Technology and Innovation

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Abstract: This essay reviews the German-language literature on technology and innovation and maps the main developments in this fragmented field from a sociological perspective. It focuses on selected topics, turns, and advances since 2000 and relates them to the international debates in the social studies of science and technology. The first topic that this paper addresses is the debate on how to conceptualize technology when it is viewed as part of and not external to society. I sketch the changes from early means–end approaches to actual forms/media concepts of technicization and social-material constellations. The second issue is the question of human agency and the responses to the provocations that ensue from artificial intelligence and actor–network theory. A third point of discussion is the turns to micro studies and to more comprehensive perspectives on socio-technological transformations. Two discursive shifts in technology and innovations studies demonstrate the latest advances towards a broad and integrated theoretical framework: one from the assessment of specific technologies to the governance of distributed innovation processes, another from a narrow economic concept of innovation to a sociological one that extends to all types of innovations in society.

Keywords: Technology, agency, innovation, social change, micro/macro

1 Mission Impossible: Pinning Down the State of the Art in a Fluid and Fragmented Field

The sociology of technology is a relatively young specialty compared to the older fields of language, knowledge, or work. It emerged in the late 1970s as a small specialty—particularly so in the German-speaking countries—with its own distinct view of its subject matter, which includes techniques of doing, all types of concrete technologies, and the modes of making, diffusing, and using them. It conceives of techniques and technologies as particular kinds of social action and as artifacts that are embedded in the socio-material dynamics of society, but not as universal natural effects or external factors on society. It all began when technology—along with its uses in everyday life as well as the dynamics of its development—was first defined as a “social process,” when technological change was no longer seen as a ‘natural’ trajectory but was viewed as contingent “historical-social projects of technicization,” and machineries were analyzed as “socio-technical systems” (see Ropohl, 1979; Jokisch, 1982; Rammert, 1983; Joerges, 1988; Weingart, 1989).

The sociology of technology originated as a special part of the international “social studies of science and technology” (STS). Both fields have similar beginnings

and concerns but different national profiles.¹ Each started with a critique—whether of the ideologies of a unified and universal science (Kuhn), of autonomous technology (Winner), or of neutral technological progress (Marcuse; Noble). And both rediscovered the scholars who pioneered the study of technological and social change, like Marx, Ogburn, Gilfillan, Mumford, Giedeon, and Leroi-Gourhan. More importantly, both fields seriously engaged in empirical studies to demonstrate how the production of scientific knowledge, the construction of technological artifacts, and the trajectories of technological innovation are interwoven with economic, political, and cultural influences in history and society. Finally, the two share the vision of a public actively involved in the discourse on technology and risk assessment and of democratic control of innovation processes in the future.

These commonalities notwithstanding, the social-scientific study of technology exhibits distinct national profiles: In German-speaking countries, the research and academic debates on technology were more strongly affiliated with sociological approaches than in other countries. Theory-building was concentrated in sociology and took place as a more “disciplined reflexivity” (Weick, 1999) than in the highly heterogeneous and rapidly growing international STS community. The reception of work in the technology field has been asymmetrical: whereas German-speaking scholars read and review nearly all English-written contributions, most of the English-publishing scholars are excluded from taking account of the ones written in German.

To address this gap, this essay will map the landscape of research mainly from a sociological perspective and provide a review of the German-language literature. It will focus on selected topics, turns, and advances since 2000 and relate them to the broader international STS debates. It will begin by sketching the main developments in both fields before that time (section 2). The review will then concentrate on four central topics of the sociological debate: the concepts, constellations, and courses of technology and of innovation (section 3). It will close with some conclusions and remarks on the prospects of the field (section 4).

¹ See the early comparative report on the state of the art in European countries (Cronberg and Sörensens, 1995), which includes a national report on Germany by the author (*ibid.*: 161–238), and the reviews in the introductions to the four consecutive editions of the *Handbook of STS* (Felt et al., 2017: 4–13).

2 A Turn in the Perspective on the Relation between Technology and Society: From ‘Social Consequences’ to the ‘Social Constitution’ of Technologies and Beyond

Early on, the social sciences, including history, economics, and sociology, treated the problem of technology mainly in terms of its impacts on society (Schimank, *SO-CIETY*, this volume). They asked general questions such as: What types of technologies have which effects on the transformation of societies? Do different technical modes of working, warfare, or communication produce epochal changes of societies, for instance, to feudal, urban, industrial, national, or imperial ones? Do certain kinds of technologies—‘small’ versus ‘big,’ ‘Western’ versus ‘convivial’ (Illich), ‘male’ versus ‘female,’ ‘authoritarian’ versus ‘democratic’ (de Solla Pool, Jungk)—have different implications for society? Early empirical research asked more precisely about the social consequences of particular technologies, such as the stirrup and the plough, the car and the airplane, or telecommunication and other media (White, Ogburn, McLuhan). It distinguished between intended and side effects; between economic, political, and cultural consequences; and between degrees of impact that range from compulsion to pressure and drift. These slightly differing perspectives on technology’s impact on society are often subsumed under the umbrella term of “technological determinism.”

