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The roles of knowledge intermediaries in sustainability transitions and digitalization: Academia driven fostering of socio technical transitions?

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Abstract

The concept of intermediation is central to current approaches to innovation policy. While the extant literature distinguishes between academia driven knowledge intermediaries supporting the commercialization of academic knowledge and public intermediaries focusing on the support of socio technical transition processes, little is known about the roles and activities of knowledge intermediaries in sustainability transitions and digitalization, even though the systemic coaction of different intermediaries is essential for policy making. This understudied issue is explored using an explorative-qualitative approach and empirical evidence from interviews of participants in regional knowledge intermediation initiatives. We find that knowledge intermediaries proactively contribute to the two socio technical transitions in question by performing three roles: (i) information dissemination via events, (ii) knowledge exchange via network building, and (iii) implementation support via consulting. Furthermore, we identify additional roles concerning the identification and monitoring of new projects emerging from the interplay between sustainability and digitalization. Working at the intersection of both transitions and cognizant of the effects of digitalization on sustainability, knowledge intermediaries are key actors in fostering digitalization processes that preclude rebound effects on sustainability or contribute to sustainability transitions. This paper contributes to current scholarly discussions by closing the conceptual gap between knowledge and transition intermediaries and emphasizing the interdependencies between digitalization and sustainability.

JEL: I29, O32, O39, Q29
Keywords: knowledge intermediaries; transition intermediaries; sustainability transition; digitalization; higher education institutions; qualitative case studies

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1. Introduction

Considering recent debates on pervasive transition processes, regions and their innovation systems face challenges (Grillitsch et al. 2019), in contributing to two major, intertwined transitions that affect regional innovative capacity: the successful transition toward more sustainable modes of production and consumption (henceforth, sustainability[1]; e.g., Markard et al. 2012; Kraker et al. 2013) and the transition toward the development and implementation of digital technologies (henceforth: digitalization[2]; e.g., Isaksen et al. 2021). Hence, current approaches argue for a shift in innovation policy that incorporates the complex needs of grand societal challenges and the implied socio-technical transition processes (Kuhlmann and Rip 2018; Schot and Steinmueller 2018), most importantly sustainability and digitalization (Ortega-Gras et al. 2021; Andersen et al. 2021).

Therefore, higher education institutions (HEIs) play a central role by serving their "third mission" of disseminating relevant academic knowledge throughout regions. HEIs are acknowledged as central constituents of regional innovation dynamics, with regard primarily to harnessing academic knowledge for entrepreneurship and technological innovation (Etzkowitz et al. 2000; Huggins et al. 2008; Etzkowitz and Zhou 2017; Klofsten et al. 2019). In this context, knowledge intermediaries working at the intersection between science and external stakeholders play an important role in fostering academia-industry relations and configuring HEIs' non-academic activities (Yusuf 2008; Clayton et al. 2018). However, although recent works postulate an extended understanding of HEIs' third mission (Trencher et al. 2014; Sedlacek 2013; Zilahy et al. 2009; Blume et al. 2017), evidence regarding the role of knowledge intermediaries and reciprocal transfer of knowledge between academia and non-academic regional stakeholders in transition-oriented policy approaches remains scarce.

Despite a recent upsurge in interest in intermediaries' roles in regional transitions (Vihemäki et al. 2020; van Boxstael et al. 2020; van Lente et al. 2020), knowledge intermediaries have seldom been addressed in this context (Kivimaa et al. 2017). Instead, studies of knowledge intermediaries mainly focus on their roles in commercializing academic knowledge via entrepreneurship and technology transfer (Siegel et al. 2007; Wright et al. 2008; Hayter 2016) and, more recently, on the formation of entrepreneurial and technology transfer ecosystems surrounding HEIs' local environments (Hayter 2016; Good et al. 2019). Studies of intermediary roles in regional transition processes largely focus on government-affiliated organizations (van Lente et al. 2003; Kivimaa 2014).

This paper focuses on academia-led regional knowledge intermediation initiatives and their roles in socio-technical transitions, with a view to closing the gap between two neglects identified in two closely related strands of literature: the research on knowledge intermediaries focuses on the intermediaries' supporting roles in the diffusion and commercialization of academic knowledge, while neglecting their contribution to transition processes; and research on transition intermediaries focuses on public agencies and their activities that foster the relations between public and economic actors while neglecting the possible effects of academia and knowledge transfer for socio-technical transitions. What is missing in the literature is a conceptual and empirical connection between the overlapping concepts of knowledge and transition intermediation that clarifies the former concept's roles in socio-technical transitions and thereby contributes to the superordinate understanding of regional transitions. Against this background, this paper addresses the following research questions using a qualitative empirical approach:

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[1] We follow the seminal work by Markard et al. 2012 and perceive sustainability transitions as "long-term, multi-dimensional, and fundamental transformation processes through which established socio-technical systems shift to more sustainable modes of production and consumption" (Markard et al. 2012, p. 956)

[2] We follow the recent approach by Isaksen et al. (2021) and perceive digitalization as a multifaceted process that exceeds the development of new technologies, requires the modification of regional assets and depends on "new competences and skills in the workforce, new firm competencies, new public attitudes and know-how, all supported by changes in the organizational and institutional support infrastructure of RISs." (Isaksen et al. 2021, p. 134)

RQ1: How do knowledge intermediaries contribute to sustainability and digitalization?

RQ2: Which additional roles for knowledge intermediaries emerge from interdependencies between sustainability and digitalization?

Drawing on the nascent strand of literature, we adopted an explorative and inductive qualitative approach to generate insights into the roles played by knowledge intermediaries in sustainability and digitalization. We conducted 62 interviews with intermediaries and stakeholders from four German regional knowledge intermediation initiatives in 2020. Based on a qualitative content analysis, we derived insights regarding the roles of knowledge intermediaries in regional transitions, the effects of the co-occurrence of and the interplay between regional transitions on knowledge intermediaries, and the resulting implications for knowledge intermediaries' roles in regional transitions. Hence, our results are of scholarly interest for two main reasons. First, the paper builds a bridge between research on knowledge intermediaries and research on transition intermediaries. Disentangling the relations between different intermediaries can help resolve the current fuzziness of the intermediation concept that has resulted from the broadening variety of actors and activities assessed, and which complicates the development of theory-backed approaches. Second, the paper enriches the burgeoning research on place-based transition processes by contributing to the growing trend of highlighting the interdependencies between sustainability and digitalization on a regional level.

The remainder of this paper is organized as follows. Section 2 reviews the literature on knowledge intermediaries and regional transitions. Section 3 introduces the cases and presents the methodological approach. Section 4 presents the central empirical findings. Section 5 discusses these findings against the background of extant literature, and finally, Section 6 concludes the paper by drawing some initial managerial and scientific conclusions.

2. Literature Review

2.1. Knowledge intermediaries and transition intermediaries

The concept of intermediation has gained significant attention in innovation policy and research during the last two decades (van Lente et al. 2003; Howells 2006; Stewart and Hyysalo 2008). Intermediation comprises various roles and activities that aim to enhance the productivity, connectivity, and functionality of innovation systems by fostering inter-organizational network building and knowledge exchange between different stakeholders (Howells 2006; Dalziel 2010; Nauwelaers 2011), and has come to be a central component of two related yet insufficiently interwoven strands of literature: *knowledge intermediaries* and *transitions intermediaries*.

