Innovation Systems for Transformations towards Sustainability? A Normatively Infused Reflection

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Abstract

This paper contributes to the refinement of an innovation systems (IS) framework for better understanding and governing sustainability transformations on a systemic and global level. In our understanding, the discussion must be guided by two assumptions: *(i)* transformations involve systemic innovations, *(ii)* transformations involve a normative dimension. Following this impetus, we can identify a "normativity gap" in prior approaches, particularly in transitions research and IS research. More specifically, we argue that the current discussion lacks a focus on *directionality* and *legitimacy*. Improving the capacity of an IS framework for dealing with transformations towards sustainability requires taking these normative issues or "the ethical dimension" of sustainability transformations more seriously into account. This also entails focusing on the complexity of paradigmatic normativity and probing into (in-)compatibilities between different sustainability-relevant norms, beliefs, and value systems to support a shift towards a sustainability-oriented paradigm. Based on these deliberations, we fathom how an extended concept of IS can help to govern transformations towards sustainability and explore the implications for and from research on innovation policy. The paper concludes by proposing a way forward: *dedicated innovation systems* as an IS framework dedicated to better understanding and governing transformations towards sustainability.

Keywords: innovation systems, normativity, policy, transformations to sustainability, transitions

Abbreviations:

DIS	Dedicated innovation system(s)
IS	Innovation system(s)
MLP	Multi-level perspective
RI	Responsible innovation
R&I	Research and innovation
TIS	Technological innovation system(s)

1 Introduction

"The gap between what we know about the interconnectedness and fragility of our planetary system and what we are actually doing about it is alarming. And it is deepening" (Bokova, 2013, p. 3).

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., Brand & Wissen, 2012). The way humans are interfering with life-maintaining earth system processes has already alarmed scientists long ago (see also Meadows et al., 1972, 2004). In fact, Rockström and colleagues (2009a, 2009b) claim that the global 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 (see also Steffen et al., 2015). The reliance on idealized market mechanisms to overcome these erroneous trends has proven to be a fatal mistake (e.g., the belief in an "invisible hand" of the market, i.e., that actors will self-organize into (Pareto-)efficient and sustainable patterns; see also Young, 2017, p. 9, in this connection). Even when accompanied by politically-induced corrections of so-called "market failures", based, for example, on environmental legislation or welfare policies, the conventional toolkits of governance have failed (Mazzucato, 2015, 2016). Many scholars argue that these crises are rooted in the underlying structures of the current societal systems. The problems have been understood to be *persistent* in a sense that they are nested in lifestyles and perceptions of the members of societies and therefore impossible to overcome by market forces or current policies (e.g., Rotmans & Loorbach 2009; Future Earth 2014; Schot & Steinmueller, 2016). Once again, Einstein is very topical with his quote: "The significant problems we face cannot be solved with the same level of thinking we were at when we created them" (Einstein, as cited in Stroh, 2015, p. 4; see also Capra & Luisi, 2014, on a related note).

Consequently, a mere optimization of the present system will not suffice to fundamentally improve the prospects of our future living conditions (Frantzeskaki et al., 2012; Schot and Steinmueller, 2016). To tackle effectively the global challenges we need radical changes, i.e., *transformations,* on a

technical, organizational, economic, institutional, socio-cultural, and political level. New and comprehensive approaches aiming at better understanding and governing these systemic transformation processes are required, emerging from a globally effective sustainability paradigm (e.g., Burns, 2012; Patterson et al., 2015). This paper seeks to contribute to the development of such comprehensive approaches, building on two fundamental and widely accepted assumptions about transformations towards sustainability:

(i) Transformations involve systemic innovations.

The approaches to solving persistent problems that are embedded in current social systems rely on innovative practices and structural adaptation (Grin et al., 2010; Leach et al., 2012). The overall goal is to change from one socio-technical system to another, more sustainable one which entails technological substitution, coevolution of social practices and institutions, and the emergence of new functionalities (Elzen et al., 2004). One prominent and fruitful approach for analyzing the complex interaction between actors within systems and the institutional infrastructure is the *innovation systems* (IS) framework (e.g., Chaminade & Edquist, 2010; Edquist & Johnson, 1997; Jacobsson & Bergek, 2011; Lindner et al., 2016). There is, however, still much work to be done (not only) to create a better understanding of the complex transformative dynamics at work.

(ii) Transformations involve a normative dimension.

