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Aligning the design of intermediary organisations with the ecosystem

Georg Reischauer[a,b], Wolfgang H. Güttel[c] and Elke Schüssler[d]

[a]Department of Strategy and Innovation, WU Vienna University of Economics and Business, Vienna, Austria; [b]Linz Institute of Technology & JKU Business School, Johannes Kepler University Linz, Linz, Austria; [c]Faculty of Mechanical and Industrial Engineering, TU Wien (Vienna University of Technology), Vienna, Austria; [d]JKU Business School, Johannes Kepler University Linz (JKU), Linz, Austria

ABSTRACT
Intermediary organisations such as technology transfer organisations (TTOs) are an important mechanism of open ecosystem governance, as they support how ecosystem participants search for knowledge. While scholars have identified TTO activities to support knowledge search, little is known about how these activities relate to the structural dimensions of TTOs or ecosystem-level factors. We propose that ecosystem search scope and problem complexity are key ecosystem-level factors that influence how TTOs support knowledge search. We further argue that coupling, specialisation, centralisation, and formalisation are the key structural dimensions of TTOs. We combine these arguments to develop TTO designs that detail the interplay of the structural dimensions and activities of a TTO given varying ecosystem-level factors. Our paper contributes to research on the open governance of ecosystems, ecosystem structures, and the ecosystem structure–intermediary organisations relation.

KEYWORDS
Organisation design; open governance; ecosystems; knowledge; digital technologies

1. Introduction

Organisations increasingly innovate by participating in knowledge ecosystems (Järvi, Almpanopoulou, and Ritala 2018; Clarysse et al. 2014; Cohendet, Simon, and Mehouachi forthcoming; Gifford, McKelvey, and Saemundsson forthcoming). Being part of a knowledge ecosystem is advantageous, as it allows organisations to search more effectively for the knowledge that they need to solve innovation-related problems (Felin and Zenger 2014; Nickerson and Zenger 2004; Stuart and Podolny 1996). However, knowledge search in ecosystems also comes with challenges such as the need to navigate different interests (Lopez-Vega, Tell, and Vanhaverbeke 2016; Perkmann 2017; Davies, Manning, and Söderlund 2018; Park and Leydesdorff 2010). Intermediary organisations, especially technology transfer organisations (TTOs) (Perkmann and Schildt 2015; Perkmann 2017; O'Mahony and Bechky 2008; De Silva, Howells, and Meyer 2018), are a key open governance mechanism to lower these challenges (Van Lente et al. 2003; Kant and Kanda 2019; Howells 2006) and shape the knowledge base of

CONTACT Georg Reischauer georg.reischauer@wu.ac.at Department of Strategy and Innovation, WU Vienna University of Economics and Business, Vienna, Austria.

an ecosystem (Brenner 2007; Malmberg and Power 2005; Cohendet, Simon, and Mehouachi forthcoming; De Silva, Howells, and Meyer 2018).

TTOs govern in an open and thus less hierarchical way by supporting how other organisations in an ecosystem search for knowledge. Thus, support is the concrete form of governing in an open manner (Schoen, van Pottelsberghe de la Potterie, and Henkel 2014; Filatotchev, Aguilera, and Wright 2020; Thomas and Autio 2020). TTOs support knowledge search because of formal settlements that relieve ecosystem participants from relevant important search-related tasks (Schoen, van Pottelsberghe de la Potterie, and Henkel 2014). From an organisational perspective (Perkmann and Phillips 2017), two elements of TTOs have been studied to better understand how they support ecosystem participants searching for knowledge. The first element are TTO activities – actions from TTOs directed at ecosystem participants. O'Mahony and Bechky (2008) identified multiple activities in the domains of monitoring, membership, ownership, and knowledge production control. Recent studies have added further activities to these domains (De Silva, Howells, and Meyer 2018) and shown the relevance of activities in two further domains, knowledge diffusion and identity (Perkmann and Schildt 2015; Perkmann 2017). The second element of a TTO that supports knowledge search is its structure. Studies suggest that aligning the structure of a TTO with contextual demands enables a TTO to better support how ecosystem participants seek knowledge (Debackere and Veugelers 2005; Schoen, van Pottelsberghe de la Potterie, and Henkel 2014; Kolodny et al. 2001). This important body of scholarship led to a better understanding of the supporting role of TTOs in ecosystem-wide knowledge search. However, three gaps remain.