Since the 1980s, the opposite perspective gained traction: What do we know about society’s impact on technology? And more specifically, what about the social formation of different kinds of technologies and their courses of development? The processual and pluralistic approaches of “social constructivism” replaced the structural and monistic views of orthodox Marxist economic or technocratic determinism. Some approaches emphasized the “social shaping” of technologies by organized interests, broader institutional settings, and, later, social processes of consumption (MacKenzie and Wajcman, 1985; Sørensen and Williams, 2002). Others analyzed the “social construction of artefacts and technological systems”: they reconstructed the “interpretative flexibility” of technological solutions at the outset and the “rhetorical closure” between different social groups in the course of practical tests (Pinch and Bijker, 1987). Still others, particularly in Germany, developed a genealogical approach of *Technikgenese* (the generation and emergence of a technology). This approach conceived of the social dynamics of technological developments with an eye to two aspects: in the short run, as a variety of visionary and strategic “projects of technicization” that were pushed and negotiated by social actors in arenas of conflict, and in the long run, as the result of the structural selection by the institutional orders of markets, power asymmetries, and cultural values (Dierkes et al., 1992; Rammert, 1993; 2002; Weyer et al., 1997).

The 1980s and '90s were also a period of an institutional consolidation of the field. The international "Society for Social Studies of Science" (4S) was established as early as 1975; it was only in 1995, however, that it began editing the serial *Handbooks of Science and Technology Studies* and renamed the series to include 'technology' in its title. The founding of the "European Association for the Study of Science and Technology" (EASST) followed in 1981. In Germany and Austria, the German-speaking community established particular sections in their respective national societies of sociology (Deutsche Gesellschaft für Soziologie [DGS]; Österreichische Gesellschaft für Soziologie [ÖGS]). Between 1982 and 1999, the German *Technik und Gesellschaft* yearbooks developed into the main platform of the sociology of technology at that time. Early topics were, for instance, the materiality of social structures; the construction or the emergence of new technologies (genetic engineering, electric cars, artificial intelligence); social movements and alternative technologies; computers, media, and society; and the processes, products, and politics of innovation.

During these foundational times, a third perspective on the relation of technology and society emerged, inspired primarily by a radical symmetrical anthropology, ethnographies of human-machine configurations, and social theories of technopragmatism. Its representatives questioned modern society's distinctions between nature and culture or technology and society. The advocates of these approaches asked how these distinctions are co-produced and by what kind of collective interagency. They detected things and technologies as the missing masses of social life that stabilize and frame social interactions. They described them as actants or agents inscribed and embodied in human-machine configurations. Some see them as immutable mobiles, others as boundary objects that enact and ensure connections between heterogeneous entities. The subjects of the work conducted in this perspective are the making of and the relations within and between these socio-technical constellations of distributed agencies and neither the social consequences nor the social construction of technologies alone.

Over the past twenty years, this perspective—and especially its most radical enactment, "actor-network theory" (ANT)—has become the mainstream in interdisciplinary and international research on science and technology. What is more, this theoretical turn has grown into a serious challenge to social theory and sociology. The sociology of technology in particular could ill afford to ignore this approach. In the following overview, we will learn how German-speaking scholars of this specialty have treated ANT as an opponent and strong sparring partner in their arena of debate.

3 Topics, Turns, and Advances in the Sociology of Technology and Innovation since 2000

As a new perspective emerges, core topics change, theoretical concepts are revised or replaced, and—after a period of research and review—patient observers can identify

some advances. New approaches, such as ANT, ethnographies, neo-institutionalism, or techno-pragmatism, and the rise and use of new technologies, such as the computer, artificial intelligence, and the Internet infrastructure have played this role of disrupter and shifted the topics of debate. The first shift concerns the debate on how to conceptualize technology when it is seen as a constitutive part of society and a genuine subject matter of sociology. The second shift pertains to the question of agency and the different responses to the challenges posed by ANT. The third shift in topics involves the divide between micro and macro approaches and the question of how to link them in a comprehensive theoretical framework. The fourth shift consists of two discursive shifts, one from technology assessment to the governance of innovation and another from a narrow economic and technological concept of innovation to a sociological approach based on the idea of innovation being a ubiquitous and a multi-referential phenomenon in society.