The knowledge and technology transfer literature discusses *knowledge intermediaries* as institutions working at the intersection between academic and non-academic stakeholders to foster the transfer and commercialization of academic knowledge (e.g., Yusuf 2008; Clayton et al. 2018; Youtie and Shapira 2008). Hayter (2016, p. 636) defines *knowledge intermediaries* as "organizations that facilitate knowledge exchange between universities and external stakeholders through the creation of bi-directional, value-added network relationships". They represent a heterogeneous group of mostly HEI-owned and publicly owned actors facilitating knowledge transfer (e.g., Villani et al. 2017; Good et al. 2019). The literature on knowledge intermediaries covers two broad objectives: the roles of HEI transfer units in fostering the commercialization of academic knowledge assets via licensing and patenting (Siegel et al. 2007; Macho-Stadler et al. 2007), thereby strengthening formal university-industry linkages (Siegel et al. 2003; Debackere and Veugelers 2005; Wright et al. 2008) and promoting academic entrepreneurship (Wright et al. 2004; Lockett and Wright 2005; Markman et al. 2005; Rothaermel et al. 2007), and the formation of nascent transfer ecosystems surrounding HEIs' local environments (Miller and Acs 2017; Huang-Saad et al. 2017; Breznitz and Zhang 2019; Lahikainen et al. 2019). However, research on the contributions of knowledge transfer and knowledge intermediaries to regional transition processes remains scarce (Kivimaa et al. 2017).

Table 1. Differentiation between Knowledge Intermediaries and Transition Intermediaries (dimensions based on Mignon and Kanda 2018)

Dimension	*Knowledge Intermediaries*	*Transition Intermediaries*
Focus	Knowledge commercialization; Technology Transfer; Academic Entrepreneurship; Technological innovation	Socio-technical transition processes on system level; Systemic innovation
Definition	"Organizations that facilitate knowledge exchange between universities and external stakeholders through the creation of bi-directional, value-added network relationships" (Hayter 2016)	"Actors and platforms that positively influence sustainability transition processes by linking actors and activities, and their related skills and resources, or by connecting transition visions and demands of networks of actors with existing regimes in order to create momentum for socio-technical system change" (Kivimaa et al. 2019a)
Sources of funding	Publicly-funded by academia or government	Publicly funded by government or municipalities (national, regional, or local)
Scope of action	Mostly actor-specific; direct support via bi- or trilateral relations; recent: create entrepreneurial ecosystems	System-specific; support vision-building and network creation
Recipients of support	Academics; Students; emerging Start-ups/Spin-offs (supply side of innovation)	SMEs (demand side of innovation)
Related literature	Yusuf 2008; Debackere and Veugelers 2005; Wright et al. 2008; Youtie and Shapira 2008; Hayter 2016; Clayton et al. 2018	van Lente et al. 2003; Kivimaa et al. 2017; Kivimaa et al. 2019a; van Lente et al. 2020; Kivimaa 2014; van Boxstael et al. 2020

The sustainability transitions literature discusses *transition intermediaries* as catalyzers of change in socio-technical systems and multi-actor processes (Kivimaa et al. 2019a). Following the definition of Kivimaa et al. (2019a, p. 1072) transition intermediaries are "actors and platforms that positively influence sustainability transition processes by linking actors and activities, and their related skills and resources, or by connecting transition visions and demands of networks of actors with existing regimes in order to create momentum for socio-technical system change". In the context of transitions, key functions of intermediaries have been discussed, such as strategy development (Cramer 2020; Hamann and April 2013; Hodson and Marvin 2012), vision building (Kivimaa 2014; van Lente et al. 2003; van Boxstael et al. 2020), knowledge brokering (Barnes 2018; Janssen et al. 2020; Kanda et al. 2019; van Lente et al. 2020) and networking (Fischer and Newig 2016; Gliedt et al. 2018; Kanda et al. 2020; Loorbach et al. 2020), exchanging knowledge (Frantzeskaki et al. 2019; Kemp et al. 1998), fostering knowledge dissemination (Fischer and Newig 2016; Hyysalo et al. 2018; Sovacool et al. 2020; Hyysalo et al. 2013), and building institutions (Bush et al. 2017; Horne and Dalton 2014; Kivimaa et al. 2019b). Table 1 sums up the differences between knowledge and transition intermediaries (based on dimensions for intermediary differentiation suggested by Mignon and Kanda 2018).

Although the concepts of both knowledge and transition intermediaries are based on the same theoretical foundations and fulfill similar functions (i.e., inducing politically favored development processes by initiating, and moderating networks and cooperative endeavors between distant and dissimilar actors from different contexts), the respective strands of literature rarely establish connections between the two concepts. A deeper understanding of the effects of intermediation in innovation and transitions calls for a comprehensive assessment of intermediary activities across their respective fields.

2.2. Sustainability transitions and digitalization

The concept of transitions has been used in science, technology, and innovation research to explain large-scale changes in socio-technical systems (Geels 2005; Geels 2019) and can be understood as the relationship between long-term technological changes and customers' changing technological preferences (Kemp and van Lente 2011).

Sustainability transitions represent the systemic technological, institutional, and ecological alterations required for a comprehensive shift toward the sustainable redesign of socio-technical and societal systems (Loorbach et al. 2017). Therefore, research on sustainability transitions has discussed the multi-level interactions of various actors and their effects on system innovation (Geels 2002; Geels 2005; Markard et al. 2012; Köhler et al. 2019). Recently, spatial analyses have contributed to a remarkable body of literature (Hansen and Coenen 2015; Strambach and Pflitsch 2018; Tödtling et al. 2021) that argues that a regional scale is the scale best suited for creating comprehensive approaches to regional challenges and the associated demands of actors (Hansen and Coenen 2015).

Popularized in business media (Fitzgerald et al. 2014; Nambisan et al. 2019), the concept of digitalization originally focused on disruptive organizational change and strategies that allow for the effective integration and exploitation of emerging digital technologies, marketing channels, and business models for increases in productivity and innovation (Matt et al. 2015; Zimmermann et al. 2021). Earlier approaches have focused on challenges that firms, especially small and medium-sized enterprises (SMEs), face in transforming their organizational structures in order to meet the requirements of a digitized economy (Chen et al. 2016; Garzoni et al. 2020; Galati and Bigliardi 2019). Whereas recent approaches, often discussed in the context of *Industry 4.0*, have attempted go beyond this organizational perspective and emphasized the relevance of different spatial innovation contexts requiring institutional adaptions that allow for effective support of digitalization (Kopp et al. 2016; Reischauer 2018). Despite the supposed nullifying effects of digital technologies on spatial peculiarities, these approaches emphasize the importance of trust-based network relations (Götz and Jankowska 2017) and the concerted bottom-up creation of a common understanding of digitalization, place-based support instruments, and digital infrastructure (Hervas-Oliver et al. 2019; Hervas-Oliver et al. 2021). In a recent study, Isaksen et al. (2021) illustrate that non-appealing regional innovation structures may hamper organizational transformation processes and, just like firms, regional innovation structures may need to re-use existing digital assets, create new regional assets, and remove non-functioning structures and assets in order to support digitalization.

Despite the ubiquity of digitalization, it remains underrepresented in transition research (Andersen et al. 2021). Only recently, and mostly in response to high-level policy strategies that claim a digital and sustainable 'twin transition' (European Commission 2019), has a burgeoning strand of literature started to assess the interdependencies between sustainability and digitalization on an organizational level (see Del Río Castro et al. 2021 for an overview). These works acknowledge digitalization as both a key element and a driver of sustainable production, as it supposedly supports resource efficiency and can lead to 'digital sustainability' (George et al. 2021; Bican and Brem 2020). Accordingly, the steady enhancement of information and communication technologies is perceived as a means of reducing traffic emissions, while Big Data is seen as an important instrument of resource management and circular economy (e.g., Boone et al. 2017; Rosa et al. 2020; Antikainen et al. 2018). However, despite a predominantly positive perception of the effects of digitalization on sustainability, recent works also highlight the threat of unintended negative effects (e.g., Stock et al. 2018). In this

vein, Liu et al. (2019) emphasize the importance of assessing the relationship between the fostering of sustainability for increasing resource efficiency and the increase of demand for resources through the expansion of digital infrastructure. Initial studies assessing the underlying relation between an increased intensity of carbon emissions and an emission reduction via the enhancement of cross-industry spillovers indicate a preponderance of the latter (Wang et al. 2021). Unfolding positive effects requires coherent place-based policy approaches making the best use of both digital technologies and 'analogous' knowledge spillovers in order to develop appealing agendas for a sustainability-oriented use and development of increasingly digitalized environments (Linkov et al. 2018; Scholz 2016).

