Article

Innovation Systems for Transformations towards Sustainability? Taking the Normative Dimension Seriously

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Abstract: The aim of this article is to complement research on transformations towards sustainability by drawing upon the innovation systems (IS) framework. The IS framework already serves as a suitable and influential basis for research on processes of technological innovation and economic change. We argue that improving the capacity of an IS framework for dealing with wicked problems and the normative complexity of sustainability requires a fundamental paradigm shift because in the current IS paradigm innovations are considered as per se desirable and in mostly technological terms. Therefore, we call for IS dedicated to transformations towards sustainability by opening up for systemic innovations beyond the technological dimension and by acknowledging that stakeholders have conflicting visions, interests, norms, and expectations with regard to sustainability goals. Taking the normative dimension of transformations towards sustainability seriously thus requires more explicit and integrative research on directionality, legitimacy, responsibility, and their interrelation in IS. The article concludes by proposing suggestions for future research based on IS-related approaches that can serve as building blocks for an IS framework capable of incorporating legitimate goal-orientation for transformative innovation by and for society.

Keywords: wicked problems; transformations towards sustainability; innovation systems; normativity; paradigms; directionality; legitimacy; responsibility; dedicated innovation systems

1. Introduction

Humanity is currently facing multiple crises: climate change, dwindling natural resources, and the unjust distribution of wealth and security are threatening the planet and its inhabitants (e.g., [1]). The way humans are interfering with life-maintaining Earth system processes has already alarmed scientists long ago (see also [2,3]). In fact, Rockström and colleagues [4,5] claim that the Earth system has already crossed several thresholds and thus transcended what they term *planetary boundaries*, beyond which safe operating space for humanity can no longer be guaranteed and sustainability is severely compromised (see also [6]). These interrelated and systemic challenges have been referred to alternatively as *wicked problems* [7–11], *persistent problems* [12,13], *complex challenges* [14], *grand challenges* (e.g., [15–17]), or even *super wicked problems* [18] in the sense that their causes are emergent and complex, they are embedded in the social structure, their effects are uncertain, and they are thus extremely difficult to

manage. It is rather unsurprising that in the context of this multiplexity of problems sustainability itself becomes a deeply normative issue often involving conflicting worldviews and contested pathways. Consequently, technological solutions will not suffice to fundamentally improve the prospects for our living conditions in the sense of a sustainable future, and an "optimization" of present systems is literally impossible [13,19,20]. Quite the contrary, tackling "wicked problems" (and all of the other problems and challenges mentioned above) requires radical systemic changes, i.e., *transformations*, in multiple dimensions (e.g., economic, institutional, technical, cultural, organizational, etc.). This, in turn, necessitates advanced and comprehensive approaches aiming at better understanding and governing these so-called transformations towards sustainability [13,21–26].

With this article, we aim to complement research on these transformations towards sustainability in two ways. First, we discuss the (lack of a) normative dimension of *innovation systems* (IS)—a framework deemed suitable for scrutinizing processes of technological and economic change. More specifically, we contribute to the development of an advanced IS framework in which issues of normativity are integrated. Our discussion ties in with recent debates on normative foundations and directionality in IS (e.g., [27–33]) and with discussions about the need for (more) responsible innovation (e.g., [15,34–37]; see also [38–40] for reviews). Second, we provide a fundamental argument for the difficulties of integrating normativity in IS, which inevitably calls for a paradigm shift in our way of thinking about IS. Based on this theoretical conception, we propose a research agenda to enhance the capacity of the IS framework to assist researchers and policy-makers in tackling transformations towards sustainability beyond technological solutions.

The paper is structured as follows: Section 2 introduces IS as the underlying concept for our argument and points to its limitations for contributing to better understanding and governing sustainability transformations. Section 3 opens a door for adapting the IS concept to the challenge of tackling wicked problems related to transformations towards sustainability: We raise awareness for the complex normativity of sustainability and emphasize the need for a new, dedicated IS paradigm. We contrast the leading assumptions, dominant values, and practices of the current IS paradigm with those of a dedicated IS paradigm and identify three important issues connected to normativity that must be dealt with when a paradigm shift is aimed at. Subsequently, Section 4 introduces recent theoretical and practical approximations towards parts of the questions raised before. These existing strands of research serve as building blocks for a new research agenda that we deem necessary for the future in order to answer the overarching question of how IS can incorporate legitimate goal-orientation for transformative innovation by and for society. Section 5 concludes the article by summarizing key arguments and avenues for further research.

