Understanding Paradigm Change in Science, Technology, and Innovation Policy: Between Science Push and Policy Pull

Ralf Lindner, Jakob Edler, and Stephanie Daimer

Abstract Science, technology, and innovation (STI) policy experienced far-reaching changes with regard to both political aims and the underlying rationales. Drawing on the concept of policy paradigms, we analyse the factors that shaped the dynamics of STI policy since the first post-war decades in the OECD world. Next to changes in the context conditions, the chapter focuses primarily on endogenous phenomena related to changes of the conceptual understanding of knowledge generation and innovation, of the main STI policy objectives, and of preferred policy solutions. Of particular interest is the role of scientific expertise in these processes of policy change. The first of the three STI policy paradigms identified is characterised by its emphasis on addressing market failures in processes of knowledge generation. The second paradigm shares key objectives of the first, but is based on the systems of innovation heuristic, aiming to improve system performance. The third paradigm supplements the primarily economic rationales of the previous paradigms with the objective of addressing societal challenges. In view of the conclusion that scientific contributions and policy advice were less influential in the second paradigm shift than during the first, we develop suggestions for a future-oriented research agenda for STI policy research.

R. Lindner (✉) · S. Daimer
Fraunhofer Institute for Systems and Innovation Research ISI, Karlsruhe, Germany
e-mail: Ralf.Lindner@isi.fraunhofer.de; Stephanie.Daimer@isi.fraunhofer.de

J. Edler
Fraunhofer Institute for Systems and Innovation Research ISI, Karlsruhe, Germany

Manchester Institute of Innovation Research (MIoIR), University of Manchester, Manchester, United Kingdom
e-mail: Jakob.Edler@isi.fraunhofer.de

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1 Introduction

Science, technology, and innovation policy (STI policy) has evolved extensively over the past decades and undergone fundamental changes in the process. These changes were related to the respective political objectives of STI policy, the underlying rationales for government action, basic conceptual and theoretical assumptions as well as the instruments employed and the governance arrangements. Since the Second World War, three distinct phases of STI policy can be distinguished in the OECD world, each of which is characterised by specific rationales and fundamental concepts (Gassler et al. 2006; Kuittinen et al. 2018; Breitinger et al. 2021); see Fig. 1.

The focus during the first post-war decades was on building or expanding the science systems and supporting the generation of fundamental knowledge. The intellectual and conceptual foundation of STI policy was primarily shaped by the mainstream neoclassical economics prevalent at that time and a largely linear understanding of the innovation process. State interventions in this linear model were justified by the need to compensate for market failures during the generation of knowledge as a public good. The 1970s saw the start of a reorientation of STI policy. The end of the long phase of economic growth and the increasing intensity of international competition led to a revision of the basic assumptions about the nature of the innovation process, which finally resulted in the rise of the systems approach in STI policy. The development of a more complex, non-linear understanding of innovation and of the crucial role of interactions between heterogeneous actors of the innovation system was particularly influential. Consequently, according to this understanding, the main task of STI policy was to improve the performance of the innovation system. While economic goals such as competitiveness and growth were

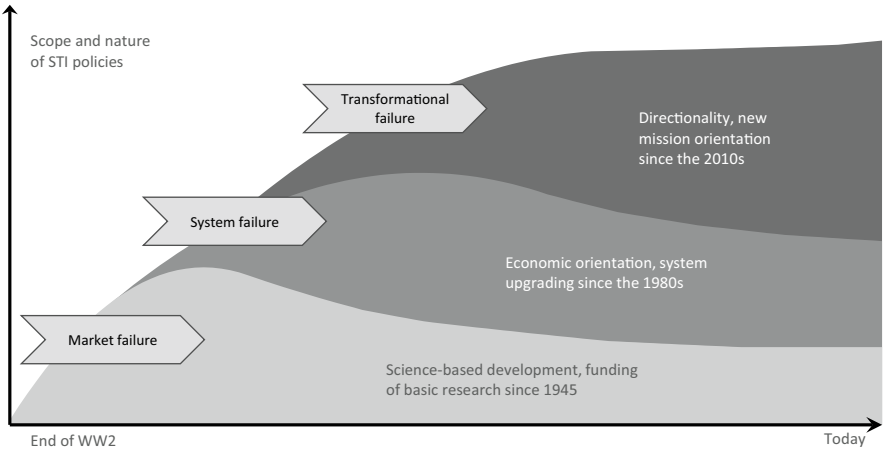

Fig. 1 Phases of STI policy. Sources: Breitinger et al. (2021); based on Daimer et al. (2012); Gassler et al. (2006)

the main reasons for state interventions in the first two phases of STI policy, from 2000 onward, these primarily economic rationales were increasingly supplemented and overlaid by the goal of mobilising knowledge, technology, and innovation to address societal challenges such as climate change. Questions about the directionality of research and innovation and the growing importance of gearing these towards societal needs are reflected, for example, in new policy approaches such as mission-oriented or transformative innovation policy. At the same time, it cannot be claimed that there was no directionality in STI policy prior to this third phase. Research programmes based on the needs of various sectors have been around for decades, such as those in the energy sector, the health sector, environmental protection, or in agriculture. The responsibility for these programmes lies partly with STI policy and partly with the respective sectoral policies. The research programmes do not primarily pursue economic goals, but rather sector-specific (policy) objectives. However, there was no overarching strategic approach in STI policy that aimed at directing a large part of applied research at specific targets or at sparking transformative change. Nor were sectoral programmes or sectoral policies necessarily oriented towards transformation.

While tracing and characterising the historical sequence of different phases of STI policy is valuable in and of itself, the main interest of this chapter is to improve our understanding of the conditions and factors that shape and drive the empirically observable dynamics of STI policy. What were the crucial influencing factors in processes of policy change, how did they interact and what effect did the changing context conditions have? There is a particular focus on the role played by scientific expertise, ideas, and conceptualisations in these processes of change. The concept of policy paradigms is useful to examine these questions more closely. It assigns strong explanatory power to ideas-based and cognitive aspects in processes of policymaking and policy change.

This chapter is structured as follows: First, the analytical framework is developed that is used to examine the developments in STI policy in recent decades. The main part of the chapter then applies this analytical framework to describe the key characteristics and development dynamics of the three major STI policy paradigms since the 1950s. The final section summarises the key findings on the processes of STI policy change and draws conclusions both for the future development of scientific policy advice in STI policy and for the applied policy-analytical tools.

2 Policy Paradigms as Framework for Analysis

Explaining policy change is an important research perspective for policy analysis. However, identifying the causes, drivers, and relevant contextual conditions of policy change is an analytical challenge due to the multidimensional factors influencing change processes. For a long time, policy change processes were predominantly attributed to the actors involved being able to assert their interests as well as to institutional conditions and exogenous events. However, since the 1990s, ideas,

knowledge, interpretations, and beliefs have also been included as key explanatory factors and have undoubtedly contributed to improving the conceptualisation of the phenomenon of policy change. The growing recognition of the role of ideas as factors in their own right in processes of policy change has made the key dimensions of policy content accessible to systemic analysis. In the literature on policy analysis, the heading of "ideas" usually refers to conceptual models, assumptions about causalities, theories but also world views, beliefs, values, and norms (Campbell 2002), with particular policy relevance given to complex, structured ideas (Carson 2004; Edler 2003). Ideas are important in the policy process because they provide interpretative frameworks that can be used to determine values and preferences and enable political and economic interests to become actionable (Carstensen and Schmidt 2016). Important contributions to this "interpretative change" (Münch 2016) or "ideational turn" of policy analysis (Daigneault 2014b) were made by approaches such as multiple streams (Kingdon 1984), advocacy coalitions framework (Sabatier 1998), the epistemic communities framework (Haas 2001), as well as approaches rooted more strongly in neoinstitutionalism, such as the punctuated equilibrium theory (True et al. 2007) and discursive institutionalism (Schmidt 2010; Edler 2003). Hall's work on policy paradigms and policy change (1990, 1993) is considered particularly influential.

While ideas represent important factors in policy change processes, they are not the only driver of transformation. On the one hand, the specific institutional and political conditions influence policymaking and thus both stability and change in policy. In particular, variants of historical institutionalism explain policy stability through the long-term effects of previous policy measures (path dependencies, policy legacies) (Béland 2009). From this perspective, policy change is predominantly incremental and is explained by institutional opportunity structures used by political actors within the framework of the given conditions (Skocpol 1992; Streeck and Thelen 2005). On the other hand, the rarely occurring, far-reaching changes are primarily explained by exogenous shocks and crises that break up established and ingrained policy pathways and open up new ones (Hogan and Howlett 2015). However, both approaches have significant blind spots when it comes to uncovering and explaining the concrete content and direction of policy—whether in the mode of incremental policy development or in disruptive, path-breaking phases. This is where the above-mentioned ideas-based, interpretative approaches come in and help to illuminate how beliefs, values, and the understanding of problems change and become effective in the complex processes of constructing meaning, agenda setting, and problem-solving (Béland and Cox 2013). In this context, it is worth recalling Heclo's famous dictum of 1974 that policymaking is not only determined by power and interests, but is shaped to a significant extent by the search for solutions to problems (Heclo 2010).

Policy paradigms can be understood as a cognitive model or a coherent set of ideas and beliefs concerning a policy problem and suitable solutions to it, which is shared by a specific group of actors and provides orientation in the relevant policy field (Carson 2004; Daigneault 2014a). Hall's analysis of monetarism displacing the macroeconomic policy paradigm of Keynesianism was groundbreaking for the link

between paradigms and policy change. The essential starting point of this approach is the observation that processes of policy formulation and design take place within the context of discursive relationships (Hall 1993). Such discourses are powerful and effective because they occur within a framework—consisting of ideas, standards, and assumptions about the relevant policy field. Hall refers to this reference framework as a policy paradigm, defined as an "overarching framework of ideas that structures policy-making in a particular field" (Hall 1990). These interpretative frameworks affect policy by determining fundamental relationships, structuring policy discourses according to the prevalent parameters and thus influencing policy goals. Once a policy paradigm has become established, fundamental disputes about its key elements usually only take place to a very limited extent and transaction costs between stakeholders in the policy field are reduced due to shared patterns of interpretation. To explain policy change that goes beyond incremental shifts, Hall draws on Kuhn's concept of scientific paradigms (1962). Following Kuhn, Hall distinguishes three modes of policy formulation (Hall 1990): While in phases of (1) first-order change, changes in a policy field are manifested as continuous further developments of existing policy instruments, in phases of (2) second-order change, revisions, or even the exchange of instruments take place in order to still achieve the goals pursued within the framework of the current paradigm despite emerging policy problems. Finally, (3) third-order change involves the fundamental departure from the previously dominant system of ideas and is accompanied by profound changes in the overarching discourse. First- and second-order changes are thus "normal", incremental phases of policy change, whereas third-order change signals a policy paradigm shift.