The concept of transformation inevitably calls for a debate about notions of optimality and teleology. Since complex problems cannot be tackled with reductionist methods, we can no longer rely on approaches that oversimplify the matter (e.g., the ones viewing sustainability-related problems as clearly identifiable and indisputable optimization problems). We must, therefore, lead an interdisciplinary discussion that also adequately considers the complexity of the normative dimension inherent in transformations to sustainability (see also Johnson et al., 2017, on a related note).

Consequently, to better understand and govern transformation processes the IS approach can serve as a useful framework that should, however, focus *more explicitly* on the normative dimension

concerning underlying paradigmatic assumptions and value systems. A thus extended IS framework may then serve as a basis for a value sensitive design of policies for sustainability transformations.

The central aim of the paper is to advance the debate by raising awareness for and helping close the "normativity gap" within the IS framework in order to contribute to governing transformations towards sustainability in terms of challenge-driven system innovations. To achieve this aim, in the following (second) section of the paper we briefly review recent approaches that have paid tribute to the first assumption regarding transformations: systemic innovation. Promising concepts of transition research and the contemporary evolution of IS theory in transformation research will be presented and critically reflected with an eye to the "normativity gap". Subsequently, in section three, we shed light on the second assumption above by addressing the ethical dimension inherent in and necessary for transformations to sustainability. Section four will then revolve around the implications of and for contemporary innovation policy and identify the need for novel solutions involving transformative governance. We conclude our paper in the fifth and final section by laying the foundations for an extended IS framework, which we have termed *dedicated innovation systems,* and by proposing avenues for future research.

2 Change, yes, but how? Or: A review of the literature

2.1 Systemic approaches to transformations towards sustainability

Various approaches have contributed to the framing of transformations and the conceptualization of their governance (e.g., Biermann et al., 2010; Loorbach, 2010; Markard et al., 2012; Patterson et al., 2016; van den Bergh et al., 2011; Voß et al., 2006). Much prior research has focused on so-called "socio-technical transitions" or "sustainability transitions", which have been defined by Markard et al. (2012, p. 956) as "long-term, multi-dimensional, and fundamental transformation processes through which established socio-technical systems shift to more sustainable modes of production and consumption." While many scholars have used the terms transitions and transformations interchangeably, others have explicitly differentiated between them (see also Feola, 2015). According to Stirling (2015), for

example, *transitions* denote more orderly, controllable processes of change that can be managed through incumbent institutional structures and often emphasize *technological* innovations, having in mind a particular and known goal, which is supposedly shared. *Transformations,* as Stirling (2015, p. 54) claims, in turn involve "more diverse, emergent and unruly political alignments" as well as disruptive *social* innovations that challenge incumbent institutional structures; hence, transformations are "subject to incommensurable knowledges and pursuing contending (even unknown) ends" (ibid.). 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. Transformations are not directly manageable" (WBGU, 2011, p. 107). For the purpose of this paper, we therefore take up the term transformations in order to stress that we are not only focusing on processes of incremental change but also on processes of "fundamental change of a system's form, structure, function and purpose" (Moser, 2016, p. 107).

Leaving terminological ambiguities behind, an extensive review of the literature on transitions or transformations towards sustainability would go well beyond the scope of this paper. However, others have already presented reviews and potential categorizations of relevant theories and approaches, including the articles by van den Bergh et al. (2011), Markard et al. (2012), and probably most recently Patterson et al. (2015) as well as the forthcoming article by Loorbach et al. (2017). Although there are overlaps and cross-fertilization, the approaches may be grouped according to different research goals or foci, intellectual history, key concepts, or other criteria. For example, van den Bergh et al. (2011) differentiate the four approaches into (1) *IS* (e.g., Jacobsson & Bergek, 2011), (2) the *multi-level perspective* (MLP) (e.g., Geels, 2002, 2011, 2015; Rip & Kemp, 1998), (3) contributions drawing on complexity theory or *complex systems* (e.g., de Haan, 2010; Rotmans & Loorbach, 2009), and (4) those employing evolutionary theory or *evolutionary systems* (e.g., Safarzyńska et al., 2012). In a similar vein, Markard et al. (2012) also identify four theoretical frameworks that have "achieved quite some prominence in transition studies" (p. 955): (1) *transition*