3.1 The conceptualization debate on technology: From ‘instrumentality’ and ‘materiality’ to ‘technicization’ and ‘media’ constellations

Before the 1970s, technology was largely a subject that had been excluded from sociological theorizing. One could rarely find categories that referred to technology in sociological dictionaries or handbooks. When ‘technical progress’ or ‘technological change’ were sometimes mentioned, they were treated as an ideological term or as a transforming force from outside society similar to technological revolutions, mechanization, or automation.

At the same time, students of the sociology of technology and STS in German-speaking countries had started to overcome this exclusion, thus leading to a gradual change in how technology was viewed. Technology gained the status of a genuine social fact, either as material artefacts with projected uses or as integral parts of society’s technostucture, and was no longer treated as nothing more than ‘ideology’ or a kind of ‘instrumental rationality’ (Habermas) that is related to external material conditions. Scholars now analyzed varieties of technology as socially instituted constellations and as cultural objectifications; technologies were no longer viewed as logical products of the natural sciences or as socially neutral engineering options.

Once this theoretical turn from technology outside to technology inside society had more or less been accepted, another debate arose around the question of how to conceptualize technological practices, processes, and products as social ones. The ‘social structure’ view emphasized the material aspect and the institutional character of installed technologies. The corresponding empirical studies demonstrated how economic interests, political norms, and cultural values were incorporated in the systems of infrastructure and expertise. The ‘social action’ view, by contrast, stressed the symbolic aspect and the practices of sense-making during the design and use of

technologies. The corresponding historical and ethnographic studies reconstructed the meaning in the making of technology or in situations of technologies-in-interaction. This debate between an ‘objectivation’ and an ‘enactment’ approach resulted in the concept of technology as a “duality” of resources and routines (Schulz-Schaeffer, 2000).

A third debate sought to adopt a more comprehensive view of technologies in order to overcome the dichotomy of ‘materiality’ and ‘sociality.’ Technology studies came to realize that one could no longer plausibly reduce materiality to concrete things or physical objects alone. A wide spectrum of ‘stuff’ was included: biofacts (such as the OncoMouse or the genetically modified tomato), symbolic artefacts (such as computer software or the cursor on the screen), and technologies that addressed the human body and the mind (such as training or nudging). Additionally, the insight was growing that sociality could not be restricted to human social action, relations, and forms of association: sense-making, communication, and institutions of society are affected by bodies, mediated by artificial things, and interwoven with biospheres. What were the conceptual answers to these challenges?

In the international debates, many scholars turned to holistic concepts and metaphors to melt both aspects into an amalgam, like ‘machinery,’ ‘assemblages,’ ‘things,’ and ‘cyborgs.’ The German-speaking sociologists of technology developed more elaborate answers as they had to justify their theorization towards their critical sociological community. One early answer was the new socio-pragmatic concept of *technicization*. Analytically, technicization distinguishes between the two aspects of (a) doing technology by developing the particular social and symbolic form of effective and reliable relations between dismembered and recombined elements (“schemata of technicization”) and (b) molding them into stuff (“material media”) such as bodies, things, or symbols that make a difference (Rammert, 2001: 271ff.; Heider, 1926). This approach translated the holistic or radical symmetrical philosophies into an analytical concept of socio-material constellations. It furthermore introduced a shift from an instrumental means–end to a relational form/media concept of technology.

Other scholars have used variants of the constellation concept to study small socio-technical ensembles and micro configurations of human–technology interactivity, while yet others have applied it to analyze large technological systems and macro constellations of sectoral or infrastructural systems. This concept overcomes the conflations of the social and technical systems vocabularies (e.g., those that speak of “socio-technical systems”) as well as the gap between overly abstract metaphorical concepts (“assemblages,” “actants,” “modes of existence”) and the “irreductions” (Latour) of unlimited empirical descriptions. It advances the opportunities for systematic comparisons between different cases and constellations.

3.2 The human–nonhuman agency debate: From ‘interactivity’ with computers to ‘collective constellations of distributed agency’

Three provocations of the sociological discipline triggered a debate on the role of technologies and their interrelation with social actors and collectivities: (1) the provocation of face-to-interface interaction with computers, (2) the provocation of artificial agents and societies in artificial intelligence (AI), and (3) the provocation of general symmetry in the actor–network methodology.