While Hall's approach has received a lot of attention and has been widely used to analyse processes of fundamental policy change, the understanding of policy paradigms has continued to evolve. Today, a generally more fluid and differentiated understanding of policy paradigms is prevalent, in which some of the central postulates of the original concept are no longer shared or shared only in a modified form. Above all, this concerns the assumption that competing paradigms are strictly incommensurable. In contrast to the arguments by Kuhn (1962) and Hall (1993), linkages and combinations of different paradigms are now regarded as possibilities (Hogan and Howlett 2015), these are sometimes referred to as "synthetic" and "hybrid" paradigms (Béland 2007; Kay 2007; Wilder 2015). The strict assumption that a new paradigm always completely supersedes and replaces its predecessor has also been watered down. Instead, different paradigms can co-exist, although often not without conflict, and a type of "policy layering" results. Sometimes there are recombinations and novel combinations of ideas that can lead to paradigms that incorporate partially contradictory ideas (Diercks et al. 2019). Additionally, with regard to the dimension of time, paradigm change is no longer understood as an exclusively revolutionary process that occurs in phases, but also as a gradual process, that takes place over longer periods of time (Carstensen 2011; Mahoney and Thelen 2010).

Based on the conceptualisation of policy paradigm change and its further developments, this chapter focuses on the following perspectives to analyse the change in

the fundamental orientations of STI policy since the middle of the twentieth century in the OECD world. A distinction is made between phenomena that are predominantly external to the policy field and those that are internal to it.

Primarily exogenous phenomena:

- What changes in the context conditions (economic, societal, political) can be identified that have played a role in fundamental change processes in STI policy?

Primarily endogenous phenomena:

- How has the main theoretical-conceptual basic understanding of the origins of knowledge and innovation changed?
- How have the STI policy objectives changed?
- How have problem constructions and the respective preferred solutions and their instrumentation changed in STI policy discourse and in application?

In all three main endogenous dimensions of analysis, it is of particular interest what role scientific policy consultation played in the processes of change in each case, and which questions research providing policy advice was confronted with in the different phases.

3 The Paradigmatic Development of STI Policy

3.1 The Point of Departure: STI Policy Centred on Knowledge Generation and Addressing Market Failures

In OECD countries, STI policy in the first two to three decades after the Second World War was strongly focused on funding, strengthening, and differentiating the science system (OECD 1972). It was considered a genuine task of the state to support the development of scientific capacities as a foundation for progress and prosperity. OECD countries generally adhered to the logic that it should be a task of the state to promote basic knowledge, which would then make its way into innovation via market processes or direct state (especially military) demand (Bush 1945). This idea was based on experiences during the Second World War, when massive government scientific programmes had laid the groundwork for military innovations (Gassler et al. 2006).

The guiding principle of the state funding basic knowledge, especially for non-state utilisation, was scientifically underpinned in the following years, primarily by economists. Science and technology were increasingly perceived as the engines of economic growth and social progress in neoclassical welfare economics (especially Solow (1957)). However, it was stated that the necessary scientific foundations could only be secured through state funding. The reason for this is the neoclassical concept of market failure as an underlying problem: The economic benefit of basic knowledge is, by its very nature, not foreseeable ex ante, and its utilisation is

therefore highly uncertain. At the same time, the potential economic benefit can usually not be limited to the actor producing the required basic knowledge due to spill-over effects. Due to these positive externalities and the associated free rider behaviour, there is insufficient incentive for private actors to invest in the creation of basic knowledge (Arrow 1962; Nelson 1959). Following this logic, the public good of basic knowledge needs to be largely financed by the state and then progresses along a linear process towards economic utilisation as innovation via the development of technologies (among others Pavitt 1976; Tidd et al. 2005; Klodt 1987).

Consequently, the state has the task of creating and maintaining the financing and research institutions relevant for the respective disciplines and state or private utilisation contexts, promoting the transfer from publicly financed research to industry, and subsidising strategic research conducted in companies (OECD 1972). Additionally, intellectual property rights have to be strengthened in this logic, especially via patents, in order to create incentives for investment in uncertain innovations (Edler and Fagerberg 2017). This also explicitly meant that the state set certain priorities in science and technologies that were viewed as particularly worth supporting in terms of state or private utilisation interests (Soete and Arundel 1993). This phase of public governance of science and technology was thus in no way devoid of setting priorities or supporting selected technology trajectories. Science and technology policy was institutionalised and differentiated in all OECD countries in the post-war period based on this understanding (OECD 1972). The first generation of large, mission-oriented research and development programmes also fall into this context, especially those in the USA such as the Apollo projects of the 1960s. These so-called "old missions" were characterised by their almost exclusive public funding and their focus on developing novel, hitherto non-existent technologies (Foray et al. 2012).

The dominant research questions of analysts in the context of this differentiation were the empirical documentation of expenditures with regard to research, development, and innovation activities (see Frietsch et al. 2024 in this anthology), in order to determine empirically what contribution science and research make to productivity, economic growth, and social progress. This included the institutional analysis and international comparison of "science systems" (OECD 1972) as well as the importance of state demand for technological innovations (Mowery and Rosenberg 1979).

The conceptual development within this underlying paradigm can be illustrated using the example of German policy advice. In a study for the then German Federal Ministry for Research and Technology (BMFT), the founding director of Fraunhofer ISI, Helmar Krupp, analysed the institutional conditions of science and its governance in Germany (Krupp 1972; see also Stucke 1993). To start with, Krupp still followed the linear model outlined above and the idea of market failure as the rationale for political steering and stated the need to particularly focus on changing the knowledge transfer and utilisation conditions. Implicitly, however, Krupp went beyond the linear model and emphasised the huge variety and heterogeneity of all the actors involved in the creation, transfer, and exploitation of scientific knowledge in innovations and who therefore contributed to the diffusion of innovations in the

economy and society. His use of the term "innovation system" already pointed the way to concepts that only experienced a breakthrough in the 1980s (see below). The early 1970s also marked the beginning of a comprehensive but prolonged revision of the understanding of the nature of the innovation process throughout the OECD world. This revision culminated in the development towards a more differentiated technology and later innovation policy (Sweeney 1985; Dodgson and Rothwell 1994; Rothwell and Zegveld 1981), see also Fig. 2.

3.2 Systems of Innovation as the Dominant Heuristic for Analysis and Policymaking

This reorientation towards a systems approach during the 1970s and early 1980s was largely driven by a generation of economists inspired by evolutionary theory. This group exchanged ideas through various expert groups and conferences of the OECD, among others, and this helped their ideas to quickly disseminate internationally and gain legitimacy (OECD 1981; Edler 1999). There were different intellectual sources for this reorientation. The broader context, founded on political science, was the fundamental optimism about steering by means of state intervention in the early 1970s. In a sort of "planning euphoria" (Mayntz 1996; Mayntz and Scharpf 1973) in the late 1960s and 1970s, there was the notion that state instruments, regulations, and incentives could be used to comprehensively steer social dynamics. The optimistic basic notion of state steering capacities came to an abrupt end in the 1980s, which also meant the steering theory of political science became less important (Mayntz 1996). Nevertheless, this fundamental belief in the state during the social democratic decade of the 1970s was an important cognitive and

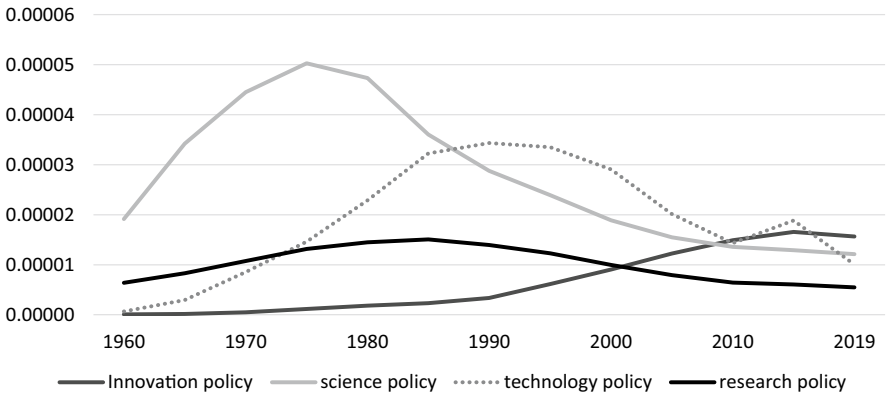

Fig. 2 Differentiation of the field from science to STI policy. Source: own representation. Based on Google Books Ngram Viewer, accessed 13.09.2023

normative basis for the academic and political discussion that then began concerning a more proactive state, which was also reflected in research and innovation policy.

On the macroeconomic level, against the backdrop of stagflation in the 1970s, the insight from welfare theory became increasingly widespread that research and development (R&D) and technological innovation were major drivers and conditioning factors for the economic and social development of national economies (Pavitt 1979; OECD 1980: 91 ff.). Entrepreneurial R&D became more central to explaining economic dynamics, but at the same time, there was an increasing emphasis on the scientific knowledge of technological innovations (Freeman 1973), with the result that the link between state-funded scientific research and private R&D became even more important. Targeted R&D directed at market innovations became the core of economic policy considerations. According to this logic, the crisis in the 1970s had to be addressed by the targeted support of R&D activities, especially in view of the stagnation in productivity development (Edler 1999).

A vital insight from the systemic view of innovation was that it is the increasingly generic and systemic character of technologies that determines these dynamics:

> [O]ne of the most important advances made in the area of the theory of technology during the last five years or so has been the move made from several sides towards an understanding of major technologies as having systemic traits (Chesnais 1982).

In concrete terms, microelectronics was the most important technological driver on which the conceptual developments were based. This was characterised as a "technical revolution" (Krupp 1975) that was going to fundamentally alter various sectors and social practices. The changes that were associated with this pervasive technology led to reflections on how technological innovations and socio-institutional configurations interacted. This was new in this form (see Heyen et al. 2024 in this anthology).

