whether the socioeconomic system under consideration is largely *untouched,* and therefore largely bereft of human influence, or whether this system is a *managed* system. If the system under consideration is mostly untouched, then the "near-equilibrium" viewpoint associated with engineering resilience is relevant. In contrast—and this is likely to denote most of the socioeconomic systems that regional scientists are interested in studying—if the system under consideration is managed, then it is a lot more probable that this system can exist in manifold stable states. In this case, the "far-from-equilibrium" perspective associated with ecological resilience is the concept to concentrate on.

Given the research of Perrings (1996), the second yardstick relates to the *number of equilibria* possessed by a socioeconomic system. If this system has a single equilibrium, then, tacitly, there is an assumption of global stability, and, hence, engineering resilience is the apposite notion to focus on. On the other hand, a managed socioeconomic system can be expected to exist in manifold stable states. Thus, in this instance, we are interested in discovering the *size* of the stability domain associated with a particular stable equilibrium, and, consequently, ecological resilience is the pertinent notion to pay attention to.

Humans are affected by a variety of functions that socioeconomic systems routinely perform. Consequently, following Holling (1996), the third yardstick involves figuring out whether to study the *efficiency* with which these functions are being performed or to analyze the *existence* of one or more of these functions. If the goal of a research project is to establish the efficiency with which system functions are being performed, then the regional scientist ought to concentrate on engineering resilience. If, on the other hand, a regional scientist's goal is either to maintain the existence of a system's functions or to determine the survival of a specific function, then this regional scientist's attention should be focused on ecological resilience.

The fourth yardstick concerns the nature of the question(s) that a researcher is looking to investigate. If the goal is to study a *particular* question about the functioning of a socioeconomic system, then it makes more sense to concentrate on engineering resilience. On the other hand, if a researcher's intent is to shed

light on *general* questions about a socioeconomic system, then I maintain that this researcher's attention ought to be focused on ecological resilience.

2.4 Resilience and Stability

The research of Dei et al. (2015) and the discussion thus far in this chapter indicate to us that regardless of whether we decide to focus on engineering or on ecological resilience, at a very basic level, the concept of resilience is very closely related to the concept of *stability*. In fact, this point has been made by the distinguished ecologist Stuart Pimm (1991, p. 13) who has explained that "theoretical and empirical ecologists [have] used the word *stability* to mean at least five different things…" and that resilience is one of these "five different things."

It is worth emphasizing Pimm's (1991, pp. 13–14) point that, in addition to resilience, ecologists have used the word *stability* to refer to related notions known as *persistence*, *resistance*, and *variability*. For regional scientists, the point to recognize is that words like *persistence* and *resistance* have well understood meanings in ecology. Hence, when a regional scientist uses a word like *resistance* to delineate something that is at odds with the way this word is used in ecology, there is considerable risk that it will create confusion about the meaning of the underlying concept in an environment in which regional scientists are already using *resilience* in different ways.

To see this point clearly, I now provide some examples from the regional science literature. Consider the research of Rose (2015). After distinguishing between what he calls *static* and *dynamic economic resilience*, Rose (2015, p. 247) provides definitions of these two concepts. He points out that static economic resilience is "the efficient use of remaining resources at a given point in time." He then tells us that dynamic economic resilience is "the efficient use of resources over time for investment in repair and reconstruction."

Abstracting away from the time dimension, the difficulty with the above two definitions of economic resilience is that they are closely related to the definition of *economic efficiency*. An economist would say that if a system is utilizing its resources efficiently then this system is Pareto efficient. This means that no one in the system can be made better off without making at least one person in the same system worse off.[16] From time to time, economists use the notion of efficiency in a narrower sense to refer to, for example, *resource efficiency*. But even in this instance, Rose's (2015) definitions of economic resilience would be comparable to the way in which economists think about resource efficiency.[17] So, regional scientists need to remember that when studying a socioeconomic system, it is unconstructive to define terms (static and

[16] See Bishop (1993), Hirshleifer et al. (2005, pp. 533–534), and Mas-Colell et al. (1995, pp. 312–313) for more details on this point.

[17] Go to https://www.resource-germany.com/topics/generel-remarks/what-is-resource-efficiency/ for more details on this point. (Last accessed 30 June 2021).

dynamic economic resilience) that are closely related to an established concept in ecology (resilience) with clear meanings (engineering and ecological) in a way that separates the defined terms from any kind of stability consideration and, simultaneously, risks conflation with other well-understood concepts in economics (Pareto efficiency and resource efficiency).

Moving on, Rose (2015, p. 248) says that research on resilience is split into two groups and that about "half of the researchers view resilience as any action that can reduce losses from disaster…" He then says that the "other camp focuses on resilience as actions following the onset of a disaster." It is important to comprehend that resilience, be it engineering or ecological, is an *attribute*[18] of systems including socioeconomic systems. It is *not* an action or even a set of actions. Therefore, if regional scientists are to make sound policy recommendations on the basis of their studies of the resilience of a socioeconomic systems, then they must first comprehend that resilience is one kind of stability property. This realization will also enable regional scientists to better understand the societal impacts of the policy measures they propose for adoption. I now ask whether it makes sense to view resilience as a *process.*

3 Is Resilience a Process?

3.1 Process

The question as to whether resilience is appropriately viewed as a process is an unsettled matter in the social sciences in general. For example, the psychologist and social worker Michael Ungar (2018, p. 3) points out that "studies of social-ecological systems tend to see resilience as the capacity of a system, closer to the description of a trait than a process…" He then says that "[p]sychologists, social workers, and other mental health professionals, on the other hand, abandoned descriptions of resilience as a trait decades ago and now describe resilience most often as a process." Finally, Ungar (2018, p. 3) maintains that this "difference between the disciplines has become somewhat blurred as social-ecological systems researchers…have shown interest in the structure and processes associated with nested adaptive cycles across scales."

Like Ungar (2018), other researchers, such as Rutter (1987) and Masten (2014), would also have us believe that resilience is a process. This notwithstanding, my view is that resilience is an *attribute* of a socioeconomic system and *not* a process. The argument to corroborate this view is in two parts. First, we return to the ecology literature, where, in the post–World War II era, resilience was first defined and studied, and pay careful attention to what distinguished ecologists have said about this concept. Two illustrations follow in the next paragraph.

[18] Other appropriate synonyms here would be "property" or "trait."

Buzz Holling, who introduced the concept of resilience into the ecology literature in 1973, says in a more recent contribution (1996, p. 32) that the resilience "of a system has been defined in two different ways in the ecological literature. These differences in definition reflect which of two different aspects of stability are emphasized." Simon Levin (2015, p. 1) says that ecological resilience is "the ability of an ecosystem to maintain its normal patterns of nutrient cycling and biomass production after being subjected to damage caused by an ecological disturbance." The clear inference I draw from these two quoted observations is that resilience is an attribute of a system and *not* a process.

The second part of my argument is to point out the need to differentiate between an *attribute* of a system and intertemporal *observations* of this attribute. A collection of observations over a period of time clearly makes up a process, but the observations themselves represent an attribute, and this attribute can be viewed statically, that is, at a point in time or intertemporally, that is, over time. In the static case, there is plainly no process, but, in the intertemporal case, we do have a process. To grasp the significance of the distinction I am making, consider the following elementary example involving humans.

There can be no dispute on the point that obesity is an attribute of a person, and we can observe how obese a person is at a point in time, and, thus, there is *no* process issue to worry about. However, we can also observe how obese an individual is *intertemporally,* and this undertaking would lead to a series of *observations* that do make up a process. The point to recognize is that the observations refer to the obesity attribute, and, hence, it does *not* make sense to say that obesity is a process. The same rationale would apply to other human attributes such as the height of an individual.

3.2 Uncertainty

Buzz Holling placed substantial weight on understanding how uncertainty affects the ability of humans to manage ecological and socioeconomic systems.[19] As such, it may be surprising to note that, in this discussion about whether resilience is a process, I have thus far said nothing about uncertainty. In other words, I have implicitly assumed that it makes sense to view a socioeconomic system as a deterministic system. Clearly, this is a simplification. When it makes more sense to view such a system as a *probabilistic* system, then an attribute such as resilience ought to be viewed as a *random variable.* In this instance, at a point in time, we would observe a *realization* of this random variable. In contrast, intertemporally, we would have a *collection* of such realizations, and this collection would constitute what is commonly referred to as a *stochastic process.* Note, though, that even in this probabilistic setting, as pointed out by Batabyal (1998), resilience would still be an *attribute,* but this attribute would now be stochastic in nature.

[19] Go to https://www.resalliance.org/news/51 for more details. (Last accessed 30 June 2021).

I contend that the above two-part argument establishes the validity of my claim that resilience is an attribute of ecological and socioeconomic systems and not a process. Let us now move on and deliberate over whether resilience is always a *good thing* that decision-makers ought to enhance.

4 Should Resilience Always Be Promoted?

4.1 The Question to Answer First

Let us focus for the moment on the wide-ranging paper by Martin and Sunley (2015). These researchers (2015, p. 1) note that resilience "is now invoked in diverse contexts, both as a perceived (and typically positive) attribute of an object, entity, or system and, more normatively, as a desired feature that should somehow be promoted or fostered."[20] Supportive of this viewpoint, Stone-Jovicich et al. (2018, p. 1) point out that "[g]rowing attention is…being focused on social-ecological resilience. Indeed, it is increasingly being adopted as a centerpiece of policy making, planning processes, and management strategies…"

These and other scholars such as Brown et al. (2017) have all argued that resilience, in general, is a *good* thing. Here, when I say *good,* I mean—as economists typically do—something of which more is preferred to less. With this interpretation of good, the policy suggestion is that decision-makers need to do all they can to augment the resilience of a socioeconomic system. Even though this perspective is fairly common, my view is that resilience is *not* always a good thing, and that, in order to determine whether resilience in a given setting is a good thing, one must first answer the query "Resilience of What?"

4.2 The Rationale

To show the soundness of my position, I begin with some comments on the probabilistic analysis of Batabyal et al. (2003) that concentrates on lakes. These researchers point out that many lakes exist in one of three potential states: a stable eutrophic state that is *bad* from the viewpoint of humans; a stable oligotrophic state that is *good* from the viewpoint of humans; and a third, unstable state that marks the border between the eutrophic and the oligotrophic states. The lake may move from the oligotrophic to the eutrophic state as a result of natural or human factors, but this move is generally probabilistic. In this situation, actions taken by a decision-maker can, theoretically speaking, shift the lake from the eutrophic to the oligotrophic state. However, whether

[20] Note that even though elsewhere in their paper Martin and Sunley (2015) say that resilience is a process, this specific reference to resilience as an *attribute* of an object, entity, or system would appear to strengthen my contention in Sect. 3 that resilience is an attribute and *not* a process.

these actions will or will not be successful is a probabilistic and not a deterministic matter. The salient point to recognize now is that the lake under consideration can be resilient in either the eutrophic or in the oligotrophic state. Since the eutrophic (oligotrophic) state is undesirable (desirable) from the perspective of humans, the objective of policy clearly ought to be to decrease (increase) the resilience of the eutrophic (oligotrophic) state. In other words, when the answer to the "Resilience of What" query stated at the end of Sect. 4.1 is "the eutrophic state," resilience in this state is *not* a good thing, and, therefore, policy should seek to diminish the resilience of the lake in this *bad* state.

In recent times, the lagging versus leading region dichotomy[21] has generated a substantial literature in regional science. In this two-part cataloging, lagging regions are generally not vibrant, they are often rural or peripheral, they are technologically retrograde, and they display slow economic growth rates. In contrast, leading regions are viewed as vibrant, they are often urban and centrally situated, they are technologically progressive, and they display relatively brisk rates of economic growth. Lagging regions are frequently resilient and, as the research of Wolman et al. (2017) and Anoni et al. (2019) demonstrates, opposed to change, occasionally even when substantial resources have been devoted to altering their lagging status. Eyeing this issue through the lens of the query "Resilience of What" ought to persuade the reader that the resilience of lagging regions is plainly *not* an enviable state of affairs.

Let me close this section by underscoring two essential points made in a thoughtful paper by a group of ecologists and economists. Levin et al. (1998, p. 226) first tell us that "[n]ot all resilient phenomena are desirable. For example, discriminatory class systems have proved resilient. Similarly, racism has proved stubbornly resistant to policies aimed at wrecking its foundations." Hence, we need to realize that "[r]esilience…makes no distinctions, preserving ecologically or socially undesirable situations as well as desirable ones" (Levin et al. 1998, p. 225). With this discussion of the three basic issues out of the way, I now move on to discuss how Buzz Holling's notion of resilience has influenced thinking about two policy-related issues in regional science. These two issues pertain to manifold stable states and the nexuses between the two concepts of resilience and sustainability.

5 Manifold Stable States

5.1 Foreseeability and Policy Fixity

Research conducted by Arthur (1989, 1990) and Perrings and Brock (2009) indicates that socioeconomic systems that are the object of inquiry by regional scientists can exist in *manifold* stable states. This central point and its ramifications for the design

[21] See Batabyal (2018), Batabyal et al. (2019), Batabyal and Nijkamp (2014a, b, 2019a), and the references cited in these papers for further details about this literature.

and implementation of what we might call "resilience sensitive" policy are of great importance but, unfortunately, insufficiently studied by regional scientists.

We begin with the simpler of two cases to corroborate the above claim. Now, if a given socioeconomic system can exist in only one stable state and, consequently, has a unique equilibrium, then it makes sense for a decision-maker to concentrate on the engineering resilience of this system. To see why, observe that when a socioeconomic system with one stable state is shocked, this system will have a tendency to return to its unique equilibrium. Of the two definitions of resilience that we have been working with in this chapter, the one that accentuates the speed of return to the stable state after a shock—or a near-equilibrium response of the system—is engineering resilience (Holling 1996). This makes clear the usefulness of engineering resilience or resilience of the first kind for such systems. A major differentiating characteristic of such "one stable-state" socioeconomic systems is that their behavior over both time and space is *foreseeable*, at least relative to truly manifold stable-state systems. Thus, *fixed* policies that are both relatively undemanding to design and to implement make more sense for such systems.

5.2 Unforeseeability and Policy Flexibility

Moving on to the more complicated and also to the more realistic case, I maintain that most—and, in all likelihood, all—socioeconomic systems that regional scientists investigate are manifold stable-state systems. Therefore, their spatial and temporal behavior is likely to be unforeseeable. As a consequence, in this instance, the attention of a decision-maker has to be on the *size* of the stability domain associated with a specific stable state. Put differently, this decision-maker needs to concentrate on the ecological resilience of the system being studied.

From the perspective of the design and implementation of policy, we need "a response system that is flexible and adaptive" (Levin et al. 1998, p. 224). My reading of the literature here substantiates the assertion of Sellberg et al. (2018, p. 906) who point out that "studies of resilience practice are still rare. Few studies have analyzed the applications of resilience thinking in real-world settings and assessed what it has actually managed to achieve." This assertion provides the rationale for my claim in the first paragraph of Sect. 5.1.

Even if one accepts the above claim, there is no gainsaying the fact that compared to fixed policies, flexible and adaptable policies are *more costly* to design and to implement. Hence, in any given situation, a decision-maker will need to participate in a benefit–cost analysis in which the hard-to-quantify benefit from following such flexible policies is compared in a consequential way with the easy-to-quantify cost of these same policies.

I now briefly highlight one final point. In contemporary times, war and civil unrest in a nation like Syria, President Trump's trade war with China, and the COVID-19 pandemic signify a breakdown of the balance of peace and security and, thus, are illustrative of "qualitative shifts in which initially small disturbances may become

magnified through non-linear feedbacks" (Levin et al. 1998, p. 225). When faced with such qualitative shifts, flexible and adaptive policies of the sort that I am promoting need to take into account more than just the present outcomes of particular actions. Specifically, decision-makers need to ponder the prospect that the *effects* of a series of small actions—where each action is undamaging by itself—will add up in a way that *destabilizes* socioeconomic systems. In such situations, decision-makers encounter yet another problem and that is this: Even for flexible and adaptive policies, we can generally forecast the *immediate* impacts of specific actions. However, it is much more difficult to forecast the impacts of a *sequence* of actions without understanding the *intertemporal behavior* of the systems that are being affected by the relevant actions. That said, I now proceed to discuss the second of two policy issues, and this relates to the connection between the two concepts of resilience and sustainability.