(1) The *first* provocation began in the 1980s when philosophers and computer scientists discussed the question, “What can or cannot computers do?” They did it mainly under the aspect of human thinking and individual intelligence. Social scientists entered the debate much later and less visibly. Nevertheless, the belated German-language contributions played a major role in shifting the question of what distinguishes humans from computers from a focus on cognition to behavior, from knowledge to interaction, and from technological concepts of communication to sociological ones (Esposito, 1993; Heintz, 1995; Baecker, 1995; Rammert et al., 1998). They changed the common view of the computer from it being a ‘machine’ that transforms symbols to it being a ‘medium of communication’ that also circulates and edits texts, pictures, and sounds. The more that the face-to-interface relation changed from instrumental use to symbolized and visualized interactivity, the more the computer has in turn been addressed as an “interactive partner” (Geser, 1989) and its use conceptualized as “mediatized interaction” (Faßler, 1996).

(2) The *second* provocation occurred when computer scientists started to program software packages that explicitly operated as ‘agents’ endowed with ‘belief, desire, and intention’ components and began to design the computer and Internet architecture to resemble ‘artificial societies’ or ‘open social systems’ to be enacted by cooperating agents. Three groups of computer and social scientists pioneered this new kind of close interdisciplinary and co-constructive activities. A British group concentrated its research on an agent-based simulation of *Artificial Societies* (Gilbert and Conte). A Californian group contributed concepts of new social interactionism to the project of “Social Computational Systems” (Hewitt, Star, Suchman). From 1999–2005, a German group established a national research and development program with the promising title *Socionics* (thus the title of the book by Malsch, 1998). The first aim of this research endeavor was to translate sociological theories (Mead, Parsons, Luhmann, Giddens, Esser) into formal concepts that could be tested in computer runs. This endeavor clearly failed. It did very little in terms of advancing general sociological theory-building, yet it did augment our knowledge about the transfer of concepts (Schulz-Schaeffer, 2002). However, in regard to its second aim, which was to develop and test agent-based information systems using sociological concepts, the project has yielded significant advances in the sociology of technology: it introduced the concept of gradual agency and the theory of distributed agency in hybrid constellations (Ram-

mert, 2012) and has influenced research and engineering programs on human–technology interaction and smart systems ever since.

(3) The *third* provocation confronted sociology with the rule-breaking methodology of a ‘general symmetry’ between human and nonhuman entities that act or between associations of people and things (Latour, Callon, Law). Many sociologists responded to the ANT attack by strictly defending the constitutive tenets upon which sociology rests. Some were nonetheless motivated to rethink exclusive human agency or the role of interactivities with and between natural beings and artificial agents, whereas the STS students with their generally looser ties to the discipline were propelled to engage in rampant research of every *thing* (see Schulz-Schaeffer, 2008; Lindemann, 2011; Roßler, 2016).

In the German-language sociology of technology, the contested agency debate took a slightly different course. This community had problematized the instrumental, consequential, or materialistic-external views of technology early on. It had already demonstrated in a continuous stream of empirical research how ‘high technologies’ became more communicative, how they changed from mechanical engineering to physical-cybernetic systems, how machines were turned into media, and—particularly in the Socionics program—how parts such as software agents displayed activities with ever higher grades of competence and autonomy within a limited domain.

Thus, the former debate on “whether computers can think” was replaced by a new one on “whether machines can act” (Rammert and Schulz-Schaeffer, 2002). If one follows the orthodox position that only humans are able to think, to act intelligently or consciously and with intention, then the debates about “autonomous technology” or “technologies-in-action” (Rammert, 2003) would be predetermined and meaningless by definition. Were one to follow the unorthodox principle of a ‘general symmetry’ to treat everyone and everything as an “actant”—insofar as any entity can intervene in an action and can be the subject in a sentence—then one would give up all the advances in disciplinary vocabularies and by theory-driven empirical research. One significant outcome of this debate, and a constructive answer to the dilemma, was a sociological theory of “hybrid” and “distributed agencies” and the concept of “gradual agency.” This theoretical approach rejects the overemphasized dogma that only humans have or show mindful agency as well as the opposite one of a “flat” concept of operational agency.

The theory of distributed agency is based on both the empirical observations of interactivities and the practical and normative attribution of meaningful agency (Schulz-Schaeffer, 2007). In contrast to ANT, it distinguishes between different levels of agency and different grades of control and autonomy between human and non-human agents in constellations of collective agency, for instance, in surgery rooms (Schubert, 2011), social-media communities (Lettkemann and Schulz-Schaeffer, 2020), and autonomous driving. The theory of distributed agency was empirically tested in simulation experiments with hybrid disposition systems in a hospital (Meister et al., 2007) and—even more impressively because of the intention to falsify it—in an experiment with an autonomous car-driving system (Fink and Weyer, 2014). It has been

referenced and contested by further studies, grounded in ethnomethodology, conversational analysis, or communication theory (Krummheuer, 2010; Muhle, 2016; Matsuzaki and Lindemann, 2016), on human–computer interaction with avatars, robots, and other embodied conversational agents.