This also involved rethinking the innovation process itself. The linear model was replaced—or rather supplemented—by a model of different phases and stages which interact with one another. The chain-linked model of Kline and Rosenberg (1986) is one prominent example among several at the time, or the coupling model of Keck (1986). Innovation was thought of as resulting from complex interactions of different actors, with feedback loops between different stages of the process (see also Mowery and Rosenberg 1979) and between different sectors and scientific disciplines. Attention was also increasingly paid to innovations not only being the result of implementing technological inventions but also emerging in response to the needs of the market or as recombinations of existing technologies. This more complex view of the innovation process and the understanding of the need for multiple horizontal and vertical interactions and collaborations had become widespread by the early 1980s (European Industrial Research Management Association 1982; Teece 1986; Rosenberg 1991; Wissenschaftsrat 1992; Edler 1999).

This new conceptualisation of the innovation process was accompanied by the development of a specifically systemic view of innovation dynamics. R&D and the generation of innovations were then conceptualised as the interplay of the economy, science, and society (Freeman 1982). This insight was also the result of empirical

analyses that were no longer able to explain productivity differences only in terms of different sectoral production functions. Instead, different socio-institutional configurations were considered important complementary explanations (Nelson and Winter 1977; Gaudin 1985; Edler 1999). Consequently, the understanding became increasingly widespread among researchers and analysts that technological innovations and socio-institutional configurations are influenced by their close interdependency.

The various academic developments then led to an explicit and broadly conceptualised innovation systems approach in the 1980s. While this term had already appeared in the early 1970s (Krupp 1972), it was conceptually elaborated by a number of leading innovation economists, i.e., Freeman et al. (1982); Lundvall (1985, 1992); Nelson (1993) as well as Edquist (1997). The different variants of the innovation systems approach place a different emphasis on cumulative learning processes and on institutional configurations, especially with regard to user–producer relationships and the relative importance of the public sector vs. the market. In addition, the different approaches are influenced to varying degrees by insights and assumptions from evolutionary economics, according to which actors behave with bounded rationality under conditions of high uncertainty and therefore develop adaptive strategies instead of striving for optimal ones (Nelson and Winter 1982; Fagerberg 2003), as postulated in a neoclassical world with perfect information and technology as external variables. These different variants were widely adopted in practical policy strategies not only in the OECD world (Lundvall 1992), but also in developing and newly industrialising countries (Chaminade et al. 2018).

From the end of the 1990s onward, the research agenda included not only actor relationships and dynamics in the innovation system, but also more holistic system considerations as objects of investigation. Alongside the evaluation of individual funding programmes, institutional evaluations became more important, i.e., the role and performance of research or research funding organisations in the innovation system were also taken into account. The evaluation of the Research Council of Norway, which was co-developed and conducted at Fraunhofer ISI, was the first to work with a graphical representation of the innovation system (Arnold et al. 2001; Kuhlmann and Arnold 2001; see also Bührer et al. 2024 in this anthology). The diffusion of the innovation system approach, which was formulated by different scientific communities, had far-reaching consequences for the role and instruments of STI policy. If innovation is the driver of economic growth and social development, if innovation is the result of a complex, recursive interplay of different actors, scientific-technological disciplines and sectors, if recursive learning processes must be enabled and enhanced, if publicly funded research remains a mandatory foundation for market-based, radical innovations, then it is incumbent upon the state to actively support and help shape the necessary socio-institutional configurations and interactions in the system. Not only the financial subsidising of existing constellations is important in this perspective, but also support for reconfigurations, for new linkages, for connections that do not result on a sufficient scale from a purely market-based logic. It is therefore a task of the state to adapt socio-institutional configurations over time or to enable this adaptation to come about in an

evolutionary way. This does not question the role of the market in generating and selecting innovations, but greater attention must be paid to the conditions under which innovations are generated and diffuse in market economies. According to this perspective, it is no longer sufficient for the state to fund science or long-term oriented R&D in companies. In terms of research and innovation policy, it was now increasingly important to think of R&D in broader contexts, as more cooperative and more systemic.

In the early 1980s, the term innovation policy became increasingly dominant for all the policies that actively addressed these systemic challenges and linked them to economic and social goals (Rothwell and Zegveld 1981; Sweeney 1985). In view of the stated complexity of the system, the relevant innovation economists were quick to point out that a number of different ministries and policy fields would have to be an active part of such an innovation policy, and at the same time, that they would be overwhelmed by the complexity of the interrelationships. Thus, although the fundamental steering optimism of the 1970s was largely obsolete and the neo-liberal or neo-conservative turn in the late 1970s and early 1980s assigned the state a more reticent role in the economy, the role of the state became de facto increasingly important for the "new" innovation policy in light of the complementary insights into the systemic nature of innovation outlined above. This was accompanied by a greater differentiation of instruments that took different forms in different countries (Rothwell and Zegveld 1981, 55 ff.; Gaudin 1985; Stuart and Kuntze 1982).

In view of the many systemic points of connection in the innovation systems approach, the concrete set of instruments continued to become increasingly differentiated over the course of the 1980s and 1990s (Edler and Georghiou 2007; Edler et al. 2016). The focus was on improving the framework conditions, and especially on incentives to support collaboration or networking among different actors. Examples include Alvey in the United Kingdom, ESPRIT and BREITE/EURAM at EC level, as well as the "Verbundprogramme" in Germany. In addition, there were cluster and network programmes, mobility programmes, knowledge and technology transfer programmes, further education and training on innovation management and entrepreneurship, as well as awareness-raising measures and the first large-scale foresight processes (see Cuhls et al. 2024 in this anthology). These were intended to provide actors in the system with more structured opportunities to jointly reflect on the orientation of innovation activities. The latter has been part of a broader understanding of policy advisory studies associated with the catchphrase of strategic intelligence (cf. Kuhlmann 2003 as well as Bührer et al. 2024 in this anthology). The differentiation and policy design of sectoral (among others, Malerba 2004), regional (e.g., Braczyk et al. 1998; Koschatzky 2001), and technological innovation systems (e.g., Carlsson and Stankiewicz 1995) became significantly more important during this phase. Accordingly, the epistemic community also broadened to include, for instance, economic geography and various forms of sustainability research.

Since both the European and, in federal countries, the regional level developed policymaking ambitions, and since it made sense to apply the innovation systems approach at different levels, this differentiation took place on all three political system levels. Simultaneously, on all three levels, the institutions of innovation policy

also became increasingly more differentiated, i.e., innovation and funding agencies, ministerial departments, advisory bodies, etc. From around the late 1980s, this led in turn to a growing need for vertical and horizontal coordination.

Similar to the institutional expansion and differentiation of the innovation systems, the field of STI policy research also experienced major steps of institutionalisation in the early 2000s. Taking advantage of an EU sponsored scheme for European Network of Excellence (NoE), a number of senior researchers, led by Philippe Larédo of Paris, initiated the NoE "Policies for Research and Innovation in the Move towards the European Research Area" (PRIME). The founders were motivated by the recognition of "major transformations in the locus, formulation and implementation of science, technology, higher education and innovation policies, which call for new theoretical and empirical research in research and innovation policy studies" (see Larédo 2003). Furthermore, as the STI policy field at the time was highly interdisciplinary and consisted of researchers dispersed in universities and non-university research organisations, it was poorly institutionalised. The intention thus was to create a pan-European intellectual homebase for researchers, in particular the young generation (Luukkonen et al. 2006). In 2010, building on the experiences of PRIME, the "European Forum for Studies of Policies for Research and Innovation" (EU-SPRI) was founded as a European Association which has meanwhile grown to include 19 member organisations (https://euspri-forum.eu/).

3.3 The "Normative Turn" and the Orientation Towards an Innovation Policy Aimed at Addressing Societal Challenges

In the early 2000s, there was a first wave of criticism of the dominant policy approach of the time, heralding, as it were, the policy shift towards addressing societal challenges. Although innovation policy as a policy of improving the system performance also set certain content-related priorities or directionality in technology or sector-based programmes, it was generally not oriented towards specifically applying innovations to solve societal problems. Aligning innovation with societal needs was left to the state or other policy areas, not innovation policy. In terms of competencies of departments and ministries, negative coordination was the dominant mode of governance, in essence leading to a demarcation of responsibilities. In the area of research and innovation funding, technology or sector programmes focused primarily on basic research and the early phases of the innovation process, while research and innovation with a stronger focus on strategic policy or societal goals such as energy efficiency or environmental protection were (and still are) the responsibility of the respective sectoral ministries. Although these disconnected responsibilities are understandable in their political-institutional context, it can be stated that the epistemic communities that were engaged in analysing and developing approaches in the respective policy areas were not able to sufficiently bridge the

gap between the different rationales. There was no overarching discussion of the different objectives and possible implications of an increased focus on sustainability issues, e.g., in the areas of energy, the environment, or water innovation (cf. the contributions in this anthology). The lack of an integrated approach has been noted over time by several authors, such as Walz et al. (2019), who criticised the lack of integration between environmental and innovation policies. Weber and Rohracher (2012) spoke in this context of policy coordination failure. So, although other policy areas were engaged in directional research and innovation funding earlier than STI policy in the stricter sense, this does not mean that this was done under the paradigm of initiating transformative change and the socio-technical system innovations necessary for it. The lack of a transformative paradigm has been noted to this day, for example, in environmental policy (Jacob and Ekins 2020).

At the same time, orienting policy to real needs was already part of the concept of innovation policy as it had been developed in the 1980s. Even in the early days of a more explicit innovation policy, innovation researchers called for innovation policy to be more strongly oriented towards societal needs and for innovation policy to be placed at the centre of government policy, as it were, in order to bring about positive change in the economy and society (Rothwell and Zegveld 1982). An international example of this is the summary of an Innovation Policy Workshop of the so-called Six Countries Programme, which was organised by Fraunhofer ISI:

> In fact, with a little thought it is possible to extend the list of things that influence innovation to such an extent that if the concept of an innovation policy is expected to accommodate all of them, then such a policy becomes almost all encompassing in relation to the wide range of already existing policies. This should make clear that by its horizontal nature the goals of innovation policy may interfere with those of other policies. In a rational innovation policy, one would expect these conflicts to be recognized and taken into account in the formulation of policies and measures, i.e. a rational and systematic approach towards moving in desired and predetermined directions (Stuart and Kuntze 1982).