6 Resilience Contrasted with Sustainability

6.1 A Basic Difference

The research of Pierce et al. (2011) indicates that the two notions of resilience and sustainability have increasingly become buzzwords. Perhaps this explains why there is now some confusion in the regional science literature about the relationship, if any, between these two concepts. As pointed out by Marchese et al. (2018), some observers accept as true the idea that these two notions are the same, whereas others think that they are different.[22] Regional scientists need to be clear on the point that these two notions are *dissimilar*. To see this, recall two points from our discussion in Sects. 2 and 3 of this chapter. First, the term resilience has two meanings, and these two meanings are *not* the same. Second, resilience is an *attribute*—and not a process—of a socioeconomic system, and, hence, it can, in principle, be investigated either at a point in time (statically) or over time (intertemporally).

It is essential to recognize that, even though the notion of sustainability at present has numerous definitions, the idea of sustainability was introduced into the social sciences literature most conspicuously in the form of the closely related notion of *sustainable development*. In particular, the Brundtland Commission, backed by the United Nations, stated in its well-known report—see Brundtland (1987, Chap. 2, para. 1)—that "sustainable development is development that satisfies the needs of the present without compromising the needs of the future." Even though other meanings are possible, one of the most familiar meanings of the word *sustain* is "to cause

[22] Go to https://www.barillacfn.com/en/magazine/food-and-sustainability/sustainability-and-resilience-refer-to-two-different-concepts/ for additional details on this point. (Last accessed 30 June 2021). See Batabyal and Nijkamp (2019b) for a discussion of related issues.

or allow something to continue for a period of time."[23] So, sustainable development is fundamentally an *intertemporal* phenomenon or a *process*. From this line of reasoning, we maintain that the more general but still related notion of sustainability[24] also has a distinct intertemporal dimension to it.

6.2 Rival Goals?

As observed by Saunders and Becker (2015), the point that resilience and sustainability are disparate concepts is now recognized by quite a few researchers. Intriguingly, this recognition appears to have led some writers such as Zolli and Healy (2012) to think of resilience and sustainability as rival goals for decision-makers. For instance, Zolli (2012, p. 1) says that "because the world is so increasingly out of balance, the sustainability regime is being quietly challenged, not from without, but from within. Among a growing number of scientists…a new dialogue is emerging around a new idea, resilience…" He then argues (2012, p. 1) that "[w]here sustainability aims to put the world back into balance, resilience looks for ways to manage in an imbalanced world."

Given this "rival goals" viewpoint, it is worth stating clearly that in the ecological economics literature, the significance of resilience for sustainable economic development has been documented at least since the research of Common and Perrings (1992). Consistent with my discussion above, this research indicates that whereas resilience is a system attribute, sustainable development is about designing and implementing policies that maintain the trajectories or time-paths of vital features of the system under contemplation. As such, the crucial point to comprehend is that if a policy diminishes the resilience of a socioeconomic system, then it does *not* make sense to attempt to sustain the (undesirable) resulting trajectory of salient system attributes with reduced resilience. Hence, Perrings (2006, p. 418) is surely right when he asserts that a "development strategy is *not sustainable* if it is *not resilient*: i.e. if it involves a significant risk that the economy can be flipped from a desirable state (path) into an undesirable state (path), and if that change is either irreversible or only slowly reversible."

I now conclude this section by bringing to the attention of regional scientists three significant results that spring collectively from the various papers published in a special issue of the journal *Environment and Development Economics* in 2006. Regional scientists studying socioeconomic systems and particularly the connections between resilience and sustainable development ought to benefit by keeping these results in mind.

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[23] Go to https://dictionary.cambridge.org/us/dictionary/english/sustain for more details on this point. (Last accessed 30 June 2021).

[24] I say "more general" because it is certainly possible to think of sustaining things that have nothing to do with economic development in and of itself.

First, for socioeconomic systems, markets may be *missing* for attributes of the system that may affect its resilience and, therefore, its sustainability. In such circumstances, prices can lead decision-makers to take actions that push the system closer to unseen *thresholds*. Second, sustainable management of a socioeconomic system depends on understanding the intertemporal behavior of the system. In turn, this affects the choice a decision-maker makes between actions that involve *adapting* to future changes and actions that *alleviate* these same changes.[25] Finally, applying the lens of modern finance, sustainable development demands that the value of the *asset base* available to a population not deteriorate over time. In this regard, a resilience point of view implies that the *composition* of this asset base is very important. This concludes my discussion of (i) some of the main ways in which Holling's (1973) notion of resilience has been used in regional science and (ii) some of the conceptual and policy-related issues to be mindful of when regional scientists conduct resilience-based studies of one or more socioeconomic systems.

7 Conclusions

In this chapter, I discussed the life of Buzz Holling and the considerable impact that he has had on the social sciences, in general, and on regional science, in particular, through the widespread contemporary use of *resilience*, a concept that he originated in the early 1970s with his research on the stability of ecological systems. In this regard, Carpenter and Peterson (2019, p. 997) have rightly noted that "[t]hrough his research, collaboration and institution building, he was a visionary of change in nature and society and central in the rise of resilience thinking." This explains why—even though Buzz Holling himself never worked in regional science—his *interdisciplinary* research and his founding of the Resilience Alliance in 1997 (Holling 2017, p. 73–78) have stimulated regional scientists to pursue research where the focus is on the development of integrative theories of change that have practical value.

My discussion of three foundational and two policy-related issues involving the use of resilience in regional science demonstrates that additional research is necessary to (i) clear up some conceptual issues, (ii) comprehend that for socioeconomic systems, resilience is not always a good thing, and (iii) focus clearly on the distinctions between resilience and sustainability when formulating regional policies. Therefore, in the years to come, we look forward to exciting new research developments arising from the use of resilience-based analyses of socioeconomic systems that are marked by the trinity of conceptual clarity, analytical rigor, and policy relevance.

[25] Following Perrings (2006), adaptation involves actions by a decision-maker that modify either the benefits or the costs of change *without* modifying the probability of that change. In contrast, mitigation involves actions by a decision-maker that *influence* the known probabilities of future outcomes.

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Karen R. Polenske (1937–): A Journey from Rural Idaho to MIT

Geoffrey J. D. Hewings

Karen Polenske. *Photo source* Regional Science Association International, "Meet the Fellows," https://www.regionalscience.org/ (Last accessed 16 May 2022)

1 Introduction

Karen Polenkse was an intellectual leader in two professional organizations, the Regional Science Association International and the International Input–Output Association. While her initial contributions focused on the modeling of multiregional

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input–output systems, she subsequently extended her contributions to regional development issues, broadly defined, and, as well, she had as an extensive influence on socioeconomic research in China. The latter work included methodological issues (especially the development of hierarchical systems of accounts from national to individual enterprises), environmental concerns, and the spatial processes of economic growth and development. Polenske also contributed significantly to the organization of science and to the training of succeeding generations of students, including several hundred from China.

I have known Polenske since she came out to the University of Washington (Seattle) in 1969 to deliver a seminar on her multiregional input–output modeling project. Looking back, I believe that this was the first presentation or lecture I had heard that was delivered by a woman, and, by this time, I was in the final year of my doctoral work. This fact is mentioned to set the stage for the context in which Polenske worked, highlighting the remarkable perseverance she exhibited in launching and sustaining her career. Gender enlightenment in higher education in both Europe and North America was still a nascent phenomenon in the 1960s; together with underrepresentation of persons of color, women faced additional challenges that made the normal trajectory of career advancement much more difficult. In many cases, discrimination extended to difficulties securing grants, promotions, and even publication in major journals. However, the inclusion of Polenske in this series is not on the basis of her sex but the variety of intellectual contributions she made to regional science that extend beyond her many important publications.

This chapter is organized as follows. The next section provides a brief overview of Polenske's life and career; thereafter, discussion of her major accomplishments will be addressed prior to some more in-depth analyses of her major research accomplishments. Given her extensive list of publications, only a small sample can be highlighted, but these have been chosen to illustrate the breadth and depth of her work. The penultimate section briefly addresses her contributions to the organization of science (her work with professional organizations) and her strong commitment to developing stronger relations with Chinese scholars. The chapter concludes with some summary evaluation of her scholarship.

2 Early Life and Career Trajectory

Polenske was born in Idaho, but the family settled near Yakima, Washington; I believe they owned an apple orchard, and, perhaps, this experience helped her early thinking about supply chains and the myriad issues associated with production economics and the marketing of output. In an interview for the Regional Science Association International newsletter (October 2009), Polenske noted:

> Some of us have wondered why more U.S. and European women are not attracted to the sciences and engineering as well as economics, regional science, and other disciplines that require mathematics. Encouragement to do mathematics (and statistics) is needed early from parents and teachers while girls are still in grade school and high school. Often young girls

> are discouraged from taking it beyond the required subjects, although the use of the computer may be changing this. I never gave much thought as to taking or not taking mathematics when I was in high school. I enjoyed maths and also enjoyed teaching other students about how to do the problem sets.
>
> In high school, when I took geometry, I was the only girl out of about 200 in my class who was still attending the mathematics class. I was planning to be an extension agent, and my teachers could not understand why I wanted to learn maths. In graduate school, I was part of the first class in the economics department at Harvard University where we had the option of taking either a language or a mathematics examination. Until then, graduates were only required to pass the language examination. I took the maths option.

However, the journey into the economics Ph.D. program at Harvard started with an undergraduate degree in home economics from Oregon State University, perhaps reflecting the parental expectations at the time for women to prepare for a life that would be devoted to "the family." Polenske obviously had other ambitions, and, after completing a degree in Public Administration and Economics at Syracuse University, she moved to Cambridge, MA, and enrolled for a Ph.D. in Economics at Harvard, working under the direction of Wassily Leontief. Polenske was awarded her Ph.D. in 1966. She remained at Harvard as an instructor, lecturer, and research associate (centered on the Harvard Economic Research Project, HERP) before moving across town to MIT in 1972 as Associate Professor in Urban Studies and Planning; she was promoted to Professor in 1981 and retired as Peter de Florez Professor of Regional Political Economy, now retaining the title of Professor Emerita. I have always gained the impression that Polenske was proud of this trajectory and has never tried to hide her early career path; it is still rather amazing to imagine this journey from rural Idaho to becoming a research associate of a Nobel Prize winner in economics (awarded to Leontief in 1973).

3 Major Accomplishments

Polenske's main research contributions and intellectual achievements will form the basis of the next section. Here, a summary will be provided of the way that two academic organizations in which she worked have recognized her work.

It would be a mistake to look back at the 1960s and 1970s through the lens of today's academic world in which, in most countries, there are significant legal and institutional pressures and incentives to encourage the hiring, promotion, and career development of women and people of color. This was certainly not the case at the time Polenske graduated. Negotiating a career in academia as a single woman in a fiercely competitive and decidedly misogynistic atmosphere was a major challenge and accomplishment. Notwithstanding these challenges, she became a pioneer in the development and application of regional and interregional models—and especially in promoting regional, environmental, and innovation modeling in China. Polenske supervised a large number of Ph.D. and M.S. students at MIT, demonstrating her strong commitment to the training of succeeding generations of scholars.

In 1996, she received the *Walter Isard Distinguished Scholar Award* from the North American Regional Science Council, reflecting the sustained level of her scholarship over many decades. In addition to being active in the Regional Science Association International (RSAI), she was equally committed to the International Input–Output Association (IIOA); she assumed the presidency of the IIOA between 1997 and 2000, becoming the second woman to hold this position (Anne Carter was the inaugural President). Both RSAI and IIOA elected Polenske as a Fellow (RSAI in 2005 and IIOA in 2007). She was the first woman in RSAI to achieve this distinction and shared, with Anne Carter, this same distinction in IIOA.

4 Research Foci

It was while at Harvard, working on HERP, that Polenske initiated the main research activity on which her intellectual contributions were initially based. One has the impression that she was essentially able to create a bubble around her close colleagues and herself that inured her from the carping and criticism that may have prevailed as a result of having a woman is such a senior position. Her accomplishments are all the more impressive given that she was a single woman during a decidedly difficult time in American academia; it speaks volumes to her commitment and self-motivation that she was able to achieve so much. It was also a time in which she product-differentiated herself from Leontief's work, although the linkage to his contributions was readily apparent.

4.1 Multiregional and Enterprise Input–Output Accounts and Models

This is probably the area in which Polenske's initial and sustaining reputation was formed. After completing her Ph.D. in 1966, she joined the HERP that same year and remained in that research association position until 1972 when she moved to MIT. Her primary responsibility was a multiregional input–output (MRIO) study of the U.S. economy, funded in part by the U.S. Department of Commerce. Up to that point, most input–output accounts were developed for single national or regional economies; a few scholars ventured as far as a two- or three-region system, but Polenske embarked on a system for the whole USA, building on the pioneering work of Leontief and Strout (LS) in the development of MRIOs under conditions of limited information. However, the empirical implementation, testing, and evaluation of alternative formulations differentiated her work from LS. What is amazing about this initiative is that, in the early stages of one's career, there is a tendency to be risk averse and to move in a more incremental fashion in building a portfolio of publications. In contrast, Polenske jumped into the most comprehensive modeling

project of its time! The MRIO project dominated her activities (and life) and resulted in a series of books published between 1972 and 1974 by Heath-Lexington (see Polenske 1972b, c, d, 1973a; Rogers 1972). These books were complemented by an article in the *American Economic Review* (Polenske 1970) and chapters in books published after the United Nations–sponsored IO conferences (precursors to the International Input–Output Association), edited by Bródy and Carter (Polenske 1969, 1972a), and the influential book *Planning over Space and Time,* edited by Judge and Takayama (Polenske 1973a, b).

In the development of the U.S. MRIO modeling system, Polenske turned to Japanese data to help in model selection. The Japanese agency, Ministry of International Trade and Industry (MITI), had been producing survey-based, multiregional input–output tables for the Japanese economy for a number of years. These data and associated models afforded Polenske the opportunity to test some alternative methods for estimating the U.S. model. Her findings were reported in an *American Economic Review* article (Polenske 1970). Table 1 shows estimation based on three models: a row coefficient model, a column coefficient model, and a gravity model. Since that time, of course, other formulations have been proposed; Wilson's (1970) entropy formulations were just appearing in print, and alternative specifications of the gravity model were still in development. Essentially, the row and column coefficient approach may be seen as a partial adjustment balancing in only one dimension.

Once again, in 2022, the testing of alternative specifications in modeling is *de rigueur*; computer time, storage, and processing capacity are not issues. However, in the 1970s, the primary motivation in terms of the application to the U.S. model was to make a choice: the cost of solving the full MRIO costs thousands of dollars, and multiple runs/alternative specifications had to be severely rationed. Polenske had to be somewhat parsimonious in the choice of formulations. The test using the Japanse data was accomplished by developing a base model for nine regions for 1960; regional final demands for 1963 were used to estimate 1963 regional outputs and interregional trade flows.

The absolute errors for the row coefficient model always exceeded those for the other two; the row model performed a little better in relative terms, but the other two models were still superior—with little difference between them. Substitution of the 1963 technology reduced errors, but there were still some challenges as a result of changes in interregional trade (subsequent work has shown this dimension is more variable, as evident from the recent literature on fragmentation and global value chains). This work was conducted during a period (in the late 1960s and 1970s) when there was a great deal of attention to being paid to the efficacy on non-survey methods of input–output construction and updating, especially at the regional and interregional level (see an excellent review by Round 1983).