2. Innovation Systems: Merits and Limits in the Light of Transformations

Understanding and governing processes of technological and economic change have been the underlying rationale for the emergence of the framework of IS, building on evolutionary economics and related disciplines (e.g., [41–45]). Notably, the rise of this framework can be seen as a revolution against mainstream economics by radically challenging unsuitable axioms and simplistic presuppositions of neoclassical economics [46]. For the purpose of a working definition, we follow Niosi and colleagues, who propose to understand IS as systems of multiple interacting agents "aiming at the production of science and technology . . . Interaction among these units may be technical, commercial, legal, social, and financial, inasmuch as the goal of the interaction is the development, protection, financing, or regulation of new science and technology" [47] (p. 212) (for extensive reviews and overviews, see [33,48–52]). IS have since served scientists as a model for understanding the complex systemic nature of innovation, they have equipped policy-makers with a basis for designing innovation policies (e.g., [53,54]), and they have informed firms to formulate innovation strategies (e.g., [55,56]). Until today, the IS literature remains the most influential one for the international innovation policy community [31]. The framework has been adapted to various levels [33,48,51] including *national* (e.g., see [57,58]), *regional* (e.g., [59]), *sectoral* (e.g., [60,61]), *technological* (e.g., [62–65]), and recently even

global IS [66]. In summary, it can be said that IS provide a heuristic framework for examining the collective of actors and institutions involved in innovation and their interactions within (more or less) defined boundaries [67,68].

　　The central aim of most research on IS has been to reveal how differences in configurations as well as interactive learning processes of the respective actors and institutions are responsible for particular (knowledge-based) economic outcomes [43,55,69]. Much of IS research has focused on analyzing how generic innovation capabilities can be strengthened [25,70]. The long-term goal of these economic outcomes, however, has not been explicated so far but rather regarded as determined by the system's actors and their specific configuration [71,72]. Remarkably enough, for a long time, the IS literature has fallen victim to the same inherent fallacy as a large part of innovation research has, namely that innovation per se is good [30,32,73–75]. Therefore, scholars have paid insufficient attention to the ethical acceptability and societal desirability of innovations. With this, we do not want to imply that IS scholars have completely neglected sustainability considerations (e.g., see [24,28,76–83]). Nevertheless, many of the approaches—particularly the so-called *sustainable systems of innovation* [79,80] or *sustainability-oriented innovation systems* [77,82]—remain focused on technological innovation with the aim of environmental protection. In the face of wicked problems, this is simply insufficient.

　　Transformations towards sustainability involve, for example, also changing practices, routines, and habits of both producers and consumers (e.g., [84–87]) and other types of innovation beyond technological solutions (e.g., [88–95]). Moreover, in order to achieve systemic changes, multiple sustainability dimensions (e.g., economic, institutional, cultural, organizational, etc.) have to be considered beyond environmental ones.

　　In summary, it can be said that research on IS enhances our understanding of conditions and actor configurations conducive to innovation [33,51,69,88] but so far lacks an explicit debate about the normativity, i.e., desirability and goals of innovation processes [28,29,31]. Furthermore, most previous IS approaches that deal with sustainability appear to have neglected its complexity by focusing on solving (only) environmental problems with (only) technological innovations [28,96]. This gap renders IS frameworks currently insufficient to address wicked problems in the context of sustainability.

3. Exploring the Normative Dimension

　　Evidently, it is anything but trivial to integrate "sustainability" in the sense of a goal-orientation in IS. Among other things, this is owed to the fact that sustainability can never be perceived as just "a technical optimisation puzzle waiting to be solved" [97] (p. 111). Instead, sustainability itself is a deeply complex normative issue that needs to be made explicit. This section, therefore, explores implications of this normative complexity for IS research aimed at transformations towards sustainability.