2.3. HEIs and knowledge intermediaries in regional transitions

Although studies on the role of universities in regional development processes postulate the incorporation of regional transition processes (Trencher et al. 2014; Sedlacek 2013; Zilahy et al. 2009; Blume et al. 2017) and a 'change agent' role for universities (Peer and Stoeglehner 2013), evidence regarding the role of knowledge intermediaries in this context remains scarce.

By focusing on the promotion of knowledge and technology transfer via commercialization and academic entrepreneurship, knowledge intermediaries act as meso-level connectors between faculties, academic management, and the regional ecosystem and thus stimulate digital innovation that fosters sustainability transition (Paniccia and Baiocco 2018). Furthermore, HEIs can contribute to regional transitions via outreach activities. These activities comprise different forms of informal engagement in non-academic contexts that call for a certain level of institutionalization and can support the ongoing knowledge exchange between academic and non-academic actors required for both transition processes (Radinger-Peer and Pflitsch 2017) and the emergence of transdisciplinary projects as a driver of transition processes (Stephens et al. 2008). However, hitherto, the roles of HEIs in regional development processes have been assessed mostly from an economic perspective (Radinger-Peer et al. 2021). As HEIs and their intermediaries often focus their activities on the promotion of technological innovation processes, they lack the specialized resources and capabilities to promote the commercialization of sustainability-related inventions (Kivimaa et al. 2017). Hence, the incorporation of sustainability-related aspects has been described as insufficient. Accordingly, Kivimaa et al. (2017) propose the broadening of existing entrepreneurial ecosystem concepts in order to meet the increasing demands and advance co-creation for sustainability.

Knowledge intermediaries have advanced from solely academia-oriented supporters of commercialization toward a major constituent of regional development dynamics and a node of regional knowledge transfer and academic entrepreneurship. However, it remains unclear if (and if so, how) they make use of this exposed position to contribute to sustainability and digital regional transition processes. The scarcity of research is in spite of the consideration of sustainability and digital transitions in (academic) entrepreneurship. For instance, Lamine et al. (2018) point toward the interdependencies between business incubation and sustainable regional development, while Schaltegger et al. (2018) denote a conceptual overlap between sustainable development and entrepreneurship in the drive for inter-organizational collaboration. On the other hand, Secundo et al. (2020) support the recently suggested "digital transformation of innovation and entrepreneurship" (Nambisan et al. 2019) by examining the concept of digital academic entrepreneurship and arguing for the assessment of 'Digitally supported University-based Entrepreneurial ecosystems'.

In sum, two current developments indicate a role for knowledge intermediation in regional transition processes and call for further investigation. First is the development of knowledge transfer, intermediaries, and HEIs' 'third mission', toward a more holistic perception of knowledge transfer. Second is the recent emphasis on sustainability and digitalization in innovation systems and (academic) entrepreneurship. Extant research regarding the role of HEIs in societal transition processes almost exclusively refers to sustainability, whereas research addressing HEIs in the context of digitalization assesses the peculiarities of digitizing universities on an organizational level (Castro Benavides et al. 2020).

3. Methodological approach

We chose an exploratory, inductive approach to analyze the roles and contributions of knowledge intermediaries in sustainability and digitalization (Yin 2018; Eisenhardt 1989). The exploratory approach gave us the opportunity to shed further light on the roles of knowledge intermediaries in transitions. Such explorative, inductive approaches have proven auspicious in identifying intermediary roles in particular topics (Polzin et al. 2016; Kanda et al. 2018; Kivimaa et al. 2020; Klewitz et al. 2012).

We adopted a regional scope, as the collaborative development of regional innovation capabilities is a key element of German innovation policy (Eickelpasch and Fritsch 2005). The four selected cases are established, publicly funded regional knowledge intermediation initiatives in the regions of Darmstadt (Case A), Eberswalde (Case B), Augsburg (Case C), and Goettingen (Case D), with HEIs coordinating and leading the initiatives (see Table 2). These cases allow for an analysis based on heterogeneous regional innovation policy approaches and incorporation of different intermediation and knowledge transfer strategies.

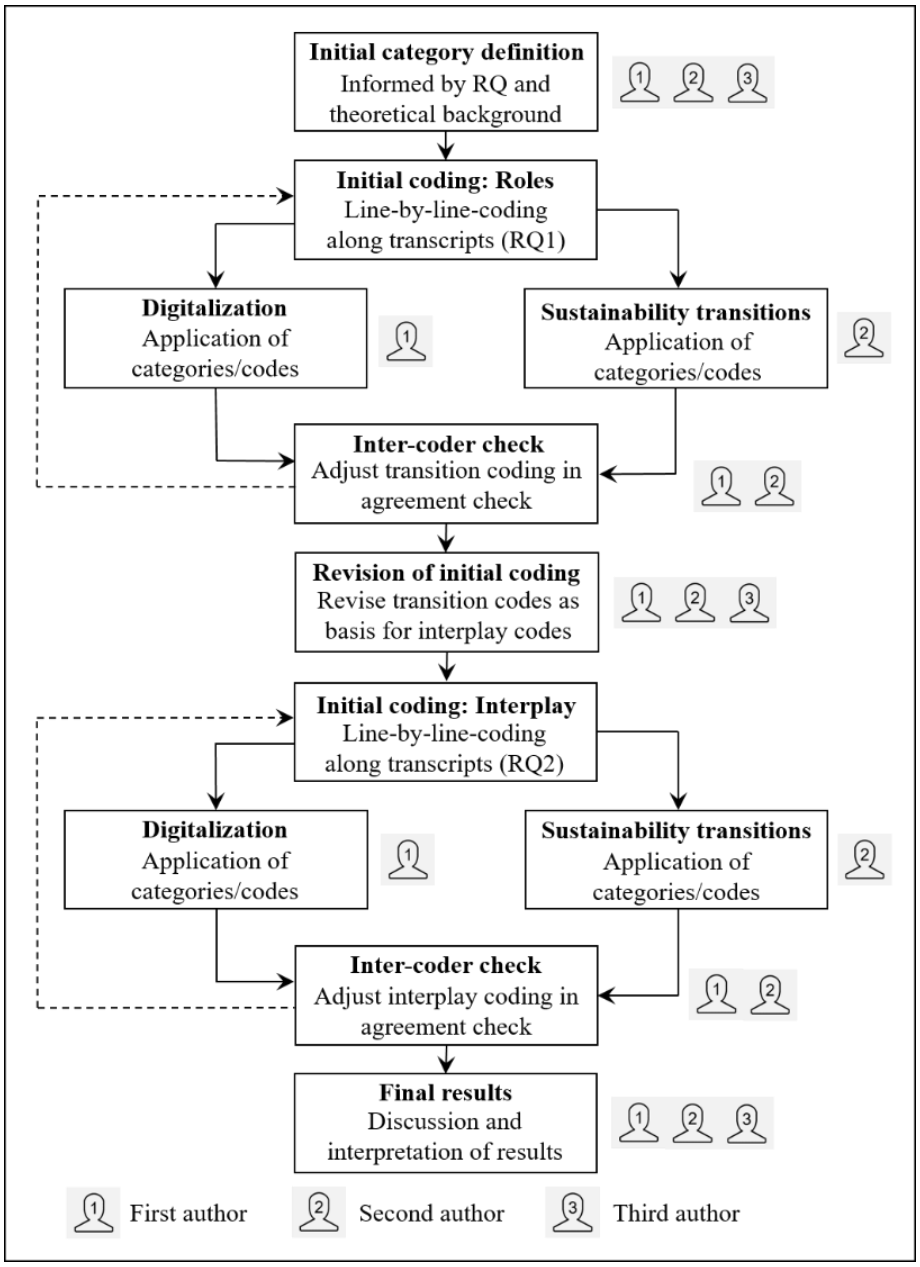
Table 2. Case overview

	Case A	*Case B*	*Case C*	*Case D*
Region	Darmstadt	Eberswalde	Augsburg	Goettingen
Assessed initiative	*s:ne*	*region 4.0*	*HSA_transfer*	*SNIC*
Focus	Focus on system innovation for sustainability	Focus on regional sustainability transition	Focus on building networks	Focus on innovativeness
No. of Interviews	17	18	13	15

Using a semi-structured questionnaire (see Appendix B), we asked theoretically informed questions focused on the roles and activities of intermediaries in transition processes (Kanda et al. 2018; Kivimaa et al. 2019a). We began by collecting information on the personal backgrounds and recent assignments of each interviewee before broaching the issues of the central structures and characteristics of involved actors, the innovation processes, the embedding of the respective initiatives in a regional context, and the role sustainability plays in the activities of the intermediaries.