Early work with the U.S. MRIO focused on gravity and column coefficient approaches; convergence turned out to be more difficult with the gravity formulation, so attention becomes restricted to the column coefficient model. A complementary project, funded by the U.S. Department of Transportation, explored the structure of trade flows in physical goods. In the initial formulations, no information was available on modal choice. Polenske claims that estimating the trade flows within an MRIO

Table 1 Summary of multiregional input–output models

	Row coefficient model	Column coefficient model	Gravity mode[a]
Trade coefficient equation	$x_i^{gh} = r_i^{gh} x^o$	$x_i^{gh} = c_i^{gh} x_i^{oh}$	$x_i^{gh} = \frac{x_i^{go} x_i^{oh}}{x_i^{oo}} \cdot q_i^{gh}$
Equation system in matrix form	$R'\Delta X = A\Delta X + \Delta Y$ $(R' - A)\Delta X = \Delta F$ $\Delta X = (R' - A)^{-1}\Delta Y$	$\Delta X = C(A\Delta X + \Delta Y)$ $(I - CA)\Delta X = C\Delta Y$ $\Delta X = (I - CA)^{-1}C\Delta Y$	$T'\Delta X = S(A\Delta X + \Delta Y)$ $(T' - SA)\Delta X = S\Delta Y$ $\Delta X = (T' - SA)^{-1}S\Delta Y$

Source Polenske (1970)

[a] The system of equations for the gravity model incorporates a simplified version of the basic gravity trade coefficient equation. The elements of S and T' in the gravity model are defined as:

$$s_i^{gh} = x_i^{go}\left[1 - \frac{x_i^{oo} x_i^{oh}}{x_i^{go} x_i^{gh}}\right] \text{ for } g \neq k \quad s_i^{gh} = 1 \quad \text{for } g = k$$

$$t_i^{gh} = x_i^{og}\left[1 - \frac{x_i^{oo} x_i^{hg}}{x_i^{ho} x_i^{og}}\right] \text{ for } g \neq k \quad t_i^{gh} = 1 \quad \text{for } g = k$$

where k can be assigned arbitrarily

framework provides the opportunity to ensure that the national aggregates are consistent with census data.[1] Further, unlike many linear programming approaches, the MRIO-based methodology facilitates cross-hauling (an attractive feature of entropy-based modeling estimation). Looking at this work from the 2020s, it is surprising to realize how the combination of faster computer capability together with the collection of additional information by various government agencies (e.g., regional gross products and their components, regional output, income and employment, and the five-year Census of Commodity Flows that at least provide the basis for initial estimation of interstate physical flows by mode) has made the development of an MRIO less arduous. Yet, there have been few serious attempts since Polenske's work. In part, in the intervening years, MRIO systems have been embedded in, or replaced by, multiregional computable general equilibrium modeling (e.g., USAGE developed by the Australian team at Victoria University) where more attention is placed on calibration rather than estimation. The Harvard MRIO program was innovative for its time, with the major innovations coming from the testing of alternative approaches, even if the tests were based on Japanese data that were far more comprehensive.

Leontief was very committed to applied work, and this perspective was clearly instilled in Polenske's research activities. One of the first papers published with Polenske's name as a co-author was a study (Leontief et al. 1965) of the economic impact, regional and industrial, of an arms' cut. This work was conducted at a time when received wisdom suggested that defense spending was such an important stimulus to economic growth that cuts would likely create significant negative impacts. In the spirit of more recent impact analyses that stress the need to explore compensating or net effects, the 20% decrease in military spending was partially compensated by a 2% increase in civilian purchases. Even so, the sectoral and regional net impacts were unevenly distributed, providing a precursor of the heterogeneity of other transformative changes—both planned and unplanned—in U.S. economic policy. While the paper challenged conventional wisdom that any reduction in defense spending would be bad for the U.S. economy, empirical evidence has never stood in the way of political decision-making!

In 1972, Polenske was offered a position at MIT, where she moved to the urban studies and planning department and became an associate professor with tenure. Nine years later, in 1981, she was promoted to professor, and she remained in that position until her retirement. The move also afforded her an opportunity to further product-differentiate her work from Leontief. Polenske's leadership in subsequent research focused on a variety of development issues. Her work in China, in particular, is noteworthy, since it combined her interest in development and input–output analysis, and this will form the basis of discussion in Sect. 4.5. However, she did continue to explore different methodological issues in input–output analysis. For example, continuing her interest in estimation issues, Polenske (1997a) provided a review of

[1] I recall a conversation with her in which she described how she had estimated national GDP by summing estimates provided by states; total GDP turned out to be several orders of magnitude higher than the official estimates for a variety of reasons, including double counting and incorrect assignment of establishment activity to individual states.

the RAS technique, including her own contributions, such as Polenske et al. (1987) where she used a linear programming approach to solve infeasible RAS problems.

4.2 Trade Flows

With Shiqiang He, Polenske revisited the discussion of the Heckscher-Ohlin-Vanek (H-O-V) Theorem and the Leontief Paradox (He and Polenske 2001). The paper provides an excellent summary of the work conducted at both the national and interregional levels and highlights the apparent inconsistency of findings at both levels (e.g., finding support for H-O-V for interregional trade but support for the Leontief paradox at the national level). Once again, the empirical tests were conducted with Japanese data, and there is a comment in the paper that their availability electronically displaced the potential use of the U.S. MRIO data on which Polenske had worked so long to assemble (see, for example, Polenske 1974, 1980).

The Japanese tests used a 9-region aggregation with 10 sectors based on 1985 data. One of the innovations of the paper was to look at trade not only between one region and all other aggregated regions (Rest of Japan, ROJ) but between pairs of regions. To provide a comparison of their work with prior testing, trials of the 2-region context (a single region and the ROJ) were first conducted. HO propositions only were tested:[2]

- A region with the higher capital/labor ration of the two (region and ROJ) should have a higher capital intensity in its outflows than its inflows.
- This region should also have a lower labor intensity in its outflows than its inflows.

The results revealed that for 6 of the 9 regions, there was no support for the proposition regarding capital, and for 4 of the 9, the proposition regarding labor was not supported. The Tohoku region supported both propositions, while Kanto and Shikoku supported neither.

The authors speculated that these findings might be a result of aggregation bias in the definition of the ROJ region—with the possibility that a region may be simultaneously trading with regions that have both higher and lower capital/labor (k/l) ratios than the region of interest—but this distinction would be lost in an aggregated ROJ definition.

Consider the case of a region with higher than average (k/l) ratio: The aggregated results support the Leontief paradox, but this may not hold for individual region pairs. What is needed is some trade-weighted analysis that captures both factor intensities and the share of total trade from a region to the others. Upon further examination of the trade between 72 pairs of regions, they found:

- 37 cases supporting the Leontief paradox with respect to capital.
- 30 cases supporting the paradox with respect to labor.

[2] Vanek's reconsiderations for multigood/multifactor cases were left for future work.

Tests of migration flows failed to support or contradict HO (and, subsequently, Borts and Stein's expectations for factor price equalization).

This paper illustrates Polenske's lifelong commitment to hypothesis testing, as well as the creative use of data to challenge expectations. This approach is even more apparent in her research on regional and industrial restructuring.

4.3 Regional and Industrial Restructuring

Polenske's work in innovation (to be discussed in Sect. 4.6) grew out of an interest in economic development strategies. In her contribution to a collection of essays in honor of François Perroux, Polenske (1988) explored the role of growth-pole theory, focusing on four issues. This paper is highlighted since Porter's (1989) work on clustering seems to have eclipsed many important prior contributions that, in addition to Perroux, would include the work on industrial complex analysis and clustering associated with Isard et al. (1959), Czamanski and Czamanski (1977), and Czamanski and Ablas (1979). First, few analysts provide the historical context for Perroux's work. Second, most of the reviews do not cover current development theories and strategies, as they were written in the early 1970s when current views of development, such as the dependency concept, were just being formulated, and there was tension between growth-pole strategy (what Hirschman refers to as unbalanced growth) and equity concerns. (Perroux would maintain that the spillover effects would address these problems but the empirical evidence to date, bolstered by the theoretical foundations laid by the New Economic Geography, would seriously challenge this expectation). Third, focus on a single region or city, and not a multiregional or multinational setting, generated important biases since much of the analysis and evaluation of the implementation of the growth-pole development strategy did not look at this broader spatial context. Fourth, relevant measures had not been devised to determine whether or not the growth-pole strategy has succeeded; consequently, most analysts were not able to arrive at clear conclusions as to the actual consequences of the strategy. In the current (2022) regional development environment, the same comment has been made about smart specialization strategies.

In considering Perroux's contributions, Polenske focused on three issues: domination, linkages, and distribution. Her evaluation highlights the historical context of Perroux's thinking—especially his focus on the network of spaces associated with the firm rather than formal regions (as Polenske notes, he never made a distinction between the notion of *growth pole* and *growth center*). She further notes:

> Perroux recognized the interregional interdependencies that were developing in the European countries, and he was concerned with the effect interregional trade had on the terms of trade with the developing countries. (Polenske 1988).

The issue of domination (in terms of firms, cities, regions, and nations) pervades both the literature on growth poles and that on dependency. The perspective of the two schools of development theory is, of course, vastly different: growth-pole theorists

maintain that the domination of certain firms is a positive factor in the development process, required to help the mass of the population, while dependency theorists argue that domination leads to expropriation of the surplus product, not for use by the masses, but for use by the capitalists.

Linkages are interpreted in many different ways in the development literature. The most frequent interpretation is in terms of interindustrial linkages, as shown through input–output tables, but reference is also made to interregional and international linkages. However, most growth-pole analysts have concentrated only on regional, rather than multiregional or multinational, growth. (Perroux is one of the few exceptions.) On the other hand, dependency theorists have had the exact opposite concentration, with primary emphasis being given to the growth of the international economy.

As noted earlier, Perroux maintained that investment centered on dominant firms was a necessary condition to obtain sufficient growth to benefit the masses. The spreading of these benefits, he said, would occur the fastest if investment was devoted to the dominant firms that had the greatest backward and forward linkages. He argued that if a country implemented this growth-pole strategy of development, the investment would generate increased output (employment and income) not only in the initial firm, but, because of the strong backward and forward linkages, a multiplier effect would transmit these increases to other firms as well.

Contrasting views are prevalent but with the same factual evidence used by both sides to support their opposing points of view! Perroux maintains that domination and interindustrial linkages are necessary, but not sufficient, conditions for rapid economic growth; at the same time, increases in the rate of economic growth are required for improved income distribution. Dependency theorists maintain that domination and linkages not only limit the increases in per capita income, but also augment the gap between the rich and the poor, both within and between countries. As Polenske (1988) notes:

> A thorough quantitative analysis to support either set of arguments is missing, but would be an important, even though difficult, task to undertake.

A great deal of discussion is currently taking place about the impacts of development strategies, incentive programs, and free trade on interpersonal and interregional equality. While there has been an increase in the use of modeling to address these issues, there have been a much smaller number of papers looking at what Miyazawa (1976) referred to as the structure of income formation, relying on the Gini or Herfindahl indices. These are dimensions on which further attention would be welcomed.

4.4 Enterprise Analysis

Polenske (1997a, b) revisited an issue (or one might say an opportunity) to integrate the more macro-representation of the economy as manifested in input–output

accounts with the operations of individual enterprises or sectors. Some years earlier, Tiebout (1967) advanced the idea of such an integration, in part to address the issue of product mix at the sector level; even with disaggregation to 500 or more sectors, there would still be evidence of bias and lack of representativeness for individual firms or for the product mix within different regions. However, it is not just the output side that may generate biases; a different product mix may also generate a different set of input requirements. The issue was taken up by Hewings (1971), Greytak (1972), and Morrison (1973), but it was Polenske (1997b) who offered a more considered strategy to accomplish this task. In essence, her proposals mirrored the spirit of Eliasson's (1978) micro-to-macro-model of the Swedish economy in which the Volvo enterprise was modeled separately and in great detail from the rest of the economy but with strong linkages between both. Polenske considered a spatial hierarchy in which enterprises, with some important exceptions, occupied the bottom layer of modeling that moved from international-national-regional-city.

The goal was not just spatial (and sectoral) disaggregation but an attempt to further integrate managerial and input–output accounts in such a way that it would be possible to assess the short-term and longer-term consequence of macroeconomic policy on individual enterprises and, in the other direction, the impact of managerial decisions, resource allocations, and potential changes in product mix on the macroeconomy. The last two years (2020–2022), during the COVID-19 pandemic, have provided an excellent illustration of the value of such a system. Consumers have been perplexed at shortages of key products, while enterprises have struggled with reallocations of products from commercial needs to domestic household needs in an era in which working from home has become more dominant. Polenske noted that managerial accounts, with their focus on internal operation and the promotion of efficiency of operations, offer a different (although complementary) role to financial accounts that are used for investment decisions. From her work in China, she was able to learn about a third set of accounts, essentially enterprise accounts. Here, the system linked managerial and financial accounts, presenting information in both physical and value terms. Data were also available on inputs and outputs within units within the enterprise, information that would be of considerable value in assessing the nature and extent of production and spatial fragmentation of production. In China, the accounts were used for targeting and quotas, often with the assistance of optimization algorithms and with strong links to the more macro-input–output accounts. This work provided a case study using the Anshan Iron and Steel; Fig. 1 shows the way in which these accounts are integrated. Having access to such detailed data—in China, for this study, and in Sweden, for Eliasson's work—one can see enormous potential in the ability to link micro- and macro-levels of analysis and to further integrate and optimize planning and allocation decisions, especially during periods when unexpected events interrupt the operation of markets.

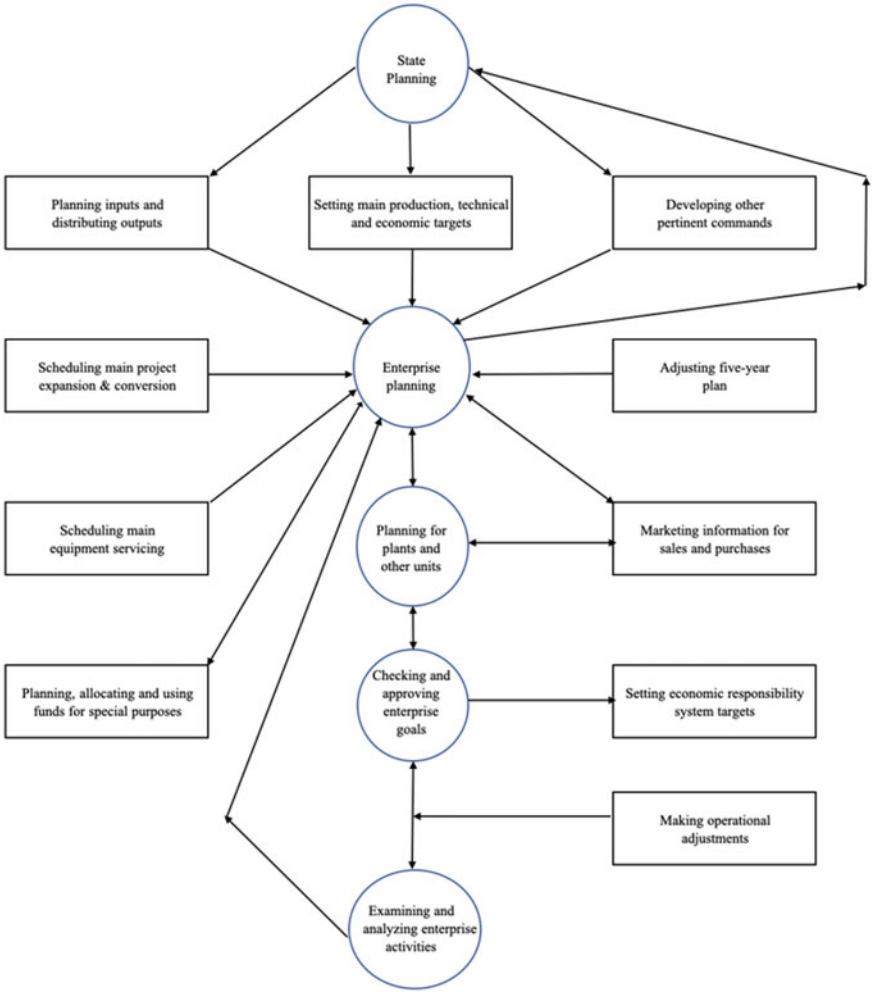

Fig. 1 Integration of accounts. *Source* Zhang (1991)

4.5 The Role of Input–Output Analysis in Chinese Economic Planning

The enterprise analysis described earlier was part of a broader focus of Polenske's work centered on China that began with a two-month visit in 1986. Her jointly edited book (Polenske and Chen 1991) contains a rich collection of articles that revealed the enormous range and sophistication of the applications of input–output analysis

in China.[3] In fact, the third part of the book has a series of case studies of enterprise input–output analyses; the rest of the book illustrates the variety of application, ranging from price reforms, dynamic input–output, a focus on agriculture and energy, and six chapters of regional modeling.