3.1. The Complex Normativity of Sustainability and the Need for a New IS Paradigm

　　It has long been recognized that sustainability per se has a deeply normative nature [98–102]. The literature on sustainability is not merely *de*scriptive about various problems, but also *pre*scriptive about practices for 'human use of the Earth' (e.g., [98,102,103]). Sustainability then provides a vision of a desirable state of what the future should look like, alongside a set of rules that indicate what ought to happen for this state to be reached [99]. However, it has been criticized that normative or ethical aspects of sustainability have often been misrepresented or even disregarded [104]. Although conceptions of sustainability share a general normative outlook, they differ on what the desired state should look like and by which means (i.e., practices) it ought to be attained (e.g., [7,105–113]). In other words, different societal actors have different worldviews and visions with regard to (pathways to) sustainability [114–116]. For example, the so-called Brundtland Report emphasizes the ability of future generations to fulfil their needs and the conservation of plant and animal species [117], while the understanding of sustainability held by the report of the World Commission on the Ethics of Scientific Knowledge and Technology (COMEST) underlines the need to discern "the earth's carrying capacity and continuity of regenerating enough resources for the sake of future generations and the vulnerable

sectors of society" [118] (p. 11). Likewise, companies such as Unilever or Shell have a different conception of what a sustainable society ought to look like from non-governmental organizations such as Greenpeace or Friends of the Earth. Against this background, it can be observed that prior research on sustainability transformations has often neglected the complexity of differing worldviews, norms, and value systems by presuming consensus about the scale and importance of sustainability-related visions [119]. From this, it follows that the worldviews shaping both current IS frameworks and those dedicated to transformations must be scrutinized. Such an endeavor requires researchers to shift attention to the *paradigm* level.

A paradigm may be regarded as a set of basic beliefs or metaphysics that deals with ultimates or first principles [120]. For our current purpose, it can be defined as a complex set of assumptions, concepts, values, and practices that constitute a worldview for the community that shares them (see also [121–123]). Hence, paradigms span a *bounded performative space* within which certain actions or practices are regarded as possible, reasonable, legitimate, and important, while others are excluded as being impossible, illegitimate, unreasonable, and unimportant [124]. This performative space actuates but also bounds the emergence and development of practices within IS.

It is important to note, however, that the relationship between paradigms and societal practices is not unidirectional. Quite the contrary, in a co-evolutionary sense, we may contend that there actually are feedback loops between paradigm and practice. Foremost, paradigms are constitutive to legitimizing social activity taking place within IS. Yet, at the same time, certain practices may push paradigms into particular intended or unintended directions as paradigms are also constituted by practices, despite their resilience. This is due to their discursive constitution by the behaviors taking place within a social field and the reflection upon them (cf. [125–129]). As Montuori puts it, "we create knowledge that in turn creates us, our ways of thinking and acting and feeling" [130] (p. 152). Thus, normativity on a practical level cannot be understood independently from a paradigmatic one, but certain practices may also serve as (leverage) points to intervene in a system to facilitate a paradigm shift [131]. Thus, it is important to contrast the current IS paradigm with an advanced one capable of integrating sustainability as a deeply normative and complex issue.

Advancing IS in such a way actually requires a two-stage process: First, IS actors and researchers must adjust their perspective to scrutinizing the ultimate purpose of innovations. This, in turn, calls for incorporating a dedication to desirable goals and tackling important problems. A dedicated paradigm entails awareness for the necessity of pursuing these goals and the relevance of the problems, thereby affording heuristics and mental frames for exploring alternative innovation avenues. We will, therefore, refer to the advanced framework as "dedicated" IS paradigm or simply *dedicated innovation system* (DIS) as already indicated by Pyka [132]. While dedication can refer to various goals and different problems, a second step is required to concretize its orientation. In the light of wicked problems and the dismal prospects of current global developments, transformations towards sustainability offer a powerful frame of reference. For the remainder of this article, we use DIS in connection to this special case of "IS dedicated to transformations towards sustainability".

Both the conventional and the DIS paradigms share the central assumption that innovation takes place in complex (evolutionary) systems. Yet, as mentioned before, first and foremost they differ in what they assume to be the desirable goal of innovation processes. While in the early days of the (conventional) IS framework (e.g., [41]), the desirable goal of innovation was economic development (e.g., including national competitiveness and the creation of income and jobs), it can be observed that today, innovation is more and more seen as a panacea and has therefore become akin to an aim in itself [30]. By contrast, in DIS it is innovations contributing to transformations towards sustainability that are desirable. However, this explicit systemic dedication requires that the complexity of normativity, as well as the wickedness of problems, are adequately considered.