First, our understanding of which ecosystem-level conditions influence how a TTO supports the knowledge search of ecosystem participants is limited. Specifically, we face limits comprehending how the structure and activities of a TTO are shaped by ecosystem-level contingencies (De Silva, Howells, and Meyer 2018; Kolodny et al. 2001) and the implications of these ecosystem-level contingencies for how a TTO shapes the knowledge base of an ecosystem (Brenner 2007; Malmberg and Power 2005; Cohendet, Simon, and Mehouachi forthcoming; De Silva, Howells, and Meyer 2018). Second, we know little about which dimensions of the TTO structure affect knowledge search in which ways. This is an issue because we know that a TTO requires a structure different from the structure of the organisations it supports (De Silva, Howells, and Meyer 2018; Kolodny et al. 2001; Perkmann 2017; Schoen, van Pottelsberghe de la Potterie, and Henkel 2014) and because different scopes of knowledge search come with different demands for its support (Stuart and Podolny 1996; Katila and Ahuja 2002; Rosenkopf and Nerkar 2001; Cyert and March 1963). However, we still do not fully understand how to design the structure of a TTO with respect to supporting knowledge search. Third, our understanding of how TTO activities are shaped by the structure of a TTO is limited. As an organisation's structure is strongly interwoven with its activities (Foss, Lyngsie, and Zahra 2015; Foss 2007; Schüßler, Decker, and Lerch 2013), we can expect that the structure of a TTO influences its activities to support knowledge search and that not all activities are possible for every structure. Nevertheless, we do not fully understand the interplay between the TTO structure and its activities or how this interplay is influenced by ecosystem-level factors.

In summary, we know little about (1) which ecosystem-level factors shape knowledge search, (2) which structural dimensions of a TTO affect its activities to support knowledge search, and (3) how to align the design of a TTO – its structural dimensions and activities –

with ecosystem-level factors. Our conceptual paper addresses these three interrelated gaps by synthesising insights from studies of TTOs (Perkmann 2017; Perkmann and Schildt 2015; O'Mahony and Bechky 2008; De Silva, Howells, and Meyer 2018), knowledge ecosystems and problem-driven knowledge search (Stuart and Podolny 1996; Rosenkopf and Nerkar 2001; Felin and Zenger 2014; Nickerson and Zenger 2004; Clarysse et al. 2014), and knowledge-driven organisation designs (Dalton et al. 1980; Foss, Husted, and Michailova 2010; Foss 2007). We address the first gap by proposing that *ecosystem search scope* (how closely the sought knowledge is related to a firm's knowledge base) and *problem complexity* (how complex the main problems for which ecosystem participants seek knowledge is) are key ecosystem-level contingencies of knowledge search. We offer insights into the second gap by arguing that *coupling, specialisation, centralisation*, and *formalisation* are the key dimensions of a TTO structure that affect how a TTO supports knowledge search. To address the third gap, we develop archetypical TTO designs that detail the interplay of the structural dimensions and activities of TTOs given the ecosystem-level contingencies ecosystem search scope and problem complexity.

Our paper contributes to research on the open governance of ecosystems, structures of ecosystems, and relationship between ecosystem structure and intermediary organisations. Overall, we offer insights that enable a better alignment of the design of intermediary organisations, especially TTOs, with ecosystems, which are becoming a key approach to innovate emerging technologies collaboratively (Järvi, Almpanopoulou, and Ritala 2018; Clarysse et al. 2014; Cohendet, Simon, and Mehouachi forthcoming). Our paper also speaks to policymakers who are setting up and shaping knowledge ecosystems (Perkmann and Schildt 2015; Järvi, Almpanopoulou, and Ritala 2018).

2. Knowledge ecosystems and the supporting role of TTOs in ecosystem-wide knowledge search

2.1. Knowledge ecosystems and knowledge search in ecosystems

With the rise of digital technologies such as digital platforms (Reischauer & Mair, 2018a, 2018b) and smart manufacturing (Reischauer, 2018), management scholars are increasingly examining how organisations innovate as participants of ecosystems. As Llewellyn and Erkko (2020) highlighted, there are different approaches to studying ecosystems with respect to the understanding and features of an ecosystem and established management theories used to examine them. One is the *innovation ecosystem* approach. Rooted in the work by Moore (1993), who championed the use of the ecosystem metaphor in management studies, innovation ecosystem studies conceptualise an ecosystem as a community of hierarchically independent, yet interdependent heterogeneous participants who create an ecosystem output for a defined audience (Thomas and Autio 2020; Shaw and Allen 2018; Mars, Bronstein, and Lusch 2012; Jacobides, Cennamo, and Gawer 2018). One example are the innovation ecosystems around the output electric vehicles (e.g. GM's Chevrolet Bolt EV) targeted at individuals who want to drive sustainably. Another example are the ecosystems around games for specific games consoles (e.g. Sony's PlayStation) targeted at individuals who aim to play graphically sophisticated games alone or with others (Jacobides, Cennamo, and Gawer 2018). As these examples show, in innovation ecosystems the 'stability of an organizational ecosystem is dependent on

keystone actors' (Mars, Bronstein, and Lusch 2012, 279). Thus, few organisations, or even a single organisation as in the previous examples of GM and Sony, tend to shape the interactions of ecosystem participants and govern the innovation processes in that ecosystem.

