

Introduction



Jakob Edler and Rainer Walz

Abstract It has become a commonplace that in order to tackle the enormous societal challenges we face throughout the globe we have to support transformation; and in order to do so, we have to mobilise innovation. As innovation and transformation are strongly intertwined, it is thus imperative essential to analyse and support their interplay.

This volume reflects on nine selected research fields in the area of systems and innovation research that have developed in the last five decades to do exactly that. It defines and delineates systems and innovation research as encompassing the scientific study of the conditions, dynamics and impacts associated with the generation and uptake of innovations and the development and transformation of functional systems satisfying essential needs such as the provision of energy or water. This allows to draw general lessons as to what drives research fields throughout their development and how their role—in particular vis-à-vis policy—changes over time. It also allows to speculate about future challenges and trends in the area of systems and innovation research. This is important because, if anything, the need to govern transformation through innovation will further grow in the future and with it the need to understand the underlying dynamics.

It is now largely undisputed that socio-technical transformations are urgently required and that innovations are key requirements for them. Policy is once again becoming much more ambitious, seeking to accelerate transformations, bringing innovation and knowledge generation in line with the directions of transformations

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and ensuring that the appropriate technological and economic foundations are in place for transformations. In addition, all of those ambitions are to be pursued in conjunction with social cohesion and innovation-driven competitiveness. This renewed ambition of the state to shape change is characterised not only by urgency, but also by growing complexity. Strategic intelligence is therefore increasingly important, and the calls for excellent, evidence-based policy advice are becoming louder and more impatient.

Against this background of rising demands, urgency and uncertainty in relation to evidence-based policy advice, we embark on a review of the history of systems and innovation research (SIR). Our intention is to reflect on the development of key research areas within SIR and its interplay with policy-making and societal developments. Based on this, we seek to draw overarching lessons concerning the development and function of that advice in the past and in the future.

We define systems and innovation research (SIR) as the area of scientific enquiry into two overlapping topic domains. First, SIR is interested in better understanding the conditions and processes through which novelties are produced and put into use and their subsequent effects as innovations on the economy, society and the environment. This approach requires thinking in innovation systems to understand the underlying conditions and processes. Second, SIR analyses the ways in which functional (sectoral) systems, such as those providing and using energy, mobility, food or water, perform and evolve over time. These simplified definitions already indicate why it is not only justified, but indispensable to consider innovation and systems together with their governance. It is impossible to fully understand the performance and transformations of functional (sectoral) systems without understanding how technological and social innovations are mobilised and diffuse in the respective systems. It is equally impossible to understand the demand for as well as the production and effects of innovations without an understanding of the role they play in the various (sectoral) systems in which they are embedded.

In our understanding, SIR is further characterised by the strong interplay between researchers and stakeholders from politics, the economy and the wider society. In fact, the impetus, the very *raison d'être* of SIR from the beginning, has been to contribute to a better understanding of societal problems and developing solutions to them. SIR is both application-oriented and problem-driven. This volume will show that the empirical questions, analytical approaches, scientific methods and data sources for SIR and its various fields have co-evolved with the policy demands in different policy fields and with the changing perception of problems.

Systems research in its own right had its beginnings after the Second World War in the USA, as earmarked, for example, through the RAND Corporation in the USA, or - some years later - the International Institute for Applied Systems Analysis (IIASA) in Austria. The history of Systems and *Innovation* Research starts roughly 50 years ago. At the end of the 1960s and in the early 1970s, a number of new research centres were established in several European countries both inside and outside universities. With regard to innovation studies, these included the Science

Policy Research Unit at the University of Sussex,¹ Policy Research in Engineering, Science and Technology at the University of Manchester, the Bureau d'Economie Théorique et Appliquée (BETA) at the University of Strasbourg, and the Fraunhofer Institute for Systems and Innovation Research (Fraunhofer ISI), whereby the latter was explicitly designed to span both systems and innovation research. While these institutes had very different institutional and disciplinary backgrounds, they all shared a common mission. They all sought to analyse the dynamics of the development and application of technologies and innovations more broadly and not as a purely academic exercise to advance knowledge. Instead, the protagonists of these fields were driven by a normative objective to support policy-making and decision-making in businesses by providing strategic intelligence of various kinds in order to improve economies and the welfare of societies. With the advent of environmental consciousness catalysed by the first Earth Day in 1970, the report of the Club of Rome in 1972 and the first international UN conference on the Human Environment in Stockholm 1972, this normative impetus included concerns regarding the long-term detrimental effects of technology. Researchers increasingly understood the significance of the systemic character of those processes that satisfy human needs but at the same time threaten the very foundation of human life.

We strongly believe that reflecting on the dynamics of SIR can help us to better understand how those fields can—and should—support decision-making in the turbulent times ahead. This is the reason why we are interested in the development of the scientific endeavours that started over 50 years ago.

Against this background, this volume includes historical intellectual journeys in nine selected fields within the broad area of SIR over the last five decades. We can neither cover all possible SIR fields nor give a full picture of the various international and national developments, especially for those research fields involving sectoral functional systems, which are largely shaped nationally. Therefore, some of the nine fields are analysed from a more international perspective, others somewhat focus on a German perspective.