Within the current IS paradigm, it is evident that economic growth, efficiency, and system improvement are regarded as important and technological innovations as per se legitimate. By contrast, the dominant values or norms of a DIS paradigm are not that straightforward in the face of the multiplexity

of visions and pathways. One potential value frame has been proposed by Renn and colleagues [99], who suggest that sustainability involves the continuity and endurance of human social and ecological systems, inter- and intragenerational justice, and a sustainable quality of life for all. Nevertheless, even this value frame remains ambiguous, particularly in terms of translating the respective norms into transformative (innovation) practices. For example, which qualitative systemic change processes should enable continuity and endurance of which particular (sub-)systems? What is justice and in which context? Who determines what a sufficient and sustainable level of quality of life should look like? Despite these and several other open questions in the context of transformations, the three norms suggested above can be a central guiding principle of DIS (i.e., IS for society), whereas in conventional IS innovation trajectories are usually not aligned with an overall systemic vision (i.e., IS *for* the sake of innovation).

In the conventional paradigm, technological innovation, competition, entrepreneurship, and knowledge creation and its diffusion play a major role (e.g., see [48,64]). Innovation processes are determined primarily by the so-called "supply side" (e.g., [88]), and policy intervention is deemed necessary for correcting *system* failures (e.g., infrastructural, transition, lock-in/path-dependency, institutional, network, and capabilities failure as summarized by [133]). These activities and practices will also be important in a DIS paradigm, but they have to be expanded by *transformative innovation* based on alternative, dedicated innovation trajectories. Transformative innovation, as explained by Steward [93], goes beyond radically new technologies, products, or (production) processes; instead, it "is about the implementation of paradigm-breaking, system-wide novelty" (p. 15). Transformative innovation processes can, thereby, be understood as collective experimentation processes by multiple systemic actors [134,135] (e.g., citizens, mediators, social and sustainable entrepreneurs, etc.). Policies will be required that go beyond the "traditional" system failures and additionally address what Weber and Rohracher [25] have called *transformational failures*. A brief summary of the comparison between the conventional and the dedicated IS paradigm is presented in Table 1.

Table 1. Comparison of the conventional and the dedicated paradigm.

	Conventional Paradigm/IS	Dedicated Paradigm/IS
Concept	Innovation Systems	Dedicated Innovation Systems
Leading assumption	Innovation takes place in complex systems	Innovation takes place in complex systems
	Implicit assumption: innovation per se desirable	**Explicit** assumption: innovations that contribute to transformations towards sustainability are desirable, but: complexity of normativity and wickedness of problems
Dominant values/norms	Economic growth, efficiency, system improvement	Continuity of ecological systems, inter- and intra-generational justice, quality of life
Key practices	Technological innovation, competition, entrepreneurship, knowledge creation and diffusion	Additionally: transformative innovation based on alternative, dedicated innovation trajectories
	Innovation processes determined primarily by "supply side"	Innovation processes determined by all systemic actors and institutions (e.g., citizens, mediators, social and sustainable entrepreneurs, etc.)
	Policies tackle system failures	Policies tackle transformational failures

To recapitulate, sustainability goals cannot be easily integrated into an IS framework because the current IS paradigm cannot accommodate the complex normativity of sustainability. Instead, this requires a shift towards an IS paradigm dedicated to sustainability transformations. Such dedication, however, inevitably calls for a more rigorous consideration of at least three central questions: transform/sustain (1) what?; (2) why?; (3) by and for whom? (based on [136,137]). Other relevant questions may also include "for how long?", "at what cost?", and "at which scale so that it will make a difference?" [136,137]. If these questions have not been posed, any attempt to answer the question of "how" to achieve transformations towards sustainability will remain either window dressing or resemble hope for a silver bullet. Consequently, an IS approach suitable for contributing

to sustainability transformations must also be related to these central questions. For the remainder of this article, we focus mainly on the questions of "what", "why", and "by and for whom" in an IS context, as we can argue that other questions will inevitably have to follow but cannot be discussed on the same level in this article.