In each region, we identified at least 13 interviewees via initial online research and subsequent referrals by interviewees. From February to September 2020, we conducted 62 interviews (see Appendix A). Because of the Covid-19 pandemic, we conducted the interviews via online video conferencing tools or telephones. One interview was conducted in person. The interviews lasted from 34 to 138 minutes and were recorded and transcribed. In addition to the interviews, we collected and reviewed internal documents, as well as reports and information published on the websites of the initiatives and actors. In each case, we carried out interviews until, in combination with data from the documents reviewed, data saturation (Glaser and Strauss 2017) was reached. We presented and discussed results in regional workshops with the interviewees, with researchers at a research seminar, and at two subject-specific international workshops. In addition, the first author, who was not involved in conducting interviews, was involved as strategic support in Case D, granting access to additional internal documents and discussions concerning this particular case.

Fig. 1. Procedure of analysis – inductive category development in a team of authors; Source: own compilation based on Mayring (2015, p. 80)



To analyze our empirical data, we collaboratively conducted a qualitative content analysis (Mayring 2015) to summarize and categorize the relevant material, namely the roles and contributions of knowledge intermediaries in regional transition processes. Informed by our research questions, we began by inductively coding the data to identify recurrently mentioned themes that indicated certain roles and activities to focus on the first research question. Informed by intermediary roles identified in previous literature (Kivimaa 2014; Kanda et al. 2018), we then deduced superordinate roles in transition processes, which the initiatives fulfill by performing these activities. Therefore, each author focused on one particular transition before adjusting codes in a first inter-coder check and engaging in discussions between the authors. Working with the revised initial coding, we focused on the second research question and shed further light on the interplay between transitions by repeating the procedure described above. **Fehler! Verweisquelle konnte nicht gefunden werden.** precisely illustrates the process of analysis and the division of tasks between the three authors.

4. Results

4.1. Knowledge intermediaries' contributions to sustainability and digital transitions

As illustrated in Table 3, we identified three different roles of HEIs and knowledge intermediaries in the context of sustainability and digitalization: information dissemination, knowledge exchange, and implementation support. It is noteworthy that the prerequisite for performing the identified roles is the HEIs joining and shaping the regional initiatives and thus making socio-technical transitions part of the HEIs' agenda.

We began our analysis by examining these roles in detail and by analyzing the main channels by which knowledge intermediaries aim to fulfill them. We then proceeded to use these initial insights as a basis for elaborating on the interplay between sustainability and digitalization.

4.1.1. Information dissemination

In information dissemination, knowledge intermediaries support the regional circulation of information regarding the necessity and possibilities of transitions. By disseminating information, knowledge intermediaries aim to sensitize regional actors to the complex subjects of digitalization and sustainability, reduce possible reservations, and raise regional actors' awareness of transition-related challenges. In this context, we find that organizing, holding, and establishing different sorts of *events* represents one of the main knowledge intermediary activities. Furthermore, information on regional projects and initiatives is offered to reach out for and attract potential partners for collaboration. The respective events differ in size, scope, and target groups.

Referring to digitalization, knowledge intermediaries organize events that address multiple regional actors, such as SMEs and public administration. These events focus on the dissemination of information on topics in digitalization such as public procurement, IT security, agile working, or different regional best practices (Row 1 in Table 3), such as experts delivering speeches to as many as 200 participants to raise awareness of strategic actions for tackling digitalization challenges. We found that academia-driven intermediaries identify relevant topics, acquire speakers, and host the events. Furthermore, knowledge intermediaries engage in more specific, small group (e.g., about 20 participants) events that focus on particular target groups and aim to introduce these groups to emerging technologies and encourage informal contacts between the participants (Row 2 in Table 3). These events often take place as on site-events in either firms or academic laboratories to demonstrate technologies and possible applications and enable peer-to-peer-learning processes. For instance, HEIs and external intermediaries in Case B held a series of events concerning various aspects of digitalization and robotics, which were presented by academics in an academic environment with the aim of enabling informal networking and encouraging dialogue between academic and non-academic actors.

Similar to their contribution to digitalization, knowledge intermediaries use events as a channel to inform regional actors about different aspects of sustainability. In addition, the events aim to reduce concerns and lower identified thresholds against sustainability efforts, such as individual overextension, high costs, and personal inconveniences (Row 3 in Table 3). Although there are also thresholds regarding digitalization, the benefits of engaging in sustainability-related measures that do not yield short-term, individual advantages need to be explained more explicitly. Knowledge intermediaries also use events to highlight ongoing regional projects and innovation processes related to sustainability. As one distinctive feature in cases A and B, events targeting sustainability can be seen to not only address industry and public administration but also include stakeholders from civil society, such as schools, associations, or cultural organizations.

As knowledge intermediaries in two cases have implemented sustainability-related practices in organizing and hosting events, we find that knowledge intermediaries act as role models and showcase sustainability measures for the participants (Row 4 in Table 3). For example, events in Case B are characterized by the offering of regional, organic catering. Furthermore, printed invitations were abandoned in favor of digital alternatives to contribute to resource-saving, so showing another example of interdependencies between digitalization and sustainability. The sustainability-related practices introduced are reported to diffuse and to be

adopted by regional partners. Initiative C created an exhibition on the impacts indicated by implemented sustainability-related measures that have been introduced and presented the exhibition in both an on-campus showroom and various off-campus spaces open to the regional public.

4.1.2 Knowledge exchange

Knowledge intermediaries span the boundaries between academic and non-academic subsystems by configuring and expanding regional networks between different groups of actors with a view to fostering knowledge exchange and learning processes between regional stakeholders. The superordinate objectives of supporting regional networks concerning transitions are to create a common understanding among regional stakeholders, adopt this understanding, and be able to bundle regional demands and interests and articulate them to academia and supra-regional policy makers. The associated HEIs act as initiators of regional networks, contributing to their knowledge transfer mission. Furthermore, the research institutions and experts of the associated HEIs represent a significant share of network participants.

Either knowledge intermediaries participate in existing regional networks concerning key topics of digitalization, such as automation or IT solutions for SMEs, which already comprise important stakeholders, or they support the implementation of completely new regional initiatives (Row 5 in Table 3). In such expert networks, intermediaries cross the boundaries between academic experts, private consultants, and practitioners to bundle regional digitalization expertise. In cooperative initiatives between several scientific institutions, these intermediaries support the development of appealing support formats for different aspects of digitalization.

Knowledge intermediaries use these regional networks and initiatives to screen and bundle regional interests, capabilities, and demands in order to act as ‘spokesmen’ for the region concerning the development of new funding programs and schemes. Interviewees emphasize their own networks with federal policy makers and recurrent involvement in the initial design of future funding schemes for knowledge transfer and innovation (Row 6 in Table 3). Knowledge intermediaries also report being part of bigger, supraregional, and national knowledge transfer networks providing access to multiple experts.

Knowledge intermediaries allow the circulation of knowledge in evolving networks by implementing a shared understanding of sustainability. Accordingly, interviewees reported difficulties in finding a common language between the heterogeneous involved actors (Row 7 in Table 3). In particular, differences in communication cultures from their respective economic, academic, governmental, or societal backgrounds made it harder for different actors to share the same perspective. These discrepancies result in actor groups being hesitant to cooperate with each other. For instance, knowledge intermediaries in Case A developed a ‘sustainability glossary’ containing central terms and definitions to offer a common ground for communication and interaction with internal as well as external actors.