A key feature of innovation ecosystems is that participants choose to become either a specialist or a generalist with respect to the ecosystem-level output. Scholars have observed that both specialists and generalists tend to interact more often with generalists and less with (other) specialists (Mars, Bronstein, and Lusch 2012; Mars and Bronstein 2018, 2020). As a consequence, frequently interacting participants form a nested structure beneficial for overall ecosystem resilience. Mars and Bronstein (2018) provided the example of Apple that, after 2011, partnered with network providers beyond AT&T. In doing so, 'Apple created a nested network with itself as the only producer of the iPhone (thus, the specialist) and the many other carriers it associates with functioning as generalists'. Another important feature of the innovation ecosystem is the participation of various actors, especially private firms, financiers, universities, activist groups, and governmental agencies (Mars and Bronstein 2018, 382; Mars, Bronstein, and Lusch 2012, 275–276).

Many innovation ecosystem studies are anchored in network theory (Shipilov and Gawer 2020) and population ecology (Mars and Bronstein 2020, 2018; Shaw and Allen 2018). While examining innovation ecosystems and thus the 'flows of services to a customer and resources related to a customer, which are recycled by business models linked into pathways' (Shaw and Allen 2018, 90) is of great value, recent advances call for the examination of dynamics that precede innovation ecosystems (Cohendet, Simon, and Mehouachi forthcoming; Gifford, McKelvey, and Saemundsson forthcoming; Llewellyn and Erkko 2020). The *knowledge ecosystem* approach follows these suggestions (Järvi, Almpanopoulou, and Ritala 2018; Clarysse et al. 2014; Cohendet, Simon, and Mehouachi forthcoming; Llewellyn and Erkko 2020).[1] A 'knowledge ecosystem consists of users and producers of knowledge, organized around joint knowledge search' (Järvi, Almpanopoulou, and Ritala 2018, 1524). Thus, shared understandings among ecosystem participants and ecosystem output are evolving around and orienting towards knowledge search (Cohendet, Simon, and Mehouachi forthcoming). The output of a knowledge ecosystem is the ecosystem knowledge base. This base results from the collective knowledge search that that no single participant would be able to create on his/her own (Leten et al. 2013; De Silva, Howells, and Meyer 2018). Thus, an organisation and its knowledge base have access to the ecosystem knowledge base.

One key feature of knowledge ecosystems is that they emerge in pre-commercialisation settings (e.g. gene sequencing), around emerging technologies (e.g. nano technologies), and around societal challenges (e.g. climate change) (Perkmann and Schildt 2015; Järvi, Almpanopoulou, and Ritala 2018). Accordingly, there are different levels of knowledge ecosystems. For example, scholars have examined them at the city level (Cohendet, Grandadam, and Simon 2010), regional level (Rong et al. forthcoming), and the national level (Audretsch et al. 2019). Another feature of knowledge ecosystems is that they are inhabited by a community of actors that tends to be more diverse than the community characteristic for innovation ecosystems. Aside from private firms, financiers, universities,

[1]As we do not focus on innovate business models, we do not discuss the entrepreneurial ecosystems approach where such business models are the ecosystem output. See Thomas and Autio (2020) for an overview of the key features of entrepreneurial ecosystems.

activist groups, and governmental agencies participate in innovation ecosystems; in knowledge ecosystems, universities, public research organisations, and intermediary organisations also take part (Llewellyn and Erkko 2020; Järvi, Almpanopoulou, and Ritala 2018). In terms of theoretical linkages, knowledge ecosystem studies often relate to research on knowledge search (Stuart and Podolny 1996; Rosenkopf and Nerkar 2001) and studies of the interplay of problem and solution in knowledge search (Felin and Zenger 2014; Nickerson and Zenger 2004).

Organisations that participate in ecosystems search for knowledge as a means to solve their innovation-related problems (Nickerson and Zenger 2004; Cyert and March 1963). Scholars agree that searching for knowledge to solve innovation-related problems as ecosystem participants comes with at least three advantages. First, as Sinnewe, Charles, and Keast (2016) argued, the attempts of an organisation to search on its own are costly. Second, being part of an ecosystem increases the requisite variety of knowledge. That is, a knowledge-seeking organisation part of an ecosystem can access more diverse knowledge, which, in turn, increases the chance of solving the problem at hand (Leiponen and Helfat 2011; Felin and Zenger 2014). Third, especially when searching along the lines of knowledge familiar to a firm's knowledge base and thus conducting 'local search', organisations search more effectively together (Yang and Kevin Steensma 2014; Roper, Love, and Bonner 2017; Stuart and Podolny 1996).