management (Kern & Smith, 2008; Loorbach, 2010; Rotmans et al., 2001), (2) *strategic niche management* (Kemp et al., 1998; Raven & Geels, 2010; Smith, 2007), and also the aforementioned (3) *MLP* and (4) *IS* (here, however, they refer particularly to research on *technological* innovation systems (TIS), e.g., Bergek et al., 2008; Jacobsson & Johnson, 2000; Hekkert et al., 2007). The five concepts of transformation distinguished by Patterson et al. (2015) show overlaps with the other reviews but also some additional literature (see the table in Patterson et al., 2015, p. 13). Another more "meta-theoretical" review is presented by Luederitz et al. (2017), who focus on archetypical transition narratives. In their article, Luederitz et al. (2017) identify and examine the following four narratives: (1) *the green economy*, (2) *low-carbon transformation*, (3) *ecotopian solutions*, and (4) *transition movements*. The authors also identify problems with these present narratives and link their criticism to the system properties targeted by the respective narratives by aptly drawing upon the literature on systemic *leverage points* (or places to intervene in a system) (Abson et al., 2017; Meadows, 1999). Considering the differences between *deep leverage points* and *shallow leverage points*, they conclude that "none of the four examined transition narratives represents blueprints for, or panaceas to, the complex dynamics of mainstreaming sustainability, in part because none seeks systemic change across all ... intervention types" (Luederitz et al., 2017, p. 404).

In summary, it can be said that nearly all approaches share a systemic perspective. Yet, there is still some diversity regarding the "mode" of systemic thinking applied by the researchers (e.g., general systems theory, complex adaptive systems, system dynamics, IS, etc.; see also Chap. II.2 in Grin et al., 2010, for an overview of complex systems theory, its development, and varieties). In addition to the somewhat scattered research on targets of systemic intervention (e.g., as criticized by Luederitz et al., 2017) it can be observed that – at least implicitly – many systems-based approaches tend "to presume consensus about the scale and importance of the problems" (Almudi et al., 2016, p. 3). Thereby, a crucial dimension of transformations towards sustainability has been under-represented, namely the complex (co-)evolutionary dynamics at the *cultural* level (e.g., de Witt, 2015; Hoffman, 2012, 2015; Hulme 2009, 2015; Lewens, 2015; Matutinović, 2007). Put differently, systemic

approaches, whether used to *de*scribe or *pre*scribe transformative change processes, call for incorporating value systems or belief systems and approaches that explicitly focus on (in-)compatibilities and feedbacks between sustainability-relevant *ideas* (Almudi et al., 2016) or *memes* (Harich, 2010, 2015).

There are good reasons for taking up each of the discussed approaches as a starting point for further extensions, especially since they often draw on common theoretical roots and share similar foci (see also Markard & Truffer, 2008, on a related note). Nevertheless, for the purpose of the present discussion, we draw primarily on the IS framework, which has already somewhat "proven" its transferability from the "ivory tower" of academia into the real world (e.g., by having been taken up by policy initiatives particularly fueled by the OECD, 1997, 1999, 2000, 2002). Moreover, since IS put an emphasis on knowledge flows as drivers of change processes, such communication channels can serve as a potential link to the social dimension and *cultural knowledge* (see already Lundvall, 1996, on a related note), including the (sustainability-relevant) ideas and beliefs that serve as the "building block" of worldviews and value systems. The following section will, therefore, present a brief synopsis of the IS framework's recent developments and contributions to framing systemic change, particularly with an eye to under-represented normative issues.

2.2 Innovation systems and their normativity gap

One way to describe, comprehend, explain – and possibly shape – the dynamics and the success factors of an economic system's (e.g., a nation state, region, or sector) innovative capacity is the IS approach. The conceptual framework has been coined by Freeman (1987), Lundvall (1992), and Nelson (1993). It has since served to inform scientists to understand innovation, policy-makers to design innovation policies (Edler & Fagerberg, 2017; Fagerberg 2017), and firms to formulate innovation strategies (Edquist, 1997; Lundvall, 2007). The notion of IS is a framework to examine the collective of actors and institutions involved in innovation and their interactions within defined boundaries. The most relevant interactions for innovation processes are knowledge-based activities like learning, searching, and exploring (Edquist, 1997; Lundvall, 1992). The aim of the IS approach is to reveal how differences in

configuration as well as interactive learning and informing of the respective actors and institutions are responsible for certain (knowledge-based) economic outcomes. The IS framework has been adapted to various levels (see also Edquist, 2005; Klein & Sauer, 2016, or Weber & Truffer, 2017, for an overview) such as national economies (e.g., the comparison of the Danish and the Swedish IS undertaken by Edquist and Lundvall, 1993), regions (Braczyk et al., 1998; Cooke, 1992; Cooke et al., 1997), sectors (Malerba, 2002, 2005), technologies (Carlsson & Stankiewicz, 1991), or specific parameters (e.g., the future-orientation of IS of Central and Eastern European Countries analyzed by Hanusch et al., 2010).

