Individual Behavior and Sustainability Transitions: Managing Uncertainty for Innovation and Resilience

Dissertation

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Abstract

The pursuit of sustainability is tied to large-scale change processes or transitions occurring within societal, ecological, and technological spheres. Innovation and resilience-centered approaches have emerged as important frameworks for analyzing sustainability transitions. While research on sustainability transitions often places innovation and resilience in the context systemic change, there is less understanding of how individuals contribute to these change processes. This is despite the potential of individuals to act as facilitators or inhibitors of change. Given that sustainability transitions introduce significant uncertainty, examining how individuals experience and manage uncertainty can provide important insights into their engagement in sustainability transitions. The four articles comprising this dissertation underscore the importance of an uncertainty management perspective in understanding individual intentions and behaviors related to innovation and resilience. This research aims to inform both research and policy in developing individual-centered approaches toward sustainability.

1.1 Introduction

The 2023 United Nations Climate Change Conference in Dubai concluded with an agreement that, according to the United Nations, signals the 'beginning of the end' of the fossil fuel era (UN, 2023). This declaration aligns with promising progress in the expansion of renewable energy, the proliferation of electric cars, and the maturation of novel food technologies. These developments indicate that the world is currently undergoing a major shift toward sustainability. At the same time, achieving important sustainability objectives seems more uncertain than ever, due to global shocks such as the COVID-19 pandemic, accelerating climate change, and a growing socio-political divide.

Both the positive and negative trends underscore the need for profound change to meet sustainability targets (Clark & Harley, 2020; Kivimaa et al., 2021; Loorbach et al., 2017). Sustainable development requires innovation-centered approaches that can decouple economic growth from environmental degradation (Silvestre & Ţîrcă, 2019; Smith et al., 2010). Similarly, sustainable development necessitates transformative approaches that can address the complex interconnected challenges of increasingly turbulent environments (Reyers et al., 2022). Therefore, innovation as a transformative force and resilience as a capacity to adapt and transform, along with their complex interdependencies, emerge as important pillars in sustainability transitions[1] (Olsson et al., 2014; Smith & Stirling, 2010; Zupancic, 2023).

Sustainability transitions depend on individuals accepting and engaging with changes at various levels of society (Huttunen, et al., 2021). By assuming roles such as voters, consumers, and entrepreneurs, individuals exert significant influence on transition processes, with their intrinsic motivation serving as a critical determinant of engagement in sustainability efforts (Avelino & Wittmayer, 2016). However, research on sustainability transitions in the innovation sphere seldom concentrates on individual-level analysis (Kaufman et al., 2021). Furthermore, much of the sustainability literature across various fields still relies on economics-based models of rational actors with perfect information (Schill et al., 2019).

The aim of this dissertation is to add to the literature on sustainability transitions by examining when and how individuals contribute to innovation and resilience. Given that sustainability transitions are fundamentally uncertain (Köhler et al., 2018, Peter & Swilling, 2014), this dissertation presents an uncertainty management perspective to investigate how

[1]To provide a unifying framework, this chapter uses the term 'sustainability transitions', which encompasses transformational and transitional changes toward sustainability. The term 'transition' is more common in the field of socio-technical studies (e.g., Köhler et al., 2019; Markard et al., 2012), while the term 'transformation' is more common in social-ecological research (e.g., Fedele et al., 2019; Olsson et al., 2014). Despite the contextual differences, both terms overlap conceptually and are often used interchangeably (see Hölscher et al., 2018 for a detailed discussion).

individuals perceive and respond to innovation and resilience. By generating an understanding of individual behavior in the context of innovation and resilience, the dissertation aims to inform bottom-up approaches to the successful management of sustainability transitions and contributes to bridging the micro- and macro-level divide in sustainability research.

1.2 Sustainability Transitions - Innovation and Resilience

The modern understanding of sustainable development has its origins in the report "Our Common Future" by the United Nations Brundtland Commission (Brundtland, 1987). The Brundtland Report defines sustainable development as "Development that meets the needs of the present without compromising the ability of future generations to meet their own needs" (p. 43). The Brundtland Commission's report has decisively shaped the modern discourse on sustainability and laid the groundwork for further international sustainability initiatives such as Agenda 21, the 1992 Rio Declaration, and the establishment of the United Nations Commission on Sustainable Development. The United Nations' Sustainable Development Goals (UN, 2015), which connect the achievement of sustainability to 17 specific goals, create an additional important foundation for the modern sustainability discourse. Together, these initiatives are a part of the United Nations' overarching mission to reconcile economic growth with solutions to social and environmental challenges. Today, prevalent descriptions of sustainable development employ three 'pillars' of sustainability: environmental sustainability, social sustainability, and economic sustainability (Purvis et al., 2019).