While searching for knowledge as ecosystem participants is advantageous, however, it also comes with challenges. A primary challenge is to balance search breadth and search depth (Meulman et al. 2018). Search breadth refers to the number of channels that organisations draw upon when searching for knowledge, such as interviews, publications, and patents. By contrast, search depth refers to the extent to which organisations use different search channels (Laursen and Salter 2006). While conducting interviews to gain an overview of a scientific field exemplifies a low search depth, a systematic review of the literature in that field represents an example of a high search depth. Ecosystem participants face relatively low costs when aiming for a high search breadth and a high search depth (Sinnewe, Charles, and Keast 2016). Another challenge faced by ecosystem participants searching for knowledge in ecosystems is different orientations, which are structurally imposed because they result from the broader societal sphere (e.g. industry or academia) in which an organisation mainly operates (Perkmann 2017; Davies, Manning, and Söderlund 2018). For example, universities have other priorities than firms simply because they are part of academia. Park and Leydesdorff (2010, 647) summarised the main orientations in academia, industry, and politics as follows: 'scholars wish to publish; industries wish to gain financially from collaboration; and policymakers represent the public interest, but also want to win elections'. These different orientations result in different prioritisations of the sought knowledge and different activities used to search for knowledge, thereby causing higher coordination costs and even conflict (Park and Leydesdorff 2010; Davies, Manning, and Söderlund 2018). Intermediary organisations have therefore been identified as an important way to cope with these challenges.

2.2. TTOs and support in knowledge search as an open form of ecosystem governance

Intermediary organisations, one of the typical actors inhabiting knowledge ecosystems (Thomas and Autio 2020; Järvi, Almpanopoulou, and Ritala 2018), broker between diverse actors of an ecosystem. Thus, in terms of types of ecosystem actors (Mars, Bronstein, and Lusch 2012; Mars and Bronstein 2018), they represent generalists. An important type of intermediary organisations are TTOs, which are 'entities founded specifically to operate at the boundary of two or more preexisting communities or fields, such as between science and politics, academia and industry, or industry and open-source software communities' (Perkmann 2017, 156). Examples include the Office of Technology Transfer at the US National Institutes of Health Technology and TTOs that connect different scientific fields and/or industries (De Silva, Howells, and Meyer 2018; Kolodny et al. 2001).

A TTO represents an open governance mechanism of knowledge ecosystems (Schoen, van Pottelsberghe de la Potterie, and Henkel 2014; Filatotchev, Aguilera, and Wright 2020; Thomas and Autio 2020). A governance of knowledge ecosystems focuses on shaping the knowledge base of an ecosystem (Brenner 2007; Malmberg and Power 2005; Cohendet, Simon, and Mehouachi forthcoming; De Silva, Howells, and Meyer 2018). The label 'open' refers to mechanisms that foresee a less rigid control of knowledge flows in favour of nudging and inspiring these flows (Filatotchev, Aguilera, and Wright 2020; Leten et al. 2013; Foss, Husted, and Michailova 2010; Foss 2007). Moreover, open governance mechanisms rely less on contractual relationships between ecosystem participants (Thomas and Autio 2020) and are more future-oriented (Heimstädt & Reischauer, 2018). TTOs put this openness into practice in that they support how other organisations in an ecosystem search for knowledge. Put differently, support in knowledge search is the specific open form of ecosystem governance characteristic for TTOs. Because of that, TTOs organically embed themselves into the ecosystems they are part of to foster mutualism. Thus, all parties of an ecosystem benefit from the support offered by TTOs when searching for knowledge (Mars, Bronstein, and Lusch 2012; Mars and Bronstein 2018).

A TTO supports the knowledge search of ecosystem participants because of formal settlements that relieve them from important relevant tasks (Schoen, van Pottelsberghe de la Potterie, and Henkel 2014). To better understand how formal settlements support knowledge search, early research examined the support functions of TTOs. Van Lente et al. (2003) argued that TTOs offer three functions: they articulate options (e.g. alternative technologies) and demands (e.g. different applications of a technology), they align actors and possibilities, and they enable learning. In a similar vein but broadening the scope, Howells (2006) proposed that TTOs can offer up to ten support functions, among them gatekeeping and brokering, accrediting the involved parties, and evaluating knowledge. Likewise, Kolodny et al. (2001), who focused on the needs of small and medium-sized enterprises (SMEs), argued that TTOs offer six support functions such as prompt responses to SME requests and balance out the weaknesses of SMEs (e.g. resource scarcity). While this scholarship has generated a good understanding of the breath of TTO support functions, it provides little insight into how TTOs support the knowledge search of ecosystem participants and how the embeddedness of a TTO into knowledge

ecosystems affects these activities. The growing cross-fertilisation between innovation and organisation studies (Perkmann and Phillips 2017) has encouraged an organisational perspective that addresses these shortcomings.