3.3 The missing micro–macro debate: From ‘technographic’ case studies to varieties of ‘socio-technical transformations’

In the early days of critical technology studies, one of the advancements was the shift in theorizing from macro to more middle-ranged concepts, from the logics of capital, class conflict, or worldview to particular institutional designs, organized interests, or cultural framings. Later on, in the wake of the pioneering laboratory studies, a broad stream of research followed this route down to the micro level, where “human–machine reconfigurations” (Suchman, 2007), the “mangle of practice” between materiality and sociality (Pickering, 1993), or “heterogenous networks” of people and technical objects could be observed (Latour, 1992). Most of these approaches share a preference for ethnographic or genealogical case studies and the methodological view that societies’ macro structures can be detected in micro situations because they are produced, reassembled, performed, and reproduced locally. (Schützeichel, *MICROSOCIOLOGY*, this volume) These approaches differ in two respects: first, in terms of the human and nonhuman forces deemed relevant and, second, in regard to how one can infer more durable macro structures from individual micro cases.

An edited German-language volume assembled some of the seminal positions and new research papers under the unifying label *Technography* and pushed the discussion “towards a micro sociology of technology” (Rammert and Schubert, 2006). It presents Latour’s ethnography of the autonomous traffic project named ARAMIS; Hutchins’ ethnography of a critical navigation situation, Preda’s genealogical study on the transformation of the trading floor by new information media; and Heath, Luff, and Knoblauch’s workplace studies on technology in action. It has expanded the fields of research by exploring the possibilities of “videography,” “webnography,” and “interactivity experiments.” The book connects the diverse fields and differing approaches by means of two propositions: first, to focus ethnographic studies on technologies and media “in action and interaction” and, second, to offer a shared analytical platform for the study of “distributed agencies” in socio-technical constellations.

The relevant agentic forces are neither single human actors nor particular technical instruments only, neither human collectives (such as teams or social groups) nor technological systems (such as physical or cybernetic ones) alone. It is rather the “socio-technical ensemble”—composed of heterogeneous entities—that produces and reproduces the relevant style and structure of action in a field. In contrast to ANT, these technographic studies show that it makes a difference how the relations are

incorporated in bodies and technologies and how they are enacted in particular situations of risk and of testing (Schubert, 2017; Potthast, 2017).

How do the different approaches scale up from micro to macro structures? Most sociologists studying technology did not follow Latour's radical concept of a flat world inhabited by actants endowed with agency of all kinds. They criticized the failure to reflect the role of the observer in this limitless land, the gap between its analytical vocabulary and empirical narrations, and the failure to account for interaction processes between entities (Schulz-Schaeffer, 2008; Lindemann, 2011). Although some of them share Latour's idea to follow human and nonhuman actors through society and describe the force of the growing assembly of entities (Latour, 1983), they have approached the problem of upscaling differently, namely, by drawing on multi-sited ethnography (Knorr-Cetina and Brugger, 2002) or by reconstructing multi-level processes of the construction, diffusion, and governance of discourses, structures, and regimes (see Kalthoff et al., 2008; Voß et al., 2006; Knoblauch, 2013).

Another German collection titled *Society and the Power of Technology* criticized the foci on micro constellations and on the generative aspect of new technologies; instead, the editors wanted "to bring technology back in" as an influential factor and pleaded for more research on its socio-economic and institutional consequences (Dolata and Werle, 2007). The book presents some approaches that share the concepts of 'technostructures' and 'socio-technical systems' on the macro level of society's infrastructures or sectors and on the meso level of firms or networks of organizations. These concepts conceive of the different types of technologies as well as their various areas of use, implementation, and public regulation as results of distinct and interdependent institutionalization processes (Bender, 2005). The analytical and gradual concept of "sector-specific transformations" then allows the analyst to diagnose different kinds of technology-driven changes according to the match or mismatch of two central factors: the "transformative capacity of technologies" and the "social capacity of adaption" (Dolata, 2013).

A steady stream of sectoral or infrastructure studies—from the biotech to the information and communication sector, from the music industry to the finance system—demonstrated the analytical utility of this transformational approach and its high potential for learning by comparisons. It has certainly been strongly influenced by Hall and Soskice's paradigmatic comparative socio-economic "varieties of capitalism" approach, an influence that is reflected in its attempt to describe and explain varieties of "socio-technical transformations." What it has accomplished is to advance our understanding of the influential role of a "technological profile" of emergent technologies in the different paths of transition that the particular areas and industries are undergoing and the role of social movements therein (Dolata and Schrape, 2013).