As early as 1985, Helmar Krupp also called for a decidedly demand-oriented approach (Krupp 1985), especially with regard to the necessary adaptation of new technologies to increase efficiency in the energy system. Moreover, Soete and Arundel (1993) developed a conceptual differentiation of innovation policy that included an explicit move towards an approach that was also "mission-oriented".

However, these notions were ahead of their time. In practical policy terms, this only changed with the development of dedicated concepts for demand or needs-based policies (Edler 2007; Edler and Georghiou 2007). The starting point for this was, on the one hand, the attempt to make greater use of government demand to generate societally important innovations (Edquist et al. 2000; Edler et al. 2005). On the other hand, political actors from other policy areas (environment, energy) also began to look more closely for opportunities to use research and innovation policy to address complex problems in their areas of responsibility. At the same time, approaches in other policy areas that had traditionally applied demand-side instruments inspired the innovation policy debate (Edler 2007). Consequently, demand-side instruments were also integrated (OECD 2011) into innovation policy with a focus on innovative procurement in the public sector. More far-reaching demands

for tools that not only integrate the demand side but also cover all the functions attributed to innovation systems in a holistic and coordinated manner (Edler et al. 2007; Edler 2007; Smits and Kuhlmann 2004) went largely unheard.

With the shift to the demand side and thus to society's needs, the bridge to other policy areas was finally established. However, the corresponding opening up of innovation policy only really began with the explicit turn towards the "Grand Challenges" and transformation-oriented innovation policy.

In addition to the early opening up of innovation policy research to include a stronger focus on societal challenges, there were simultaneous policy developments in the early 2000s that supported the existing paradigms (and they continued to dominate the majority of research articles published on the topic).

At the EU level, the Lisbon Strategy identified shortfalls in public investment in R&D and it was agreed that EU Member States would make a voluntary commitment to increase their overall economic spending on R&D to three percent of their GDP. At the same time, the lead market idea was emphasised with the aim of bundling and streamlining programmes in terms of topic and technology at both European and national level in order to achieve a stronger focus on promoting fields of strength or key technologies that had been identified. The newly created mission statement of the European Research Area was intended to support these ambitions and create the necessary systemic conditions at the same time.

The so-called Aho Report (Aho 2006) on the "Grand Challenges" was a first impulse in the direction of the emerging transformation in STI policy into the third paradigm on the policy level. In this report, innovation researchers and high-ranking representatives from politics and industry urged that innovation policy should be mobilised to solve societal problems in the EU. This was in no small part a response to the overall disappointing innovation dynamics in the context of the Lisbon Strategy. A few years after publication of the Aho Report, in the Lund Declaration in 2009 (Swedish Presidency 2009), 350 participants from science, politics, industry, and research funding called on European policymakers to focus European-funded research on the grand societal challenges of the day and also to align national research funding accordingly in a conference organised by the Swedish EU Council Presidency in preparation for the 8th EU Research Framework Programme (later Horizon 2020). The statement already addresses the necessary political processes and course-setting that were to determine the debates for more directionality in innovation policy a few years later. In this context, the Lund Declaration (2009) emphasises that the "Grand Challenges" must be identified in a joint process involving politics, business, administration, NGOs, and the research community.

However, the financial crisis of 2008/2009 shifted the focus of many European governments back to stabilising economic strength, with particular attention paid to strengthening the industrial base. Although research and innovation had been considered important drivers of economic strength under the first two paradigms, many governments actually decreased their investments in R&D. The legal basis adopted in 2011 for the EU's 8th Research Framework Programme Horizon 2020 (European Commission (2014)), for example, was dominated by the crisis and emphasised the growth and competitiveness of European industry as its primary goals. Although,

for the first time, the programme did not contain any theme-based sub-programmes, it did organise funding along seven societal challenges. However, the instruments used were not changed in any way that would have been conducive to the new paradigm that was emerging. The societal challenges were merely included in the broad research agenda, and mostly only in the form of expected "impacts", whereas the instruments continued to address primarily science and industry as the traditional R&D actors. Further developments of these instruments were primarily focused on strengthening SMEs and the innovativeness of companies (new instruments for SMEs and the subsequent piloting of the European Innovation Council, EIC). Similar developments occurred at the national level. In Germany, for example, the so-called High-Tech Strategy was launched in 2006 (Bundesministerium für Bildung und Forschung 2006), in which societal goals were increasingly proclaimed over successive generations of this strategy (Bundesministerium für Bildung und Forschung 2010, 2014, 2018). However, a consistent shift to the new paradigm had not yet taken place.

The adoption of the United Nations Sustainable Development Goals (SDGs) in 2015, as well as the rapidly worsening climate crisis and internationally agreed climate targets once again increased the pressure on STI policy to focus its approaches more strongly and systematically on addressing these overarching issues. These developments at policy level were accompanied by and interrelated with conceptual developments in innovation research.

After Christopher Freeman, Bengt-Ake Lundvall, Charles Edquist, and Luc Soete, a second generation of innovation economists and researchers played a pivotal role. These included, for example, the economist Mariana Mazzucato, who gained popularity with her call for the state to take a more active role and to shape markets in response to important societal challenges (Mazzucato 2013, 2018). The innovation policy debate in Germany also opened up cautiously in the direction of a needs-based and directional approach as a result of the greater focus on evolutionary economics in the Expert Commission for Research and Innovation (EFI) appointed by the German government. However, the broader research community that was specifically concerned with STI policies dealt with the new issues comparatively cautiously and published only with some delay in reaction to the developments, especially at the European level. An early influential paper from 2012 by Weber and Rohracher created a foundation for broadening the legitimacy base for policy intervention by placing a third group of rationales for government intervention alongside the established ones of market and systemic failures, namely: "transformational failures". Fraunhofer ISI also addressed the issue in its commemorative publication as part of its 40th anniversary celebrations (Daimer et al. 2012) and by organising the European Forum for Studies of Policies for Research and Innovation (EU-SPRI) conference under the heading "Towards Transformative Governance? Responses to mission-oriented innovation policy paradigms" (Fraunhofer Institut für System- und Innovationsforschung ISI 2012). The call for the conference postulated the emergence of a third paradigm for STI policy:

> This (author's note: The Lund) declaration has taken up and reinforced a development in the past few years in which governments and the European Union have adopted a new strategic rhetoric for their research and innovation policy priorities which addresses the major societal challenges of our time. This is evolving into the third major policy rationale besides economic growth and competitiveness.

The third paradigm essentially assumes that science, technological development, and innovation produce relevant contributions to solving the societal challenges of our time and, in particular, trigger transformations in the direction of sustainable development.

The STI policy science community is now intensively addressing issues related to this latest policy paradigm and is increasingly interacting with communities researching sustainability transitions. This has further substantiated the impetus of the third paradigm in normative and conceptual terms. Thus, approaches such as the multi-level perspective were taken up, from which the need for policy interventions aimed at supporting new market niches (technologies or applications) can be derived (Geels 2002; Smith et al. 2010). A conceptual combination of approaches from the two research traditions, i.e., approaches from STI policy and sustainability transition research, and thus an explicit derivation of the third paradigm was provided by another influential publication by Schot and Steinmueller (2018), which popularised the term transformative innovation policy.

Although the new paradigm of innovation policy, which aimed at directionality, problem-solving, and system transformation, quickly became widely accepted (e.g., OECD 2015), little has changed so far at the instrumentation level. Policymakers may have accepted the new objectives ("policy agenda"), but they have not yet fully adapted a broader concept of innovation, which would ultimately have far-reaching implications for innovation policy instrumentation (Diercks et al. 2019).

A broad conception of innovation goes beyond a purely science-based and technological understanding of it to include forms such as "doing, using, and interacting", which places a great deal of emphasis on social or organisational innovation. This also implies that the group of innovating actors is defined more broadly, encompassing not only research and industry, but also a wider range of actors in the public and, above all, the civic sectors (cf. also Warnke et al. 2016). A third crucial point is that, in addition to the supply side ("technology supply"), the demand side (end users, so-called "need owners") is also an important starting point for policy design.

Many of the policies established in recent years address the new objectives, but in effect still remain constrained by a narrow definition of innovation. The above-mentioned example of Horizon 2020 is one of them, as are some of the national innovation strategies initiated in the past decade, such as the German High-Tech Strategy (Bundesministerium für Bildung und Forschung 2018) or the Dutch Top-Sector Strategy (Ministry of EZK 2019). Despite their mission-oriented focus, both these national strategies rely primarily on research and technology and allude, mainly rhetorically, to wider definitions of actors and innovation, but do not actually apply them in the instruments used.

There are systemic instruments that are suitable for addressing the new paradigm because they deal with diagnosed systemic failures in a differentiated way and are suited to integrating a wider definition of innovation and directionality (orientation towards societal challenges). These include, above all, approaches that strengthen the ability of actors to learn and reflect, such as adaptive, supportive, and interactive evaluations of funding programmes, or foresight processes that are designed to be inclusive and systemic (Daimer et al. 2012; Lindner et al. 2016).

Whereas at the strategic level, the alignment of STI policy with the Grand Challenges can now be observed on a broad scale in the OECD world, the understanding of innovation and its instrumentation has by and large not followed suit. Against this background, STI policy in a number of OECD countries as well as at the EU level has increasingly adopted mission-oriented approaches in recent years (Larrue et al. 2019; Larrue 2021), in order to make the unspecific Grand Challenges politically manageable and to operationalise them by defining concrete targets and time horizons (Lindner et al. 2021). Accordingly, current research is concentrating on the new mission-oriented approaches (Janssen et al. 2021; JIIP 2018; Kuittinen et al. 2018; Wanzenböck et al. 2020; Wittmann et al. 2021a, b). It can be observed that mission-oriented approaches are becoming increasingly differentiated and a number of challenges related to governance have been identified, which still stand in the way of effectively implementing mission approaches (Edler and Boon 2018; Lindner et al. 2021). Simultaneously, the first attempts are being made to evaluate these new policy approaches (Ghosh et al. 2021; Haddad and Bergek 2023; Wittmann et al. 2022), which are primarily concerned with the question of how to measure political and societal "impacts" (cf. Bührer et al. 2024 in this anthology on this and on the generally increasing impact orientation). Another major issue that has so far been discussed mainly in research is the need for the transformation of entire systems, understood as a reconfiguration of the provision of important societal functions such as mobility or energy supply. This requires a complex process of transformation involving not only technological but also non-technological innovations and changes in actor behaviour, as well as the reconfiguration of actor networks (Borrás and Edler 2020; Grillitsch et al. 2019).