3. An organisational perspective on TTOs

Studies from an organisational perspective have examined two elements of TTOs to better understand how they support knowledge search: activities and structure.

3.1. TTO activities

Organisational activities related to knowledge refer to predefined ways to purposefully manage knowledge flows (Foss 2007). Several TTO activities to support knowledge search were identified. Table 1 summarises studies that follow the suggestions by Cohendet, Simon, and Mehouachi (forthcoming) and Foss (2007) that organisational activities to exchange knowledge in ecosystems should aim for both formal outcomes (e.g. contracts) and informal outcomes (e.g. a sense of community) and the fact that TTOs represent an open mechanism of ecosystem governance (Filatotchev, Aguilera, and Wright 2020; Leten et al. 2013).

O'Mahony and Bechky (2008) argued for four activity domains – monitoring, membership, ownership, and knowledge production control – that each contain different activities by which a TTO supports knowledge search.[2] For example, within the monitoring domain, a TTO observes the ecosystem structure and participants. Defining the rights of participants is an example of an activity of the membership domain. An

Table 1. TTO activities to support knowledge search in ecosystems.[3]

Activity domain	Activity within a domain	Source
Monitoring	Establish ecosystem participant representation	O'Mahony and Bechky (2008)
	Ensure pluralistic control	O'Mahony and Bechky (2008)
	Observe the ecosystem structure and participants	De Silva, Howells, and Meyer (2018)
Membership	Define the rights of ecosystem participants	O'Mahony and Bechky (2008)
	Sponsor contributions to the ecosystem	O'Mahony and Bechky (2008)
Ownership	Obtain task assignment rights	O'Mahony and Bechky (2008)
	Develop contribution agreements	O'Mahony and Bechky (2008)
	Manage surplus contributions	O'Mahony and Bechky (2008)
	Capitalise on knowledge	De Silva, Howells, and Meyer (2018)
Knowledge production control	Manage the ecosystem participant control of contributions	O'Mahony and Bechky (2008)
		O'Mahony and Bechky (2008)
	Manage technical directions	De Silva, Howells, and Meyer (2018)
	Advance knowledge	
Knowledge diffusion	Mediate knowledge revealing	Perkmann and Schildt (2015)
	Enact a space within which to pursue multiple goals at the same time	Perkmann and Schildt (2015)
		De Silva, Howells, and Meyer (2018)
	Span knowledge	
Identity	Manage and maintain social boundaries	Perkmann (2017)
	Create a cosmopolitan interpretative scheme	Perkmann (2017)

[2]O'Mahony and Bechky (2008) examined a TTO set up to govern online communities. While we preserve the meaning of their activities, we exchange some of the original labels to better fit the terminology of ecosystem research.

exemplary activity for the domain of knowledge production control is to manage the control of contributions from participants.

Recent research has added further activities to these domains (De Silva, Howells, and Meyer 2018) and also argued for two further domains, knowledge diffusion and identity. TTOs foster knowledge diffusion by mediating the revealing of knowledge and providing a space to enable the pursuit of multiple goals at the same time (Perkmann and Schildt 2015). As Perkmann (2017) further proposed, activities within the domain of identity are also important to support knowledge search. TTOs shape the identity of ecosystem participants with two activities. First, they manage and maintain social boundaries to stabilise existing identities. Second, TTOs create a cosmopolitan interpretative scheme that allows diverse organisations to participate in line with their interests. Overall, these activities – that are grouped into the domains 'monitoring, 'membership', 'ownership', 'knowledge production control', 'knowledge diffusion', and 'identity' – demonstrate how a TTO is a generalist that fosters mutualism in terms of knowledge exchange (Mars, Bronstein, and Lusch 2012; Mars and Bronstein 2018). Other studies from an organisational perspective have examined TTOs by focusing on its structure.