While there is a broad consensus in academia that sustainable development is desirable (George et al., 2016; Giovannoni & Fabietti, 2013; Redclift, 2006), in practice society struggles to achieve sustainability goals. For instance, it is increasingly unlikely that global warming will be constrained to below the 1.5°C target set in the landmark 2015 Paris Accord (Gabric, 2023) and no country is currently meeting the basic needs of its population while using sustainable amounts of resources (O'Neill et al., 2018). One reason for the challenges in achieving sustainability goals is that sustainability is a so-called 'wicked problem' (Hollands, 2023; Pryshlakivsky & Searcy, 2013). Achieving sustainability requires an understanding of complex interconnected social, technological, and ecological systems (Olsson et al., 2014; Voulvoulis et al., 2022) and careful consideration of systemic trade-offs between sustainability objectives (Bowen et al., 2017).

Aside from considering systemic dependencies, the literature highlights that sustainable development requires the management of change (Becker, 2014; Loorbach & Rotmans, 2006; Silvestre & Ţîrcă, 2019). Indeed, sustainable development is increasingly understood in terms

of transitions occurring within social-ecological, socio-institutional, and socio-technical systems (Loorbach et al., 2017; Ollivier et al., 2018; Schlaile & Urmetzer, 2021). By itself, the term 'transition' describes a long-term systemic change, entailing non-linear shifts from one equilibrium to another (Elzen & Wieczorek, 2005; Loorbach et al., 2017). Based on existing definitions in the literature (Geels, 2018; Lorbach et al., 2017; Markard et al., 2012; Schlaile and Urmetzer, 2021), this dissertation refers to sustainability transitions as fundamental change processes to solve 'grand challenges', encompassing shifts in domains such as business, governance, technology, practices, and cultural meanings toward more sustainable modes of production and consumption.

The literature distinguishes between different analytical perspectives on sustainability transitions (Loorbach et al., 2017; Ollivier et al., 2018; Peter & Swilling, 2014). One major perspective focuses on socio-technical transitions (STT), which refer to the co-evolution of society and technology toward sustainability (Geels, 2005). Research on STT emerged from the field of innovation studies (Geels, 2019; Kern, 2012; Smith et al., 2010), and utilizes innovation to understand system dynamics such as path-dependencies, lock-in, and disruption (Loorbach et al., 2017). Another significant perspective concentrates on the sustainability of coupled social-ecological systems (SES). Within SES literature, a central objective is the pursuit of resilience through transformation and adaptation (Olsson et al., 2014; Reyers et al., 2022; Walker et al., 2004). Resilience refers to the capacity of SES to absorb disturbance and recombine themselves to allow continuous development (Folke, 2006). Collectively, innovation as part of STT and resilience as part of SES are important lenses to understand how system dynamics inform sustainability transitions.

1.2.1 Sustainability Transitions and Innovation

The Multi-Level Perspective (MLP, Geels, 2002; Rip & Kemp, 1998) is the most popular framework in the field of STT. The MLP defines three analytical levels: niches, socio-technical regimes, and the socio-technical landscape. 'Niches' describe spaces where radical innovations emerge and develop. 'Socio-technical regimes' refer to the dominant practices, rules, institutions, and technologies. The 'socio-technical landscape' represents the broader exogenous context. Technological niches provide a protective environment for radical and disruptive innovations to develop independently from existing market pressures, forming the seeds of sustainability transitions (Geels, 2019).

Following the MLP, socio-technical change results from relatively short-term interactions between the regime and niche levels and from longer-term interactions between the

niche and landscape levels (Geels & Schot, 2007). An incumbent socio-technical regime is the result of various lock-in mechanisms that reinforce technological path dependencies (Klitkou et al., 2014). However, exogenous landscape shocks, such as climate change, can put pressure on the regime to create windows of opportunity for radical niche innovations to emerge and transform the socio-technical regime (Schot & Geels, 2008). This breakout of radical innovations from niches occurs gradually, as the innovations are used in subsequent applications and domains (Geels, 2002).

Within the MLP framework, not all niche innovations eventually become transformative as radical innovations can end up fitting and conforming to an existing socio-technical regime (Raven et al., 2016; Smith & Raven, 2012). While fitting and conforming to the regime implies that innovations end up fitting into existing rules and institutions, stretching and transforming the socio-technical regime results in a deeper change of the system toward sustainability, including its institutions, practices, and rules (Smith & Raven, 2012). For instance, smartphones made from sustainable materials exemplify fit and conform innovations when they seamlessly merge into existing markets. In contrast, electric vehicles can stretch and transform the regime if they not only replace traditional cars but also drive systemic changes, such as promoting new infrastructure like charging stations, influencing urban planning, and shifting public policies. Whether the innovation for sustainability fits and conforms to the regime or stretches and transforms the regime depends not only on niche-internal factors such as price and performance but also on whether the innovation can mobilize resources and collective action that influence selection environments to become favorable to the innovation (Smith & Raven, 2012).

The MLP can be used as a heuristic to assess policies to govern sustainability transitions (Borrás & Edler, 2020; Kern, 2012). Governance can entail policies to support technological niches, for instance through research and development funding schemes, targeted subsidies, innovation platforms, or relaxing regulatory conditions for experimentation (Kivimaa & Kern, 2016). Governance of sustainability transitions can also involve the targeted discontinuation of the existing regime, for instance, through phasing out existing technologies (Stegmaier et al., 2014). Discontinuation also requires the management of regime resistance (Johnstone & Newell, 2018), as the incumbent regime may attempt to slow the pace of transitions through coalitions and relationships with state institutions (Aklin & Urpelainen, 2013).