Considering the evolutionary and emergent nature of IS, it is obvious that they will never reach an optimal state (Edquist, 1997) but rather offer an experimental environment that includes and accepts failure. While the actors are expected to be in constant search for technological and institutional solutions, IS are subject to change at all levels of consideration. Not only do firms change with the emergence of novelties created by themselves or within their sectors, also institutions adapt to new conditions and change or are replaced. This way, novel technology, changed regulation, entry and exit of firms and organizations, and other events change the configuration of IS over time in persistent pursuit of better responses to changed surrounding conditions. On this note, Hekkert and colleagues (2007) add a temporal perspective to the IS framework. They suggest mapping the *dynamics* of a system rather than the *structure* at one point in time since the success of an IS does not only depend on the structure of the actors and institutions involved (as initially suggested by the founders of the framework) but also on the activities inducing change (see also Liu & White, 2001).

Attempts have been made to account for change in IS in the sense of a system transformation due to adaptation to changed environments or paradigms in primarily technological terms. Freeman (1987) described a system's capability to produce novel kinds of institutions and technological trajectories along with changed fields of education. Such technological revolutions ultimately result in new techno-economic paradigms. Galli and Teubal (1997) worked towards a model of IS transition as an evolutionary response to trends such as globalization, liberalization, or technological advance.

Although the IS framework has been continuously adapted and refined (Klein & Sauer, 2016, Weber & Truffer, 2017), improving its applicability in terms of spatial boundaries, empirical validity, system components, and functional processes, two major elements of a "normativity gap" can been identified and are to be further explored with respect to its potential contribution to understanding and governing transformations to sustainability: *directionality* and *legitimacy* (e.g., Daimer et al., 2012; Lindner et al., 2016; Quitzow, 2011).

Firstly, IS research has focused too much on analyzing the strengthening of *generic innovation capabilities* and less on teleological aspects such as the *direction* or long-term goal of change (Weber & Rohracher, 2012; Wydra, 2015). While it has long been implicitly agreed that the overall success criterion for an IS was strengthening innovation capability (Daimer et al., 2012) and its goal therefore a purely economic one (Edquist, 2001), the re-formulation of a goal (e.g., sustainability) requires a new form of intentionality. The consideration of direction, however, is deeply contradictory to an evolutionary reflection of innovation processes characterized by true uncertainty and carried out by fallible, boundedly rational people equipped with inadequate information (see, e.g., Arrow, 1991; Berkhout, 2005; Kline & Rosenberg, 1986). Nevertheless, it seems that, for a long time, innovation studies have fallen victim to an implicit normative assumption that innovation *per se* is good (Blok & Lemmens, 2015; Buenstorf et al., 2013; Schlaile et al., 2017; Soete, 2013), thereby paying insufficient attention to adverse effects such as unintended side effects or the destructive element endogenous to the novelty creation process (i.e., *creative destruction,* Schumpeter, 1943/2003). This "optimistic fallacy" is also closely related to the general discussion on *teleology* versus *teleonomy* of evolutionary processes. Even when we take the focus shift to socially sound and relevant innovations seriously (as, e.g., advocated by Stirling, 2015, and in much of the transformations literature), we can observe a similar problem, namely that much of social innovation research has followed an under-theorized instrumental view, thereby oversimplifying the complexity of open-ended processes and agency (Cajaiba-Santana, 2014; Haxeltine et al., 2016).