3.2. TTO structure

The structure of an organisation denotes the rules guiding activities and behaviours (Dalton et al. 1980). Structure is important, as it guides knowledge flows and how organisational units search for knowledge (Burns and Stalker 1961; Lawrence and Lorsch 1967; Foss, Husted, and Michailova 2010). Traditionally, scholars have examined how the structure of a single organisation shapes its knowledge flows (Foss, Husted, and Michailova 2010; Tushman et al. 2010; Foss, Lyngsie, and Zahra 2013). Recent studies emphasise the relevance of structure for collaborative knowledge flows (Schüßler, Decker, and Lerch 2013; Malmberg and Power 2005; Reischauer and Schober 2016). However, as we discuss next, studies have thus far identified few effects of the TTO structure on knowledge search.

Debackere and Veugelers (2005) suggested combining decentralised teams and incentives with a centrally offered service such as intellectual property management. The study by Schoen, van Pottelsberghe de la Potterie, and Henkel (2014) examined how to configure a TTO structure to govern a TTO. Thus, the study did not focus on the role of the TTO structure in supporting the knowledge search of ecosystem participants but for governing the TTO. The authors suggested considering four elements: discipline specialisation (which disciplines the TTO serves), task specialisation (whether a TTO offers research funding services, intellectual property management, and/or spin-out services), autonomy (how dependent a TTO is on other organisations), and exclusivity (whether a TTO serves only one or more organisations). Likewise, the review of the TTO literature by Good et al. (2019) used a broad understanding of the TTO structure that included the ownership structure (ownership of a TTO), governance structure (degree to which a TTO is integrated into other organisations), and 'internal organisational structure', the understanding of structure that underpins this paper and the organisation design literature (Dalton et al. 1980). For the

[3]We exclude the activity to shape the ecosystem knowledge base suggested by De Silva, Howells, and Meyer (2018), as this targets the overall ecosystem and not, as all the other activities, ecosystem participants.

internal organisational structure of a TTO, Good et al. (2019) identified centralisation as an important structural dimension and distinguished TTOs only along this line. Centralised TTOs are characterised by a central support office, whereas decentralised TTOs place technology offices in departments and research centres.

3.3. Towards an integrated organisational perspective of TTOs

While the insight that centralisation is a key dimension to design the TTO structure is important, Good et al. (2019) provide little guidance on how to configure this dimension with respect to supporting the knowledge search of ecosystem participants. This insight is indicative of many studies of TTOs carried out from an organisational perspective. While they created a solid understanding of the role of the TTO structure and TTO activities in supporting knowledge search in ecosystems, they are fragmented. Specifically three gaps remain and prohibit a more integrated organisational perspective of TTOs.

First, our understanding of which ecosystem-level conditions influence the support of a TTO is limited. Specifically, gaps remain with respect to how the structure and activities of a TTO are shaped by ecosystem-level contingencies (De Silva, Howells, and Meyer 2018; Kolodny et al. 2001). This presents a crucial gap, as ecosystems are becoming increasingly important for knowledge search within academia (Walsh and Lee 2015) and between industries and academia (Park and Leydesdorff 2010; Järvi, Almpanopoulou, and Ritala 2018). Moreover, the implications of ecosystem-level contingencies for shaping the ecosystem knowledge base, a key concern of ecosystem governance more broadly, are not fully clear (Brenner 2007; Malmberg and Power 2005; Cohendet, Simon, and Mehouachi forthcoming; De Silva, Howells, and Meyer 2018).

Second, although some steps have been taken (Schoen, van Pottelsberghe de la Potterie, and Henkel 2014; Debackere and Veugelers 2005), we still know little about which dimensions of a TTO structure are relevant for and affect how a TTO supports knowledge search. This is an issue, as a TTO requires a different structure from the structure of the organisations it supports (De Silva, Howells, and Meyer 2018; Kolodny et al. 2001; Perkmann 2017; Schoen, van Pottelsberghe de la Potterie, and Henkel 2014) and different scopes of knowledge search come with different demands for a TTO (Stuart and Podolny 1996; Katila and Ahuja 2002; Rosenkopf and Nerkar 2001; Cyert and March 1963). However, we do not yet have a detailed understanding of which dimensions of the TTO structure shape how it supports the knowledge search of ecosystem participants.

Third, we know little about how TTO activities are shaped by the structure of a TTO. As an organisation's structure is strongly interwoven with its activities (Foss, Lyngsie, and Zahra 2015; Foss 2007; Schüßler, Decker, and Lerch 2013), we can expect that the structure of a TTO shapes the choice and enactment of its activities. However, the interplay between the TTO structure and TTO activities with respect to supporting knowledge search as well as which activities are possible given which structural configuration are unclear. Moreover, our understanding of how to align the design of a TTO – its structural dimensions and activities – with ecosystem-level conditions is also limited (Park and Leydesdorff 2010; Järvi, Almpanopoulou, and Ritala 2018). However, such an understanding that focuses on the key contingences for TTOs is strongly needed given that TTOs are an important mechanism to openly govern ecosystems at different levels (Perkmann and Schildt 2015; Järvi, Almpanopoulou, and Ritala 2018; Cohendet, Grandadam, and Simon 2010).