The innovation of the book was that Polenske was the only non-Chinese contributor; obviously, a great deal of work went into the selection of authors and the careful editing of their contributions. Looking back now, it is easy to underestimate this challenge, and the uniqueness of the contribution was that it established Chinese scholarship in this field at the forefront of the international spectrum.

Polenske (2006) continued her work in China and her interest in steel-making and related industries with a volume that explored the intersection of technology-energy-environment and health, focusing on coke-making in Shanxi Province. Once again, Polenske engaged with Chinese scholars, supplemented by other international specialists. Attention was directed to a number of specific issues ranging from the choice of technologies and the role of energy efficiency and profitability. Here, production ranged from state enterprises to smaller units run by townships and even villages. The intersection of interest was the local economic dependence on these smaller village-level enterprises, but which came with a "cost" in terms of high levels of pollution and a concomitant negative effect on the environment and, ultimately, health. Local residents (as well as the workers in these enterprises) were exposed to ultrafine particles that comprised their health. Several chapters in the collection address these issues, with a broad focus on the socioeconomic-health-environment impacts. This work continued her longtime interest in linking input–output accounts and models with the environment (e.g., Forssell and Polenske 1988).

4.6 Innovation

Polenske's interest in economic development continued throughout her career; even the work in China had strong overtones of engagement with development issues. In 2007, she edited a book, *The Economic Geography of Innovation.* The motivation came in large part from a special seminar she organized for her students. They assisted in identifying scholars whose work they wanted to explore, and the selected scholars were subsequently invited to MIT to deliver lectures on their chosen topic. There, they were grilled and interrogated by very well-prepared graduate students. Subsequently, chapters were submitted, and Polenske, with assistance from some of the more senior students, assembled the book. I think that her work in China has highlighted the enormous variations in technology, innovation, and spatial diffusion

[3] Professor Chen Xikang, Polenske's co-editor of the 1991 book, became Fellow of the International Input–Output Association primarily for his work in Input–Output Occupancy Analysis in which the usual I-O accounts were extended to include the use (occupancy) of assets.

of technologies. Hence, the authors were asked to focus on how technology, innovation, and alternative means of transferring knowledge changed the spatial relationships among firms. In fact, the role of space plays a dominant role throughout the book, providing a counterbalance to other collections that looked at the process in an aspatial context. In her introductory remarks, Polenske (2007) highlighted the enormous intellectual debt owed to the work of Schumpeter. A further example of this interest is her work on clustering versus dispersal in space (Polenske 2008), in which she explored the role of economies of scale and innovation and the way they helped make regional development sustainable. This paper built on an earlier exploration of regional supply chains, both internal and external, and the way they enhance the competitive advantage of regions.

In the next section, some of Polenske's contributions to the organization of science will be acknowledged, a recognition of the fact that her work embraced not only science but the organization of science, mentoring, and, especially, the training of the next generation of students.

5 Organization of Science and Mentoring[4]

Karen Polenske was among the key individuals in the creation of the North American Regional Science Council at the time that the Regional Science Association was morphing into the Regional Science Association International. Whereas in both Europe and the Pacific Rim autonomous organizational structures were already in place to oversee conferences, the North American Meetings had through the 1980s been hosted under the auspices of the RSA itself, with David Boyce of the University of Pennsylvania as the lead organizer. Under the new, umbrella RSAI structure, a third "super-" or "supra-"regional organization was needed.

Professor Boyce convened a day-long constitutional convention prior to the opening of the 35th North American Meetings in Toronto in 1988. The goal was to brainstorm a new system for hosting the meetings and for affiliating, under a common structure, the five independent North American regional organizations that pre-existed the new organization as member sections of the RSA. Polenske was among the invited delegates, and she contributed wise counsel regarding a number of the ideas that were ultimately incorporated into the NARSC Constitution. Among those was what came to be called the "Polenske Clause" regarding the role of the NARSC President. It was decided that the President should serve in a mostly honorary role, with primary responsibility for presenting a Presidential Address to open the conference. The President, appointed by the NARSC Council, was to be a scholar from the region of the North American member organization whose turn it was to host the meetings but, Polenske argued, should be an individual who did not

[4] Part of this section was prepared by David Plane who was able to observe these contributions at first hand.

have organizational responsibilities for organizing the conference or for chairing the council during the year in office.

The NARSC Constitution resulting from the Toronto discussions, and as drafted by a sub-committee chaired by David Plane, was agreed to by the five member organizations at the subsequent 36th North American Meetings in Santa Barbara, as well as being approved in 1989 by a mail-ballot vote of the members of RSAI based in North America. The same ballot contained the names of nominees for the first at-large members of NARSC Council, with Professor Polenske's among those. She was elected and subsequently served for a term extending from 1990 through 1993. The newly created organization would experience some birthing pangs during her tenure on the council. Contentious issues about finances, procedures for running the meetings, and the autonomy of member organizations vis-à-vis NARSC—as well as the relationship of NARSC vis-à-vis RSAI—would be resolved, thanks in no small measure, to Professor Polenske's sensible, wise counsel and her vision of what is most central to the mission of science and scholarly organizations.

Polenske was devoted to her students; she was enormously proud of them and their accomplishments, and the research they worked on was embedded in her work. It has been difficult to collect an accurate number of the doctoral students she supervised (I have an incomplete listing of 10),[5] but colleagues estimate that she has supervised over 200 in the master's and doctoral programs at MIT. Many of these students are from China, and, in Polenske's honor, they have funded a student prize, The ACSP/AACP Karen Polenske Best Student Paper Award, for an outstanding paper on a China planning topic. This award is given annually to International Association of China Planning (IACP) student members who present excellent research at the conferences of the Association of Collegiate Schools for Planning (ACSP). Given Polenske's huge investment of time and resources in research on China—she was Visiting Scholar in the Chinese Academy of Sciences at least six times and a frequent visitor on other occasions—it is a suitable acknowledgment of her sustained contributions.

6 Summary Evaluation

Polenske was appointed as Peter de Florez Professor of Regional Political Economy at MIT in 2009. I think her designation as an endowed professor of political economy is really appropriate. While her early work was deeply involved in the construction and testing of models, for the last three decades, or more, she has worked at the interface between economy and society, with a primary spatial focus in the USA and China. However, I think that she would also agree to a label as an applied regional economist: see for example, Polenske (2004), where she shows the delight she took in proselytizing on behalf of Leontief's "magnificent machine." The China experience

[5] The list includes Ngozi Okonjo-Iweala (Ph.D., 1981), who assumed Director General's position in the World Trade Organization in March, 2021.

provided the opportunity to modify, enhance, and expand the focus on this machine, and it engendered her transformation to a regional political economist. Her last ten publications explore topics such as land recycling in China, bioenergy, energy in the food system, clustering, impacts of dust storms, and innovation, while only one focuses exclusively on input–output analysis.

Polenske has been very imaginative in extending the scope of the "magnificent machine." As well as addressing important problems, Polenske has shown that having an effective analytical framework can raise the quality of contributions to policy formulation and evaluation. Her regional science focus, like her input–output perspectives, has been manifested in extending research to consider spatial dimensions. I think she felt equally at home among input–output and regional science perspectives because she was intellectually bilingual, often merging the two successfully.

Professor Polenske's intellectual contributions are matched by her commitment to professional organizations and by the time and care she has expended in encouraging women to not only participate but assume leadership roles. Her early experiences in less than tolerant environments made her acutely aware of the need to change the attitudes toward female participation. Through her sustained intellectual leadership and devotion to mentoring, she encouraged successive generations of women to "stay the course." The honors she has received from RSAI and IIOA bear eloquent testimony to her contributions that embrace scholarship, the organization of science, and a lifelong commitment to students. The journey from her birth in rural Idaho and childhood in an agricultural region of Washington State was a long and difficult one at times, but colleagues in regional science and input–output analysis are grateful that she took this path and was so successful.

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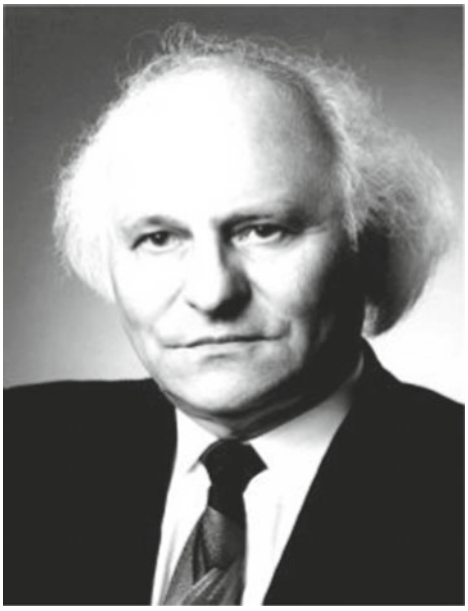
Wolfgang Weidlich (1931–2015): A Pioneer in Sociophysics

Denise Pumain



Wolfgang Weidlich. *Source* Shoolman (2015) by permission of Harvey Shoolman

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1 Introduction

I had the immense pleasure to work with Wolfgang Weidlich in the 1980s and 1990s. The theoretical approach and the models he proposed were at that time well in line with the expectations of geographers interested in dynamic formalizations to represent socio-spatial transformations. The work of this physicist inspired many people and marked an important moment in the opening of regional science to system dynamics. It will undoubtedly have profound repercussions in the coming decades for advancing our understanding of the evolution of opinions as revealed from handling the massive data generated by various uses of mobile sensors and social networks.

Wolfgang Weidlich was a luminous speaker and a smiling, caring person, a man deeply imbued with humanism and culture. I would claim with Shoolman (2015) that:

> ...it may well be that succeeding generations will realize that Weidlich was one of the great intellects of the 20th century. Weidlich is recognized as the founder of a relatively new discipline which he called 'Sociodynamics', the attempt to treat social and cultural phenomena in the same way that we model physical systems.

Indeed, I shall try to show that his contribution was more than that and, perhaps moreover, different.

2 A Life With Bifurcations

Wolfgang Weidlich was born in Germany, in the city of Dresden, on April 14, 1931. He studied at the Technical University of Berlin and then at the Free University with a marked predilection and talent for mathematics and physics. He completed his "Habilitation" in relativistic quantum field theory in 1963. The outstanding quality of his work led to his being recruited by the University of Stuttgart as a lecturer in 1963 where he became Professor in 1966. He lived in Stuttgart with his wife, Ursula, and his two daughters, Sophia and Irene, until his death on September 21, 2015. This seemingly straightforward path to an exemplary career in theoretical physics at a major German university was, on the contrary, bifurcated by two factors, geographical and thematic.

The decision of Wolfgang's parents to move from eastern to western Germany when he was 13 years old was indeed not geographically trivial at the time and probably changed the course of his life. The semantic bifurcation in his research interest may appear paradoxical but is linked with his changing places, since it was when he discovered laser physics and Haken's (1977) synergetics in Stuttgart that Wolfgang Weidlich embarked on the path of demonstrating its possible applications to the human and social sciences. The physical theory of synergetics shows how the numerous particles of a system can under certain conditions interact, exhibiting correlations over long distances relative to their dimensions, to generate, in a mathematically predictable way, more complex structures at a higher level of organization.

This is the case in lasers when the usually chaotic course of photons "self-organize" for becoming an intense beam of energy. By no means would Wolfgang Weidlich consider human beings as unconscious particles, but he believed that the mathematical models inspired from synergetics could help in understanding some intriguing regularities in human mobility and collective behavior.

Above all, the theory predicts that several configurations are possible for a state of the system at the macroscopic level from the same description of the microscopic states. The dynamics of these systems combine stable trajectories and moments of instability, during which the macroscopic state of the system can evolve toward different forms of organization, in an unpredictable way, according to bifurcations. It thus includes hypotheses of the irreversibility of time, of the unpredictability of the future and of the uniqueness of the "historical" trajectories of each system, made up of an original succession of bifurcations. These are proposals that make applications from physics reconcilable with the universe of social sciences, where these ideas are not inherently novel in their own right! In fact, if these ideas are attractive, it is because they are accompanied by mathematical models, which simulate social processes and which are capable of generating with the same equations a very great diversity of forms and evolutions. Not only are their hypotheses less reductive than those of deterministic or linear models, they also allow social scientists to indulge in the asceticism of model testing with a better conscience!

In the perspective of modeling social interactions that can lead incrementally to abrupt changes, Wolfgang Weidlich discovered a way to answer a question that had nagged him all his life, to understand how German opinions were able to align together at the time of Nazism. Harvey Shoolman explains, with more detail than I knew, the initial motivating trauma:

> Behind such an intellectual project lay Weidlich's intense discomfort and shame at the enormities Germany had perpetrated in his youth. As a 12 year old member of the *Dresdner Kreuzchor*, Weidlich indelibly recalled a concert the choir gave in Silesia in fall 1943. Just 2 kilometers away in the distance he could see a complex of squat wooden buildings and black smoke emanating from tall chimney stacks. This was Auschwitz at full working capacity. That same day the choir visited the I. G. Farben chemical works (the company that manufactured Zyklon B gas, used to kill millions at Auschwitz and other camps) and there the boys were witness to the meaninglessly cruel toil of pin-striped slave labourers from the nearby camp. Weidlich never forgot such scenes. That experience planted the seeds of the unremitting determination he came to feel that such things should never happen again and that he shouldered a moral responsibility to devote his intellectual energies to finding out precisely how and why they came to pass in the Germany of his youth and in the culture whose artistic and scientific heritage he venerated. (Shoolman 2015)

Before my first encounter with Wolfgang Weidlich, I attended several meetings organized in France by the *Association Française pour la Cybernétique Economique et Technique* (AFCET), led by an economist, Bernard Paulré. I also participated in two international conferences marking my entry into a universe of systemic references: the first organized in Boston at MIT in 1981—still largely dominated by Forrester-type systems analysis—and the second in Brussels in June 1982 (AFCET-SOGESCI 1982) organized by the Prigogine's laboratory and which was already

largely devoted to self-organization theories. For the record, it was during a conference on entropy organized in Créteil University in March 1982 that I had met Peter Allen and discovered through Prigogine's theory of self-organized systems a more general formalization of the observations we had made about the socio-economic evolution of French cities with Saint-Julien (Pumain and Saint-Julien 1979). We had started a collaboration with the Brussel's team for applying the model developed by Allen and Sanglier (Allen et al. 1981) to the socio-spatial evolution of Rouen's urban agglomeration (Pumain et al. 1983) and later on to five other large French urban regions (Pumain et al. 1986, 1989). I had this in mind when I attended the NATO Advanced Studies Institute "Transformations through space and time" that the American geographer, Dan Griffith, organized in July 1982 in San Miniato (Tuscany, Italy). Listening to Günter Haag's presentation "A dynamic model for the non-linear migration of human populations" extracted from the Weidlich and Haag's book on quantitative sociology (1983),[1] I could easily recognize the same kind of paradigm that was, however, not yet familiar to most of our colleagues from North America. Wolfgang Weidlich and Günter Haag were at the time already fully involved in the field of human sciences, mainly geography and regional science, because their dynamic quantitative sociology used the spatial dimension for representing social transformation. They started working intensively with scientists interested in social applications in different parts of the world.