Furthermore, to support sustainability transitions, knowledge intermediaries build specialized multi-actor networks. Our data indicate that knowledge intermediaries, in comparison to digitalization, more actively identify, select, persuade, and align heterogeneous actor groups in order to build regional networks capable of contributing to sustainability (Row 8 in Table 3). Actor selection strategies therefore consider the potential contributions to sustainability of participating actors. To contribute to sustainability, knowledge intermediaries aim for heterogeneous networks of actors, as these are expected to facilitate transition processes (Row 9 in Table 3). These networks explicitly include public actors such as schools, environmental protection parks, and museums, as well as civil organizations like churches, NGOs, and actors from the creative sector. Interviewees describe the building of specialized networks as a long-term effort, but positioning themselves in the center of new and existing regional networks provides knowledge intermediaries with the opportunity to bundle and articulate regional demands.

4.1.3 Implementation support

Information dissemination and network building cover preliminary aspects of transition processes and seldom address particular firms or stakeholders. Knowledge intermediaries also participate in more distinct activities that

aim for the implementation of tools, technologies, and processes directly related to digitalization and sustainability. These consulting activities include support for public fund application, development of transition strategies, initiation of student projects, and individual adjustment of technical solutions. In this context, the HEIs offer the subject-related expertise that the intermediaries can build their support on.

The configuration of these consulting activities differs across cases. Some interviewees put special emphasis on their involvement in the development of innovation and digitalization strategies in several firms. Thereby, they aim to go beyond sensitization and precisely explain existing technological and supporting opportunities in order to support the identification of those that meet the respective demands. In some cases, knowledge intermediaries employ their own personnel for fostering digitalization projects (Row 10 in Table 3). Our analysis indicates that one reason for the intensified involvement of HEIs is the expectation of higher levels of trust in their technological expertise. In addition, knowledge intermediaries initiate different sorts of student projects that aim to analyze firms' structures and take a first step in preparing the ground for digitalization.

On an even more tangible level, knowledge intermediaries contribute to the support of bringing these newly generated strategies to life. For instance, they try to accompany the application for public funds from both perspectives (i.e., the firm seeking additional expertise and the scientists seeking options to tie their research to existing demands and hence secure transfer activities) (Row 11 in Table 3). In this sense, knowledge intermediaries try to complement partnering institutions' consultations and add additional expertise. For example, a chamber of handicrafts, an HEI, private consultants, and a carpenter teamed up for the development of an IT security strategy in Case B. A distinctive feature of digitalization is that there are proven solutions available on the market for implementing the transition process. The innovative aspects therefore refer to technologies that are new to the organization but not new to the market. The main challenge is therefore not the development of new solutions, but the implementation of existing solutions in organizations that are not able to manage these change processes, for example, due to a lack of expertise or insufficient finances.

Referring to sustainability transitions, knowledge intermediaries actively induce change processes in multi-actor projects and closely moderate and accompany these projects. In contrast to digitalization, and in place of providing technical implementation support, they support vision building and actor learning processes and exploration skills that enable actors to contribute to sustainability transitions. Instead, they adapt and implement participatory methods to help regional actors identify impediments to transition. The applied methods serve to identify and develop a common understanding of relevant problems to contribute to sustainability and align actors' interests from the start. In Case A, for example, knowledge intermediaries enable participants to develop a common understanding of impediments to system innovation related to sustainability in specific socio-technical systems by the use of participatory methods to allow solutions development and legitimization within a predefined group of actors (Row 12 in Table 3). Participating actors develop solutions in moderated workshops that target system innovation in particular value chains. On the basis of future scenarios, problems are forecasted and response activities are formulated. The knowledge intermediaries thereby aim to align actors' interests and raise their awareness of opportunities that enable them to contribute to sustainability transitions. In Case C, however, intermediaries targeted the integration of existing local initiatives into superordinate policy objectives. The approach forms a core group of regional partners in order to legitimate policy goals. In the later stages of the projects, knowledge intermediaries encourage additional regional actors to participate. Intermediary activities support directing expectations, visions, and efforts toward sustainability in early stages of implementation processes (Row 13 in Table 3).

In summary, our interviews indicated that intermediaries contribute to digitalization and sustainability through the roles that they perform. They use events to disseminate information and to raise awareness of the targeted goals. The building of networks allows the information and knowledge necessary for innovation processes to circulate. Furthermore, they support the implementation of regional innovation processes by helping to identify problems or by promoting technical solutions.

Table 3. Roles of knowledge intermediaries in sustainability and digital transitions

	Transition	*Role*	*Description*	*Main Channel*	*Examples*	*Representative quotes*
1	D	Information dissemination	KI support the regional circulation of comprehensive information regarding the necessity and possibilities of sustainability and digital transitions	Events	Hosting informative events concerning particular digitalization topics and upcoming trends (up to 200 participants)	"For example on-site events in firms, that describe how they tackle the whole digitization topic. Such typical Good Practice events, which always attract 120 persons." [CASE-C-3]
2	D				Hosting singular and sequential workshops in firms or laboratories to demonstrate digital technologies (~20 participants)	"We already had like nine or ten workshops concerning different aspects of digitalization. We had about 15 craftsmen invited and service providers invited […] and they got the opportunity to test new technologies." [CASE-B-10].
3	S				Hosting informative events concerning potential reservations of regional actors towards sustainability transitions	"So it is communicated from the outset that it is quite subliminal. So there is a certain amount of input, of course. The professors introduce themselves. But they are also very pragmatic." [CASE-B-2]
4	S				Utilizing own events to function as role models and sensitize regional stakeholders for sustainability	"So in any case, the role model effect. So how we organize our events. That everything is done in line sustainability, well, there is simply a guideline. Procurement, too, of course. So we set an example of what is possible." [CASE-B-2]
5	D	Knowledge exchange	KI support the building of regional multi-actor networks concerning strategies for sustainability and digitalization	Network building	Forming regional networks of academic, public and private experts in digitalization	"For digitalization, we also have the [experts network], which is a new initiative in which we united several experts not only from academia but also from private firms." [CASE-C-3]
6	D				Articulating demands and interests between federal/national governments and regional stakeholders	"So we got the [federal digitalization funding scheme] which funds Software, Hardware and consulting. […] And in this sense, I think, we are intermediaries between national government, federal government and firms. And governments keep asking us: 'What else can we do?'" [CASE-B-4]

	Transition	*Role*	*Description*	*Main Channel*	*Examples*	*Representative quotes*
7	S				Establishing a common regional understanding to enable learning and strategy development	"We have already included a glossary in the application. And the feedback, especially from the practitioners, is that it is enormously helpful to have something like this. Because you can come to an agreement on that here, anyway." [CASE-A-1]
8	S				Incorporating actors from civil society in regional projects and initiatives	"And our partners are quite explicitly businesses. But also public institutions, administrations, politics, civil society, associations, clubs and even individual citizens and initiatives. Because of course, the less institutionalized they are, the more difficult it is to engage in systematic communication." [CASE-B-1]
9	S				Identifying, selecting and including heterogeneous regional stakeholders	"What is the sustainability challenge for leather? And how are the supply chains structured? What are the rough positions of the different actors? That you already have an overview. I have more or less familiarized myself with this. And I also started to build up a network very early on. And I simply wrote to the actors quite wildly at the beginning. And I also invited them a bit to join us in this project, which is very inclusive." [CASE-A-13]
10	D	Implementation support	KI support the implementation of tools and technologies concerning sustainability and digitalization or the application for public funding	Consulting	Creating additional regional support structures	"That is the SME competence center. That is two jobs, Ms. [X] and Mr. [Y], that have been created to foster digitalization projects. And that is located within the HEI." [CASE-B-4]
11	D				Providing support for the application for public funds concerning digitalization of firms (and maintain long-term relationship)	"To us, it is not only important to provide a contact but to be a stable contact person because that is how new projects emerge. If you know each other, the firm is more likely to approach you with new ideas and we can find new funding opportunities for digitization or other topics." [CASE-D-15]

	Transition	*Role*	*Description*	*Main Channel*	*Examples*	*Representative quotes*
12	S				Enabling and closely moderating change processes in multi-actor projects	"Yes, […] in everything we do, we have the claim to contribute to the sustainable development of the region and to promote it. And so we enable […] the processes, the projects that we support and accompany and advise. So I would say we also do our part to support and promote sustainable development." [CASE-B-3]
13	S				Supporting vision building and peer-to-peer learning processes	"Then the offer after the kick-off workshop was, if you want to move forward, we invite you to a scenario process. Scenario process means four or five full-day meetings where you think together about the future. In other words, we do scenario back casting and identify drivers, classify them in their interactions, and so on. In order to arrive at scenario stories in the end, and the practitioners were ready for this. […] And in the end we had two scenario stories that the practitioners formulated themselves. In other words, they provided the input for the driving and driven factors that comprise the market situation of leather chemistry in 2035." [CASE-A-1]

4.2. Interplay between sustainability and digital transitions

"The idea was not to make IT for the sake of IT. But IT as an enabler of sustainable development."