An obvious shortcoming is the lack of debate between these two methodological movements so far. Even though each claims to reveal the full range of the socio-technical dynamics driving a technological development, each has specific limitations. Representatives of the first movement start by analyzing the interactivities, relationships, and frames in a situation between people (e.g., researchers, brokers,

surgeons, or software engineers) and objects (e.g., bacteria, instruments, screens, or computer programs). They then expand the range by conducting multi-sited ethnographic studies that follow the actors, things, and symbols in the field and theorize about the observed rules and micro structures in order to draw diagnostic conclusions about the cultural and structural changes in one or more fields of society. What they risk neglecting, however, is the emergence of self-producing orders and the intensified differentiation between the institutional spheres and regimes that this entails.

Representatives of the second movement begin their investigations by analyzing the interdependencies, structural features, and instituted orders between institutional spheres (politics, the economy, science and technology, and so on) and between collective actors (movements, organizations, heterogeneous networks). They do so usually at the national level of a society and employ international comparisons to understand varieties of institutional orders and the mechanism of structural changes. The risk here is to overemphasize the stability of institutions and underestimate the creative doing or destructive undoing of institutions (Meyer and Schubert, 2007).

Over the last two decades, there have been attempts to develop more comprehensive approaches with the potential to integrate both movements. These approaches have shifted the focus of research from the development of technologies to the complete and complex processes of socio-technical innovation. These shifts shall be discussed in the following section.

3.4 The expanded innovation debate: ‘From technology assessment’ to the governance of ‘the innovations of society’

In recent decades, we have witnessed two significant shifts in the topics of and approaches to research on technology and innovation. The first shift—from technology to innovation—is one of research interest. It signals a conceptual and institutional change from a narrow view of technological development or technology assessment to a wider view that considers the management and governance of the entire innovation process. The second shift—from economic to social innovation and beyond—is one of definition. It has opened a debate between social scientists on how to conceptualize the various phenomena of innovation in economy and society. Both shifts have enhanced the relevance of sociological approaches and expanded the scope and scale of technology and innovation studies.

What are indicators of the *shift of interest from technology to innovation*? As early as the mid-20th century, one could observe an emerging political and public interest in technological changes, their risks, and their specific impacts on society and demands for monitoring, assessing, and governing them. The concept of technology assessment (TA) and the institutionalization of regular reports for government and parliaments answered to these demands. The subject matter of these reports were the intended and non-intended consequences of particular technologies, such as cars, airplanes, skyscrapers, telephones, and many more, in all areas of life and all social domains.

Over the last two decades, the focus of this kind of research and the political interest in policy advice shifted from exclusively concentrating on monitoring and assessing the consequences of a technology to a ‘constructive’, ‘participative,’ and ‘integrated’ TA. Since the millennium, the German Institute for Technology Assessment and Systems Analysis (ITAS) in Karlsruhe and the German federal government have widened their joint program of TA toward a combined “innovation and technology analysis” (Grunwald, 2010). Advances in sociological research on the development of new technologies redirected attention from individual technologies and their consequences to more complex constellations and longer innovation trajectories. This shift has even entailed an institutional change from a bureaucratic ‘office’ of TA to a network form of organization that opened up the iterative assessment process to allow for a plurality of approaches, public participation, and political governance procedures (see Bora et al., 2005). Finally, the contested TA vocabulary, which had been too closely affiliated with a technocratic form of political consultation and an engineering style of evaluation, was replaced by a more promising framing of TA in the context of an approach centered on innovation and “pragmatic innovation management” (Bogner, forthcoming) and a turn from merely assessing the present to shaping it by projecting scenarios of the socio-technical future (Lösch et al., 2019). This shift paved the way for a paradigmatic turn from ‘ruly’ technology and unlimited technological progress to rule-breaking innovation and the reflexive creation of novelties.

The second shift broke with two traditions in technology and innovation research: the predominance of an economic definition and explanation of innovation and the habit of most inquirers to restrict the topic to technological innovations.

Before the millennium, the economy of innovation and the sociology of technological change exhibited parallel developments: both dissented from mainstream economics and sociology, and both widened the scope and scale of their research. Marxist and neo-classical economic approaches still claim today that profit-seeking “rational choices of technology and markets” explain technological development, whereas the neo-Schumpeterian ones contradict and argue that in the long run “routines and evolutionary mechanism” are of greater importance. Path-dependency approaches add that “history and critical incidents” also matter, whereas neo-Marxists insist that “class conflict and power” are the critical forces. Social constructivists, however, emphasize the role of sense-making and negotiation processes between social groups and demonstrate that “visionary projects and cultural interpretations” are crucial factors. Neo-institutionalist policy approaches, finally, maintain that “institutional settings and actor-constellations” are decisive variables (see more explicitly Rammert, 2016).