The discussion about (a new) direction or goal also points to the second element of the normativity gap in the IS framework: the consolidation of innovation, economic growth, and sustainability (e.g., Bajmócy & Gébert, 2014). It raises difficult questions of *legitimacy,* responsibility, and power relations within IS. Historically, systemic transformations have always involved extensive structural change affecting not only one but many sectors and industries. Such structural change was also the main focal point of Schumpeter's work (see Fagerberg, 2003, for an overview). He was at pains to stress that radical innovation is usually met by fierce resistance of various sorts (e.g., social inertia), and that human agency is therefore essential for a successful outcome. But he did not consider the social, institutional, and political legitimacy aspects of such processes in much detail. As Truffer (2015) summarizes some critiques of the TIS approach, it still rather neglects necessary transformative processes like "reorientation of user practices, power relationships, regulatory structures, mind sets and public discourses" (p. 65). This is in line with criticism concerning the role of the consumers to be reduced to the determination of demand (see also Mueller et al., 2015; Schlaile et al., 2017, on a related note). As, for example, Warnke et al. (2016; p. 1) argue, "societal actors can no longer be assigned to the role of 'demand articulation'. Rather they actively contribute or sometimes even take over the generation of knowledge and innovation ideas as well as other functions such as financing, e.g. through crowdfunding activities." By extending the role of societal actors in IS from mere consumers to transmitters (and creators) of knowledge, facilitators and co-designers of innovation, as well as active participants in vision-creation and policy-formulation, transformations towards sustainability can gain legitimacy and – ultimately – momentum.

As these deliberations imply, IS frameworks are already well equipped to increase our understanding of radical innovations in the sense of transformative systemic changes. However, as soon as such changes go beyond ex post analysis and are expected to meet sustainability requirements, IS have to incorporate the elements of directionality (where do we want or have to go?) and legitimacy (who formulates the goals and the pathways to get there?). This inevitably calls for a more extensive

discussion about normative issues. Hence, the following section will particularly focus on the normative or ethical dimension of transformations towards sustainability.

3 The ethical dimension of sustainability transformations

This section tentatively develops a couple of basic normative concepts that can be included into an IS framework in order to tackle the "normativity gap" found in the current approaches (see previous section). First, the argument is made that sustainability must be understood as a deeply normative issue. Second, normativity on a paradigm level is discussed to point to the necessity of addressing deeper issues of normativity that are constitutive to those on the practical / governance level.

3.1 Sustainability as a deeply normative issue

Despite it not being structurally incorporated by the IS framework, it has long been recognized that sustainability has a deeply normative nature (Kates, 2001; Renn et al., 2009; Swart et al., 2004; Walsh et al., 2016; Wang 2011). It is not merely normative about what already is the case, but also about what 'ought to be human use of the Earth' (Hahn, 2009; Kates, 2001; Wang, 2011). 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 in order for this state to be reached (Renn et al., 2009). The growing sensitivity of researchers to moral issues is also reflected in an increase in normatively-oriented research strategies and innovation studies (see also Lindner et al., 2016). Nevertheless, it has been observed that, still, the normative or ethical aspects of sustainability "are often neglected, misinterpreted, or misrepresented, and that there is a need for adequate ways to approach and include the ethical dimension of sustainability in public and academic discussions" (Becker, 2012, p. vii). Although conceptions of sustainability, in general, share a normative outlook, they differ on what the desired state should look like and how it ought to be attained (see also De Wit & Meyer, 2010; de Witt, 2015; Franceschini et al., 2016; Hoffman, 2012, 2015; Hulme, 2009, 2015; Peterson, 2009). For example, the Brundtland Report emphasizes the conservation of plant and animal species for future generations (World Commission on Environment and Development, 1987) while the understanding of

sustainability held by the report of UNESCO 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" (COMEST, 2015). From a review of the literature of concepts of sustainability by Renn et al. (2009) three overarching norms emerge that are of special importance:

- to guarantee the continuity of ecological systems,
- to act in accordance with inter- and intragenerational justice, and
- to ensure an optimal level of quality of life.

For transformations towards sustainability to be successful they need to be shaped according to the norms related to the different conceptions of sustainability while following the directives provided by the concepts of how these norms can be translated into concrete plans of action. Consequently, an IS approach or framework governing transformations must effectively facilitate and accommodate the normative dimension concerning underlying assumptions and value systems.

This focus, however, introduces an additional challenge to IS. Because norms are inherently contested (Blok et al., 2015), dealing with normativity and norms inherently adds a layer of complexity. For example, companies like Unilever or Shell have a different conception of what a sustainable society ought to look like from NGOs such as Greenpeace or Friends of the Earth. Due to its contested nature, sustainability can never be perceived as just "a technical optimization puzzle waiting to be solved" (Walsh, 2016). Rather than neglecting them, an articulation of the ethical assumptions and implications underlying sustainability is called for. Acknowledging sustainability as a deeply normative issue also makes complexities apparent on a deeper, underlying level of the paradigms in which particular outlooks and understandings of sustainability are grounded (Renn et al., 2009; Swart et al., 2004).