The SIR fields in this book represent a subjective selection, but not an arbitrary one. We applied a set of conditions to justify their selection: First, they need to have been relevant in all or most of the past five decades, as our main interest is in their development over time. Second, they need to be directly relevant for policy development, engaging with policy-makers at different levels. While certain individuals and institutes within those fields have contributed to excellent academic publications and driven the development across various disciplinary fields, the bulk of the work was directed at supporting a better understanding of problems and opportunities and providing the relevant decision-makers with sound insights and evidence as a basis for policy-making. Third, while all nine fields have a variety of links to established

¹For an impressive case study of SPRU as an example of transformational changes in the study of science, technology and innovation and related policies, see Soete, Luc. "Science, technology and innovation studies at a crossroad: SPRU as case study". *Research Policy* 48.4 (2019): 849–857

academic fields and sub-fields, they have always been multi-disciplinary, where different disciplines were mobilised in parallel, and in parts inter-disciplinary, where epistemic approaches of different disciplines were combined and partly integrated. All fields always have been and are strongly application-oriented at the same time, with all nine fields developing—to various degrees—their very own disciplinary norms and practices.

We deliberately do not deal with a more recent field of research, i.e. transition studies. This field has evolved in the last 20 years or so and has become an increasingly important field to understand socio-technical system transitions. A strong epistemic community of scholars has developed its own conceptual basis building on a range of conceptual sources in (transition) management, evolutionary economics and the science and technology studies. While various chapters in this volume refer to their specific relationship with this field, a history of transition studies deserves its own compilation.

We have selected research fields that cover a broad range of functions for stakeholders. Five of the nine fields are horizontal in nature, developing analytical and methodological approaches to understand, support and manage systems development and applying them across a range of (sectoral) functional systems:

The first field is Conceptualising and Analysing STI Policy. The authors base their analysis on the conceptualisation of policy paradigm change. In addition to exogenous changes in the economic, societal and political context conditions, the authors focus on primarily endogenous phenomena in three areas: changes in the main theoretical-conceptual basic understanding of the origins of knowledge and innovation, changes in STI policy objectives and changes in problem constructions and preferred policy solutions.

Our second field is concerned with the development of innovation monitoring and innovation indicators, which aims at analysing the dynamics and performance of innovation systems. The authors analyse the development of the generation and use of indicators in the context of changes in the conceptual understanding of the innovation process. In addition, they look at changes in political demands to understand innovation dynamics and the consequences for developing innovation indicators over time.

Our third field, Foresight, deals with strategic intelligence through forward-looking analytical and participatory approaches on a systems level. The authors analyse how foresight has changed drastically over time from more deterministic views to open and diverse future perspectives, and towards participative approaches and the integration of AI in a flood of “big data”.

The fourth field focuses more narrowly on the evaluation of public research and innovation policies. The authors discuss the interplay between Research and Innovation (R&I) policy and evaluations that aim to capture the function and influence of such policies as well as considering the goals, instruments and approaches to evaluating research institutions. The chapter focuses on the German and the European level with regard to evaluation practice, but also includes Anglo-American literature with regard to evaluation theory.

The fifth field, Technology Assessment, emerged out of the awareness of the ambivalence of technologies increased in politics and public life at the end of the 1960s. The authors describe the development of the research field by focusing on the paradigmatic changes in Technology Assessment from an expert-based approach to a participatory one and on towards the current pragmatic approach.

The remaining four research fields are vertical in nature and focus on selected (sectoral) functional systems:

The sixth field is concerned with the research on the development of production technologies and their systemic embedding. Although the process of deindustrialisation started in the 1970s, manufacturing is still considered a driver of the high innovativeness and competitiveness in particular of the German economy. The authors analyse the development in this research field by looking at changes in the central production paradigms over the last 50 years and the systemic embedding of changing production technologies and highlight the major issues steering German manufacturing industries.

The seventh field focuses on research on renewable energy. Since the Limits to Growth report in 1972, renewable energies research has made key contributions to the debate surrounding the scarcity of resources and energy transition, with the topic continuing to become ever more important, not least due to the rise of climate policy. The authors identify the main research topics and assess project types, key methods and research approaches and how these have changed over time.

The eighth research field, energy demand and modelling of energy systems, has been a cornerstone of systems analysis ever since the publication of the Limits to Growth report and the first oil embargo by the OPEC countries in late 1973. The authors have organised this chapter by decades and show how the research field has developed, driven by the interplay of economic and political context factors, increasing energy efficiency options and policies, and the progress achieved in modelling approaches.

The last field is concerned with water systems research and focuses on the sustainable use of water. The authors have structured this chapter by distinguishing three phases over the last 50 years. They analyse the interplay of pressure to act, changes in research activities and important measures and regulations. The underlying analysis focuses on the national development in Germany, but includes links to developments at EU level.

Each of the nine chapters on the research fields explores their origin, how the associated methods, data sources and concepts have developed and, most importantly, how the major research questions and policy decisions have interacted with each other over time. Based on this, each chapter speculates about the future demands and opportunities to inform policy-makers and decision-makers more broadly in the future.

In a final chapter, we develop an analytical model to draw overall conclusions of the development of the SIR fields. In particular, we look at what we regard as most critical, i.e. the dynamic interaction between policy demands and research practice, concepts and methods over time. In doing so, we argue that it is absolutely vital for

the future that each of these fields opens up and integrates perspectives and insights from other fields to a much greater extent. Given the complexity of system development, and the need for productive contributions of science, technology and technological as well as social innovation to tackle our societal challenges, a more holistic approach in each of our fields and a better integration of the fields is needed. This will not only improve the production of scientific evidence, it will also render policy advice for system transformation and innovation-based competition more meaningful and relevant.

We do hope in analysing SIR in its historical development this volume is a contribution towards such a more holistic—and more impactful—analysis in the future.

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