[Case-A-1]

Knowledge intermediaries acknowledge digitalization and sustainability as two of their main fields of activity and as superordinate objectives that are also supported and directed by federal ministries and other policy makers (along with other omnipresent societal challenges, such as mobility). Consequently, as illustrated by the introductory quote, our analysis of knowledge intermediary roles in two interconnected transitions provides insights into several interdependencies between the support of digitalization and sustainability.

First is the facilitating and accelerating effects of digital technologies on sustainability. Many innovative digital solutions afford the opportunity of optimizing firm-internal processes or enhancing working conditions, while at the same time reducing energy or resource usage. Accordingly, knowledge intermediaries view the fostering of digital innovation as an increasingly important part of their work that inevitably enhances their contributions to sustainability. Second, this positive viewpoint is contrasted with a more critical one, which questions these desirable effects and finds fault with the inflationary use of sustainability labels for the legitimation of digital innovation projects. Table 4 illustrates and contrasts both perceived interplays. These diverging perceptions of the interdependencies between digitalization and sustainability transitions result in different additional roles and activities that relate to the interdependencies between digitalization and sustainability transitions and complement the roles discussed above. We found that knowledge intermediaries perceive themselves as potential 'sustainability validators' who monitor digital and technological transfer and innovation processes in terms of sustainability effects.

In discourses about the interplay between digitalization and sustainability transition processes, the enabling and accelerating effect of digital solutions on sustainability transitions is brought to the fore. These effects are reflected in the interview data. Progress in digitalization is considered an important driver and prerequisite for the development of sustainability. Knowledge intermediaries report fostering digitalization by screening HEIs' research portfolios in order to identify digitally oriented research projects with potential positive sustainability effects and enable as many regional actors to participate in transition processes as possible. Furthermore, they report supporting emerging projects by organizing cooperation processes. For instance, knowledge intermediaries in Case A identified a project to digitally optimize urban traffic conditions in favor of a publicly financed sharing system for electric cargo bikes and subsequently organized and monitored the resulting innovation process. Thus, they first carried out one of the roles discussed above by organizing a dialogue event to address multiple regional stakeholders. However, it became obvious during this process that prioritizing e-bikes in urban traffic led to extended traffic light phases for cars, which in turn induced air pollution and fuel consumption. As a result, knowledge intermediaries acquired further academic expertise so that they could cooperatively develop and implement a monitoring tool.

In Case B, knowledge intermediaries supported the development of a digital regional delivery platform that makes use of public buses to enhance the degree of capacity utilization in rural areas. Therein, knowledge intermediaries participate in, and in some cases lead, inter-organizational working groups that connect different actor groups and therefore create special positions within HEI administrations. Furthermore, knowledge intermediaries span the boundaries between regional sustainability projects and academics, who provide additional knowledge and interregional networks and so complement these projects with digital solutions.

Table 4. Main perceptions of the interplay between sustainability and digitalization and of emerging roles for knowledge intermediaries (own compilation)

	Digitalization as a driver of sustainability	High potential of digital technologies as a threat to sustainability evaluation
Effects	Digitalization and digital innovation support sustainability via resource efficiency and/or enhanced working conditions	Deficient monitoring/evaluation of rebound effects in anticipation of digital improvements
Rating	Supportive/Positive	Critical/Negative
Representative quotes	"In addition, these projects are permeated by digitalization, industry 4.0, IT, artificial intelligence. That is a very important topic. At the end of the day, we hope that these technologies that are developed here will have a significant positive effect on the topic of resource efficiency, because that's what the planet indispensably needs." [CASE-C-6]	"Of course, it's fine if you create digital solutions. However, is it okay if the benefits focus on a handful of companies that make billions while, on the other hand, you destroy hundreds of thousands of jobs? We ought to evaluate every technological innovation in a broader context considering social and ecological aspects. I miss that in the whole concept of technology transfer." [CASE-C-6]
	"In the matter of digitalization, basically everything is sustainable." [CASE-B-10]	"And usually, especially if it is about a lot of money, the topic of sustainability is not in the foreground. Instead it is digitalization, artificial intelligence, robotics, assisting systems." [CASE-C-8]
	"And our task was to identify potentials for sustainable development by digitalization. […] Therefore, we reactivated a format we had already used before, namely the [dialogue events with several stakeholders]." [CASE-A-1]	"I bet that any innovation project in [other innovation system] can pick at least one SDG with no struggles. […] And in case of a digitalization project, it's education or resilient infrastructure or whatever. Unfortunately, the application of SDGs is unlimited." [CASE-A-14]
Roles for knowledge intermediaries	Targeted identification and development of digital projects potentially valuable for sustainability	Monitoring/evaluation of (digital) knowledge transfer projects in regard to sustainability dimensions

The second perspective that we identify in our interviews suggests a lack of reflection in current technology transfer processes, which can be seen in several interviews. With sustainability and digitalization being omnipresent megatrends, interviewees considered the lack of critical questioning about sustainability in cases where an idea yields promising digital results. Accordingly, interviewees criticized the vague existing standards and the manifold options for labelling almost all transfer and innovation projects as 'sustainable' while not taking into account possible adverse secondary effects on certain sustainability dimensions. In this vein, interviewees

criticized innovators for using different dimensions of sustainability to legitimate their oftentimes digital projects while rejecting sustainability goals in favor of technological and monetary progress when high turnovers are expected. According to the interviewees, this leads to a scenario in which high-tech solutions are fostered without assessing possible side effects on sustainability. This second perspective points toward an additional role for knowledge intermediaries concerning the monitoring of transfer and innovation processes. However, although the lack of this function was criticized at some points, the interviewees did not report having fulfilled the role of monitoring.

5. Discussion

Both knowledge intermediaries and transition intermediaries are at the center of recent scholarly debates. This paper adds to these debates by assessing apparent theoretical overlaps and thus contribute to disentangling the interplay between different intermediating actors and thus the understanding of intermediaries. Moreover, this paper adds to the nascent discussion concerning the interdependencies between different socio-technical transition processes.