The San Miniato two-week workshop was remarkable in having attracted many young regional scientists and geographers together with mathematicians and physicists who started interacting from that first meeting and whose names would become famous in the following decades.[2] After that meeting, Wolfgang Weidlich and Günter Haag spent a few months at the Institute of Physics at Cleveland's Case Western Reserve University. While in North America, they encountered Yorgo Papageorgiou at McMaster University in Hamilton and discovered they could enrich the migration model that had been presented in San Miniato with regional attractiveness parameters. This refinement, together with an empirical application to Canadian data, resulted in a paper published in *Geographical Analysis* (Haag and Weidlich 1984). They also met in the USA with another San Miniato participant, Dimitri Dendrinos, who invited Günter Haag to Kansas. The two subsequently published a pair of papers on the dynamics of interacting processes leading either to limit cycles or, in more dimensions, to chaotic development (Haag and Dendrinos 1983; Dendrinos and Haag 1984). During this same period, Wolfgang Weidlich was invited to IIASA in Laxenburg (close to Vienna) where he met Michael Sonis, another San Miniato participant.

[1] This book is prefaced by Herman Haken, and both authors dedicate it to their parents, "who conveyed their experience from more difficult times to their sons."

[2] Among others: Robert Bennett, Cesare Bertuglia, Roberto Camagni, William A. V. Clark, Leslie Curry, Dimitrios Dendrinos, Lidia Diappi, Günter Haag, Robert Haining, Giorgio Leonardi, Silvana Lombardo, Bernard Marchand, Peter Nijkamp, Silvia Occelli, Jean Paelinck, Yorgo Papageorgiou, Denise Pumain, Giovanni Rabino, Aura Reggiani, Lena Sanders, Eric Sheppard, Michael Sonis, and Harry Timmermans.

The ground-breaking event in San Miniato was followed by a second NATO summer school in Hantsholm, Denmark, in 1985, where Wolfgang Weidlich and Günter Haag were both present. There Wolfgang Weidlich presented on "A phase transition model of spatial agglomeration processes" and his discussants were David Plane (University of Arizona) and Dominique Peeters (Université de Louvain). Wolfgang Weidlich and Günter Haag made a new presentation of their migration model using the master equation and invited colleagues to experiment with it for comparative research on the dynamics of interregional migration. They organized a small meeting with Michael Sonis, Giovanni Rabino, Ingvar Holmberg, Jacques Ledent (recommended by Yorgo Papagiorgiou), Nikias Sarafoglou, Rolf Rainer, Martin Munz, and Denise Pumain. We all together discussed a possible book that would apply the same Weidlich-Haag migration model to interregional migrations in eleven different countries. The kick-off meeting was launched in 1986 at Blindenmannshäusle, Günter Haag's family second home in the countryside near Stuttgart, and, after many stays there, as well as international data exchanges through pioneer electronic devices (precursors of the Internet),[3] the book comparing the evolution of the interregional migration patterns in eleven countries was published in 1988 (Weidlich and Haag 1988). Many co-authors participated at the ceremony organized in 1991 at the University of Stuttgart to celebrate Wolfgang Weidlich's 60th birthday (Fig. 1). Wolfgang Weidlich met for the first time Peter Allen in 1989 in the 6th European Colloquium of Theoretical and Quantitative Geography (ECTQG) that we organized at Chantilly. That conference was also attended by another Great Mind, Peter Haggett, who published the photograph of the attendees in his book, *The Geographer's Art* (Haggett 1990). Later on, I invited Wolfgang Weidlich to participate in the 18th ECTQG meeting in Dourdan near Paris in 2013 where he discussed the theme "Geography and Complexity" with Peter Allen and Michael Batty.

At a time when oral presentations were not yet based on slide projections, Wolfgang Weidlich's lectures impressed all his listeners by their extraordinary clarity and precision. In spite of the difficulty of the physical and mathematical notions he was enunciating, his speech was always articulated according to a great logic, without any rhetorical effect or superfluous detail: It was a delight of conciseness and intelligence, and thus, you could not help but understand the ideas!

[3] After reading the software that was written in Fortran, I was able to solve the mystery of the contradictory interpretation we had about migration preferences, because while geographers understood in migration matrices a M_{ij} flow as a movement from region i to region j, physicists were used to the reverse notation, interpreting it as migration from region j to region i.

Fig. 1 Celebration of Wolfgang Weidlich's 60th birthday in 1991 at Stuttgart University with Giovanni Rabino (to his right), Günter Haag (to his left), and Denise Pumain behind. *Photo source* Günter Haag, published with his permission

3 Applications of the Master Equation to Geographical Movements and Social Interactions

What really mattered to Wolfgang Weidlich was a political question that he tried to investigate from the perspectives of all fields in the social sciences through the powerful instruments of theoretical physics. As early as 1971, he wrote in a British statistical journal his views about the roots of polarization in societies (Weidlich 1971). That topic is examined again in the book he published in 1983 with Günter Haag on quantitative sociology (Weidlich and Haag 1983). The chapters deal with opinion formation, attitude space, migrations and birth/death processes in populations, non-equilibrium theory of investment ("the Schumpeter clock"), and interactions between competitive societies, applying to each topic a "master-equation" framework that is first explained in a natural sciences context. Having said that "synergetics is the science of collective static or dynamic phenomena in closed or open multicomponent systems with 'cooperative' interactions between the units of the system" (p. 1) the authors develop a probabilistic theory of the evolution of such

systems. At the micro-level, an equation of motion describes the transition probabilities from one state to the next and how their outcome can display a diversity of configurations in the statistical distribution at the macro-level.

The master-equation method relies upon theoretical principles used in the field of synergetics. It is potentially of great interest to regional and urban research because it links explicitly the state transition probabilities of individuals at a micro-level and the evolution of some variables describing a macroscopic structure. The master equation describes the variation in time of the probability of the possible configurations in the space of the state variables. This probability of transition from one configuration to another depends on the assumptions made about the number and nature of parameters affecting the individual transition probabilities. This stochastic formulation is then used to derive a deterministic equation for the evolution of the mean values, which, in turn, allows the estimation of the parameters on empirical data.

The method can be illustrated with the Haag and Weidlich (1984) model of interregional migrations. Individual transition probabilities from one spatial subdivision to another are defined as functions of the difference in the attractivity of regions (interpreted sometimes as individual utilities). These flows are aggregated to define an equation of movement of the probability of states of the system (e.g., all possible configurations of population repartition among regions). The dynamics of the spatial system is then related to trend parameters whose values may be compared from one country to another,[4] or over time (a global mobility rate; a "co-operation," i.e., an agglomeration effect, and a saturation effect), and results in a set of preferences for each region. The socio-economic variables that could explain these preferences are not included in the dynamic model. However, when fitted by a regression model upon a temporal series of preferences as established from the model (from annual or several periods' migration tables), they allow a prediction of future migration patterns and of the further evolution of the spatial configuration of population. The dynamic model, moreover, makes it possible to evaluate the gap between the current and future distribution of the population and the one that would result from the continuation of current migration trends. A correlation coefficient is calculated between the distribution of the population in the regions at each date and a fictitious distribution which is obtained by letting the migration process develop with the same pattern of territorial preferences (that of the period under consideration), over a long period of time. For the first time, the Weidlich and Haag (1988) book provided comparable figures quantifying the migratory trends in eleven countries that are very different in scope, in number of territorial subdivisions, and in mobility rates.

In addition to the fact that it is a dynamic model, Weidlich and Haag's model deviates from previous spatial interaction models (such as the gravity model) in one essential aspect: The physical distance between regions does not explicitly act as a brake on movement; a coefficient playing this role is estimated for each pair of regions based on observed migrant flows (Pumain 1988). It is assumed to have a symmetric effect for any pair of regions, so it is only the non-symmetric part of the flows

[4] This is clearly an improvement to previous experiments with gravitation models whose estimated parameters are dependent on the number of spatial subdivisions and do not enable such comparisons.

that is used to define regional preferences and identify residual flows. This model therefore does not imply the assumption of a uniform level of interregional mobility, and it substitutes for physical distance a more phenomenological expression of the separation between regions estimated on the basis of observed migratory flows (Haag and Pumain 1991; Pumain and Haag 1994).

Sanders (1992) applied this model to a large set of French cities observed between 1954 and 1982. She related the shift of the migratory preferences from the north-eastern cities to the southern ones to the emergence of business services as a major source of differentiation in the contemporary dynamics of the system of cities. She also provides various scenarios of possible further evolution, which can be obtained from different hypotheses about the future migratory trends (Haag et al. 1992).

The formalism of the master equation was also introduced by Wolfgang Weidlich in at least two other major fields of interest for regional scientists. A model of nonlinear economics simulates the dynamics of competing firms:

> A configuration of macro-economic variables whose probabilistic evolution is coupled to the decision making of agents is described by a master equation where transition rates are modelled in terms of utility measures of the agents. Beyond a critical value of a "competitivity parameter" a homogenous market will develop into an inhomogeneous one with winning and losing firms. (Weidlich 1991, p. 233).

The master-equation framework was also used for developing a dynamic theory of settlement formation that was published in the *Annals of Regional Science* (Weidlich and Munz 1990) deploying a model using synthetic data; the theory, to my knowledge, was never experimented upon with empirical data.

4 A Flourishing Interdisciplinary Context for Complex Systems Science

Wolfgang Weidlich's work is part of the emergence of new forms of dialog between the disciplines of the physical, biological, and social sciences, which, from the 1950s onward, schematically led to the succession of three currents in systems thinking. A first step was a cybernetic approach, named "system dynamics," developed at MIT by Forrester (1969), which questioned the autonomy of open systems in relation to their environment and proposed simulations of interactions in terms of stocks and flows using a dedicated computer language, Dynamo. A second approach, mainly developed in Europe, consisted of theories of self-organization that were independently proposed in Belgian chemist Ilya Prigogine's dissipative structures (Prigogine and Nicolis 1967) and in German physicist Haken's (1977) synergetics. Both designed models describing the two levels of transition between behaviors of individual elements and attributes of collective organizations by means of systems of nonlinear differential equations. The evolutions of these systems lead to stable trajectories, oriented by attractors, and to moments of bifurcation; the latter are abrupt modifications of the trajectories under the effect of internal fluctuations or

external perturbations which make the trajectory jump from one attractor to another with several possible solutions according to variable probabilities. The third approach is global and covers the complexity sciences developed in Italy at ISI (Institute for Scientific Interchange, founded in 1983), in the USA at the Santa Fe Institute (founded in 1984), and in Europe with the Complex System Society launched by Bourgine and Lesne (2010) and Johnson et al. (2017),[5] and in many other laboratories for complex systems in the world. The complexity paradigm encompasses the previous theories and models and emphasizes the notion of emergence or novelty in systems, elaborating mainly agent-based computer simulation models for testing a variety of theories in all scientific fields.

According to physical theories such as the dissipative structures of Prigogine or synergetic theory as developed by Haken, phenomena of self-organization and bifurcation may occur in open systems when they are maintained under an influx of energy. These systems may organize themselves into structures that are created or destroyed during the evolution of the system. This evolution is both deterministic—according to a trajectory that can be predicted using the equations of a model describing interdependencies between variables—and random, or undetermined, during periods of instability when a change in structure (or a phase transition) can occur. The equations of the model may therefore admit several solutions that are different dynamic equilibria. The state variables of the system may follow one or another possible trajectories corresponding to qualitatively different structures. The system may be driven toward one branch or another, toward a given form of organization, sometimes by the huge amplification of a very small change in the value of one variable or one parameter. Many sources of instability intervene in the evolution of such open systems when they are situated far from equilibrium. On the one hand, they continually undergo internal fluctuations, variations in the level of their characteristic variables (which may result from changes in the micro-states of the elements of the system); on the other hand, they are always subject to external perturbations stemming from their environment. An open system is thus continually adjusting the level of its variables or the size of its subsystems. It maintains a relative structural persistence only when this structure constitutes, under the given conditions, a stable state for the system: that is, a state toward which the system returns after having distanced itself a little. The structure is then viewed as an attractor on the system's trajectory. The dynamical instability may induce a passage from one trajectory to another, from one structure to another structure, i.e., from a given qualitative behavior of the system to another, through a bifurcation point.

The models of spatial interaction and regional dynamics developed at Leeds under Wilson's (1981) direction are explicitly inspired by the mathematical catastrophe theory of Thom (1974). Obviously, they are also linked to the above-mentioned analytical approach since they can be subdivided into sub-models generating travel-to-work or residential shopping patterns of flows, allowing for some analytical descriptions of the morphogenesis of the location pattern of places of residence

[5] https://cssociety.org/community.

or of shopping centers. Bifurcations and equilibrium points may be studied analytically for variations of one parameter, the others being held constant. The determining effect of the sensitivity of people to travel costs in shaping the pattern of residences and the strong impact of a parameter describing the sensitivity of consumers to scale economies in generating a concentrated or dispersed pattern of shopping centers illustrate the concept of bifurcation. Above a critical value of the parameter, the city evolves toward a concentrated pattern, whereas below this value, the pattern will become fully dispersed. For more complex formulations of the models, linking the supply side and the demand side of the urban dynamics, and disaggregating the variables into various income groups, types of housing, or kinds of economic activities, the global dynamics of the system can be studied by means of simulations.

Weidlich's ideas together with the self-organization paradigm percolated more deeply in Europe than in the USA among geographers and regional scientists. The Weidlich and Haag (1988) book on migration is not quoted in papers on spatial migration patterns in the USA (for instance, Plane and Mulligan 1997) nor in reviews of migration research in regional science from a North American perspective (Greenwood et al. 1991; Newbold 2012). Wolfgang Weidlich's impact was rather great among Italian regional scientists and partly inspired many publications such as those of Camagni et al. (1986); Bertuglia et al. (1987, 1990); Diappi (2004); Haag and Lombardo (1991); and Lombardo and Rabino (1984). Nijkamp and Reggiani (1988a, 1991, 1993) designed many models for analyzing regional dynamics through spatial interaction, referring to "chaos theory" and linking that with models of discrete choice (Nijkamp and Reggiani 1988b). Nijkamp also developed that field with the Austrian geographer Fischer (Fischer and Nijkamp 1985; Fischer et al. 1988). Notably, Wolfgang Weidlich's work was quoted by the North American Brian Arthur (1994) in his seminal book on increasing returns and path dependence in the economy. Wolfgang Weidlich and Herman Haken's synergetic theory also were major sources of inspiration for Portugali (1999), who was interested in designing models of urban sociospatial segregation and models of spatial cognition. Synergetics is a fundamental reference for analyzing how social processes of avoidance, isolation, or conquest lead to more or less pronounced spatial segregation of certain social categories (Haken and Portugali 2003).

From my point of view, Wolfgang Weidlich's influence in his chosen domain of social physics may have been limited by the German academic system, which overvalued the status and function of the "Herr Professor," but for a long time left brilliant assistants in relatively precarious condition. The latter occupied contractual positions and had the greatest difficulty in being admitted to the full academic staff. This limitation was probably even more restrictive in thwarting the development of innovative disciplines located at the margins of the most recognized sectors and especially those that transgressed the boundaries between natural and social sciences. We have thus deplored the fact that the German participants in the first European colloquia on theoretical and quantitative geography—those who represented a third of the participants in Strasbourg in 1978, who were still present in Cambridge in 1980, and who organized the next one in Augsburg in 1982—have subsequently practically disappeared, as this specialty has been countered by the establishment. Among the

most well-known and accomplished disciples of Wolfgang Weidlich, Günter Haag never obtained an academic position at the University of Stuttgart despite his strong international recognition and his participation in the teaching of theoretical physics and synergetics. Haag was able to innovate in a different way by creating a research and consulting firm that used master-equation models and developed neural network applications to urban planning issues for Stuttgart and regional planning for the land of Baden Württemberg. Aware of this situation, Wolfgang Weidlich asked me to propose a thesis topic in France to Pierre Frankhauser, although Pierre had already obtained a doctoral gradation in physics (with a thesis applying entropy measurements to the development of a system of cities) but was still without a permanent position and being paid on contracts at the age of 40. When one knows the rest of his career—the international recognition of his work with a French doctorate on fractals (Frankhauser 1994) and then his obtaining a position as University Professor in Besançon and a senior position at the Institut Universitaire de France—one can measure the loss for this German system among the potential successors of Wolfgang Weidlich.