3.2. Directionality, Legitimacy, and Responsibility: Questions to Be Answered

The first central question "what" to transform or sustain concerns the overarching issue of directionality or goal-orientation of IS [29,31]. Directionality primarily involves the question "what is the ultimate goal of an IS?" In the context of sustainability, it is also a question of "the right" transformation pathway(s) for social, economic, ecological, cultural, technological, and other relevant (sub-)systems. Therefore, directionality is not only about challenging the contemporary implicit focus on technological innovation and economic growth but also about opening up the IS approach for a variety of pathways (e.g., [19,115,138–140]) and actors [88] while closing down other, non-sustainable options.

However, previous discussions about directionality often seem to assume that steering is possible as if we already knew "the right direction", which is questionable in the context of wicked problems. There are several additional problems when we make directionality explicit: First, the consideration of direction is quite contradictory to the evolutionary nature of innovation processes characterized by emergent properties, feedback effects, non-linearity, uncertainty, and a collective of fallible and boundedly rational actors [141–143]. In a similar vein, the authors of the flagship report by the German Advisory Council on Global Change (WBGU) stress that "[t]ransformations are usually open-ended processes, the results of a collective steering are never certain, and not clearly foreseeable, despite a defined goal" [144] (p. 107). Second, as mentioned above, a consensus on the desired transformation or systemic "goal" will hardly be reached as we are dealing with wicked problems and multiple actors with potentially conflicting interests and expectations [145]. It is, therefore, necessary to ask which (groups of) agents would be in the position and have the power to address matters of directionality and guide societies towards socially desirable outcomes.

This discussion inevitably leads us to the second central question mentioned above: the question of "why" to transform/sustain, which essentially relates to issues of legitimacy. In the context of wicked problems and sustainability, legitimacy is about finding answers to questions along the lines of "why should IS have a particular transformation goal?" and "who decides or determines the respective direction or pathway?" It is futile to rely only on top-down approaches by the government because, in the so-called network society, the monopoly of the state to produce social regulation and judicial norms is no longer self-evident [146]. Transformations have different initial conditions (e.g., geographically, culturally, economically) [147] and involve trade-offs. They radically change existing system structures and actors' power relations, which makes compromises and negotiations necessary on various levels and sub-systems. At the same time, bottom-up participatory approaches cannot guarantee that "the right" innovative solutions to wicked problems will be found, even if all actors agreed on pursuing a particular pathway. Our knowledge about future impacts of solution attempts to wicked problems is principally limited [73]. Moreover, transformative grassroots movements face the additional problem of having to acquire a critical mass to be capable of "creatively destroying" non-sustainable industries and power relations in a truly Schumpeterian sense [148]. As Gowdy phrases it: "Can the human propensity for cooperation and community building be harnessed sufficiently to scale up and challenge a global system built on competition and accumulation?" [149] (p. 35). One of the major determinants of community building and scaling up human cooperation for sustainability is arguably culture, which is, however, still under-researched in the sustainability context [116,150,151].

It has often been argued that values, goals, norms, and beliefs that make up a paradigm are shaped by cultural evolutionary processes (e.g., [152–159]), thereby creating barriers and enablers for both the "what" and the "why" questions. For example, through the paradigm, culture shapes also systemic adaptations and responses to wicked problems such as climate change (e.g., [108,109,160]). Accordingly, cultural change itself is usually listed among the dimensions of the required sustainability transformations. This is

why various authors have recently called for inquiries into how cultural evolution can be influenced to contribute to the emergence of more sustainable practices, institutions, and paradigms (e.g., [161–165]).

However, influencing evolutionary processes is far from facile and also relates to the third central question mentioned above: "by and for whom?", which essentially concerns issues of responsibility. In the context of transformations, responsibility is closely related to agency as it is a matter of who holds the power to bring about change, and who bears the consequences.