4 Conclusions and Outlook

4.1 Making Sense of Paradigmatic Changes

The development of STI policy in the OECD world can be divided into three distinct phases that differ in terms of the underlying theoretical basic assumptions about how knowledge and innovations emerge, the policy goals, the dominant approaches to solutions, policy instruments and governance structures as well as the contributions of (policy advising) innovation research.

1. In the first post-war decades, the theoretical foundations for early STI policy were clearly dominated by the key postulates of neoclassical economics. State intervention in processes of knowledge generation was justified by the need to address phenomena of market failure, especially in the funding of basic research. However, the policy paradigm was not without contradictions at the level of instrumentation, as priorities and steering of technology policy already existed, albeit in a comparatively weak form that were in conflict with neoclassical orthodoxy. Over the course of the 1970s, there were the first cautious conceptual developments from science that challenged the previously dominant basic assumptions and problem constructs. These were based on a gradually improved understanding of knowledge generation processes as well as initial approaches of a systemic understanding of innovation processes.
2. From the end of the1970s, the second STI policy paradigm gradually asserted itself as the dominant perspective. As with the first paradigm, the key policy goals of STI policy focused mainly on economic objectives such as growth and competitiveness. The main drivers behind this paradigm shift were the end of the long period of economic growth in the first post-war decades and intensified international competition, which significantly increased the importance of national (and later also regional and sectoral) innovation performance as an essential prerequisite for economic prosperity in the political and scientific debates. In this context, these were the expansion of the theoretical and conceptual foundations of the STI policy paradigm to also include concepts from evolutionary economics and other academic disciplines (such as political science) on the one hand, and new insights into innovation processes and their factors of influence on the other. When combined, at the time, these provided convincing epistemic explanations to challenge STI policy. The goals of STI policy remained basically the same compared to the first paradigm (economic growth), but with a much stronger emphasis on company-based innovation activities. At the level of instruments, the new paradigm was accompanied by numerous innovations in the form of "system-strengthening" instruments. However—and this is an indication of the phenomenon of policy layering—key instruments from the first policy paradigm were largely continued without any changes. Criticism of the goals of the system-strengthening paradigm started at the beginning of the 2000s, mainly due to the insufficient orientation of STI policy towards society's needs.
3. The rise of the third STI policy paradigm became apparent around the mid-2000s. The main characteristic of this most recent paradigm is the targeted orientation of STI policy towards addressing urgent societal challenges. Within this paradigm, STI policy measures are justified by the potential contributions that STI can make to addressing the Grand Challenges. This new orientation at the level of objectives was mainly driven by the growing pressure of problems related to worsening of the climate crisis and the crossing of planetary boundaries as well as the growing realisation that previous STI policy approaches were unable to effectively mobilise science, technology, and innovation and direct them to tackle current problems. However, economic crises have slowed down the transformation process and reinforced the strong influence of established STI policy

paradigms. Overall, the fundamental objective of the third policy paradigm has become established over the last 10–15 years and it is now widely recognised that this new generation of innovation policy should not only address market and system failures, but also the failure to transform (Weber and Rohracher 2012). However, the debate in STI policy research on the conceptual foundations and implications of the new paradigm has largely only taken place as a follow-up to the strategic reorientation of STI policy, which, as has been shown, was strongly influenced by the course set at EU level. Important discursive contributions to the paradigm shift from research are related, for example, to re-assessing the function of the state in research and innovation processes, which is in contrast to the main, primarily neoclassically influenced axioms of previous policy paradigms, as well as to systematically deriving the policy intervention rationale for the new paradigm. The fact that a significant mismatch between paradigm objectives, on the one hand, and the instruments and governance structures, on the other, can still be observed is also an indication that the process of paradigm change is still ongoing.

Table 1 provides an overview of the three STI policy paradigms based on the key analytical dimensions of this chapter.

In order to further develop the policy-analytical understanding of the processes of paradigm shifts, some conclusions can be drawn, at least with regard to the STI policy field. That policy paradigms are not subject to strict incommensurability and that one paradigm does not have to be completely replaced by the next is supported by the analysis of the three STI paradigms. The fact that the dominant paradigm in each case has incorporated theoretical and conceptual elements as well as partial goals of the previous paradigms clearly confirms empirically the possibility of recombinations and hybrid forms. This rather "soft" form of paradigm shift is coupled with predominantly incremental processes of paradigm shift that take place over longer periods of time. One explanation for the fact that the process of paradigm shift in STI policy has not been characterised by a clear replacement of one paradigm by another, as conceptualised by Hall (1990, 1993), could be that he based his analyses on the replacement of an economic policy paradigm, whose basic assumptions were developed and discussed exclusively by one scientific discipline. In STI policy, on the other hand, a number of different disciplines have played a role since the 1970s at the latest, with the consequence that academic discourses are more diversified and thus the processes of paradigm change could also be more multi-layered. We have seen that, at least in the two most recent STI paradigms, the degree of coherence between the systems of ideas is low, given the coexistence of sometimes contradictory intervention logics, approaches, and goals.

The three STI policy paradigms have thus been superimposed on one another in an additive manner in the sense of policy layering, reducing the effectiveness of the preceding, older paradigm in each case, but not displacing it completely. This sometimes results in considerable tensions both between and within the paradigms. This last point applies, for example, to certain measures of targeted technology support that took place within the framework of the first and second paradigms, but which

Table 1 Overview of the three STI policy paradigms

Analytical dimensions	Paradigm 1: STI policy to generate knowledge and address market failures	Paradigm 2: Innovation systems approach	Paradigm 3: Directionality and problem orientation, transformative change
Context conditions	Post-war years with a specific focus on reconstructing science systems	End of the long phase of economic growth in the post-war decades; stagflation in Western industrial nations	Growing political urgency of the "Grand Challenges" and the need for system transformations
Basic understanding	Development and expansion of scientific capacities, public funding, especially for the generation of basic knowledge; Neoclassical welfare theory as a guiding theoretical and conceptual idea	Ideas based on evolution theory; Research and technology as particularly important drivers of economic growth	STI as an essential prerequisite for and contributor to solving societal challenges; Emerging change: increasingly broad understanding of innovation, which also sees non-research-based forms of innovation as key to addressing societal challenges
Policy objectives	Promoting growth and competitiveness through research	Growth, economic dynamism, and competitiveness through innovation	Focus increasingly on addressing societal challenges, complemented by economic goals such as competitiveness
Problem constructs and solutions	Since knowledge is conceptualised as a public commodity, government funding is required (basic research, research institutions); Utilisation of linear understanding predominantly through spill-over effects Support through IP governance; To some extent technology policy priorities	Systems of innovation and interaction between actors as dominant heuristic; Understanding the innovation process in a recursive way; Government interventions aimed at improving the performance of the innovation system (systemic instruments); Supply orientation; Innovative companies as the key to globally competitive economies	Systems of innovation remain key; Sustainability transformation concepts find their way into STI policy discourses; At the level of instruments, largely as in paradigm 2, quantitative growth of thematic research funding; First approaches of MOIP and transformative innovation policy; Growing impact orientation; Need for system transformations

(continued)

Table 1 (continued)

Analytical dimensions	Paradigm 1: STI policy to generate knowledge and address market failures	Paradigm 2: Innovation systems approach	Paradigm 3: Directionality and problem orientation, transformative change
Main focus of (policy advising) research	Requirements of knowledge generation in publicly funded research and in industry; Requirements for the transfer of basic knowledge to its application	Further development of the understanding of innovation processes and the implications for innovation support; Identification and analysis of requirements and effects of the innovation system and its deficits (also comparatively); Instruments for system upgrading and their effects	Further development of STI policy instruments and their governance to achieve directionality; Interplay between innovation and system transformation; Identification of innovation paths that contribute to solving problems; Mobilising strategic intelligence, including impact analysis, to support transformations

were at odds with the dominant economic assumptions of the time. With regard to the third paradigm, there is a potential conflict of goals with the earlier paradigms, both of which, in different ways, aim at the economic growth of separate, mainly national, innovation systems. As already stated in the Club of Rome report "The Limits to Growth" (Meadows et al. 1972), planetary limitations such as resource availability necessitate a move away from a definition of welfare that is based exclusively on economic growth. In addition, sustainable innovation needs to diffuse as quickly as possible. This implies that the necessary demand-side support can become support for innovation imports and thus contribute to positive economic benefits in other innovation systems (Edler 2010).

The overall picture also reveals differences in the contributions of the STI policy research community and scientific policy advice community to the processes of paradigm change. This becomes clear when looking at the recent STI policy paradigm shift, which differs from the previous one primarily in terms of changes at the level of objectives, while the shift from the first to the second paradigm was significantly driven by changes at the level of basic theoretical assumptions and conceptions of the problem. To put it bluntly, the first case was therefore primarily science-driven, while the second paradigm shift was and is more strongly influenced by shifts at political and normative levels. In both paradigm shift processes, however, changes to the context conditions—in brief: end of the growth phase of the post-war decades and stagflation crisis, urgency of the climate and environmental crises—created important prerequisites for paradigm reorientation. It is a perplexing finding that, apart from a few exceptions, the scientific community in the field of STI policy has not actively promoted and prepared the conceptual basis for the most recent paradigm shift, but has delayed incorporating it into the research agendas. One reason for this omission may be the process of professionalising the

discipline of innovation research in recent decades. This has led to establishing and formalising the discipline of innovation research at universities and non-university institutions, but at the same time might have been accompanied by a tendency to close off innovation research from related disciplinary discourses, such as sustainability transition research. A perspective that was strongly influenced by economic and industrial policy also prevented a discourse being established with the epistemic communities of important sectoral policies, where the directionality towards sustainability became apparent early on, which was also reflected in the corresponding sectoral research and innovation funding programmes. It was not until the rise of the third STI policy paradigm that efforts were actively made to correct these past omissions.