A related, more explicitly policy-oriented framework for sustainability transitions is the technological innovation systems framework (TIS, Bergek et al., 2008). A TIS comprises actors, and institutions that operate in a technological context (Köhler et al., 2019). The TIS emphasizes the significance of dynamic interactions among network members that facilitate the

development, diffusion, and implementation of innovations within a specific institutional infrastructure (Markard et al., 2012).

The TIS framework has been applied, for instance, to the study of new energy technologies (Li et al., 2022; Nevzorova & Karakaya, 2020), exploring how these technologies emerge, along with related policy support, cooperation, and global knowledge flows. Recently, the TIS has also been used in the context of technological life cycles (Markard, 2020) to demonstrate that sustainability transitions are not final but part of a wider phenomenon of technological emergence and decline. An advantage of the TIS is that it provides a useful heuristic for examining internal dynamics of technological innovation systems (Walz et al., 2016). In comparison to the explicit consideration of niche-regime interactions in the MLP, the TIS is less descriptive of feedback mechanisms between the technological innovation system and the larger socio-technical environment (Köhler, 2016).

Taken together, prominent approaches to Socio-Technical Transition (STT) emphasize how innovations can facilitate sustainability within a complex interplay among various actors and processes at different levels of a socio-technical system. A key point is that sustainability transitions through innovation are not solely the result of specific characteristics of innovation but also depend on a broader societal context that nurtures and empowers innovation through various actors, institutions, and the emergence of novel practices and networks.

1.2.2 Sustainability Transitions and Resilience

While STT research explores the intersection of society and technology, SES research focuses on the interdependent connections between social and environmental changes. A fundamental principle within SES is that human well-being, as well as consumption and production patterns, are influenced by economic, social, and environmental factors, considering that humans depend on ecosystems for vital services (Arrow et al., 1995; Folke, 2006). Transitions within SES can manifest in either the ecological or social spheres (Loorbach et al., 2017). While human activities can drive SES beyond certain tipping points and planetary boundaries (Galaz et al., 2012), transitions within the social domain can also sustain or enhance ecosystem stability (Loorbach et al., 2017; Olsson et al., 2014). Similarly, environmental pressures can precipitate shifts in the social sphere. Recognizing these dynamics is essential for guiding SES towards sustainable development pathways, underscoring the importance of understanding how these systems respond and adapt to changes (Folke, 2006).

Resilience refers to the capacity of SES to maintain system functioning in the face of disturbances (Walker et al., 2004). Resilience involves not just the passive absorption of shocks

but also the ability to adapt, transform, and reorganize, which leads to innovation and development (Folke et al., 2010; Walker et al., 2004). This conceptualization of resilience - as a system's capacity to absorb, adapt, and transform - extends beyond specific disciplines, influencing, for instance, approaches to resilience in health systems (Fridell et al., 2020; Gilson et al., 2017) and organizational resilience (Hillmann, 2021; Ortiz-de-Mandojana & Bansal, 2016).

Resilience is linked with sustainability because both concepts are fundamentally concerned with systemic survival. Against the backdrop of an uncertain future, resilience captures the means to adapt and persist, which are important foundations for achieving sustainability goals such as intergenerational equity in the long term (Xu et al., 2015). Furthermore, sustainable development depends on resilience as sustainability cannot be achieved in a stable equilibrium given that increasing complexities and volatilities require constant adaptation from systems (Fiksel, 2006).

In the context of SES, a loss of resilience can lead SES toward unsustainable trajectories as they lose the adaptive capacity for reorganization and renewal (Xu et al., 2015). In contrast, resilient SES can sustain social and economic well-being without reducing resource stocks below critical thresholds (Xu et al., 2015). Through their capacity to adapt and reorganize, resilient SES can transform into more sustainable configurations that better align human-environment interactions. Another argument is that resilient systems, thanks to their robustness, are less disturbed by external shocks, enabling them to consistently pursue and achieve sustainability goals (Marchese et al., 2018).

A key concept for resilience within sustainability science is the idea of panarchy (Berkes and Ross, 2016). Panarchy illustrates how complex systems operate in nested, interdependent adaptive cycles across different temporal and spatial scales (Gunderson & Holling, 2002). Adaptive cycles transition through phases of growth, stasis, collapse, reorganization, and renewal. Resilience arises from the interplay between adaptive cycles at different scales. Lower-order, faster-moving cycles can overwhelm higher-order, slower-moving cycles through rapid change, whereas higher-order cycles can restore lower-order cycles through their 'memorizing' capacities for renewal. Panarchy thus illustrates the interplay of change and stability within complex systems and the dependence of resilience on both higher- and lower-order influences across time (Folke, 2006).