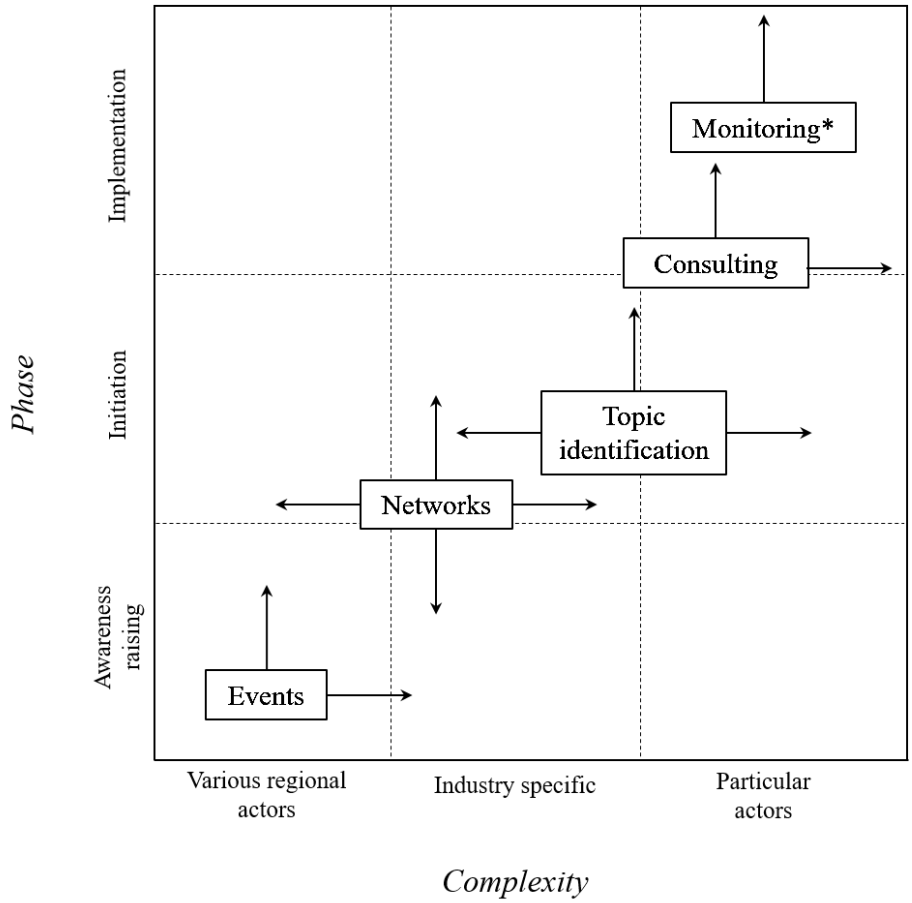
5.1. HEIs in regional transition processes

In order to add to the burgeoning discussion about the third academic mission, and driven by intensifying political and societal demands, scholars have recently started to assess the roles of HEIs in regional sustainability transitions and emphasize their importance as regional drivers of change at the intersection between different innovation subsystems. Therein, extant studies discuss several dimensions and activities that HEIs use to contribute to sustainability (Peer and Stoeglehner 2013; Purcell et al. 2019; Radinger-Peer and Pflitsch 2017; Trencher et al. 2014; Zilahy et al. 2009). However, the manifold forms of participation seem rather fragmented and institutionally supported knowledge transfer and knowledge intermediaries usually play a minor role (Blume et al. 2017; Radinger-Peer et al. 2021). Our study allows us to make several contributions to this discussion. First, our results corroborate the prevalent perception of HEIs as proactive participants in regional transitions. In all the initiatives assessed, HEIs have admitted their regional responsibility by taking leading roles. Second, as indicated by the regional initiatives, all emerging roles are based on close collaboration between HEIs and non-academic, mostly public, regional stakeholders. Considering recent conceptualizations of HEI-centered ecosystems for technology transfer and entrepreneurship (Good et al. 2019), these collaborative structures suggest a group of particularly transition-oriented activities that result from these ecosystems. Third, the willingness to participate in strategic collaboration indicates an organizational shift toward a permanent intensification of transition-related activities. This willingness is underlined by certain first organizational adjustments, such as the creation – and the funding – of additional personnel and internal mechanisms that lay the foundations for sustainable and digital role modeling. In a nutshell, the collaborative acting on transition-related topics represents an additional facet of the broadening of the regional mandate of HEIs that bridge between transition intermediation and HEI-centered entrepreneurial ecosystems.

5.2. Knowledge intermediaries in regional transition processes

Whilst knowledge and transition intermediaries are vibrantly discussed in separate strands of literature, research focusing on the roles of knowledge intermediaries in sustainability transitions and digitalization is emerging at best (Kivimaa et al. 2017; Paniccia and Baiocco 2018). The roles we identify show several overlaps with the previously identified roles of transition intermediaries, as they relate to the articulation of demands and the formation of regional networks (Kivimaa 2014; Kanda et al. 2018).

Fig. 2. Activities of knowledge intermediaries in regional transitions; Source: own compilation



*role suggested but not reported

What seems rather unfamiliar is the proactive interpretation of these roles that contradicts extant research inasmuch as these works state that a "lack of explicit procedures to functionally integrate sustainability into innovation support" results in a "dominance of traditional roles of technology transfer related to intellectual property and start-ups" (Kivimaa et al. 2017, p. 11) and that "their role can be regarded as responsive rather than active" (Radinger-Peer and Pflitsch 2017, p. 182). Hence, on the one hand, our nuanced investigation of knowledge intermediary roles generally corroborates the relevance of HEIs in transitions by showing a multi-dimensional participation of HEI actors in transition-related initiatives. On the other hand, these findings point towards an underrepresentation of said actors in extant research on transition processes. The proactive formation and development of networks with non-academic regional actors means that it is particularly important to assess which roles intermediaries play in HEIs' transition agendas and how they can contribute to the development of comprehensive strategies that make efficient use of academic resources by streamlining the contributions made via research, teaching, and knowledge transfer.

Given this proactive perception of their own role in regional transition processes, the overarching question of interest for scholars, policy makers, and practitioners is how knowledge intermediaries and their capabilities can be used to foster sustainability and digitalization and how their roles in innovation systems alter in regard to constantly intensifying transitions. Our analysis carves out two diverging effects of digitalization on sustainability that have previously been identified in extant literature: (i) the resource-saving effects of digitalized processes as a driver for sustainability and (ii) the high innovative potential of digital solutions as a threat for sustainability-related evaluation (e.g., Brenner and Hartl 2021; Del Río Castro et al. 2021).

Analyzing the identified roles with a particular focus on the underlying objectives on the one hand and the composition of addressed actors on the other, leads to the assumption that the main activities form a coherent

portfolio that aims to support different challenges on different levels of concreteness and complexity. Our data indicate that the interplay between digitalization and sustainability affects the functions of knowledge intermediaries whose transition-related activities pervade multiple stages of sustainability and digitalization. Awareness-raising activities, mainly different sorts of *Events*, address various regional actors that are not yet active in digitalization and sustainability endeavors. Subsequently, sensitized actors are addressed in industry-specific regional *networks* to develop more specific support mechanisms. Hence, actors who develop competencies can be addressed in more specific activities to *identify particular topics* and projects. Such projects are then supported via *Consulting* and *Monitoring* activities to secure their success. Figure 2 illustrates this progression of complexity in the activities during the different phases. Concerning the progression of complexity, knowledge intermediaries' participation in different states of transition processes, which in turn require the addressing of actors with different states of knowledge, indicates an approach in which knowledge intermediaries prepare the ground for their core activities, that is, ensuring regional knowledge dissemination and peer learning between target groups, before processing particular implementation processes that may require academic knowledge.

5.3 Interdependencies between digitalization and sustainability

The ambiguous attitudes toward digitalization identified in our interviews, which range from euphoria for the support of resource efficiency to skepticism in apprehension of rebound effects on sustainability, reflect the current discordant status of the scholarly discussion (Brenner and Hartl 2021). These inconsistent perceptions of transition processes and their relations indicate an insecurity in the handling of these fields of activity, which are represented and addressed in current activities and political expectations without including particular guidelines for their incorporation in 'regular' activities. Furthermore, these perceptions reflect a dilemma immanent to the diversification of knowledge intermediaries' traditional mission of fostering research commercialization and the emerging aspiration to addressing certain issues of sustainability. While the former would suggest a focus on projects concerning commercially relevant topics such as digitalization, including the latter requires a distinct focus on sustainability, including monitoring activities for all other goals pursued. Dissolving this position between the requirements of the two transitions would require more in-depth research on the interdependencies between them. That would allow the incorporation in political strategies and the subsequent definition of roles for knowledge intermediaries.