5 Current Relevance of Weidlich's Work

The models that are derived from the theory pioneered for the social sciences by Weidlich are operational. They enable exploring possible futures starting from more realistic scenarios than those generally resulting from speculations because they incorporate the past dynamics of the system being considered. Further progress is to be expected from a more explicit integration in these models of the relations between individual behaviors captured in their variety, the interactions between these behaviors, and the transformations of the consecutive spatial forms. The "multi-level" models linking the diversity and evolution of individual characteristics at micro-level with the configuration and evolution of urban and regional patterns are now much more feasible thanks to the big data deluge and high-performance computing (Raimbault 2021). The relationship to be established between the variables, the categories which reflect at micro-level the intentions or the strategies of the individuals, as often derived from their observed behavior, and the variables that describe at macro-level the aggregate structures, that is, the categories that make sense at the level of regional entities, remains however, a very delicate passage in these models, especially because it also implies to integrate different scales of time (Pumain and Sanders 2013).

In contrast to the models of the New Geographical Economy, Wolfgang Weidlich's work does not refer to a general principle of spatial equilibrium, but, on the contrary, describes systems far from equilibrium. In addition, it does not rely on a simple rule such as that of increasing returns or random proportional growth to explain differences in economic concentration according to location. On the other hand, his models fully incorporate the idea of "path dependency," of the persistence over time

of geographical locations and concentrations, which evolve much more slowly than the factors that change their content (Haag 2017).

In the applications of systems theory to urban systems, a noticeable evolution can be observed in the scientific domains where analogies are drawn. The first uses of a concept such as entropy, for instance, was in reference to statistical mechanics, and then to information theory. The dynamics of cities as open systems far from equilibrium was first conceived with reference to "dissipative structures" or "synergetics," conveying analogies with physical systems. An alternative way of thinking is now more and more guiding the work of urban theorists and modelers. They still use the mathematical tools first proposed by physicists (or mathematicians) for building and testing their models, but their theoretical analogies are more often made to living systems. A shift has taken place from the pure concept of "dynamics" to the concept of "evolution" (Allen 1997), and, especially, "co-evolution" (Pumain 2021). Although urban systems can be described as largely self-organized open systems, whose structure and evolution depend upon internal fluctuations as well as external perturbations, they also have a historical and evolutionary behavior, as well as an adaptive hierarchical structure and a power of creativity, which invites to develop more analogies with living systems. Nevertheless, the more recent publications by Wolfgang Weidlich maintain an interest for mathematical modeling in the social sciences (Weidlich 2006), the formation of political opinions (Weidlich and Hubner 2008), and quantitative sociology conceived from social interactions (Weidlich and Haag 2012).

6 Scientific Recognition in the Literature

Wolfgang Weidlich's influence is remarkable because it is mainly transdisciplinary. An obituary praised his outstanding research contributions in theoretical physics, inside the Stuttgart team:

> Among other things, they recognized the laser transition as a cooperative phenomenon, revealed the statistical properties of light near the laser threshold and laid the foundations of the modern theory of quantum statistical master and Langevin equations. (Grabert et al. 2015, p. 50)

Indeed, more than 5000 citations now appear on Google Scholar, but most of the titles are not in physics, they are in the social sciences! You have to wait until the sixth page to find references related to physics (such as Weidlich 1976). As early as 1991, Wolfgang Weidlich shared his interest in transferring models from physical statistics to social sciences in an article in a famous journal of physics (Weidlich 1991). The influence of synergetics seems widely recognized in sociology where 635 citations are found for his book on Sociodynamics (Weidlich 2006) and 867 for the book he published with Günter Haag on Quantitative Sociology (Weidlich and Haag 2012). The citation counts, however, are not so numerous for topics of interest in regional

science or geography: 275 citations for the collective work on interregional migration Weidlich and Haag edited in 1988, 81 for explaining agglomeration processes as phase transition in an article in the *Journal of Regional Science* (Weidlich and Haag 1987), 114 citations for a paper in economics (Weidlich and Braun 1992), 44 for a paper on settlement formation in a regional science journal (Weidlich and Münz 1990), and only 37 for an article about the evolution of settlement systems (Weidlich 1999). A few papers in transdisciplinary journals, such as Weidlich (1997) or Weidlich and Helbing (1998), did not receive much attention.

The story of scientific recognition for Wolfgang Weidlich's work is not finished however: For instance, in a recent call for a Ph.D. in geography,[6] Olivier Bonin announced a modeling exercise for urban transition in connection with transportation systems and quoted the "creators of complexity theories: soliton for the passage from scholasticism to humanism (Thom 1974) and laser physics for voting behavior in social groups (Weidlich 2006)." I can add that Wolfgang Weidlich's spirit could fruitfully inspire deep-learning analyses of the massive data about opinion shifts that are more and more produced from social networks, as attested to by his being quoted this past year in a journal of physics article dealing with opinion formation (Gaudiano and Revelli 2021).

7 Policy and Societal Impact of Weidlich's Studies

I cannot survey the practical impact of Weidlich's research on matters of regional analysis and planning, but his principal intellectual heir, Günter Haag, must be mentioned for his remarkable creation of a rather large consulting firm applying and developing Wolfgang Weidlich's theories: the STASA firm in Stuttgart. This firm operates many applications in urban and regional dynamics and transport activities (five EU-projects instituted to date) based on the master-equation approach. Analysis and modeling of population dynamics, demographic change, and unemployment activities have been carried out for projects funded by the EU, the German government, the German Federal Employment Agency, and other institutions. Mass data analysis, visualization of data, modeling, simulation, and software development are also currently in the firm's focus. Applications are being developed in different fields, including regional science, demography, and transport, but also in the analysis of production data, production modeling for the auto industry, unexploded bomb detection, and so on.[7] The software STASA QC is based on an algorithm that Günter Haag developed in 1992 for self-organized neural networks. As Senior Research Fellow, Günter Haag is a member of the FSTI (Ferdinand-Steinbeis-Institut,[8] with its focus on distributed ledger, digital twins, deep learning, and IIC (industrial internet consortium).

[6] From an announcement on the geotamtam list of a call for Ph.D. candidates at the IFFSTAR laboratory of the Gustave Eiffel University, March 5, 2021.

[7] www.stasa.de.

[8] www.steinbeis-fsti.de.

8 Conclusion

Great Minds are sometimes difficult to deal with. This was not at all the case with Wolfgang Weidlich. His open and warm personality and deep humanity are emphasized by all those who came into contact with him. Harvey Shoolman describes him as: "A truly remarkable human being whose spiritual largesse and gift for warm and sustained friendship profoundly endeared him to everyone he met" (Shoolman 2015). Passionate about theology, Wolfgang Weidlich was also a brilliant musician, a pianist of the highest order. He was a bon vivant who loved wine and food. He loved to laugh, and, among his good stories, he told me one that made him very happy: While visiting the Neuschwanstein palace, a Japanese colleague specializing in pattern recognition exclaimed, "What a huge goose" while contemplating the fresco of Lohengrin's swan on the ceiling. Humor, kindness, and generosity were not the least of the qualities of this Great Mind.

Let us take away insight from Wolfgang Weidlich's life-long engagement with understanding how individuals' opinion may become socially oriented in harmful directions and from his deep concern for finding tools helping to avoid intolerance and brutality. Let's put these attitudes into practice! A great impact on the social sciences and more applications of Wolfgang Weidlich's findings can be expected with the coming of massive individual data and researches on opinions, sensations, and socio-spatial interactions.

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Alan Wilson (1939–): A Renaissance Man in Regional Science

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Alan Wilson

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1 Overview

We build too many walls and not enough bridges.

—Sir Isaac Newton

Sir Alan Geoffrey Wilson is not an ordinary regional scientist. Some sixty years ago, he began his career as a mathematician and theoretical physicist analyzing bubble chamber events at the Rutherford Laboratory in Harwell, England. However, he soon realized that his ambition was to study and model people in cities rather than particles in gas chambers. His move to work with a transportation planning research group in Oxford in 1963 would mark the beginning of a long, productive, and impactful (and still very active!) career in regional science. Yet, he did not entirely abandon physics: Concepts, theories, and mathematics from physics would serve as a basis and motivation for many of his ideas and innovations, including his signature entropy-based, spatial interaction framework.

Over the years, Alan Wilson's "sphere of interest" has remained relatively focused on cities and systems of cities, and, particularly, the modeling of spatial interaction, location activity, and urban evolution. In these areas, he has made significant theoretical and methodological contributions, which are spotlighted in several articles and special issues (Gombrich and Oléron-Evans 2019; Clarke 2009, 2011; Waldorf et al. 2004; Johnston 2019). He has published countless papers, books, reports, and commentaries, drawing upon and impacting various disciplines and subdisciplines, including outside the conventional walls of regional science. However, Alan Wilson is not just a scientific giant. In his lifetime, he has worn many badges: educator, administrator, philanthropist, planner, politician, businessman, and entrepreneur, and in all these roles, he has been highly successful. But Alan Wilson is even more than that: He is also an artist and a philosopher.

Truly transformative scientific advancements and revelations are the product of two interrelated forces: "…curiosity, which drives one on toward discovery, and a love of play (*gout de jeu*) or sheer enjoyment of the game itself, which encourages inventive thought" (Le Lionnais 1969). These are the defining features of a creative genius—a scientific artist—and the essence of Alan Wilson. Wilson is engaged "with the world of ideas" (Grombrich and Oléron-Evans 2019), intellectually curious about everything from how cities evolve and morph over short and long periods to how concepts and methods from the natural sciences transfer and translate to a regional science context. His scholarly adventures often begin with an idea from another field, an analogy—or a mystery worth pursuing. Alan Wilson also has a love of play, i.e., a "*genius for synthesis.*" He has a creative capacity to harness and combine seemingly disparate approaches, principles, and perspectives and to "connect-the-dots" in novel and metaphoric ways. In the process, he builds on the "shoulders of giants," exploiting the work of other Great Minds who have already begun to "pave the way" or who "planted a seed." Moreover, he is continually taking stock of, synthesizing, and clarifying the state of knowledge—painting an ongoing portrait of the scientific landscape.

All of this is encapsulated in Wilson's philosophy of science, which he follows himself and communicates to the regional science community regularly. For theory and model development, as well as planning and education—and problem-solving, more generally—the "Wilsonian" philosophy emphasizes a systems perspective and algorithmic and systematic approaches infused with creativity and imagination. To this end, inter- and cross-disciplinary ideas and viewpoints, along with cooperation and coordination between researchers, planners, policymakers, and even politicians, are imperative. According to Wilson, such bridges are crucial for engendering analytical frameworks and theoretical advancements that are unifying, universal, versatile, and, ultimately, transdisciplinary. In fact, as Wilson notes, to arrive at "a general paradigm, eclecticism and integration are the order of the day" (Wilson 1972).

This chapter provides an up-to-date *tour d'horizon* of Alan Wilson's long list of contributions to science and society, highlighting his ingenuity for bringing together and bridging people, disciplines, concepts, and techniques systematically, deliberately, and creatively to solve a broad spectrum of problems.

2 Personal and Professional Journey

You have to make the rules, not follow them.

—Sir Isaac Newton

On the surface, Alan Wilson's personal and professional trajectory appears to be a "random walk"—i.e., a path consisting of a succession of indiscriminate steps. However, his trajectory has been more like a thermodynamic system, characterized by critical junctures and transitions, with each phase bringing new opportunities, roles, focal points, experiences, and accomplishments that build on and leverage those of the prior stages. While Alan Wilson has faced enormous barriers and challenges throughout his life and career, he has been able to overcome them "simply by being smart enough to rise above them" (Kelly 2003). In doing so, he sets his own rules, intervening proactively to steer his course in desirable directions—to facilitate positive phase transitions—which has contributed to great successes and accolades and to a life and career that has been anything but conventional.

Alan Wilson was born in Bradford, Yorkshire, on January 8, 1939. His upbringing was relatively modest, but supportive. In his own words, "I was brought up in the poorest part of Bradford: Laisterdyke. My father was a wool-sorter at Whitehead's. Both my parents had left school at 14 but were determined that I got a good education." (Kelly 2003). When his family moved from Bradford to Darlington, Alan enrolled in the Queen Elizabeth Grammar School, which would be a pivotal initial condition in his career. According to Wilson, unlike Bradford, which had several schools, Darlington was a one-grammar-school town that sought to send a handful of students to Oxford or Cambridge (Kelly 2003). Alan Wilson was one of them; he was accepted to Cambridge at Corpus Christi, and off he went.

In 1960, Alan Wilson graduated from Cambridge with training in mathematics and theoretical physics. He then went on to join the Rutherford Laboratory, a laboratory involved in analyzing real-time particle physics experiments at CERN in Switzerland (Kelly 2003). Wilson's duty was to carry out computer-based statistical analysis and testing, which, as he says, "was an unbelievable responsibility. If my bit didn't work, a multimillion-pound experiment didn't get analyzed" (Kelly 2003).

Yet, Alan Wilson aspired to pursue a more "social" and "useful" field while still being a mathematician (Wilson 2021). After "hawking" himself around Oxford to secure a research position that could enable him to transition from the physical sciences to the social sciences (Kelly 2003)—and a series of rejections along the way (Wilson 2021)—he took a different route, accepting an elected position as Labour Councillor in Oxford. As he notes about that job, it "was an important early experience for me, functioning in a political environment, convinced that it was possible to change things for the better" (Reisz 2017). Wilson then successfully landed a research-oriented appointment at the Institute of Economics and Statistics in Oxford to work with a transport group comprised of economists, marking another turning point in his professional journey, setting in motion his career in regional science. After two years in this role, he went on to serve as Head of the Mathematical Advisory Unit, Ministry of Transport (1966–1968). On being hired as a mathematician rather than a social scientist, Wilson remarked, "The civil service flew into a flap because he couldn't be admitted as an economic adviser because he wasn't officially an economist. They asked me what I was. I said a mathematician. So they made me a mathematical adviser…" (Kelly 2003). Wilson then served as Assistant Director of the Centre for Environmental Studies in London (1968–1970). In 1969, Alan Wilson founded the journal *Environment and Planning A*, serving as an editor until 1991, and since then, as Honorary Editor.

In this phase of his career, Alan Wilson's passion for urban modeling and planning—and reputation as a regional scientist—began to blossom and take off. At the Institute of Economics and Statistics, he "was given the job of modeling person flows, such as the journey-to-work, in cities" (Wilson 2021), which was a valuable and inspirational experience for him. As he notes about the job, "The deal was that I did all their maths and computing, and they taught me economics along the way! I was lucky enough to solve a problem that was waiting to be solved—how to model transport flows in cities—and I was accepted as a social scientist" (Reisz 2017). Reflecting on what he had learned about the physics of gases, Wilson developed the idea of using entropy maximization to model trip distribution—i.e., the allocation of travelers between origins and destinations. The work took him only a couple of weeks, an effort well worth it, as it launched "his name internationally in a field he had only just entered" (Kelly 2003). At the Ministry of Transport, Alan Wilson had an opportunity to apply this framework in a real-world context, specifically to the United Kingdom. In his role at the Centre for Environmental Studies, he was given "the freedom to shift towards attempting to build a comprehensive urban model," which, he has said, "ended up being a life's work!" (Wilson 2021).

Alan Wilson's professional journey then branched off in a different but related direction. In 1970, he was appointed Professor of Urban and Regional Geography at

the University of Leeds, a quite impressive feat given that he did not have a geography degree or a Ph.D. While at Leeds, he was "one of a small number of academics with a genuinely international reputation." He also served as Pro-Vice Chancellor (1989) and Vice Chancellor (1991–2004) at the university. In this administrative capacity, he was highly successful, increasing enrollment and research income in magnitudes or order (Grombrich and Oléron-Evans 2019). Wilson had essentially transformed the university from a "sleepy and underfunded" institution to a vibrant and prosperous epicenter of intellectual and scholastic activity (Riesz 2017).

In the late 1980s, Alan Wilson (with geographer Martin Clarke) founded the company Geographical Modeling and Planning (GMAP) Ltd., which used entropy-based modeling to advise retailers on where to locate their stores. It ended up being one of the most successful ventures to spin out of Leeds University. The company had "major blue-chip clients," including "Ford, Exxon/Mobil, BP, Barclays, Sainsbury's, Asda, Thomas Cook, and HBOS" and was "the largest geographical consultancy in the world" at the time (Clarke 2009).