4.2 Challenges for the STI Policy Community

Looking at the changing paradigm of STI policy since the post-war period has clearly revealed the profound interplay between changing environmental conditions, new normative policy objectives, and the conceptual work of the scientific community. Looking at the future development of STI policy poses the question with which research agenda, but also with which understanding of its role STI policy research can make the most constructive, future-oriented, and socio-politically relevant contributions. This seems to require a three-pronged approach:

1. Coherence: In the course of the policy layering of the three distinct phases of STI policy to date, tensions and contradictions are evident in some of the central basic assumptions as well as in the orientation of STI policy actions derived from them. Contributing to a more coherent theoretical-conceptual framework of STI policy and its further development seems to be an important task for the relevant STI policy researchers and their scientific policy advice services. According to Hogan and Howlett (2015) and Daigneault (2014a), the coherence of idea systems or policy paradigms plays a major role in determining how influential and "policy effective" they are. As effective contributions of science, technology, and innovation to the complex processes of system transformations are increasingly called for, greater urgency is attached to questions concerning the right balance and effective interplay between market-oriented mechanisms and primarily state-orchestrated directionality. So far, the tensions between the market-oriented basic assumptions of the first two paradigms and the problem- and/or solution-oriented approach of the third paradigm have hardly been addressed. One exception is the attempt by Breitinger et al. (2021) to productively combine findings from classic innovation research with the requirements of transformation processes.

   Of even more fundamental importance is the conflict between the goals of economic growth and the need to respect planetary boundaries, which has so far only been touched upon marginally in the STI policy community. The discourses

on green growth, de-growth, or post-growth have so far largely taken place without any significant participation of innovation researchers. A systematic examination of the question of how innovation processes can be shaped under a different growth policy premise appears increasingly necessary.

2. Positioning: It is obvious that findings from STI policy research can make significant contributions to the effective design of transformation processes. Particularly relevant STI policy perspectives include questions of improving the performance of innovation systems, the diffusion speed of new applications and innovative processes, or the analysis of policy and governance capacities. While the need to mobilise STI for transformation processes is indisputable, there has been no approach to date that effectively links STI policy with sectoral policies. The problem is illustrated by the example of mission-oriented innovation policy (MOIP), which often claims to be transformative, but in fact remains mostly within the traditional confines of the STI policy field in terms of its main focus. The fact that effectively integrating STI policies into the broader policy mixes of sectoral transformation processes might also be accompanied by a relative weakening of the role of STI policy in relation to the respective sectoral policies has hardly been openly discussed so far, although the field of sectoral policy research has touched upon this. Here, STI policy is conceived as part of an overarching policy mix that complements sectoral policies which play a role primarily in innovation diffusion and the exnovation of established solutions (e.g., Kivimaa and Kern 2016; Rogge and Stadler 2023).

   The growing importance of transformation processes raises further questions of identity and positioning for the STI policy community. Since successful transformations aim at comprehensive behavioural and structural changes, generating winners and losers and often intervening to a great extent in people's everyday lives, transformative policies generally receive more political and media attention than conventional innovation policies. The question of how to deal with the potential politicisation of transformation processes also arises indirectly for (policy advising) academia. So far, it seems that STI policy researchers have not paid much attention to these issues.

3. Responsiveness: The last few years have been repeatedly marked by turbulent developments such as the COVID 19 pandemic or the deep geopolitical upheavals resulting from Russia's military aggression. In general, the STI policy community has responded quickly to each crisis. For example, in the case of the pandemic, methods were developed to assess the effectiveness of crisis response (Weber et al. 2021). Fundamental questions of systemic resilience (cf. Roth et al. 2021) in response to increased crisis probability or technology sovereignty (Edler et al. 2023) in the face of growing geopolitical uncertainties and global trade conflicts were also incorporated into the research agenda. In view of the growing frequency and intensity of crises, the question also arises as to the implications for STI policy research. Two things seem obvious: in the short to medium term, the aim is to improve the responsiveness of research and innovation actors without compromising quality and content; in the medium to long term, it will be a matter of further developing research and innovation systems in

the direction of resilient yet transformation-capable structures. The idea behind this is that policymaking based on a concept of the reasons for failure will always remain reactive. This should be accompanied by a more forward-looking, proactive approach to policymaking that enables policy interventions based on a potential future failure to address crisis-related developments (Kubeczko and Weber 2009). Especially for the latter, the STI policy community seems rather well equipped due to its wealth of knowledge and experience with system analyses.

References

Aho E (2006) Creating an innovative Europe: Report of the Independent Expert Group on R & D and Innovation appointed following the Hampton Court Summit, 2006th edn. EUR, vol 22005. Office for Official Publications of the European Communities, Luxembourg

Arnold E, Kuhlman S, van der Meulen B (2001) A singular council: evaluation of the Research Council of Norway. Technopolis, Brighton, England

Arrow KJ (1962) Economic welfare and the allocation of resources for invention. In: Universities-National Bureau Committee for Economic Research, Committee on Economic Growth of the Social Science Research Council (ed) The rate and direction of inventive activity: economic and social factors. Princeton University Press, Princeton, NJ, pp 609–626

Béland D (2007) Ideas and institutional change in social security: conversion, layering, and policy drift. Soc Sci Q 20–38

Béland D (2009) Ideas, institutions, and policy change. J Eur Public Policy 16:701–718. https://doi.org/10.1080/13501760902983382

Béland D, Cox RH (2013) The politics of policy paradigms. Governance 26:193–195. https://doi.org/10.1111/gove.12034

Borrás S, Edler J (2020) The roles of the state in the governance of socio-technical systems' transformation. Res Policy 49:103971. https://doi.org/10.1016/j.respol.2020.103971

Braczyk H-J, Cooke P, Heidenreich M (1998) Regional innovation systems: The role of governance in a globalized world. UCL Press, London

Breitinger JC, Edler J, Jackwerth T, Lindner R, Schraad-Tischler D (2021) Good-Practice-Beispiele für missionsorientierte Innovationsstrategien und ihre Umsetzung. Innovation for transformation / Bertelsmann Stiftung, Ergebnispapier 1. Bertelsmann Stiftung, Gütersloh

Bührer S, Edler J, Kuhlmann S, Seus S (2024) Evaluating public research and innovation policies: a short history of co-evolution. In: Edler J, Walz R (eds) Systems and innovation research in transition: Research questions and trends in historical perspective. Springer, Heidelberg

Bundesministerium für Bildung und Forschung (2006) Die Hightech-Strategie für Deutschland. Kommunikation und publizitisk GmbH, Bonn

Bundesministerium für Bildung und Forschung (2010) Ideen. Innovation. Wachstum.: Hightech-Strategie 2020 für Deutschland, Berlin

Bundesministerium für Bildung und Forschung (2014) Die neue Hightech-Strategie: Innovationen für Deutschland, Berlin

Bundesministerium für Bildung und Forschung (2018) Forschung und Innovation für die Menschen: Die Hightech-Strategie 2025, Berlin

Bush V (1945) Science, the endless frontier: A report to the President. United States Government Printing Office, Washington

Campbell JL (2002) Ideas, politics, and public policy. Annu Rev Sociol 28:21–38

Carlsson B, Stankiewicz R (1995) On the nature, function and composition of technological systems. In: Carlsson B (ed) Technological systems and economic performance: the case of factory automation, vol 5. Springer, Dordrecht, pp 21–56

Carson M (2004) From common market to social Europe?: Paradigm shift and institutional change in European Union Policy on Food, Asbestos & Chemicals, and Gender Equality. Stockholm studies in sociology, N.S, vol 22. Acta Universitatis Stockholmiensis

Carstensen MB (2011) Ideas are not as stable as political scientists want them to be: a theory of incremental ideational change. Polit Stud 59:596–615. https://doi.org/10.1111/j.1467-9248.2010.00868.x

Carstensen MB, Schmidt VA (2016) Power through, over and in ideas: conceptualizing ideational power in discursive institutionalism. J Eur Public Policy 23:318–337. https://doi.org/10.1080/13501763.2015.1115534

Chaminade C, Lundvall B-Å, Haneef S (2018) Advanced introduction to national innovation systems. Elgar advanced introductions. Edward Elgar, Cheltenham, UK

Chesnais F (1982) Schumpeterian recovery and the Schumpeterian perspective—some unsettled issues and alternative interpretations. Emerging technologies. JCB Mohr, Tübingen

Cuhls K, Dönitz E, Erdmann L, Gransche B, Kimpeler S, Schirrmeister E, Warnke P (2024) Foresight: Fifty years to think your futures. In: Edler J, Walz R (eds) Systems and innovation research in transition: Research questions and trends in historical perspective. Springer, Heidelberg

Daigneault P-M (2014a) Puzzling about policy paradigms: precision and progress. J Eur Public Policy 21:481–484. https://doi.org/10.1080/13501763.2014.893080

Daigneault P-M (2014b) Reassessing the concept of policy paradigm: aligning ontology and methodology in policy studies. J Eur Public Policy 21:453–469. https://doi.org/10.1080/13501763.2013.834071

Daimer S, Hufnagl M, Warnke P (2012) Challenge-oriented policy-making and innovation systems theory: reconsidering systemic instruments. In: Fraunhofer ISI (ed) Innovation system revisited: Experiences from 40 years of Fraunhofer ISI research. Fraunhofer, Stuttgart, pp 217–234

Diercks G, Larsen H, Steward F (2019) Transformative innovation policy: Addressing variety in an emerging policy paradigm. Res Policy 48:880–894. https://doi.org/10.1016/j.respol.2018.10.028

Dodgson M, Rothwell R (1994) The handbook of industrial innovation. Edward Elgar, Cheltenham

Edler J (1999) Die Bedeutung von Leitideen bei der Genese und Implementierung europäischer Forschungspolitik am Beispiel BRITE. PhD dissertation, Universität Mannheim

Edler J (2003) Change in European R&D policy as a complex consensus-building process: Experiences from the past and what they can teach us for the present. In: Edler J, Kuhlmann S, Behrens M (eds) Changing governance of research and technology policy: The European research area. Edward Elgar, Cheltenham

Edler J, Ruhland S, Hafner S, Rigby J, Georghiou L, Hommen L, Rolfstam M, Edquist C, Tsipouri L, Papadakou M (2005) Innovation and public procurement. Review of Issues at Stake. Fraunhofer ISI, Karlsruhe

Edler J (ed) (2007) Bedürfnisse als Innovationsmotor: Konzepte und Instrumente nachfrageorientierter Innovationspolitik. Studien des Büros für Technikfolgen-Abschätzung beim Deutschen Bundestag, vol 21. ed. sigma, Berlin

Edler J (2010) Demand-based innovation policy. In: The theory and practice of innovation policy: an international research handbook. Elgar, Cheltenham, pp 275–301