1.2.3 Integration of Innovation and Resilience Research in Sustainability Transitions

Although innovation and resilience approaches share common ground in placing sustainable development within the context of transitions, they adopt distinctive perspectives on how these transitions are conceptualized. In STT research, the emphasis is on the transformation of the system through innovation, implying a transition toward a more sustainable state. In contrast, resilience approaches are concerned with stabilizing system dynamics within sustainable pathways, which can include transitions to new stability domains (Folke et al., 2010; Moore et al., 2014). Therefore, STT approaches focus on transition management toward new, sustainable paradigms, whereas SES approaches prioritize adaptive management to maintain the ability of SES to adapt to complex and uncertain changes (Voß & Bornemann, 2011)

Despite their conceptual differences, both innovation and resilience approaches link sustainability to managing non-linear change processes in complex systems that involve multi-actor dynamics (Loorbach et al., 2017; Voß & Bornemann, 2011). Both STT and SES entail a multi-level perspective, where sustainability transitions arise from the intricate interplay of lower and higher-order processes. In the STT literature, higher-order socio-technical regime shifts are precipitated by the emergence of lower-level technological niches (Geels, 2002), while in the SES literature, panarchy demonstrates how fast-moving 'revolts' originating from lower-order adaptive cycles can drive system transformation by triggering a process of collapse and renewal (Olsson et al., 2022).

STT and SES approaches provide opportunities for integration (Ollivier et al., 2018). For instance, novelty and innovation are important mechanisms through which resilient systems achieve transformation and remain within critical thresholds (Folke et al., 2010). Similarly, the concept of lock-in in socio-technical regimes can be addressed with concepts from resilience thinking, such as 'lock-in traps' (Allison & Hobbs, 2004; Ollivier et al., 2018), where highly resilient but unsustainable regimes persist due to high connectivity and a low ability to change.

1.3 Individual Behavior and Sustainability Transitions

In the social sciences, research can be categorized into micro- and macro-level approaches[2] (Goldspink & Kay, 2004; Raub & Voss, 2017). Macro-level research focuses on broader system dynamics, such as societal structures, institutions, and norms, to describe and explain system behavior. Conversely, micro-level research concentrates on individuals,

[2]Although the focal point of this chapter is the micro-macro link, social scientists also explore the meso-level, which encompasses social contexts such as groups, communities, or organizations. There have been calls within innovation and resilience research to bridge the micro- and macro-levels by examining individual behavior within meso-level social units, including organizations (e.g., Bergström and Dekker, 2014; Upham et al., 2020).

including their cognitions, affects, and behaviors, examining how intrinsic and extrinsic factors shape individual responses. Thus, while macro-level research addresses globality, structures, and systems, micro-level research delves into actors, behaviors, and agency (Alexander, 1987).

Following a microfoundations perspective in sociology, macro-level phenomena are understood to emerge from individual actions (Jepperson & Meyer, 2011; Raub et al., 2014). The link between micro- and macro-level phenomena finds prominent illustration in the so-called 'Coleman boat' scheme (Coleman, 1986; 1990), which depicts individual behaviors leading to societal outcomes through mechanisms of aggregation, and vice versa, societal phenomena influencing individual behavior through transformative mechanisms. In addition, the microfoundations literature emphasizes social interactions and group dynamics (Jepperson & Meyer, 2011), noting that interactions between individuals produce complex, often unpredictable emergent outcomes at higher levels (Barney & Felin, 2013). Taken together, microfoundation approaches can provide depth and texture to accounts of macro-level relationships, analyzing the evolution of collective phenomena as a function of individual behavior and social interactions (Hollands, 2023; Powell & Rerup, 2017).

Microfoundations approaches can enhance the understanding of sustainability transitions by examining the relationship between dynamics of societal, technological and environmental change and individual behavior. Microfoundations research can focus on everyday practices such as consumption, recycling, or commuting, as they mediate between individual agency and structural outcomes, acting as a source of empowerment or inertia for transitions (Kaufman et al., 2021). A microfoundations perspective can further explore how individuals perceive sustainability transitions, identifying cognitive and affective processes that motivate individuals toward private and public engagement in sustainability-related behaviors. Further, as tensions and controversies are often central to transition processes (Sengers et al., 2019), a microfoundations perspective can enhance the understanding of how these conflicts manifest at the individual level, for instance in the form of resistance to sustainability-related policies and innovations. In essence, individuals can be considered the ultimate agents of sustainable change and hence much depends on their motivation and commitment (Sen, 2016).

As highlighted in a review of the STT literature by Kaufman et al. (2021), individual behavior is a 'significant, underdeveloped area in transitions' (p. 2), indicating a gap in understanding the connection between behavior change and system change. In SES research, several scholars have employed agent-based modeling to conceptualize the link between individual behavior and resilience (e.g., Egli et al., 2019; van Strien et al., 2019). However, the SES literature has been less developed in incorporating social and psychological theories of

decision-making, continuing to predominantly utilize economic models of rationality (Schlüter et al., 2019; van Voorn et al., 2019). Theories from environmental psychology, such as the Theory of Planned Behavior (TPB, Ajzen, 1991; 2012) and the Value-Belief Norm Model (VPN, Stern et al., 2019), have significantly contributed to understanding pro-environmental behavior (e.g., Ateş, 2020; Gkargkavouzi et al., 2019; Klöckner, 2013; Oreg & Katz-Gerro, 2006). Yet, this field has primarily focused on explaining behaviors within the private sphere (Liobikienė & Poškus, 2019; Lülfs & Hahn, 2014), and less is known about how these private sphere behaviors translate into system change. Therefore, the question arises as to what analytical perspectives can explain what motivates individual engagement in sustainability transitions. Systematic approaches that describe how individuals perceive and contribute to innovation and resilience could offer valuable insights into individual roles in sustainability transitions.