3.2 The complexity of paradigmatic normativity

A *paradigm* may be regarded as a set of basic beliefs (or metaphysics) that deals with ultimates or first principles (Guba & Lincoln, 1994). For our current purposes, it can be defined as a set of *assumptions, concepts, values, and practices* that constitute a way of viewing reality for the community that shares

them (e.g., cf. *Oxford English Dictionary*). Moreover, paradigms are also normative: they determine what is viewed as "important and unimportant, reasonable and unreasonable, legitimate and illegitimate, possible and impossible, and what to attend to and what to ignore" (Ratcliffe, 1983, p. 165).

Together, the *ontology*, i.e., the form and nature of reality, the *epistemology*, i.e., the nature of knowledge and how it can be acquired, and the *axiology*, i.e., that which is of value or worthwhile, of a paradigm thus span a bounded performative space within which certain activities or actions are regarded as possible, reasonable, legitimate, and important, while others are excluded as being impossible, illegitimate, unreasonable, and unimportant.

In this view, the basic beliefs on which paradigms rest must ultimately be accepted simply on faith (however well-argued) as "there is no way to establish their ultimate truthfulness" (Guba & Lincoln, 1994, p. 107). Moreover, it is inherently impossible to think outside a paradigm as it bounds our thinking. Gestalt psychologists were following the idea of shifts in perspectives when they used pictures that could be seen in two quite different ways (bird/rabbit); moving from one paradigm to another then involves a gestalt switch: after converting to a completely new way of conceptualizing the world, one can no longer operate in the old paradigm (cf. Donmoyer, 2008).

To understand transformations towards sustainability as a normative concept, the axiology, in relation to the ontology and epistemology, of the newly emerging sustainability paradigm must be investigated relative to the prevailing economic industrialization paradigm (Burns, 2012) by systematically studying the cultural and moral attitudes held within each paradigm. To this purpose, for example, the axiological and ontological differences can be reflected upon between neoclassical and ecological economics (see, e.g., De Groot et al., 2003), as well as between underlying notions such as that of linear versus circular economy (Andersen, 2007; Blok & Gremmen, 2016).

We may contend that interaction between paradigm and practice is twofold: foremost, ontologically, epistemologically, and axiologically, paradigms are constitutive to legitimizing social

activity taking place within IS. 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. Donmoyer, 2008, p. 593; Morgan, 2007). Thus, normativity of sustainability on a paradigmatic and a practical level cannot be understood independently.

4 How do we get "there"? Implications from and for innovation policy

4.1 Innovation policy and sustainability transformations

Instead of just emphasizing problems and limitations (as criticized, e.g., by Rodrik, 2009, 2014), we should ask: how can our deliberations regarding the normativity gap of recent approaches be used to make policy-making more effective? In recent years, vast literature has emerged on how policy can contribute to structural change and sustainability transformations (see, e.g., Mazzucato & Perez, 2015; Mowery et al 2010; Nill & Kemp., 2009; Voß et al., 2009). Much of this is inspired by evolutionary theorizing on the role of innovation in structural change and economic growth (see also Safarzyńska et al., 2012), and the large body of empirical literature that this has given rise to (Fagerberg, 2005; Freeman, 1974; Kline & Rosenberg, 1986). Hence, many scholars have focused on the role of innovation diffusion for long-run economic development and structural change (and what influences it), including implications for policy (Boekholt, 2010; Edquist 2011; Fagerberg, 2017; Lundvall & Borras, 2005). Some of the more specific policy-relevant approaches for dealing with sustainability transformations at various scales or levels have been developed during the last few decades (see section 2.1, above).

While most of these approaches focus mainly on specific sectors or technologies, extensive structural changes of the type discussed above have implications for many if not most parts of the economy. Thus, the question of what can be done to support and sustain such transformative changes

(and how policy can contribute to this outcome) becomes of critical importance. Indeed, the absence of dedicated frameworks constitutes an important shortcoming of extant research on sustainability transformations. In our view, there is a need for (re-)formulating an IS approach, which can translate the complexities of sustainability transformations into manageable policy programs thereby giving policy-makers an accessible platform and language for discussion.

In this regard, a relevant strand of research to be considered is the recent literature on innovation policy. 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., Cantner & Pyka, 2001; Edler & Fagerberg, 2017, for an overview). However, innovation policies aiming at transforming an economic system towards sustainability, i.e., transformative innovation policies (Steward, 2012), may be seen as being oriented towards both objectives and, hence, much more ambitious than earlier policies, thus requiring new approaches in order to succeed (Mazzucato & Perez, 2015; Mowery et al., 2010). Mazzucato (2013, 2015, 2016), for example, argues that traditional approaches to innovation policy seriously underestimate the potential for the state to provide clear goals (direction) to a society's innovation journey through a systematic use of various policy instruments (an "entrepreneurial state" as she puts it).