After the millennium, these critical encounters between the various schools led to a few interdisciplinary enterprises with the aim of developing a more expanded and integrated framework. In 2002, the Volkswagen Foundation launched a program on innovation research that intended to build bridges between economics, law, history, and sociology and sought to overcome the fragmentation of this multifaceted research field. This endeavor yielded a considerable number of unique German-language

contributions. Some early books collected and thoroughly reviewed the internationally leading approaches (Braun-Thürmann, 2005; Aderhold and John, 2005; Blättel-Mink, 2006). Several empirical field studies analyzed the effects of a growing diversity of paradigms, social tempi, or cultures on the course of innovations. One of these studies showed that the epistemic diversity in the wide field of ubiquitous computing facilitated the successive technological reconfiguration of the IT infrastructure towards the “smart home” and its adaptation to “gerontological” requirements (Peine, 2006); another study argued that the synchronization of the different tempi in the economy, science, and politics plays a critical role in the success and failure of “virtual reality” (Rollwagen, 2008); a third one illustrated, in the case of a regional network of innovation, how the fragmentation of different professional cultures could be bridged by an incidental act of cooperation and not only by fostering optimal conditions and providing sufficient resources (Manger, 2009). The idea of transferring approaches from human-life-course research to the technological sphere has led to the new genre of *innovation biographies*. Work in this vein has reconstructed how varying constellations influenced the development of wind energy (Bruns et al., 2007) and electronic microscopy (Lettkemann, 2016) and spelled out the concept of “the multiple identity of technology” (Lenzen, 2020).

Other studies analyzed how path dependency and path creation affect the course of innovations (Windeler, 2003; Sydow et al., 2012). These books and projects are only a small selection from a growing body of mainly sociological research on technology and innovation. Yet in spite of their expanded scope and scale, they remain biased towards new technologies, products and processes, or technosciences.

This shift made its greatest leap when researchers started to expand the innovation zone from economic to social innovation and finally to innovations of society. The international discussion extended the subject from innovative ‘entrepreneurs’ and ‘firms’ to ‘national systems,’ ‘arenas,’ and ‘networks’ of innovations (Hage et al., 2000). One early German paper on “social innovation” (Zapf, 1989), however, paved the way toward a more radical turn from an *economic* to a *sociological* concept of innovation. This sociological concept of innovation included all areas of society and referred to social, political, public-administrative, educational, and other instances of innovations at the social-structural level, thereby following Ogburn’s idea of parallelizing technical and ‘social inventions.’ Since the last decade, a growing number of researchers have further elaborated this concept of social innovation and proposed new research programs.

What are the shared observations and indicators among these approaches that attest to a change in society’s relationship to innovation? What differences do we observe in the theoretical debates around innovation phenomena?

The observation of an expansion of the innovation zone is widely shared, as indicated by the broad acceptance of the notion of “*ubiquitous innovating*” (Braun-Thürmann, 2005: 10ff.). Concepts of political, social, cultural, and sustainable innovation reference this spread of innovation activities in society. There is, however, a heated discussion over whether this phenomenon indicates an imperial expansion of

economic criteria of innovation or a liberal expansion of the concept of innovation towards social innovation with different codes of evaluation (Rammert, 2010). Many approaches in innovation studies also share the empirical insight that the objects of innovation include a wider spectrum of new practices, symbolic artifacts, and institutional reforms beyond the usual types of market-oriented product and process innovations.² In this context, however, there is another ongoing debate over the issue of normative bias. One group has applied an analytical-normative interpretation of social innovation that distinguishes between dominant ‘technical’ and neglected ‘social’ innovation and has been infused with positive views of social bottom-up movements and local communities (Howaldt and Schwarz, 2010; critically Schubert, 2017). This group intended to raise public awareness of social innovations and emphasize their significance compared to the dominant technological ones. In accordance with this orientation, the advocates of this approach have posited a shift toward a “post-industrial innovation paradigm” (Howaldt and Jacobsen, 2010) and have leveraged it to criticize the technology bias in national and European funding and policy programs to support innovation (see the 2011 “Vienna Declaration” by Hochgerner, Braun, Howaldt, and others).

Another group developed the more comprehensive theoretical-analytical framework of *reflexive innovation* and the thesis of a fundamental change towards a “post-Schumpeterian innovation regime” (Rammert, 2000). This approach combines three theoretical perspectives: the eminent role of *discourses* that define, communicate, and justify what counts as an innovation; the necessary grounding of recombinatory *doings and practices* that co-produce deviant and disruptive changes in fragmented fields of innovation; and the inter-institutional processes of creating new or disrupting established paths of innovation at the societal level (Rammert et al., 2018; Jungmann and Windeler, 2020).