In summary, we know little about (1) which ecosystem-level factors shape knowledge search, (2) which structural dimensions of a TTO affect its activities to support knowledge search, and (3) how to align the design of a TTO – its structural dimensions and activities – with the ecosystem structure. Addressing these interrelated questions is vital to generate a more integrating understanding of the role of TTOs in supporting knowledge search in ecosystems. In what follows, we address each gap. Throughout this discussion, we provide examples, especially from the domain of information and community technologies (ICTs).

4. Ecosystem-level contingencies of the TTO structure

The question of which ecosystem-level factors shape knowledge search puts the spotlight on the contingencies of organisation design. As Donaldson (1996) puts it: 'there is no single organizational structure that is highly effective for all organizations'. Instead, the configuration of a structure is contingent upon contextual conditions. Thus, an organisation has the optimal structure if its structure is aligned with these conditions and thereby creates a 'fit' with contextual contingencies (Burns and Stalker 1961; Lawrence and Lorsch 1967).

To identify contextual contingencies at the ecosystem level, the context for knowledge search (Järvi, Almpanopoulou, and Ritala 2018), we build on the literature on local and distant knowledge search (Stuart and Podolny 1996; Katila and Ahuja 2002; Rosenkopf and Nerkar 2001; Cyert and March 1963) and follow Felin and Zenger (2014, 14) who posited that knowledge search should aim for a 'match between problem types and governance forms'. We argue for two key ecosystem-level contingencies: ecosystem search scope and problem complexity. We discuss both, focusing on the variations in and implications of these variations for the organisation of TTOs.

4.1. Ecosystem search scope

Following the literature on scopes of knowledge search (Stuart and Podolny 1996; Katila and Ahuja 2002; Rosenkopf and Nerkar 2001; Cyert and March 1963), we propose that one key contingency factor is the scope of knowledge search in an ecosystem, ecosystem search scope for short. In an ecosystem, the majority of participants conduct either a local search or a distant search.

When ecosystem participants conduct a *local search*, they search for knowledge closely related to their existing knowledge base (Stuart and Podolny 1996; Roper, Love, and Bonner 2017; Katila and Ahuja 2002). For example, Silicon Valley hosts multiple ecosystems with producers of knowledge that specialise in a certain ICT field such as social media. Likewise, firms operating a social media platform may search for knowledge by examining publications on this topic. As engaging in a local search means searching in ones' 'neighbourhood' (Yang and Kevin Steensma 2014; Roper, Love, and Bonner 2017), participants understand the knowledge base of the ecosystem. As a consequence, they revisit and refine existing their knowledge bases and co-evolve their capabilities with the ecosystem knowledge base. This also comes with the downside of a possible path-dependent ecosystem knowledge base at which participants no longer adapt to changing conditions (Schüßler, Decker, and Lerch 2013; Malmberg and Power 2005; Katila and Ahuja 2002). When organisations in an ecosystem mainly conduct a local search, a TTO

should aim to strike the right balance between their goals and the overall goal of the ecosystem (Järvi, Almpanopoulou, and Ritala 2018).

By contrast, when conducting a *distant search*, organisations explore the potential of knowledge that resides outside their 'neighbourhood' such as other industries. Thus, the sought knowledge is not part of a firm's knowledge base (Rosenkopf and Nerkar 2001; Schoenmakers and Duysters 2010; Katila and Ahuja 2002). An example of an ecosystem with mainly distant search is an ecosystem consisting of research organisations from different disciplines and firms from different industries that seek solutions for artificial intelligence-driven ways to sequence genes. Another example are medical supply manufacturers searching for knowledge in the social sciences for developing new products. Typically, the problem for which knowledge is sought tends to be ill-defined and the solutions tend to be identified ad-hoc when searching (Meulman et al. 2018). Thus, when distant search is the dominant search scope, the constant challenge is to ensure that the 'raison d'etre of the problem is understood and "translated" into a language other industries can understand' (Lopez-Vega, Tell, and Vanhaverbeke 2016, 131). As a consequence, ecosystems with a focus on distant search tend to lack a clear character and are ambiguous. To navigate this ambiguity, TTOs should focus on supporting the loose relationships among a larger number of ecosystem participants and coordinate participants in a more formal manner (e.g. with intellectual property management; Järvi, Almpanopoulou, and Ritala 2018).