Edler J, Boon WP (2018) The next generation of innovation policy: Directionality and the role of demand-oriented instruments—Introduction to the special section. Sci Public Policy 45:433–434. https://doi.org/10.1093/scipol/scy026

Edler J, Fagerberg J (2017) Innovation policy: What, why, and how. Oxf Rev Econ Policy 33:2–23

Edler J, Georghiou L (2007) Public procurement and innovation—Resurrecting the demand side. Res Policy 36:949–963

Edler J, Beckert B, Betz R, Blind K, Bührer S, Bührlen B, Ebersberger B et al (2007) Bedürfnisse als Innovationsmotor: Konzepte und Instrumente nachfrageorientierter Innovationspolitik. Edition sigma, Berlin

Edler J, Gök A, Cunningham P, Shapira P (2016) Introduction: Making sense of innovation policy. In: Edler J, Cunningham P, Gök A, Shapira P (eds) Handbook of innovation policy impact. Edward Elgar, Cheltenham

Edler J, Blind K, Kroll H, Schubert T (2023) Technology sovereignty as an emerging frame for innovation policy. Defining rationales, ends and means. Res Policy 2021–11 50(9):104341, 52:104765. https://doi.org/10.1016/j.respol.2023.104765

Edquist C (ed) (1997) Systems of innovation: technologies, institutions and organisations. Pinter, London

Edquist C, Hommen L, Tsipouri L (2000) Public technology procurement and innovation. Kluwer, Dordrecht

European Commission (2014) Horizon 2020 in brief. The EU framework programme for research & innovation. Luxembourg (KI-02-13-413-EN-C)

European Industrial Research Management Association (EIRMA) (ed) (1982) The role of R&D in the innovation process. Working group report, 27, Paris

Fagerberg J (2003) Schumpeter and the revival of evolutionary economics: an appraisal of the literature. J Evol Econ 13:125–159

Foray D, Mowery DC, Nelson RR (2012) Public R&D and social challenges: What lessons from mission R&D programs? Res Policy 41:1697–1702. https://doi.org/10.1016/j.respol.2012.07.011

Fraunhofer Institut für System- und Innovationsforschung ISI (ed) (2012) Towards transformative governance? Responses to mission-oriented innovation policy paradigms

Freeman C (1973) A study of success and failure in industrial innovation. In: Williams BR (ed) Science and technology in economic growth. Springer, Cham

Freeman C (1982) The economics of industrial innovation, 2nd edn. Pinter, London

Freeman C, Clark J, Soete L (1982) Unemployment and technical innovation: A study of long waves and economic development. Contributions in economics and economic history, vol 50. Greenwood, Westport, CT

Frietsch R, Reiß T, Schmoch U (2024) Development of innovation monitoring and innovation indicators in the past 50 years. In: Edler J, Walz R (eds) Systems and innovation research in transition: Research questions and trends in historical perspective. Springer, Heidelberg

Gassler H, Polt W, Rammer C (2006) Schwerpunktsetzungen in der Forschungs-und Technologiepolitik: eine Analyse der Paradigmenwechsel seit 1945. Österr Z Polit 35:7–23

Gaudin T (1985) Definition on innovation policies. In: Sweeney G (ed) Innovation policies: an international perspective. Frances Pinter, London

Geels FW (2002) Technological transitions as evolutionary reconfiguration processes: a multi-level perspective and a case-study. Res Policy 31:1257–1274. https://doi.org/10.1016/S0048-7333(02)00062-8

Ghosh B, Kivimaa P, Ramirez M, Schot J, Torrens J (2021) Transformative outcomes: assessing and reorienting experimentation with transformative innovation policy. Sci Public Policy 48:739–756. https://doi.org/10.1093/scipol/scab045

Grillitsch M, Hansen T, Coenen L, Miörner J, Moodysson J (2019) Innovation policy for system-wide transformation: The case of strategic innovation programmes (SIPs) in Sweden. Res Policy 48:1048–1061. https://doi.org/10.1016/j.respol.2018.10.004

Haas PM (2001) Epistemic communities and policy knowledge. In: Smelser NJ, Baltes PB (eds) International encyclopedia of social and behavioral sciences. Elsevier, Oxford, pp 11578–11586

Haddad CR, Bergek A (2023) Towards an integrated framework for evaluating transformative innovation policy. Res Policy 52:104676. https://doi.org/10.1016/j.respol.2022.104676

Hall PA (1990) Policy paradigms, experts and the state. In: Brooks S, Gagnon A (eds) Social scientists, policy and the state. Prager, New York

Hall PA (1993) Policy paradigms, social learning, and the state: the case of economic policymaking in Britain. Comp Polit 25:275. https://doi.org/10.2307/422246

Heclo H (2010) Modern social politics in Britain and Sweden: From relief to income maintenance, 2nd edn. ECPR, Colchester
Heyen NB, Friedewald M, Jochem E, Reiß T, Thielmann A (2024) Assessing technological innovations: From early warning to the governance of socio-technical transformations. In: Edler J, Walz R (eds) Systems and innovation research in transition: Research questions and trends in historical perspective. Springer, Heidelberg
Hogan J, Howlett M (2015) Reflections on our understanding of policy paradigms and policy change. In: Hogan J, Howlett M (eds) Policy paradigms in theory and practice. Palgrave Macmillan, London, pp 3–18
Jacob K, Ekins P (2020) Environmental policy, innovation and transformation: affirmative or disruptive? J Environ Policy Plan 22:709–723. https://doi.org/10.1080/1523908X.2020.1793745
Janssen MJ, Torrens J, Wesseling JH, Wanzenböck I (2021) The promises and premises of mission-oriented innovation policy—A reflection and ways forward. Sci Public Policy. https://doi.org/10.1093/scipol/scaa072
JIIP (2018) Mission-oriented research and innovation : assessing the impact of a mission-oriented research and innovation approach: Final report. Publications Office, Brussels
Kay A (2007) Tense layering and synthetic policy paradigms: the politics of health insurance in Australia. Aust J Polit Sci 42:579–591. https://doi.org/10.1080/10361140701595775
Keck O (1986) Die gesellschaftliche Steuerung der Technik: Ein institutioneller Ansatz. In: Mayer-Krahmer F, Beckmann G (eds) Technologiepolitik und Sozialwissenschaft, Frankfurt a.M., pp 17–42
Kingdon JW (1984) Agendas, alternatives and public policies. Little Brown, Boston
Kivimaa P, Kern F (2016) Creative destruction or mere niche support? Innovation policy mixes for sustainability transitions. Res Policy 45:205–217. https://doi.org/10.1016/j.respol.2015.09.008
Kline SJ, Rosenberg N (1986) An overview of innovation. In: Landau R, Rosenberg N (eds) The positive sum strategy: harnessing technology for economic growth. National Academy Press, Washington, DC, pp 275–304
Klodt H (1987) Wettlauf um die Zukunft: Technologiepolitik im internationalen Vergleich. Kieler Studien, vol 206. Mohr, Tübingen
Koschatzky K (2001) Räumliche Aspekte im Innovationsprozess: Ein Beitrag zur neuen Wirtschaftsgeographie aus Sicht der regionalen Innovationsforschung. Wirtschaftsgeographie, vol 19. LIT, Münster
Krupp H (1972) Die Funktion der Fraunhofer-Gesellschaft im Innovationssystem der Bundesrepublik Deutschland: Studie für das Bundesministerium für Bildung und Wissenschaft, Karlsruhe
Krupp H (1975) Strukturpolitisch orientierte Forschungspolitik: ihre Möglichkeiten und Grenzen. Wirtschaft und Wissenschaft
Krupp H (1985) Public promotion of innovation: disappointments and hopes. In: Sweeney GP (ed) Innovation policies: an international perspective. St. Martin's Press, New York, pp 48–79
Kubeczko K, Weber KM (2009) Proaktive legitimation FTI-politischer interventionen: Jenseits von Markt-und systemversagen. In: Innovationsforschung und Technologiepolitik in Österreich. Neue Perspektiven und Gestaltungsmöglichkeiten. StudienVerlag, pp 127–153
Kuhlmann S (2003) Evaluation as a source of "strategic intelligence". In: Shapira P, Kuhlmann S (eds) Learning from science and technology policy evaluation: Experiences from the United States and Europe. Edward Elgar, Cheltenham, pp 352–379
Kuhlmann S, Arnold E (2001) RCN in the Norwegian research and innovation system: background report no 12 in the evaluation of the Research Council of Norway
Kuhn TS (1962) The structure of scientific revolutions. University of Chicago Press, Chicago
Kuittinen H, Polt W, Weber M (2018) Mission Europe? A revival of mission-oriented policy in the European Union. In: RFTE—Council for Research and Technology Development (ed) Re: thinking Europe. Positions on shaping an idea. Verlag Holzhausen, Vienna
Larédo P (2003) Six major challenges facing public intervention in higher education, science, technology and innovation. Sci Public Policy 30(1):4–12