A third approach has adopted an even wider view than this previous group of authors. One of its most prominent proponents, Andreas Reckwitz, has diagnosed the formation of an aesthetic capitalist society that implicates a fundamental shift in the “social regime of the new” from the disposition of perennial improvement to the ‘dispositif’ of creativity as an aesthetic stimulus (Reckwitz, 2017).

Finally, the debate itself has broadened to include the question of what the driving forces and the change mechanisms are that are reconfiguring the relationship between innovation and societal transformations. Some see at work here the “reciprocally reflected communicative construction of the new” and its objectivation into independent discourses (Knoblauch, 2018). Others emphasize the indeterminacy or irritational potential of newness and a shift towards a creative “experience economy” (Hutter, 2018; Hutter and Farias, 2017). And yet others identify as the critical locus of

² See, for instance, the kindergarten, Germany’s feed-in tariff law for renewable energy, the architecture of the Internet, or the social-security system as examples of the open range of innovation, from conceptual to architectural to infrastructural.

“reflexive innovation” the inter-organizational level of “organizational fields” under the structural influences of capitalist economization, industrialization, and rationalization (Windeler, 2018; Meyer, 2016). Another group of scholars bases its theorizing on the creative practices and distributed processes of doing innovation for its own sake; they diagnose a shift from the established functionally oriented differentiation of societal domains to a kind of “fragmental regime” of ubiquitous and multi-referential innovation (Rammert, 2006; Passoth and Rammert, 2018; Lindemann, 2019).

4 Final Remarks: Conclusions and Prospects

There remain many more topics, texts, and theoretical positions that would merit being included in this review.³ While perhaps not doing justice to all of them, the selected debates should nonetheless provide an exemplary impression of important developments and advances in the sociology of technology and innovation in the German-speaking world.

Two features were responsible for the advances in the German-language scholarship reviewed here: the intensive exchange with neighboring fields and the translation of the diverse experiences into a sociological framework. The critical reception of philosophies of technology and the constructive cooperation with computer scientists inspired the turn from a hard and closed concept of technology to a gradual and multi-relational one. The provocations of artificial intelligence and of a symmetrical anthropology were accepted but translated into a genuine sociological concept of collective distributed agency. Ethnographies of work and science and anthropologies of human–technology configurations stimulated adopting a micro-sociological view to explore situations of technologies in action, interactivity, and socio-technical constellations, whereas the socio-economics of institutional change triggered the comparative studies of economic sectors and technological transformations. Finally, the economy of innovation and the political debate on disruptive or responsible innovations prompted the German-speaking sociological community in particular to redefine the economic and technological concept of innovation and to develop an integrated framework for the comparative study of diverse cases and individual courses of societal innovation.

What can we expect for the future development of the research field? Two challenges currently dominate public discourse: the coronavirus crisis and the digital transformation of society. They raise questions concerning the close entanglements of human bodies with nature, medical technologies, and bio-politics⁴ on one side and the overwhelming role of symbol-processing technologies in the emergence of a

³ For further information, see Häußling, 2014; Lengersdorf and Wieser, 2014; Bauer et al., 2017; Schubert and Schulz-Schaeffer, 2019, and Blättel-Mink et al., 2020.

⁴ See the ERC grant to Thomas Lemke: *Suspended Life: Exploring Cryopreservation Practices in Contemporary Societies* (2020).

“society 4.0”⁵ on the other (Baecker, 2018; Maasen and Passoth, 2020). The sociology of technology is intellectually well prepared to address these issues. The processual concept of technicization has already incorporated the technologies of bodies and behavior (Gugutzer/Peter, (FELT) BODY. SPORTS, MEDICINE, AND MEDIA, this volume) as well as the technologies of symbols and symbolic media (Hepp, MEDIA AND COMMUNICATION, this volume). Whether this potential comes to fruition, however, will be a matter of organizing and funding heterogeneous cooperation between disciplines and theoretical approaches in the future. We should not miss out on the opportunity to overcome the looming risk of a continued or even deepening fragmentation of the field.

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⁵ See the ERC grant to Elena Esposito: The Future of Prediction: The Social Consequences of Algorithmic Forecast in Insurance, Medicine and Policing, Nassehi (2020), and the contributions by Lindemann, Passoth/Rammert, and Philipps to the Symposium on Nassehi's “Muster,” *Soziologische Review*, 43 (3), 2020, 301–327.

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