Responsibility has probably received even less attention in the IS literature than issues of directionality and legitimacy. While the notion of corporate social responsibility has a long scholarly history and is well-established, it cannot be easily adapted to collective innovation and transformation processes in complex systems involving multiple heterogeneous actors and often fundamentally uncertain outcomes. Some kind of liability for emergent outcomes of complex systemic interactions can hardly be the kind of responsibility we are looking for, although some authors stress the importance of accountability also in the context of transformations towards sustainability (e.g., [23,166]). As a consequence of this complexity, however, neither individual nor collective responsibility concepts (e.g., [167,168]) are entirely suitable in the context of IS and transformations. This is owed to unknown causalities, unintended consequences, and the fact that positive or negative systemic impacts are mostly the result of a combination of individual and collective action as well as involuntary feedback effects.

To sum up, we argue that transformative systemic changes towards sustainability can be described and analyzed on the basis of an IS framework. The precondition is a paradigm change which requires engagement with issues of directionality (what future do we want?), legitimacy (why do we want this future, who defines it?), and responsibility (transformation by and for whom?). We have seen, however, that these questions are difficult to answer in a unilateral way in the case of wicked problems that call for transformations towards sustainability in multiple dimensions.

4. Theoretical and Practical Building Blocks for a New Research Agenda

These questions of directionality, legitimacy, and responsibility are already partly dealt with by theoretical and practical endeavors of IS-related research and policy that tackle some isolated aspects that can be used as building blocks for a DIS paradigm.

On the one hand, governments around the world usually do not struggle to provide direction by formulating general policy goals—also related to sustainability aspirations. The orientation of the corresponding innovation journeys is, on the other hand, much harder to achieve. This is particularly well-demonstrated by arguably unsuccessful agreements on the transnational level ranging from the Kyoto Protocol to the Paris Agreement, including so-called Grand Challenges (e.g., [15–17]) or the seventeen United Nations Sustainable Development Goals [169], which do not adequately consider the interrelatedness of (wicked) problems and the resulting trade-offs between solution attempts. Moreover, the relative ease with which individual governments such as the Trump administration of the United States of America can withdraw from such transnational agreements points to the importance of entrenching sustainability goals among all IS actors.

The innovation (systems) community has, to some extent, already addressed issues of directionality by investigating how innovation policy has an impact on the quality of the outcomes of structural change (see, e.g., [170–174]). Much of this research is based on evolutionary theorizing and modeling (see also [175]) and the large body of empirical literature this has given rise to (e.g., [176–178]). Traditionally, innovation policies have been classified as either generic, focusing on promoting innovation diffusion, structural change, and economic development in society more generally, or oriented towards coping with more specific challenges that policy-makers care about, so-called "mission-oriented" innovation policies (see, e.g., [53,179], for an overview). However, innovation policies aiming at transforming an IS towards sustainability are much more ambitious than earlier policies. Recently, so-called *transformative innovation policies* have been suggested (e.g., [19,139,180,181]), which aim at "directing socio-technical systems in socially desirable directions and embedding processes of change in society" [19] (p. 21).

Another way to introduce goal-orientation in IS is *innovation systems foresight*, recently proposed by Andersen and Andersen [182,183]. Innovation systems foresight is defined as a "systemic, systematic, participatory, future-intelligence-gathering and medium-to-long-term vision-building process aimed at present-day decisions and mobilising joint actions to improve innovation system performance with the ultimate goal of improving desirable socio-economic performance" [182] (p. 281). This framework has been developed on the basis of foresight and futures studies and has already served as a tool for strategically guiding IS transformations towards desirable directions [183].

But why should IS have a particular transformational goal in the first place and who determines the respective direction? Mazzucato [184–186] argues, for example, that traditional approaches to innovation policy seriously underestimate the potential for the state to provide clear goals (direction) to a society's technological innovation journey through the systematic use of various policy instruments (an *entrepreneurial state* as she puts it). However, top-down policy-making may not be the most suitable approach to tackling wicked problems such as climate change [146,187,188]. Building on earlier work by Evans [189], Rodrik [190] suggests, for example, that a *green industrial policy* is needed where policy-makers embed policy processes better in society and involve a broader segment of actors in order to increase policy learning. Thereby, the probability of myopic turnarounds by contemporary administrations may also decrease. Due to the simple fact that policy-makers are not perfectly informed social planners, policy-making should be distributed. Furthermore, including key stakeholders becomes a necessary and integral part of innovation policies [183]. Aside from the substantive value of participation [191], mobilizing many actors at multiple scales can create legitimacy in general [192,193] and for sustainability goals [19,81,194,195] of an IS in particular.