1.3.1 Individual Behavior and Innovation

The literature suggests that the diffusion of innovations depends on individual perceptions of innovations and their subsequent adoption behavior (Agarwal & Prasad, 1997; Rogers, 1962). A key mechanism through which individual adoption leads to diffusion is through peer networks (Kaminski, 2011; Valente, 1996). Within these networks, individuals exhibit varying propensities toward adopting new innovations (Deroıan, 2002; Kaminski, 2011), and their adoption decisions are influenced by the adoption status of a critical mass within their peer group (Valente, 1996). This observation aligns with the microfoundations perspective, suggesting that collective innovation adoption is not merely the sum of individual decisions but is fundamentally driven by social interactions related to the innovation.

In the context of sustainability transitions, the adoption of sustainable innovations by consumers can significantly boost sustainable production and sustainability-related business models (Kaufman et al., 2021). Entrepreneurial adoption of innovation can drive market transformations and establish new industry standards, thereby reinforcing the spread of sustainable practices across sectors. In addition, support from influential figures, such as politicians and business leaders, can influence policymaking related to innovation, encouraging experimental approaches, and facilitating market access. However, the STT literature still lacks an overall definition and structure of actors and their impact on innovation (Fischer & Newig, 2016). Thus, devising systematic approaches that link individual innovation adoption to the broader success of sustainability transitions offers a valuable direction for future research.

Research on individual innovation adoption during sustainability transitions can benefit from incorporating an uncertainty management perspective. Radical innovations introduce significant uncertainty (Hoeffler, 2003; Lin-Hi et al., 2022), especially when regime-changing innovations alter norms, practices, and socio-economic structures. These perceived uncertainties can significantly impact individual decision-making. Individuals who are uncertain about benefits or wary of risks may resist adopting novel innovations, which can influence the pace and direction of sustainability transitions. While some scholars in the STT literature have acknowledged the role of uncertainty perceptions in innovation adoption (e.g., Eastwood & Renwick, 2020; Meijer et al., 2006), their analyses often encompass a broad range of actors and lack a precise focus on the individual level.

1.3.2 Individual Behavior and Resilience

Resilience and adaptation in social-ecological systems (SES) depend on transformative processes, where individual determinants such as worldviews, values, and cognitions play an important role in understanding individual engagement (O'Brien & Sygna, 2013; Pelling et al., 2015). A key psychological factor influencing individual engagement in resilience-building is the concept of individual agency (Brown & Westaway, 2012; Cinner & Barnes, 2019; Westley et al., 2013). In the resilience discourse, agency transcends simple free will, embodying the belief that one's actions can significantly impact the system (Cinner and Barnes, 2019; Coulthard, 2012). Exploring individual agency can uncover mechanisms of collective agency, revealing shared meanings and values that guide the direction and design of sustainability-oriented transformative change (Charli-Joseph et al., 2018).

Individual agency plays an important role in explaining variations in people's adaptive behaviors in response to environmental threats, as their perceived self-efficacy in coping with shocks informs their efforts to prepare and adapt to environmental change (Blennow & Persson, 2009; Brown & Westaway, 2011). A strong sense of agency can motivate individuals to become change agents, using crises as opportunities for resilience-driven innovation and entrepreneurship (Westley et al., 2013). Moreover, research suggests that individual agency can empower people to engage in experimental solutions for resilience and to share their insights through social learning (Otsuki et al., 2018).

An uncertainty management perspective can provide valuable insights into when and how individuals contribute to resilience. The Uncertainty Reduction Theory (URT, Berger & Calabrese, 1974; Miller & Jablin, 1991) suggests that individuals seek to reduce uncertainties in their environment through information-seeking behaviors. This drive to reduce uncertainties

could motivate individuals to work together and develop methods for improving adaptive capabilities, such as engaging in social learning and collective efforts towards resilience-promoting policies. In addition, an uncertainty management perspective can shed light on why individuals participate in resilience-building activities to varying degrees. For instance, research suggests that the perception of risks affects individuals' readiness to adapt and adopt environmentally friendly behaviors, by increasing the subjective value of preparedness (e.g., Bradley et al., 2020; Osberghaus et al., 2010; Wachinger et al., 2013). Considering that uncertainty is frequently experienced as an uncomfortable or aversive feeling (van den Bos, 2009), unresolved uncertainty could lead individuals to withdraw from proactive change efforts, potentially impeding resilience.