Moreover, it has been argued that transformative innovation policies will require extensive coordination between different parts (levels) of government and other important actors in society (Braun, 2008; Fagerberg, 2017; OECD, 2010), something that may be very challenging as it runs against established practices in public administration (e.g., Flanagan et al., 2011; Flanagan & Uyarra, 2016). However, policy coordination may arguably be achieved in different ways. Rodrik (2014), for example, points out that traditional top-down policy-making may not be the most effective approach in tackling climate change. Building on earlier work by Evans (1995), he suggests that policy-makers need to do more to embed policy processes better in society and involve a much broader segment of stakeholders

in order to increase policy learning (while at the same time adjusting policy design so that the autonomy of policy-makers is retained). Indeed, there is a great instrumental value – next to the substantive value of participation (Sen, 1999) – from mobilizing many actors at multiple scales in dealing with extensive structural change in general (Acemoglu & Robinson, 2012) and for sustainability transformations in particular (Andersen & Johnson, 2015; Ostrom, 2010), not least to create legitimacy for the induced change.

In summary, we identify a need for a new approach for guiding innovation policy-making to address increasingly complex and comprehensive systemic change. Such an approach must be able to incorporate a response to the complexity of the ethical dimension of sustainability transformations discussed in the previous section and distil challenges in such a way that strategies can be meaningfully formulated.

4.2 Normativity on a practical level? Responsible innovation and participatory policy

One potential way to accommodate the normative dimension in IS and tackle the issue of stakeholder engagement for innovation policy may be the *responsible innovation* (RI) approach. RI is a recent approach that incorporates a normative outlook into innovation practices (Geoghegan-Quinn, 2012; Stilgoe et al., 2013). RI aims to achieve (ethically) acceptable, sustainable, and societally desirable outcomes and marketable products of innovative processes (von Schomberg, 2012). Tying in with sustainable development, research and innovation (R&I) thus becomes a key factor as an enabler of the smart, sustainable, and inclusive growth that is aimed for by policy-makers (Stahl, 2012; Timmermans, 2017).

RI includes a wide range of (pre-existing) theories and approaches (see, e.g., Timmermans, 2015). The thread that is suggested to bind all these different components together is the concept of responsibility (Fisher & Rip, 2013; Grinbaum & Groves, 2013; Grunwald, 2011; Jacob et al., 2013; Stilgoe et al., 2013; van den Hoven, 2013). On the one hand, the term “responsible” hints towards the desirable state aspired by RI in which R&I processes and products become ethically acceptable,

societally desirable, and sustainable. On the other hand, it can provide practical guidance about how that state could be attained, namely understanding responsibility as a practical way to relate normative issues to particular activities and behaviors of (R&I) actors (see, e.g., Grunwald, 2011; Stahl et al., 2013; Timmermans et al., 2017).

However, whether it is regarding the process or product of innovation, attributing and taking responsibility for sustainability transformations is problematic because sustainability-related problems can be viewed as *wicked problems* (Blok et al., 2015). Wicked problems are highly complex because they concern global issues like climate change, desertification and poverty, and cannot be solved in traditional ways or by simple solutions (Rittel & Webber, 1973). This also is the case for sustainability (see, e.g., Swart et al., 2004; Wiek et al., 2011). In fact, as Rotmans and Loorbach (2009, p. 185) elucidate, our society even faces several so-called *persistent problems*, which "are the superlative of what Rittel and Webber ... refer to as 'wicked problems'" (see also Grin et al., 2010). Because sustainability problems lack a closed form and are concerned with complex systems in which cause and effect are uncertain or unknown, they have no simple solutions (Blok et al., 2015). This complexity is further exacerbated when innovation policies involve multiple stakeholders, one of which are future generations. Thus, it is unclear and contested what RI would entail in that context.

In summary, it can be said that although an integration of RI within an IS framework may help close some gaps particularly with an eye to participative innovation policy, currently RI does not (yet) provide a comprehensive systemic approach for dealing with wicked problems (Schlaile et al., 2017).