6. Concluding implications

The starting point of this paper was the apparent yet under-researched conceptual overlap between different types of intermediaries in regional innovation systems. Aiming for a contribution to closing this gap, the paper links the concept of knowledge intermediation to current discussions about co-occurring socio-technical transitions and assesses the contributions of knowledge intermediaries. Concerning the first research question about knowledge intermediaries' contribution to sustainability and digitalization, we find that intermediaries contribute in three major ways. First, they disseminate information and raise awareness of transition goals by events. Second, knowledge intermediaries build specialized networks that allow the information and knowledge necessary for innovation processes to circulate. Third, they support the implementation of regional innovation processes that identify problems or promote technical solutions. Regarding the research question concerning additional roles emerging from the interplay between sustainability and digitalization, we find that the interplay of interdependencies leads to extended roles for knowledge intermediaries. Knowledge intermediaries are aware of the potential positive and negative effects of digitalization on sustainability. Working at the intersection of both transitions, they are key actors in developing digitalization projects that avoid rebound effects on sustainability or contribute to sustainability transitions.

From a policy perspective, these contributions are of interest for three reasons. First, the consideration of socio-technical transition processes requires the reformulation of regional innovation policies, of which knowledge intermediaries are central constituents. Second, intermediaries operating at the intersection between multiple regional actor groups play a central role in fostering these transition processes. Third, knowledge intermediaries represent the institutionalization of entrepreneurial and engaged strategies that were adopted by most HEIs and that necessitate the investigation of societal roles that make the best use of their manifold resources while not degrading the traditional missions of research and education. Our analysis shows that the support of regional transitions, including information dissemination, networking, and implementation support, represents a promising component of such roles. Hence, these findings suggest a vital role for knowledge intermediaries for regional innovation and development dynamics that exceeds the mere commercialization of technological knowledge and incorporates activities that contribute to grand societal challenges while not necessarily focusing on direct financial reflows.

Thus, for policymakers, our results suggest that interdependencies between different socio-technical transitions require coherent regional strategies. Concerning the regional organizational landscape, this indicates the need to strive for complementary capabilities between different intermediaries. Concerning the content and activities of policies of knowledge intermediation, the analysis suggests two amendments: First, knowledge intermediation approaches should purposefully include mission-oriented activities to support regional transition processes. Although commercialization and entrepreneurship may still be at the core of knowledge intermediation, knowledge intermediaries evolved from university-internal administrators of technology transfer to constituents of regional innovation and development contexts. Consequently, they must be designed and endowed in accordance with a broadening field of activities. Second, the societal effects of knowledge and technology transfer should be taken into consideration. As reflected in our data, most current knowledge and technology transfer approaches presuppose desirable effects, especially in digitalization projects, and neglect possible negative side effects of the innovations they support. Their unique position at the intersection between creators and users of knowledge enables knowledge intermediaries to fulfill monitoring functions valuable for a development toward sustainability-oriented innovation.

From a scholarly perspective, our explorative approach is a first step in disentangling the interdependencies between knowledge and transition intermediaries as well as between sustainability transitions and digitalization. Tailored to the incorporation of sustainability aspects of publicly funded knowledge intermediary initiatives, our data provides a rich database for identifying and illustrating self-perceived roles. However, we can we elaborate on the underlying motivations and the organizational embeddedness of the identified roles, nor assess their effects on the ambiguous position of knowledge intermediaries within the academic system.

Future research could enrich the current discussion by focusing on these aspects. To do so, these analyses should incorporate insights and opinions from scientists, firms, regional policy makers, and members of other relevant target groups that have participated in intermediation formats and thus evaluate intermediaries' roles from an external perspective and allow for additional design implications. Furthermore, blurring the lines between the roles and activities of different sorts of intermediaries fuels the ongoing debate on the regional interplay between intermediaries. Hence, future research should focus on organizational drivers, barriers, and peculiarities of intermediary collaboration to support the development and formulation of comprehensive policies that combine innovation-focused and sustainability-focused approaches.

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Appendix

B. Interviews

No.	*Case*	*Sector*	*Role*	*Duration [min.]*
1	Case A	Academia	Professor	112
2	Case A	Academia	Research Associate	40
3	Case A	Civil society	Research Associate of a foundation	54
4	Case A	Industry	Representative of chamber of commerce	61
5	Case A	Academia	Research Associate of a Research Institute	66
6	Case A	Academia	Research Associate of a Research Institute	36
7	Case A	Academia	Research Associate	65
8	Case A	Academia	Senior Researcher of a Research Institute	91
9	Case A	Academia	Senior Researcher	90
10	Case A	Industry	Representative of chamber of commerce	91
11	Case A	Public admin.	Innovation support manager	34
12	Case A	Industry	Representative of Business Association	40
13	Case A	Academia	Senior Researcher	58
14	Case A	Industry	Sustainability consultant	57
15	Case A	Academia	Representative of university sust. office	45
16	Case A	Academia	Representative of presidential board	59
17	Case A	Public admin.	Representative of university transfer office	42
18	Case B	Academia	Professor	80
19	Case B	Academia	Innovation support manager	94
20	Case B	Academia	Innovation support manager	97
21	Case B	Industry	Innovation support manager	138
22	Case B	Public admin.	Business developer	61
23	Case B	Academia	Professor	53
24	Case B	Public admin.	Business developer	64
25	Case B	Academia	Project manager	61
26	Case B	Civil society	Representative of a civil association	71
27	Case B	Industry	Innovation manager	89
28	Case B	Industry	Innovation manager	66
29	Case B	Civil society	Representative of a civil association	91

30	Case B	Public admin.	Knowledge transfer manager	58
31	Case B	Industry	Representative of regional craft sector	77
32	Case B	Public admin.	Representative of biosphere reserve	100
33	Case B	Academia	Professor	70
34	Case B	Academia	Professor	70
35	Case B	Academia	Professor	76
36	Case C	Academia	Professor	103
37	Case C	Academia	Professor	86
38	Case C	Public admin.	Representative of innovation support	77
39	Case C	Academia	Program Manager	73
40	Case C	Public admin.	Business developer	35
41	Case C	Public admin.	Representative of an innovation center	54
42	Case C	Industry	Representative of chamber of commerce	54
43	Case C	Academia	Representative of university transfer office	72
44	Case C	Academia	Research associate	73
45	Case C	Public admin.	Representative of university sust. office	54
46	Case C	Academia	Communication manager	77
47	Case C	Civil society	Representative of a foundation	62
48	Case C	Civil society	Representative of a civil association	73
49	Case D	Academia	Professor	87
50	Case D	Academia	Project manager	92
51	Case D	Public admin.	Representative of SNIC Office	72
52	Case D	Public admin.	Innovation support	62
53	Case D	Civil society	Representative of a foundation	59
54	Case D	Academia	Professor	75
55	Case D	Public admin.	Business developer	64
56	Case D	Public admin.	Business developer	48
57	Case D	Academia	Innovation scout	50
58	Case D	Industry	Representative of chamber of crafts	71
59	Case D	Public admin.	Business Developer	50
60	Case D	Industry	Representative of chamber of commerce	78
61	Case D	Academia	Innovation scout	55
62	Case D	Public admin.	Business developer	52

B. Interview guide

Section 0: Background of the interviewee

- Please briefly describe your job/function?
- How do you/your organization understand "knowledge transfer"?

Section 1: Knowledge transfer structures and characteristics of key stakeholders

- Please describe the [organizational] structures of regional knowledge transfer.
- Please give an example of how knowledge transfer takes place in the region.
- Can you describe how learning processes are induced the knowledge transfer?

Section 2: Innovation processes

- Please describe what kind of innovations have already been developed so far.
- Please describe what kind of innovations are currently being developed.
- Please describe your role in an [exemplary] innovation process.

Section 3: Evaluation and assessment of results

- How do you evaluate your activities and results in terms of knowledge transfer?

Section 4: The regional innovation system

- Please describe special features of the regional innovation system.
- What are the barriers to knowledge transfer in the region?

Section 5: Sustainable development

- What role does sustainable development play in your organization/work?
- What is the importance of innovations related to sustainable development for you?

What contributions to sustainable development do you see through the project /
the knowledge transfer structures / and the resulting innovations?