1.2.3 An Uncertainty Management Perspective for Individual Behavior and Sustainability Transitions

Although innovation adoption and agency are two distinct approaches to understanding when and how individuals contribute to sustainability transitions, they are not mutually exclusive. For example, the literature on STT has employed the concept of agency to emphasize the role of collective and individual actors in sustainability transitions (e.g., Fischer & Newig, 2016; Huttunen et al., 2021). Similarly, resistance to innovation can limit the options available for individuals to adapt, potentially reducing their perceived agency in coping with change. In addition, there is a possibility that agency and innovation adoption may conflict in the context of sustainability transitions. For instance, an overreliance on technological solutions or private adaptation strategies to address sustainability challenges can hinder comprehensive approaches that integrate adaptive capacity building and innovation.

An uncertainty management perspective offers an integrative approach to linking individual behaviors with sustainability transitions. Sustainability transitions arise from highly complex systems and are characterized by non-linear changes and limited predictability (Peter & Swilling, 2014; Turnheim et al., 2015). An uncertainty management perspective examines how macro-scale uncertainties, stemming from non-linear changes in complex systems, affect individual perceptions and behavior. During sustainability transitions, individuals must manage uncertainties resulting from profound changes in societal systems such as business, consumption, practices, and norms. Moreover, individuals need to navigate uncertainties related to external shocks, such as climate change and crises that disrupt everyday life and require adaptation. Research suggests that individuals exhibit various cognitive, emotional, and behavioral responses to uncertainty (Bottesi et al., 2019; Brashers, 2001). Analyzing these

responses can provide insights into when and how individuals contribute to sustainability transitions. The following discussion presents two ways in which an uncertainty management perspective can be integrated into research on sustainability transitions.

First, an uncertainty management perspective can focus on individual uncertainty perceptions. Research based on perception can identify key uncertainties within the transition environment and assess how they influence individual behavior. For instance, in the context of adopting renewable energy technologies, individuals might perceive significant uncertainties regarding the reliability, cost, and technical compatibility of these innovations. An uncertainty-based approach can reveal how perceptions of risk and benefits around such contingencies - like potential power interruptions or upfront installation costs - affect whether individuals choose to adopt these innovations or remain reliant on traditional energy sources.

Second, an uncertainty management perspective can examine how individuals respond to uncertainty. This research can shed light on whether disruptive events, such as radical innovations or systemic shocks, catalyze new behavioral patterns that, at the micro-level, can either facilitate or impede sustainability efforts. This perspective delves into the cognitive-affective states and behaviors that emerge in response to uncertain situations, going beyond mere perceptions of uncertainty. For instance, in the aftermath of a natural disaster - a systemic shock that introduces high levels of uncertainty - communities may adopt new behaviors in response to the disruption. These behaviors could include the development of community-based disaster response strategies, demonstrating how uncertainty can catalyze collective learning and resilience.

In sum, adopting an uncertainty management perspective offers a nuanced approach to understanding individual contributions to sustainability transitions. This perspective shifts the focus from top-down strategies to a more individual-centric analysis, recognizing the importance of individual agency and perceptions of contingencies in managing broader systemic change.

1.3 Aims and Structure of the Dissertation Thesis

The aim of this dissertation is to provide a novel perspective on how individuals contribute to innovation and resilience in the context of sustainability transitions. It focuses on individual perceptions and behaviors, aiming to enrich the discourse on microfoundations approaches in sustainability management. By employing an uncertainty lens, the dissertation seeks to offer an integrative view, illustrating how individuals' experiences of uncertainty relate to their contribution to innovation and resilience.

The dissertation explores individual contributions to innovation in the context of novel health technologies, radical innovations for sustainable consumption, and digital change. The dissertation approaches individual contributions to resilience in the context of food system resilience and health system resilience. In addition, in response to calls to link the micro- and macro-level in resilience research by observing behavior at the meso level (Bergström & Dekker, 2014), the dissertation investigates the role of individuals for organizational resilience.

Different theoretical approaches, such as cognitive dissonance theory, URT, and uncertainty-based conceptual frameworks, along with qualitative analysis, are employed to incorporate the uncertainty management perspective. Through a combination of quantitative and qualitative studies, cross-sectional and longitudinal data collection, and field experiments, and by conducting single-level and multi-level analyses and examining both attitudinal and behavioral outcomes, the dissertation aims to harness a broad spectrum of social science tools to provide an in-depth understanding of individual perceptions and responses. To further enrich this understanding, the dissertation investigates diverse topics, including organizational change, food innovation, digitalization, and healthcare, and it considers the perspectives of various stakeholders, such as blue-collar and white-collar workers, technology users, consumers, and managers. The goal is to deliver a comprehensive and nuanced view of how individuals engage with sustainability transitions and to offer insights that can inform sustainability management and policy strategies. The next section will provide summaries of the four studies that constitute the dissertation.

1.3.1 The role of ethics in technology acceptance: analysing resistance to new health technologies on the example of a COVID-19 contact-tracing app

Article 1 explores the role of individual uncertainty perceptions for acceptance of novel health technologies. Novel health technologies can inform crisis management and improve the resilience of healthcare systems, contributing to the sustainable development goal (SDG) of good health and well-being (SDG 3).