Political economists have stressed the importance of inclusive institutions as vital rules of a system [192] that can empower citizens to make politicians pursue the interests of society as a whole. An IS framework incorporating such institutions has been introduced as *inclusive IS*, in which "relatively high levels of inclusion characterize the processes of learning and innovation and in which there is a relatively strong focus on innovation addressing the needs of the lower income strata" [81] (p. 284). The inclusive IS framework has been used to analyze a set of empirical cases to show how social inclusion impacts the (wicked) challenges of a low-carbon development.

In a similar vein, Bryden and Gezelius [28] address innovation's legitimate purposes by exploring how institutions for innovation could be designed in order to address sustainability goals. They combine the IS framework with insights from business ethics (especially the influential ideas of Triple Bottom Line accounting [196–198]) and frame their concept as an IS for *Human Rights-Based Triple Bottom Line* (HRB-TBL) outcomes. Thereby, this novel conception explicitly goes beyond the technological paradigm and environmental dimension of the sustainability-oriented IS approaches mentioned above.

In order to endogenize directionality and thus create legitimacy in IS, Lindner and colleagues [31] propose to fuse IS with reflexive governance [174]. They develop ten quality criteria for *reflexive IS* including examples of relevant actors, indicators, and policy implications [31].

Another important insight into how systemic processes of change can be legitimized is provided by the proponents of sustainability transitions research (e.g., see [199–203], for reviews). These sustainability transitions have been defined as "long-term, multi-dimensional, and fundamental transformation processes through which established socio-technical systems shift to more sustainable modes of production and consumption" [201] (p. 956). At the operative level, transitions research has developed frameworks such as *transition management* [204–206], *strategic niche management* [207–209], and the *multi-level perspective* (e.g., [210–213]) that open up spaces for legitimization processes, including so-called transition arenas [205] or niche-related actor networks that may include citizens and environmental groups [207]. These frameworks have already been implemented in political practice, for example, in the Netherlands and Belgium [205,206,214].

Finally, to address issues of responsibility in innovation processes, a relatively new strand of literature has been developed around the notion of responsible research and innovation or

simply *responsible innovation* (RI) (e.g., [15,34–40,215–217]. RI incorporates a normative outlook into multi-stakeholder innovation practices (e.g., [36,218]) and aims to achieve (ethically) acceptable, sustainable, and societally desirable outcomes of innovation processes and their marketable products [15,37]. Arnaldi and colleagues [219] even consider responsible research and innovation as the key to "steer[ing] the innovation process from the inside towards societal goals" and thus leaving behind the traditional emphasis of responsibility on fault, punishment, risk, compensation, and coping with "negative externalities" (p. 26). RI includes a wide range of (pre-existing) theories and approaches (see, e.g., [38–40]). Lubberink and colleagues [39] compile six central dimensions of RI based on a systematic review of the literature, namely anticipation, reflexivity, inclusion, deliberation, responsiveness, and knowledge management, and they suggest operationalization strategies for each of these dimensions.

In summary, there have been many IS-related approaches that address elements relevant for taking the normative dimension seriously: transformative innovation policy, innovation system foresight, the entrepreneurial state, green industrial policy, inclusive IS, the HRB-TBL, reflexive IS, frameworks developed on the basis of transitions research, and RI. However, the questions of transforming/sustaining what, why, and by and for whom are highly interrelated and call for more integrated theoretical and practical approaches that consider directionality, legitimacy, and responsibility in a holistic way. The overarching question for further research will, therefore, be: How can DIS incorporate legitimate goal-orientation for transformative innovation by and for society?

Hence, while these scattered strands of literature and policy endeavors have contributed a lot to solve parts of the issues related to the paradigmatic normativity of IS, various open questions remain to be answered by future research, including the following issues:

1. Although policy-makers can be given an accessible platform and a common language for discussion by drawing upon an IS framework, further investigations are needed on the systemic causes of resistance to change associated with directionality, legitimacy, and responsibility. Examples of research objects may include the paradigmatic "lock-in" in unsustainable value systems and the issue of *bounded morality* [84] of systemic actors.