5 Conclusion and prospects for future research

It has become apparent that the IS framework holds a lot of potential to enhance our understanding of and inform our strategies for transformations towards sustainability. We agree with Weber and Truffer (2017, p. 102), who argue that "the IS approach still has a huge potential to offer for future research and policy, but that a reframing ... is needed to move the field forward." Transition research and transformation governance approaches have also pointed to two elements of a "normativity gap"

within this framework, namely issues of directionality and legitimacy. The first one concerns the epistemological challenge of teleology in innovation processes in general (innovation involves uncertainty), while the second one, legitimacy, involves extending the role of societal actors and entails a call for more extensive discussions on agency, power relations, and responsibility within in IS.

To move the IS concept forward, we propose to follow the new notion of *dedicated innovation systems* (DIS) recently suggested by Pyka (2017), which we adopt to denote an overarching framework for responding to the identified gaps. In this context, "dedication" encompasses the provision of a creative environment for mutual learning and knowledge creation in the pursuit of transformations towards sustainability, which require the willingness to explore new avenues, including paths and trajectories that destroy competencies of incumbents. Ideally, such dedicated systems offer a new perspective on shaping (and accelerating) transformations to sustainability on the operative level of an economy while considering the paradigmatic level of sustainability-relevant worldviews. However, one major challenge of an applied DIS framework will be to steer and accelerate development starting from utmost diversity and heterogeneous preconditions. The other major challenge is uncertainty: As Young (2017, p. 7) notes, although "sophisticated systems analysis may reduce the frequency of surprises ... for the foreseeable future, we must reckon with the fact that steering these systems will require decision-making under uncertainty, a condition that even the most sophisticated forms of risk assessment cannot alleviate." Hence, any attempt of "designing" DIS must acknowledge the open and experimental nature of systemic innovations. This situation highlights the need for reflexive and adaptive governance instruments (e.g., iterative planning and stakeholder engagement instead of fixed long-term and top-down strategies). In this sense, DIS do not prescribe a pre-defined goal or purport a strict vision of the future. Since we lack a benchmark or an optimal configuration of DIS, their setup requires *dedication* rather than *direction* (see also Berkhout, 2005, on a related issue). DIS, therefore, revolve around sustainability-oriented, responsible, and social innovations, complementary to the required scientific and technological advances. Based on such approaches, actors within a DIS can be

empowered to become co-responsible citizens, e.g., shape production systems as well as change consumption habits (see also Schlaile et al., 2016, on a related note).

Future research thus needs to address several issues, including (but not limited to) the following ones:

1) Developing a systemic "dedication" involves fusing the IS framework with research on *collective intentionality* (e.g., Schmid, 2009, 2012; Searle, 1990) and evolutionary approaches to intentional change (e.g., Wilson et al., 2014).
2) Further research on transformative innovation policies (Steward 2012) is needed to develop the necessary reflexivity and adaptive capacity of governance approaches and to provide answers to the question of how to bridge the gap between national and international policies to avoid piecemeal solutions. More precisely, our previous section suggests that research on innovation policy may benefit from the participatory approaches developed within the RI community, which also require further work to better address the complexity and systemic nature of transformations.
3) The multiplexity of the persistent problems we are facing calls for complementary approaches that enable researchers to translate their DIS-related thought models into computational test laboratories. Recent discussions on the merits of computational modeling and simulations for tackling transformations towards sustainability (e.g., Bergman et al., 2008; Holtz, 2011; Holtz et al., 2015; McDowall & Geels, 2017; Moon, 2016) clearly suggest that further development of the DIS concept can profit from such approaches.
4) As Weber and Truffer (2017) note, IS research was inspired by but "did not draw extensively on any of the elaborated systems theories" (p. 104). This implies: Future research on DIS should integrate more of the findings from research on *complex (adaptive) systems* (e.g., Capra & Luisi, 2014; Meadows, 2008; see also Chap. II.2 in Grin et al., 2010), particularly regarding the sustainability-related *a)* system characteristics of *design* and *intent* (Abson et al., 2017) and *b) tipping points* (Lamberson & Page, 2012).

5) Adequately considering the complexity of paradigmatic normativity described above calls for future research explicitly focusing on the role of sustainability-promoting or impeding worldviews and their (in-)compatibility and (co-)evolution with DIS. Many promising pathways and methods exist, one of them involves drawing upon *cultural evolutionary studies,* which have recently gained momentum (e.g., Brewer et al., 2017; Buenstorf & Cordes, 2008; Lewens, 2015; Mesoudi, 2016).

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