In 2004, Alan Wilson once again altered his career trajectory, accepting the appointment of Director-General for Higher Education in the United Kingdom. Not only was he the first to serve in this post, but he broke the mold of a typical politician. As Kelly (2003) wrote soon after Wilson took the job, "In Wilson, the government will have an adviser who, for once, does not spring from that cadre of bureaucrats who have little working knowledge of poverty." Alan Wilson played a "critical role in the government's drive to promote inclusion and diversity in higher education" during his term. In this regard, he was highly successful. For instance, he was responsible for establishing the Office for Fair Access, which opened new avenues for underserved communities to access a college education. Wilson was also instrumental in cutting "red tape" in the UK government (Riesz 2017).

In 2006, Alan Wilson briefly returned to his alma mater, Cambridge, at Corpus Christi, after being elected Master of the school. One year later, he joined the spatial complexity powerhouse, the Centre for Advanced Spatial Analysis (CASA) at University College London (UCL), as Professor of Urban and Regional Systems. In this period, Wilson also served as Chair of the Arts and Humanities Research Council (2007–2013), Chair of the Home Office Science Advisory Council (2013–2015), and Chair of the Lead Expert Group for the Government Office for Science Foresight Project on The Future of Cities.

From 2016 to 2018, Alan Wilson served as founding CEO of the Alan Turing Institute. He was then appointed Executive Chair of the Ada Lovelace Institute, where he is now actively involved in leading research teams in big data, machine learning, and artificial intelligence (Gombrich and Oléron-Evans 2019). Emphasizing the importance of convening different people and perspectives to advance data science in a transformative, ethical, and inclusive way, Alan Wilson remarked after joining the Ada Lovelace Institute that:

> A key component of the Institute's mission is to convene diverse voices to create a shared understanding of ethical issues in data and AI, and my first priority as Chair will be to recruit a Board that reflects this diversity. We are seeking people from different sectors and disciplines to set the strategy and remit of the Ada Lovelace Institute and to actively participate in its

> work. The Board will connect academic fields such as philosophy, data science, and social science, with civil society and public deliberation, policy and regulation, and international perspectives.[1]

In recognition of his impressive scholarly and professional achievements and successes, Alan Wilson has received numerous awards, medals, and honors. He is a Fellow of both the distinguished Royal Society and the British Academy and was awarded the Laureate d'Honneur by the International Geographical Union and the Prize in Regional Science by the European Regional Science Association (ERSA). In 2001, he was knighted by the Queen of England, approximately three centuries after the first scientist to be bestowed that honor, Sir Isaac Newton.

3 Research Trajectories, and Transitions

> *I do not know what I may appear to the world, but to myself I seem to have been only like a boy playing on the seashore, and diverting myself in now and then finding a smoother pebble or a prettier shell than ordinary, whilst the great ocean of truth lay all undiscovered before me.*
>
> —Sir Isaac Newton

Like his professional journey, Alan Wilson's research trajectory is characterized by well-defined transitions and phases that build on each other. In chronological order, these areas generally include the modeling and analysis of (1) bubble chamber events, (2) spatial interaction and location behavior using entropy maximization and mathematical optimization, (3) complex urban structure and dynamics using nonlinear dynamic equations, dynamic systems theory, and microsimulation, and (4) global networks and comprehensive urban systems using big data, machine learning, and other related analytical tools. Wilson has also written extensively about higher education, urban and regional planning, and science philosophy. The word cloud in Fig. 1 highlights the evolving and expanding universe of Alan Wilson's areas of interest in greater detail.[2]

[1] https://www.nuffieldfoundation.org/news/sir-alan-wilson-appointed-executive-chair-of-the-ada-lovelace-institute (Last accessed 22 April 2022).

[2] The word cloud is based on a bipartite network of terms from the titles of his publications to the years in which they were published (using data from Google Scholar). A community detection algorithm was employed to group terms and years to delineate in some detail the phases of his research. Colors (shown in the on-line version only) pertain to communities and node sizes to the overall frequencies of the terms.

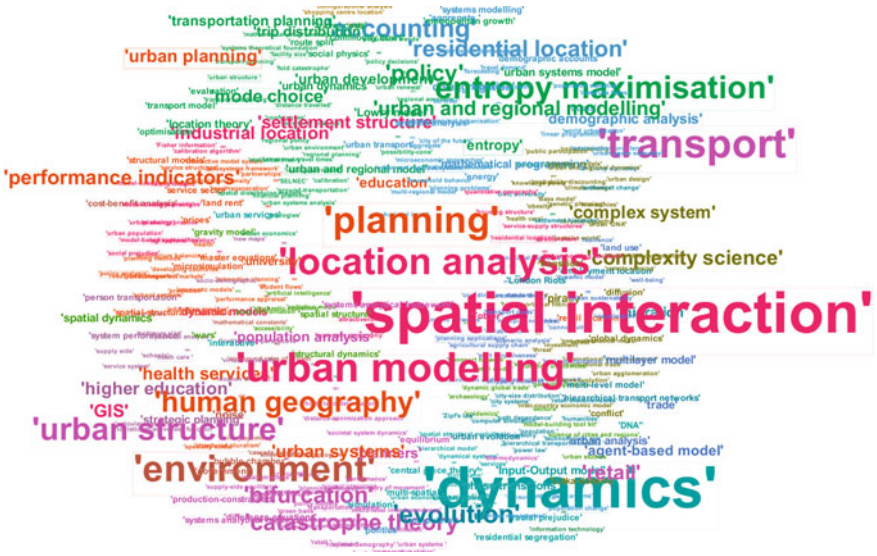

Fig. 1 Evolving and expanding universe of Alan Wilson's research

3.1 Entropy Maximization, Spatial Interaction Modeling, and Location Analysis

If I have seen further than others, it is by standing upon the shoulders of giants.

—Sir Isaac Newton

The 1950s ushered in the era of large-scale urban transport and land-use modeling, particularly in the USA. In this context, the gravity model adapted from Newton's law of gravitation, as well as the intervening opportunities model and "back-of-the-envelope" approaches (i.e., lookup tables and diversion curves), was *en vogue*, used as the primary vehicles for predicting the flows of people and goods within cities. Yet, there was no consensus on which theory or method was most appropriate, nor on specific questions about how to incorporate the effects of policies, appropriately calibrate the deterrence function to account for distance decay, and disaggregate the framework to account for the varying characteristics of trips and individuals (Williams 2019). Moreover, as Alan Wilson noted, there was a mathematical inconsistency in the gravity model. Specifically, it did not "conform to the method of bounds," and it could "generate nonsense predictions," such as more people traveling to a destination than realistically possible. Thus, the equations required "fudge factors" to get the right answers, corrections that he recognized from "the statistical mechanics of gases" (Kelly 2003). Wilson also had concerns about the gravity model lacking a behavioral foundation (Clarke 2009).

In the mid-1960s, Alan Wilson set out to develop an analytical framework that could address these issues and shortcomings (Clarke 2009). In doing so, Wilson was influenced by complexity scientist Warren Weaver. Weaver (1948) distinguished between three types of problems or systems: simple, disorganized complexity, and organized complexity, suggesting the appropriateness of methods for analyzing each type of system. Alan Wilson saw large numbers of people moving around in a city, such as via commuting activity, as interacting only weakly, constituting a system of disorganized complexity. Thus, according to Weaver (1948), statistical mechanics and probability theory were the most appropriate means for modeling such phenomena (Wilson 2021). Wilson was also inspired by economist and regional planner Gerald Carrothers, who provided a "germ of the idea," but one that had not been acted upon (Wilson 1972). Carrothers (1956) wrote:

> The behavior of molecules, individually, is not normally predictable, while in large numbers their behavior is predictable based on mathematical probability. Similarly, while it may not be possible to describe the action and reactions of the individual human in mathematical terms, it is quite conceivable that interactions of groups of people may be described in this way.

Another source of inspiration came from Edwin Thompson Jaynes and others (see, e.g., Jaynes 1957), who were applying entropy maximization to various problems outside of physics (Wilson 2021).

The stars aligned, and Alan Wilson had a "eureka" moment. He realized that the gravity model's balancing constraints were analogous to partition functions from statistical mechanics. Using Boltzmann methods and maximizing an entropy function, Wilson formulated a spatial interaction framework that remarkably addressed all the concerns raised about the gravity model and other approaches being used for transportation and land use planning at the time (Williams 2019). Wilson had creatively applied the "laws that predict the average behavior of atoms to the average behavior of the population of cities" (Kelly 2003).

In 1967, Alan Wilson unveiled his entropy-based spatial interaction model (SIM) in "A Statistical Theory of Spatial Distribution Models" using trip distribution as an archetypal illustration (Wilson 1967). This paper, which has ended up being one of his most cited manuscripts, was published on a whim (without peer review) in *Transportation Research* to fill a gap in the journal's first issue (Wilson 2021). A few years later, Wilson demonstrated that an entire family of spatial interaction models could be derived from entropy maximization through accounting principles and mere adjustments of the production and attraction constraints (Wilson 1971). The singly constrained model was significant for regional science in that it added a "locational dimension to the spatial interaction model" (Wilson 2010a, b).

Wilson's early work on entropy maximization was summarized in the book *Entropy in urban and regional modelling*, which is recognized as a classic and trail-blazing book in regional science (Waldorf et al. 2004). As Gould (1972) wrote soon after its publication, "The book not only presents an extraordinarily valuable approach to solving relevant spatial and social problems at the very time we need every approach we can muster, but stands as one of the most imaginative and

thought-provoking works in geographic literature." In another monograph, *Urban and Regional Models in Geography and Planning* (1974), Alan Wilson gave a "much more complete account and organized the field's technical apparatus." In his review of the book, Michael Batty wrote: "Alan Wilson is an acknowledged master of the field and his individuality, brilliance and style are stamped on this book, like on all of his works. He is bringing to urban studies what people like Chomsky have brought to Linguistics and Rashevsky to mathematical biology and this book is worthy of his contribution" (Batty 1975).

Alan Wilson's entropy maximization framework brought many innovations in urban and regional modeling, planning, and evaluation (Boyce and Williams 2015; Williams 2019; O'Kelly 2010). First, it improved spatial interaction and transportation models by introducing:

1. "balancing" factors related to the Lagrange multipliers in optimization, which translated to standard accessibility indices
2. a generalized cost function for characterizing spatial separation between origins and destinations (going beyond simple distance-based metrics) and that can capture travelers' perceptions of impedance
3. a negative exponential function of generalized cost to capture friction decay
4. the capacity for disaggregation by types of activities and groups and different levels of spatial resolution.

Additionally, entropy maximization was found to be consistent with utility maximization, thus providing a behavioral foundation to the method (Wilson 1971; Reggiani et al. 2021). Moreover, as a statistical averaging or probability maximizing process, the method was consistent with Bayesian inference and, accordingly, could be used in situations where there is a paucity of information or data (Wilson 1970). Thus, Wilson's entropy maximization framework provided a statistically grounded, theoretically based, and policy-sensitive method (Williams 2019), creating new and expanding opportunities for urban regional modeling and analysis.

Indeed, the work was revolutionary in both a practical and scientific sense. It catalyzed a paradigm shift in "theoretical and methodological perspectives on spatial flows in cities," essentially replacing sole use of Newtonian principles for spatial interaction modeling, much like how Newton's physics paradigm upended the view of the world developed by Aristotle thousands of years before him. Furthermore, similar to how Newton's cosmological synthesis provided a universal and unifying exposition of the earth and the cosmos enabling others to stand on his shoulders (including regional scientists!), entropy maximization was an integrated and versatile foundational methodology upon which other creative individuals could build. As Wilson himself notes, entropy maximization "opened up a set of ideas that could be applied more widely … it was a high-level methodology that had applications in many disciplines" to address a spectrum of problems (Wilson 2010a). Entropy maximization was also germane to a "wide range of SI phenomena" and "person movements for different reasons—e.g., commuting, migration, goods movement, telephone calls, marriage selection, newspaper circulation, bank cheques, and spread

of innovation," and frankly, any system involving spatial interaction and location behavior (Wilson 1971).

As Morton O'Kelly wrote about Wilson's book *Entropy in urban and regional modelling*: if it "was an initial stock offering, the original units would now have split many times and the original investors no doubt handsomely rewarded!" (O'Kelly 2010). In fact, many Great Minds (including Alan Wilson) have built on the method, contributing to various theoretical and methodological advances, including "extensions of the core model, links to mathematical programming, the relationship to economics, and the introduction of a dynamic spatial structure hypothesis" (Wilson 2010a). Moreover, Wilson's entropy maximization framework has been applied in various domains, disciplines, and contexts, including geography, transport, urban studies, economics, business, migration, criminal justice, defense, security, international trade, education, archeology, history, economics, healthcare policy, and political science. It has even been referenced in the computational mechanics literature on modeling stress distributions in rocks (see, e.g., Mishnaevsky 1998).

Figures 2 and 3 provide visual perspectives of the "offspring" of Alan Wilson's entropy maximization framework based on citations to his book *Entropy in urban and regional modelling*. Figure 2 highlights individuals who have referenced Wilson's book, while Fig. 3 shows journals in which these individuals published. In each case, only the giant component—the largest connected subgraph—is shown. The colors (shown in the online version only) reflect communities of authors and journals, and the sizes of the nodes indicate the number of times an author or journal has referenced the book.

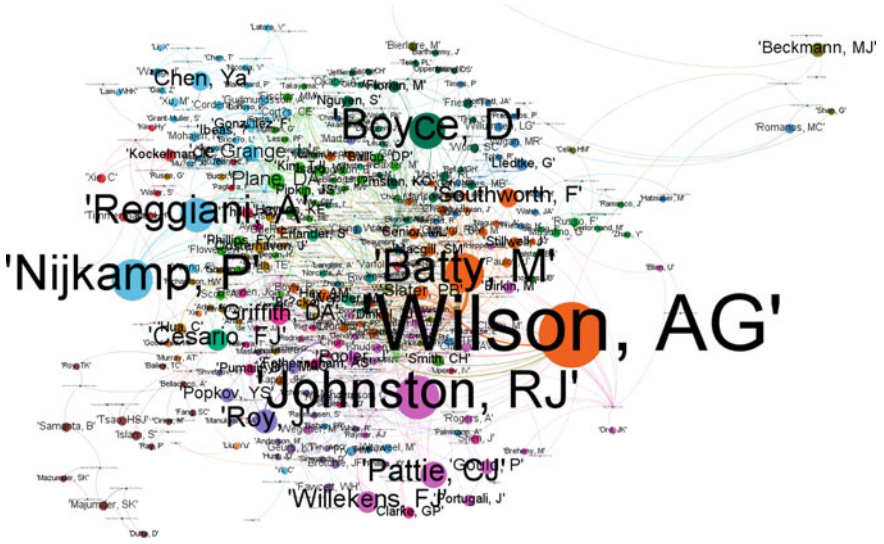

Fig. 2 Main offspring of Alan Wilson's entropy maximization framework (Authors)

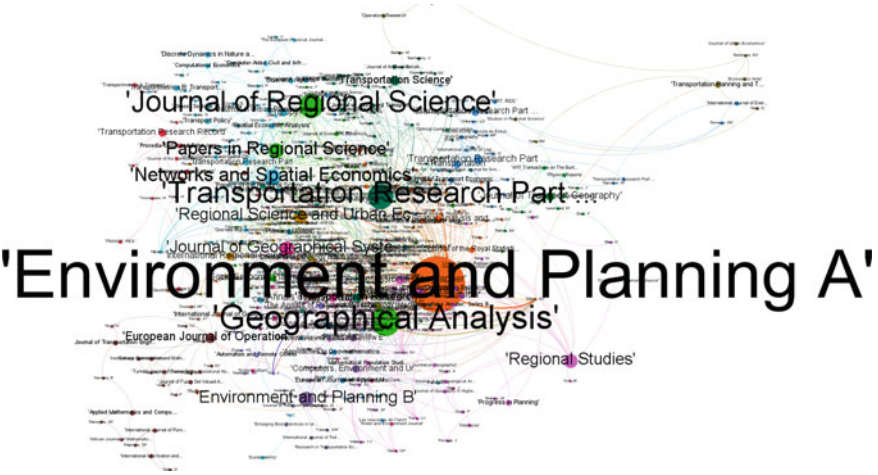

Fig. 3 Main offspring of Alan Wilson's entropy maximization framework (Journals)

3.2 Evolutionary Dynamics of Complex Urban Systems

> *An object in motion tends to remain in motion along a straight line unless acted upon by an outside force.*
>
> —Sir Isaac Newton

In the late 1970s, Alan Wilson began to shift gears, reorienting his focus from fast dynamics in cities to longer-term urban evolution and the "spatial distribution of people and organizations and corresponding physical structures"—or slow dynamics (Clarke and Wilson 1983). At this juncture, he was also determined to develop a "kitbag of techniques" that "could be useful in real-world settings"—from business to planning (Clarke 2009). Part of his motivation to go off in this direction was to address a growing number of criticisms of large-scale urban modeling, including that such models were not practical or accessible (Clarke 2009). Additionally, accelerating improvements in computing capabilities made using microsimulation, cellular automata, network analysis, agent-based modeling—and computer-simulated solutions to large models—feasible, enabling a shift from simpler to more complex urban modeling.