2. Researchers need to shift attention from trying to find "the one" solution to acknowledging that there are multiple transformation pathways and an epistemic insufficiency to predict "the right" future. This calls for enabling a continuous feedback mechanism between setting goals, formulating normative strategies to reach these goals, while reflecting on the legitimacy of these strategies.

3. Future research must address ways to influence the evolution of complex systems, for example, by drawing upon the literature on so-called *leverage points* as places to intervene in IS (e.g., [131]).

4. The literature on RI has so far not established sufficient references to the IS literature and vice versa. It is still under-researched what RI would entail in the context of IS. Therefore, further research is needed on how a systemic concept of responsibility can be developed.

5. As it has been stressed by others, one of the important aspects of responsibility in the context of innovation is that it is shared (e.g., [36]). Since responsibility is frequently regarded as a correlate of power (e.g., [220,221]), a notion of shared responsibility in an IS context implies that future research is advisable on the role of power and capabilities (e.g., [222,223]) of systemic actors (see also [75,84]).

6. Policy programs are required that tackle transformational failures [25] and sustainability-related ecosystem failures [114] by means of adaptive and reflexive governance instruments allowing for experimentation and inclusion of relevant stakeholders.

7. Further research is needed on questions of how participatory elements (e.g., stakeholder engagement in innovation) for transformative efforts can be fostered and governed, and how "the right" stakeholders could be selected (because an inclusion of all stakeholders guarantees neither consensus nor selection of adequate solutions).

8. It will also be important to investigate which actors and elements of DIS are universal, which are contingent and depend on geographical or cultural particularities. DIS concern multiple levels (e.g., global, national, regional, sectoral, technological, etc.) and do not aim at developing a "one size fits all" paradigm.

9. In this connection, the differences in temporal structure and dynamics between varieties of DIS should be explored (e.g., co-existence of old and new systems, the role of early adopters, pioneering roles of advanced economies, specific designs of innovation: e.g., engineering vs. frugal).

Notwithstanding the necessity of these research endeavors, we must keep in mind what Sendzimir and colleagues wrote already more than a decade ago: "No system of analysis, policy, or practice will ever eliminate surprise and uncertainty. Innovation and novelty as well as wicked problems incessantly emerge from evolving systems of nature and humanity, and will continue to do so. . . . Our responsibility to address the impacts of evolution through new ways of learning, managing, and discussion must engage uncertainty as a stimulus to explore innovations and not as a basis of apprehension and apathy" [224] (p. 157).

5. Conclusions

IS offer a widely accepted and broadly used framework to analyze innovation processes. Because of the heterogeneity of involved actors and the dynamics and imponderables of learning processes as well as knowledge diffusion, the analysis of innovation processes generally requires a framework open for complexity. This is even more important when the nature of innovation becomes more fundamental and includes radical systemic changes such as transformations towards sustainability. We argue that the current IS framework is insufficient because it focuses too much on technological solutions and implicitly follows the normative assumption that innovation is per se desirable. Therefore, shifting attention to the paradigm level is the only way to potentially integrate the complex normativity of sustainability in IS. The guiding assumptions, values, norms, and practices of the current IS paradigm must be challenged in order to achieve a systemic dedication to sustainability. A dedicated paradigm or an IS dedicated to transformations towards sustainability can in principle allow for innovation trajectories that are to be subordinated to a sustainability goal. However, wicked problems and conflicting interests, expectations, and visions concerning sustainability require researchers to delve into questions of directionality, legitimacy, and responsibility. Previous IS-related approaches to these issues are scattered but already provide valuable building blocks for a more integrative investigation as proposed above. Future research is needed on how DIS can incorporate legitimate goal-orientation for transformative innovation by and for society. This research agenda covers various avenues. We commence with three rather general proposals: to explore systemic causes of resistance to change, to identify potential places to intervene in IS, and to engage in a stronger fusion of IS with RI. We then move on to the specific research objects of potential policy instruments for reflexive governance and stakeholder inclusion. Finally, we call for a substantiation of the introduced DIS framework, including questions of a spatial and temporal scale.

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