Larrue P (2021) The design and implementation of mission-oriented innovation policies: A new systemic policy approach to address societal challenges. OECD science, technology and industry policy papers 100
Larrue P, Machado D, Yoshimoto T (2019) New mission-oriented initiatives as systemic policies to address societal challenges: Analytical framework and typology. In: 2019 EU-SPRI conference—Science technology and innovation policies for sustainable development goals, Rome, 06.06
Lindner R, Daimer S, Beckert B, Heyen N, Koehler J, Teufel B, Warnke P, Wydra S (2016) Addressing directionality: Orientation failure and the systems of innovation heuristic: Towards reflexive governance. Fraunhofer ISI discussion papers innovation systems and policy analysis, no. 52. Fraunhofer ISI, Karlsruhe
Lindner R, Edler J, Hufnagl M, Kimpeler S, Kroll H, Roth F, Wittmann F, Yorulmaz M (2021) Missionsorientierte Innovationspolitik: Von der Ambition zur erfolgreichen Umsetzung. Perspektiven—Policy Brief / Fraunhofer-Institut für System- und Innovationsforschung ISI, 2021, 02. Fraunhofer-Institut für System- und Innovationsforschung ISI, Karlsruhe
Lundvall B-Å (1985) Product innovation and user-producer interaction. Industrial development research series 31
Lundvall B-Å (ed) (1992) National systems of innovation: Towards a theory of innovation and interactive learning, 1st edn. Pinter, London
Luukkonen T, Nedeva M, Barré R (2006) Understanding the dynamics of networks of excellence. Sci Public Policy 33(4):239–252
Mahoney J, Thelen K (2010) A gradual theory of institutional change. In: Mahoney J, Thelen KA (eds) Explaining institutional change: Ambiguity, agency, and power. Cambridge University Press, Cambridge, pp 1–37
Malerba F (ed) (2004) Sectoral systems of innovation: Concepts, issues and analyses of six major sectors in Europe. Cambridge University Press, New York
Mayntz R (1996) Politische Steuerung: Aufstieg, Niedergang und Transformation einer Theorie. VS Verlag für Sozialwissenschaften
Mayntz R, Scharpf FW (1973) Planungsorganisation: die Diskussion um die Reform von Regierung und Verwaltung des Bundes. Piper
Mazzucato M (2013) Financing innovation: creative destruction vs. destructive creation. Ind Corp Chang 22:851–867
Mazzucato M (2018) Mission-oriented research & innovation in the European Union: A problem-solving approach to fuel innovation-led growth. Publications Office of the European Union
Meadows DH, Meadows DL, Randers J, Behrens WW (1972) The limits to growth: a report for the Club of Rome's Project on the Predicament of Mankind. Universe Books, New York
Ministry of EZK (2019) Missies voor het topsectoren- en innovatiebeleid, Den Haag
Mowery DC, Rosenberg N (1979) The influence of market demand upon innovation: A critical review of some recent empirical studies. Res Policy 8:103–153
Münch S (2016) Interpretative Policy-Analyse: Eine Einführung. Springer, Wiesbaden
Nelson RR (1959) The simple economics of basic scientific research. J Polit Econ 67:297–306
Nelson RR (1993) National innovation systems: a comparative analysis. Oxford University Press on Demand, Oxford
Nelson RR, Winter SG (1977) In search of useful theory of innovation. Res Policy 6:36–76. https://doi.org/10.1016/0048-7333(77)90029-4
Nelson RR, Winter SG (1982) An evolutionary theory of economic change. Harvard University Press, Cambridge
OECD (1972) The research system: Vol 1—France, Germany, United Kingdom. OECD, Paris
OECD (1980) Technical change and economic policy. OECD, Paris
OECD (1981) Science and technology policy for the 1980s. OECD, Paris
OECD (2011) Demand-side innovation policies. OECD, Paris
OECD (ed) (2015) System innovation. Synthesis report. Online https://archiwum.pte.pl/pliki/2/1/OECD%20System.pdf

Pavitt K (1976) Governmental support for industrial research and development in France: Theory and practice. Minerva 14:330–354. https://doi.org/10.1007/bf01096276
Pavitt K (1979) Technical innovation and industrial development. Futures 11:458–470. https://doi.org/10.1016/0016-3287(79)90044-2
Rogge K, Stadler M (2023) Applying policy mix thinking to social innovation: from experimentation to socio-technical change. Environ Innov Soc Transit 47. https://doi.org/10.24406/publica-1205
Rosenberg N (1991) Critical issues in science policy research. Sci Public Policy 18:335–346. https://doi.org/10.1093/spp/18.6.335
Roth F, Warnke P, Niessen P, Edler J (2021) Systemische Resilienz: Einsichten aus der Innovationsforschung. Perspektiven—Policy Brief / Fraunhofer-Institut für System- und Innovationsforschung ISI, 2021, 03. Fraunhofer-Institut für System- und Innovationsforschung ISI, Karlsruhe
Rothwell R, Zegveld W (1981) Industrial innovation and public policy: Preparing for the 1980s and the 1990s. Contributions in economics and economic history, no. 42. Greenwood Press, Westport, CT
Rothwell R, Zegveld W (1982) Innovation and the small and medium sized firm. Frances Pinter, London
Sabatier PA (1998) The advocacy coalition framework: revisions and relevance for Europe. J Eur Public Policy 5:98–130. https://doi.org/10.1080/13501768880000051
Schmidt VA (2010) Taking ideas and discourse seriously: explaining change through discursive institutionalism as the fourth 'new institutionalism'. Eur Polit Sci Rev 2:1. https://doi.org/10.1017/S175577390999021X
Schot J, Steinmueller WE (2018) Three frames for innovation policy: R&D, systems of innovation and transformative change. Res Policy 47:1554–1567. https://doi.org/10.1016/j.respol.2018.08.011
Skocpol T (1992) Protecting soldiers and mothers: The political origins of social policy in the United States. Belknap Press of Harvard University Press, Cambridge, MA
Smith A, Voß J-P, Grin J (2010) Innovation studies and sustainability transitions: The allure of the multi-level perspective and its challenges. Res Policy 39:435–448. https://doi.org/10.1016/j.respol.2010.01.023
Smits R, Kuhlmann S (2004) The rise of systemic instruments in innovation policy. Int J Foresight Innov Policy 1:4–32
Soete L, Arundel A (1993) An integrated approach to European innovation and technology diffusion policy (a Maastricht memorandum). Commission of the European Communities, SPRINT Programme, Luxembourg
Solow RM (1957) Technical change and the aggregate production function. Rev Econ Stat 39:312. https://doi.org/10.2307/1926047
Streeck W, Thelen K (2005) Beyond continuity: Institutional change in advanced political economies. Oxford University Press, Oxford
Stuart G, Kuntze U (1982) National innovation policies: the challenges in looking ahead. Monografia, Karlsruhe
Stucke A (1993) Institutionalisierung der Forschungspolitik: Entstehung, Entwicklung und Steuerungsprobleme des Bundesforschungsministeriums. Schriften des Max-Planck-Instituts für Gesellschaftsforschung, Bd. 12. Campus, Frankfurt a.M.
Swedish Presidency (2009) Lund declaration: Europe must focus on the grand challenges of our time. https://era.gv.at/object/document/130
Sweeney GP (ed) (1985) Innovation policies : an international perspective. St. Martin's Press, New York
Teece DJ (1986) Profiting from technological innovation: Implications for integration, collaboration, licensing and public policy. Res Policy 15:285–305. https://doi.org/10.1016/0048-7333(86)90027-2

Tidd J, Bessant J, Pavitt K (2005) Managing Innovation: Integrating technological, market and organizational change. Wiley, Chichester

True JL, Jones BD, Baumgartner FR (2007) Punctuated-equilibrium theory: explaining stability and change in American policymaking. In: Sabatier P (ed) Theories of the policy process, 2nd edn. Routledge, New York, pp 97–115

Walz R, Ostertag K, Eckartz K, Gandenberger C, Bodenheimer M, Peuckert J, Ramel F, Gigli M, Doranova A, Miedzinki M (2019) Ökologische Innovationspolitik in Deutschland: Bestandsaufnahme und Handlungsempfehlungen. Umwelt, Innovation, Beschäftigung, 01/2019. Umweltbundesamt, Dessau-Roßlau

Wanzenböck I, Wesseling JH, Frenken K, Hekkert MP, Weber KM (2020) A framework for mission-oriented innovation policy: Alternative pathways through the problem-solution space. Sci Public Policy 47:474–489

Warnke P, Koschatzky K, Dönitz E, Zenker A, Stahlecker T, Som O, Cuhls K, Güth S (2016) Opening up the innovation system framework towards new actors and institutions. Fraunhofer ISI discussion papers innovation systems and policy analysis, no. 49. Fraunhofer ISI, Karlsruhe

Weber KM, Rohracher H (2012) Legitimizing research, technology and innovation policies for transformative change. Res Policy 41:1037–1047. https://doi.org/10.1016/j.respol.2011.10.015

Weber, KM, Biegelbauer P, Brodnik C, Dachs B, Dreher C, Kovaéc M et al (2021) Agilität in der F&I-Politik: Konzept, Definition, Operationalisierung. Studien zum deutschen Innovationssystem. Berlin (8-2021). Online http://hdl.handle.net/10419/231476

Wilder M (2015) What is a policy paradigm? Overcoming epistemological hurdles in cross-disciplinary conceptual adaptation. In: Hogan J, Howlett M (eds) Policy paradigms in theory and practice. Palgrave Macmillan UK, London, pp 19–42

Wissenschaftsrat (1992) Empfehlungen zur Internationalisierung der Wissenschaftsbeziehungen. Köln

Wittmann F, Hufnagl M, Lindner R, Roth F, Edler J (2021a) Governing varieties of mission-oriented innovation policies: A new typology. Sci Public Policy 48:727–738

Wittmann F, Hufnagl M, Roth F, Yorulmaz M, Lindner R (2021b) From mission definition to implementation: Conceptualizing mission-oriented policies as a multi-stage translation process. Fraunhofer ISI discussion papers innovation systems and policy analysis, no. 71. Fraunhofer ISI, Karlsruhe

Wittmann F, Roth F, Hufnagl M, Lindner R, Yorulmaz M (2022) Towards a framework for impact assessment for mission-oriented innovation policies: A formative toolbox approach. ftval J Res Technol Policy Eval 31–52. https://doi.org/10.22163/fteval.2022.540

Ralf Lindner is the Head of the Department Policy and Society at the Fraunhofer Institute for Systems and Innovation Research ISI. He is particularly interested in policy design and governance approaches for transformative change, responsible research and innovation, and processes of policy learning. In recent years, the main focus of his research has been on the analysis and conceptualisation of mission-oriented innovation policies (e.g., in the context of the German High-Tech Strategy) and the development of practitioner-oriented approaches supporting their design, implementation, and evaluation.

Jakob Edler is Managing Director of the Fraunhofer Institute for Systems and Innovation Research ISI since October 2018. The Anglo-German is also Professor of Innovation Policy and Strategy at the Manchester Institute of Innovation Research (MIoIR), which he led from 2011 to September 2018. His research focuses on analysing and conceptualising governance, policy and management of innovation. J. Edler is Speaker of the Fraunhofer Group Innovation Research, member of the German Science Council, the German Academy of Science and Engineering (Acatech) and the Royal Society for the Encouragement of Arts, Manufactures and Commerce (UK).

Stephanie Daimer is the Coordinator of the Business Unit Policy for Innovation and Transformation in the Competence Centre Policy and Society at the Fraunhofer Institute for Systems and Innovation Research ISI. Her research interests are in the analysis and evaluation of national and European research and innovation (R&I) policies, and more recently in policies for transformative change and the role of public administrations as agents of transformation.