The literature offers various theoretical frameworks for deriving acceptance factors for novel technologies. Among the most influential theories are the Technology Acceptance Model (TAM, Davis et al., 1989) and the Unified Theory of Acceptance and Use of Technology (UTAUT, Venkatesh et al., 2003). The existing frameworks suggest that technology acceptance results from cognitive, affective, and normative appraisal processes. Article 1 is based on this fundamental logic but does not explicitly draw on existing technology acceptance frameworks, as the novel health technology was not yet available to users. For TAM and UTAUT to apply,

users must be able to reliably assess the characteristics of a technology, such as its usefulness and ease of use (Fox et al., 2021).

To derive acceptance factors for novel health technologies, Article 1 proposes an uncertainty-based conceptual framework. The proposed acceptance factors relate to uncertainty-coping mechanisms, uncertainty-related health perceptions and uncertainty-reducing personal characteristics. Considering that innovations, in particular in complex sectors like healthcare, introduce significant uncertainties (Dew & Sarasvathy, 2007; Fisher et al., 2012), ethics is posited as a powerful mechanism to reduce user uncertainties. Article 1 incorporates ethics as an uncertainty-coping mechanism in the form of ethical optimism and perceived governmental responsibility. The other proposed acceptance factors, derived from the literature on health technology acceptance, relate to uncertainty-related health perceptions (perceived health threat) and uncertainty-reducing personal characteristics (positive privacy attitudes, technology readiness). The uncertainty-based conceptual framework was tested via structural equation modeling using online survey data from 1145 German participants, focusing on acceptance of a COVID-19 contact tracing app.

Results from Article 1 underscore the impact of acceptance factors related to uncertainty-related health perceptions and uncertainty-reducing personal characteristics on acceptance of novel health technologies. In addition, the findings from Article 1 support the notion that uncertainty-coping mechanisms in the form of ethical optimism and governmental responsibility positively affect health technology acceptance.

As a theoretical contribution, Article 1 demonstrates the role of ethics in the acceptance of novel health technologies. The uncertainty-based conceptual framework proposed in Article 1 could inform further theory building on the acceptance of novel health technologies. As a practical contribution, the findings from Article 1 contribute to the management of innovation-oriented public health campaigns, by identifying health technology acceptance factors and demonstrating the positive contribution of ethics.

1.3.2 The How and Why of Organizational Resilience: A Mixed-Methods Study on Facilitators and Consequences of Organizational Resilience Throughout a Crisis

Article 2 examines individual responses to uncertainty by analyzing how managers of companies in the Global South understand and achieve organizational resilience during crises. Through ensuring organizational survival, organizational resilience can contribute to sustainable economic growth (SDG 8), sustainable consumption and production patterns (SDG 12), and insulate employees from crisis-induced stressors (SDG 3).

The article is situated within the wider academic debate on conceptualizations of organizational resilience. The literature on organizational resilience is highly fragmented (Linnenluecke, 2017) with no unifying theory toward organizational resilience existing. A review by Duchek (2020) lists three common analytical perspectives toward organizational resilience, conceptualizing organizational resilience as an outcome, a capability, or a process. The understanding of organizational resilience in Article 2 is grounded in more recent integral perspectives (e.g., Darkow, 2019; Duchek, 2020). Article 2 approaches organizational resilience as a dynamic meta-capability that evolves over time and builds on facilitators tied to an organization's behaviors, resources, and capabilities.

Article 2 explores facilitators of organizational resilience, building on the resource-based view of the firm (Barney, 1991), which posits that a firm's sustained competitive advantage depends on internal rather than external factors (Barney, 1995). In addition, Article 2 applies the job demand-resources model (JDR, Bakker and Demerouti, 2007), which states that employee well-being depends on a balance between job resources and stressors. Article 2 employs JDR to argue that organizational resilience is an important job-related resource that can mitigate employee emotional exhaustion during crisis. Using a mixed-methods multi-study approach, Article 2 presents results from qualitative interviews with 17 Pakistani decision-makers in textile factories during the COVID-19 crisis, and from a longitudinal survey series among 146 Pakistani middle- to upper-level managers.

The qualitative results from Article 2 indicate a broad set of organizational resilience facilitators, which can be differentiated across content-related and temporal properties. Quantitative findings confirm the central role of 'soft' facilitators, related to organizational culture, learning orientation and employee-focused practices. In terms of outcomes, results from Article 2 emphasize that organizational resilience contributes to business success and the emotional well-being of employees during crisis.

As a theoretical contribution, Article 2 advances the relatively limited body of empirical studies on organizational resilience over the course of a crisis. Furthermore, Article 2 confirms the value of integrative conceptualizations of organizational resilience in understanding organizational behavior in a crisis setting. As a practical contribution, Article 2 can inform the management of organizational resilience, underscoring the value of employee-focused practices and learning.