Wilson's first major contribution in this area (with urban planner Britton Harris) was to demonstrate how the exemplar problem of retail location could be embedded in a dynamic equilibrium framework (Harris and Wilson 1978). Once again, he was influenced by Weaver (1948). Specifically, Wilson saw retail competition as a problem of organized complexity, in which retail outlets are interacting strongly to compete for customers and revenue. Thus, the appropriate methodological foundations for modeling such phenomena were not in statistical mechanics but instead in applied nonlinear dynamics (and differential equations) (Harris and Wilson 1978),

tools that Sir Isaac Newton had developed and used centuries before Wilson to characterize spatial dynamics in our universe. Wilson also saw an analogy with the prey-predatory problem, particularly that "species competing for resources were similar" to retailers' rivalry and competitive behavior, thus making Lotka-Volterra (L-V) equations a suitable basis for model formulation. This work was significant in that it demonstrated that "nonlinearities and interdependencies can lead to bifurcation properties in system development" and, consequently, "the possibility for multiple equilibria" in urban models. It also marked the beginnings of "a method for modelling the evolution of cities, using the urban analogue of the equivalent issue in developmental biology" (Wilson 2018).

Wilson (with geographer Martin Clarke) then moved on to modeling cities in disequilibrium, recognizing that "systems of organized complexity tend to be out of equilibrium because the interacting subsystems each have different rates of change" (Clarke and Wilson 1981; Harris and Wilson 1978). This work's analytical and mathematical underpinnings were in dynamic systems theory and catastrophe theory, as summarized in his book *Catastrophe theory and bifurcation: applications to urban and regional systems* (Wilson 1981). Beginning again with retail location as an archetypal example, Wilson demonstrated how complex interdependencies between urban subsystems introduce "new bifurcation properties, which can lead to transitions at critical values of new parameters from stable solutions to periodic solutions" (Wilson 1981; Clarke and Wilson 1983, 1985). Thus, slight parameter changes could "flip systems from one state to another," leading to profoundly different urban dynamics and structures (Clarke 2009). During this phase of his research, Wilson also showed how a dynamic systems approach could be integrated with other methods such as spatial interaction modeling and microsimulation to model interrelated urban subsystems, including agriculture, industrial location, retailing, residential location, housing (Clarke and Wilson 1985).

Later, Wilson re-connected with statistical mechanics and thermodynamics. He realized that Boltzmann's methods could be applied to a broader range of systems and disciplines than what was recognized at the time (Wilson 2008). He demonstrated how Boltzmann techniques and Lotka and Volterra (BLV) equations could be integrated to model spatial interaction and structural evolution, providing a richer modeling framework than that based on scale-free networks (Wilson 2009). Additionally, recognizing that the "use of Ising models in physics represented a kind of locational structure problem" with dynamics in the form of phase transitions, Wilson developed a set of analytical frameworks for modeling discontinuous change and related dynamics in urban systems (Wilson 2009). These models, along with visualization techniques, provided planners with the tools for assessing how to "avoid undesirable phase transitions" or how to "invest bring about desirable ones" (Wilson and Dearden 2011).

Alan Wilson was instrumental in bringing microsimulation—including in a Geographic Information System (GIS) context—to regional science. According to Wilson, analytical methods are not appropriate for modeling certain kinds of systems,

particularly those for which "there is a lot of heterogeneity amongst components"—e.g., in healthcare systems involving patients with different characteristics and needs. In such situations, systems should ideally be modeled from the bottom up.

4 The "Wilsonian" Philosophy

> *We are certainly not to relinquish the evidence of experiments for the sake of dreams and vain fictions of our own devising; nor are we to recede from the analogy of Nature, which is wont to be simple and always consonant to itself.*
>
> —Sir Isaac Newton

As highlighted, Alan Wilson has an affinity and flair for solving complex problems. His philosophy of science, which he began to nurture and articulate in the early stages of his career (Wilson 1968, 1969a, b, 1972) and continues to follow religiously, is essentially a grand roadmap for problem-solving. In *Knowledge power*: *Interdisciplinary education for a complex world*, he summarizes key aspects of this philosophy, referred to here as the Wilsonian philosophy. In essence, it is a framework—or "intellectual toolkit"—for engendering the capabilities—or "knowledge power"—to address complicated and seemingly intractable problems within and across systems, disciplines, and domains—from research to education to planning and beyond (Wilson 2010b). In this regard, super-concepts that transcend disciplinary boundaries are crucial for developing the breadth and depth of knowledge necessary for tackling complex problems, as are generalized frameworks and models for addressing generic issues—i.e., super-problems.

The Wilsonian philosophy exploits concepts and theoretical principles from complexity as a strategy for handling difficulty and complexity. Thus, to address problems, a dynamic, systems approach is in order, precisely one that encompasses the following[3]:

1. Systematic and algorithmic approaches, coupled and integrated with abstraction, artistry, and inquisitiveness (coding, computation, creativity, curiosity)
2. Diversity of methods, perspectives, and strategies along with sensing mechanisms to promote desirable phase transitions and avoid negative ones (control, consciousness)
3. Sharing of knowledge across and between different groups (i.e., policymakers, planners, politicians, researchers, administrators, business persons, educators, and citizens), fields and disciplines, and even humans and machines! (communication, coordination, collaboration)
4. Lifelong learning to facilitate knowledge accumulation, pattern recognition, and situational awareness (cognition, classification, culture).

[3] Following Andersson's criteria for a successful society, Wilson believes three C's—cognitive, creative, and communication—are necessary for producing knowledge power (Wilson 2010b). I see a broader set of C's as necessary ingredients in Wilson's philosophy.

Alan Wilson stresses the importance of abstract thinking, including analytical and symbolic reasoning, along with systematic and algorithmic approaches, for framing issues and understanding problems and systems through model-building, testing, analysis, and evaluation. As a scientific method, he favors hypothetico-deductive reasoning, which uses theory and abstraction to develop mathematical models that can be used for systematic testing to draw inferences about a specific example. In particular, Wilson believes that the "the essence of scientific activity is the making of hypotheses or theories and the testing of predictions of these against empirical information and observations" (Wilson 1972), in contrast to the Newtonian inductive approach, which draws broad generalizations through statistical testing on specific examples or observations. As he points out, it is impossible to "derive general truths from facts," as Newton's method seems to imply. Theories only represent "the best approximation to truth at any time" and are, therefore, always subject to change and the possibility of being invalidated altogether (Wilson 1972).

In fact, Alan Wilson can be credited for bringing the hypothetico-deductive approach to regional science, particularly at the height of the quantitative geographic revolution. At the time, he argued that geographers were placing far too much emphasis on inductive reasoning and empirically driven, statistically based research. Thus, they were disusing "imagination, invention, deduction, and the various other mental faculties that contribute to the attainment of a well-tested explanation." Quoting Davis and Johnson (1909), Wilson remarks, it is like "walking on one foot, or looking with one eye, to exclude from geography the 'theoretical' half of the brainpower, upon which other sciences call as well as the 'practical'" (Wilson 1972). At the same time, he does not advocate for the complete dismissal of the inductive approach; both types of reasoning are essential elements of the toolkit to be used appropriately (Wilson 2010b).

Wilson's "process of invention" provides a recipe for developing universal analytical frameworks that can be modified to address and study particular problems at hand. The process begins with a "good idea"—an analogy from another field or discipline, which he notes requires "exercises of creative imagination of the highest order," although he recognizes that ingenuity is not easily or automatically manufactured. (As he points out, we do not even yet fully understand how such processes work and transpire in the human mind!). The next step is to engage model builders from another field or discipline and apply the model to a new context. The last stage is to modify models through disaggregation and shifts in scale or level of resolution, where the nature of the problem under consideration dictates an appropriate lens—e.g., modeling a household or a neighborhood or sector versus an entire transportation and land system in a city.

While indeed the use of analogies and metaphors in the regional sciences has a long tradition (e.g., Newtonian laws of gravitation for modeling spatial interaction), Alan Wilson can be credited for popularizing and expanding their utilization for urban modeling and planning (Sui 2010). Wilson believes that analogies are not only essential for developing novel ideas and solutions, but they also provide a critical link to urban systems modeling. Here, he distinguishes between direct and formal analogies, where the former applies to systems with common physical characteristics

and the latter to situations where "there are similarities of form, but not of physical characteristics." Formal analogies are the basis of systems science, thus providing the foundations and motivation for dynamic systems approaches in urban planning (Clarke and Wilson 1985).

However, as Wilson emphasizes, it is critical to exercise caution when transferring concepts, methods, and theoretical principles from the natural sciences to the social sciences. In regional science, analogies must be framed in relevant geographic and spatial economic theory and offer new interpretations of existing theories of cities and regions (Wilson 1969a, b). Moreover, models borrowed from other fields must be tailored to the particular problem being modeled or analyzed which. At the end of the day, the analogy must be tossed out, and one should arrive at concepts that cut across disciplinary boundaries—i.e., "super-concepts." According to Wilson, entropy is one of those super-concepts. Specifically, entropy maximization is not a "strict" analogy from physics but rather a higher-level model and conceptual frame of reference that can be applied broadly across disparate disciplines and contexts (Wilson 2021).[4]

The Wilsonian philosophy emphasizes the vital role that technology (especially the computer) plays in understanding and solving complex problems across different domains. In this regard, it is imperative to always be on the frontier of new computing capacities and capabilities, to assess and exploit what can be done with the state of technology at any point in time. Modeling large, complex systems requires using computers for simulation purposes and solving the equations, as opposed to simpler systems, which are handled analytically in algebraic or other terms (Wilson 2010a, b). However, Wilson does not view computers as mere calculating machines; computers also provide a powerful mode of communication and artistry. For example, with the advent of Geographic Information Systems (GIS) in the 1970s, he immediately saw the potential of computerized mapping to visualize the inputs and outputs of analysis and modeling, ultimately making them more palatable and compelling to end-users. Moreover, according to Wilson, computer-based visualization is also a way to "see" cities and regions in ways not possible with the raw data alone. As he remarks, "A colour map is worth a thousand lines of code!" In all these ways, "there is a critical interaction between computer power and mind power"—i.e., human–machine synergy, is a dimension of knowledge power (Wilson 2010b).

One of the primary tasks of the planner is to anticipate and control the trajectory of a system of interest—e.g., a city or institute of higher education. Yet, this poses an array of challenges, especially for systems of organized complexity, which are subject to path-dependent processes, nonlinearities, and phase transitions, artifacts that are difficult to predict. Additional challenges relate to the fact that the same events do not recur over time in social and economic systems, unlike natural systems where similar events are repeated, making their future paths easier to anticipate.

As maintained by Alan Wilson, modeling and visualization are essential tools for understanding and managing these complexities and ultimately steering the course of a system in a desirable direction. In particular, models enable one to conduct

[4] This is a point Wilson made in reaction to a leading article in a planning journal ("People are not Particles"), which asserted that he was using a rigid analogy from physics (Wilson 2021).

"what if" forecasting scenarios to assess how different interventions might impact the structure and dynamics of a system. Through sensitivity analysis, it is possible to assess the spectrum of possible outcomes given different parameter settings and initial conditions and generate what Wilson refers to as "possibility cones," an idea inspired by hurricane prediction cones. For urban planning, the "DNA" of a city can be used "to explore and visualize the possibilities of transition given the structural starting point," which, as Wilson notes, is a sort of "genetic medicine' approach" (Wilson 2009). This tactic is beneficial in that it limits the "space of development possibilities by focusing on a set of starting conditions."

According to Wilson, cyberneticist and psychologist Ross Ashby's Law of Requisite Variety, which specifies that the controlling system "must have at least as much variety as the system it is trying to control in order to be effective," provides additional insight on how to manage complex systems (Wilson 2010b). In this regard, a maximum diversity of approaches—integrating "the best of the ideas from this variety"—is imperative, especially for ensuring that "a variety of attacks on problems is possible" (Wilson 1968). Further, inspired by the work of neuroscientists Karl Friston and Klaus Stephan, Wilson envisages the planning system as a human brain. He argues that planners can intervene in an urban system to promote desirable outcomes, similar to how the brain minimizes free energy to avoid phase transitions (Wilson 2009; Deardon and Wilson 2011). Combining this idea with Ashby's Law, he concludes, "If the brain is replaced by 'urban planning system' and its environment by 'the city,'" then "the planning system has to model the city in order to have a chance of success"—i.e., modeling is key to effectively controlling a complex, urban system (Wilson 2009). Moreover, as Wilson observes, Ashby's Law of Requisite Variety and Friston's free energy model are two sides of the same coin: They both come down to entropy maximization!

Finally, the Wilsonian philosophy stresses the importance of coordination, collaboration, and communication between all partners in the "knowledge space" (i.e., scientists, educators, administrators, planners, policymakers, politicians) (Wilson 2010b). Each entity has unique knowledge to bear, and thus through the exchange of knowledge, the knowledge power of each entity can be maximized. Planners must have a solid understanding of policy to articulate objectives and decide what the planning process should ultimately achieve (Wilson 1968). Planners and policymakers should be cognizant of the political process, as it dictates what plans are eventually implemented (Wilson 1968). In this respect, performance indicators are helpful; they provide a way for communicating effectively with politicians to argue for the best alternatives (Wilson 1968). There should also be a two-way exchange between researchers and planners, both of whom have an action focus. Research is necessary for stimulating innovations in modeling, and planning provides a real-world laboratory for testing and evaluating models (Wilson 1968). Lastly, educators play a crucial role in the entire system, especially in shaping the minds of future regional scientists and practitioners by providing them with the skills and tools, along with the creative capacities necessary for solving complicated problems through knowledge power (Wilson 1968, 2010b).

5 Concluding Remarks

> *In one person he combined the experimenter, the theorist, the mechanist—and, not the least, the artist in exposition.*
>
> —Albert Einstein writing about Newton

Alan Wilson is a gravitational force in regional science. He is a great attractor, bringing together ideas and people to advance our knowledge of cities and regions and enhance our ability to analyze, model, and predict such systems, not unlike how Sir Isaac Newton integrated and unified the body of knowledge at his time, revolutionizing our understanding of the celestial and terrestrial worlds and our capacity to model such phenomena mathematically. However, contrary to Newton, who quipped, "I can calculate the motion of heavenly bodies, but not the madness of people," Alan Wilson has expanded our ability to model "people in motion," especially in an urban and regional context.

Indeed, Alan Wilson is a person of many talents, including those of an artistic and creative nature. He is a polymath with breadth and depth of knowledge and insight across and within a spectrum of disciplines, domains, and contexts. He has an insatiable curiosity about cities and regions—how they work, how they can be modeled, and how they can be disrupted in ways that advance societal interests. He also exhibits determination and perseverance in all of his endeavors. These are the traits common to all Renaissance Men in history (Elfmar and Griffiths 2012)—from Aristotle to Sir Isaac Newton to Ada Lovelace to Albert Einstein to Alan Turing. Accordingly, Alan Wilson is aptly referred to as a Renaissance Man in Regional Science.

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