1.3.3 Internal Change through External Actions: The Impact of External Corporate Social Responsibility on Employee Readiness for Change

Article 3 delves into how external organizational activities relate to individual change-related uncertainties and employee readiness to change. Organizational change can be a foundation of sustainable growth (SDG 8) and innovation (SDG 9). However, the success of organizational change depends on employee support (Erwin & Garman, 2010).

The management literature has identified various change-facilitating organizational practices but lacks a structured theoretical approach toward employee readiness for change. Most practices investigated for increasing employee readiness for change can be considered internal and employee-oriented such as change communication (Faupel & Helpap, 2021) or change participation (Jimmieson et al., 2008). A possible reason for the effectiveness of these internal practices is that they alleviate change-related uncertainties, through involving employees in the change process.

Based on these considerations, Article 3 argues that external organizational activities can contribute to employee readiness for change if they reduce change-related uncertainties. The theoretical foundation for this argument lies in the URT. Following URT, individuals aim to reduce uncertainty through information-seeking behaviors. Article 3 contends that external organizational activities (i.e., organizational interactions with external stakeholders) reduce uncertainty for employees as they create predictability in organizational behavior. Specifically, Article 3 suggests that external corporate social responsibility (CSR) can act as a signal that the organization is committed to the well-being of its stakeholders, increasing the perception of organizational support (POS) and reducing change-related uncertainty. Article 3 embeds these relationships in a sequential mediation model where external CSR increases POS, and POS decreases change-related uncertainty, which in turn leads to higher employee readiness for change. The proposed model was tested using structural equation modeling on a sample of 377 employees from 29 organizations undergoing digitalization.

Results from Article 3 provide support for the notion that external organizational activities increase employee readiness for change by increasing POS and reducing change-related uncertainty. In addition, findings from Article 3 underscore the critical role of POS, as POS not only reduced change-related uncertainty but also directly increased employee readiness for change.

As a theoretical contribution, Article 3 provides the first evidence that external organizational activities can contribute to employee readiness for change. In addition, Article 3 contributes to URT by indicating that observing external organizational activities can reduce change-related uncertainties. As a practical contribution, Article 3 emphasizes the role of external CSR in increasing employee readiness for change. The pursuit of external CSR can

create win-win situations for the management of sustainability transitions, as both CSR (Schönherr et al., 2017) and organizational change (Olafsen et al., 2021) can contribute toward sustainable development.

1.3.4 The performative effect of radical innovations for sustainable consumption: An experimental investigation on the example of cultured meat

Article 4 focuses on individual responses to uncertainty by exploring how individuals respond to future radical innovations for sustainable consumption. Radical innovations are key to sustainability transitions and can contribute to more sustainable production and consumption patterns (SDG 12), as well as to innovation and sustainable economic growth (SDG 8 and SDG 9). Radical food innovations, particularly, are needed to make progress toward a more resilient food system (Siegrist and Hartmann, 2020; SDG 2)

As a theoretical foundation, Article 4 is grounded in the theory of cognitive dissonance (Festinger, 1957). The theory of cognitive dissonance posits that psychological discomfort arises when individuals hold contradictory cognitions. Individuals are motivated to reduce this dissonance and can do so by altering their cognitions or behavior (Festinger, 1957). Research suggests that altering cognitions is often easier than changing behavior (Heimlich & Ardoin, 2008; McGrath, 2017), which explains why individuals often choose to disregard inconvenient information that challenges their unsustainable consumption habits and maintain unsustainable behavior.

Against this backdrop, Article 4 investigates whether the expectation of future radical innovations can lead to more sustainable attitudes or behaviors. In the domain of consumption, radical innovations can enable more sustainable consumption patterns as they allow consumers to satisfy their existing needs in a sustainable manner (Sharma et al., 2024). Article 4 introduces the novel perspective that radical innovations for sustainable consumption can influence consumers even prior to their market introduction, a phenomenon that the Article connotes as the performative effect of future radical innovations for sustainable consumption. "Performativity" captures the notion that expectations and visions about future technologies influence the present (Borup et al., 2006; van Lente, 2012). As an exploration of the proposed performative effect of future radical innovations, Article 4 reports findings from two experimental studies where meat-eaters were first exposed to cognitive dissonance-inducing information followed by information on cultured meat, serving as the future radical innovation for sustainable consumption in Article 4.

The results of the two experiments in Article 4 showed that awareness of the future radical innovation increased the credibility of inconvenient information and encouraged more sustainable consumption, as participants in the treatment group voiced higher belief in animal welfare concerns than those in the control group and chose fewer meat-based food options. The findings from Article 4 suggest that the expectation of radical future technologies can diminish the likelihood of defensive strategies and reduce unsustainable consumption, demonstrating the performative effect of radical future technologies to contribute toward more sustainable consumption patterns.

As a theoretical contribution, Article 4 enriches the analysis of performativity in the science and technology literature, by finding support for a mechanism in which performative expectations and visions about future innovations not only motivate efforts to realize the innovation through cooperation, institutional change and resource mobilization but also affect individual consumer behavior. As a practical contribution, Article 4 underscores that creating awareness about possible future sustainable consumption pathways can be a productive tool for sustainability management, as it can lead individuals to be more open to behavior change.

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