4.2. Problem complexity

Knowledge in ecosystems is sought to solve innovation problems. Accordingly, 'the problem [serves] as our central unit of analysis in guiding the governance of innovation' (Felin and Zenger 2014, 916). In line with Felin and Zenger (2014), we argue that problem complexity is the second important ecosystem-level contingency of the TTO structure. The level of complexity concerns the number and degree of knowledge sets, pieces of knowledge that together are used in a consistent way, such as a certain technology (Nickerson and Zenger 2004). As we show next, problems can be either of high or of low complexity.

Problems of high complexity are characterised are by a high number of interdependent knowledge sets. Due to this strong interwovenness, problems of high complexity cannot be evaluated easily and can hardly be decomposed. Moreover, organisations often struggle to find knowledge to develop solutions for complex problems. An example is the development of an aeroplane with an electronic engine. As a consequence, problems of high complexity are typically solved using theory-guided search: organisations engage in a systematic and structured search (Felin and Zenger 2014; Nickerson and Zenger 2004). In terms of the TTO structure, a problem of high complexity requires a structure that allows dealing with this complexity and thus one that does not foster the decomposition of a problem (Brusoni and Prencipe 2013).

By contrast, *problems of low complexity* have fewer knowledge sets with less interdependencies. This lower number of knowledge sets can be divided into sub-problems more easily. Because of this feature, organisations tend to search for solutions using a trial-and-error approach; they look for simple solutions and engage in multiple feedback loops (Felin and Zenger 2014; Nickerson and Zenger 2004). Consider the example of firms finding an application of the blockchain technology in predefined parts of their

supply chain. In terms of organisational structure, a low problem complexity benefits from clear means to subdivide problems (Foss, Husted, and Michailova 2010).

5. Dimensions of the TTO structure

To clarify what parts of an organisational structure to design, scholars have developed the notion of structural dimensions. A structural dimension contains a set of consistent rules that prescribe and restrict activities (Dalton et al. 1980, 51). In organisation design studies, there is a long and successful tradition of examining the effects of the 'specialisation', 'centralisation', and 'formalisation' dimensions (Dalton et al. 1980). Innovation scholarship has provided ample evidence that these dimensions also matter for knowledge search (Foss, Lyngsie, and Zahra 2013; Foss, Husted, and Michailova 2010; Pertusa-Ortega, Zaragoza-Sáez, and Enrique 2010; Jansen, Van Den Bosch, and Volberda 2006). In addition, recent innovation studies have shown the relevance of the 'coupling' dimension (Hofman, Johannes, and Song 2017; Brusoni, Prencipe, and Pavitt 2001; Brusoni and Prencipe 2013; Grandori and Soda 2006). Against this background we argue that four structural dimensions of a TTO are relevant for knowledge search. In what follows, we discuss the variation in each dimension and, if identified by previous research, the relationship between that variation and ecosystem-level contingencies.

5.1. Coupling

The concept of coupling highlights that organisations are to some extent related to each other while still preserving their interdependency (Weick 1976). Scholars have observed two variations of coupling. *Loose coupling* refers to 'the image that coupled events are responsive, but that each event also preserves its own identity and some evidence of its physical or logical separateness' (Weick 1976, 3). Studies have found that loose coupling is best suited for distant search (Hofman, Johannes, and Song 2017; Brusoni, Prencipe, and Pavitt 2001; Brusoni and Prencipe 2013), which requires the flexibility to adjust to knowledge that is not yet known to a firm's knowledge base (Rosenkopf and Nerkar 2001). By contrast, *tight coupling* denotes interorganisational relationships with stronger interdependencies such as alliances. Tightly coupled organisations tend to engage in local search (Grant and Baden-Fuller 2004; Stuart and Podolny 1996). Thus, tight coupling is recommended when local search is the dominant search scope (Stuart and Podolny 1996).

5.2. Specialisation

Specialisation refers to the number of different tasks an organisation faces (Dalton et al. 1980). It is also a key dimension of knowledge search (Foss, Husted, and Michailova 2010) and is either high or low. A *high specialisation* (i.e. a low number of different tasks in an organisation) arises in focused interfirm alliances and narrowly defined university–industry partnerships (Dittrich and Duysters 2007; Bercovitz, Janet and Feldman 2007). The study by Brusoni, Prencipe, and Pavitt (2001) of a multi-technology firm found that its specialised knowledge base allowed it to cope with the irregularities that result from unstable technology developments and product interdependencies. A high specialisation is thus suitable when problems of high complexity that require theory-guided search occur (Felin and Zenger 2014).

By contrast, an organisation with a *low specialisation* is characterised by a high number of tasks (Dalton et al. 1980). Consider the example of interdisciplinary and interindustry TTOs that typically offer a wide range of tasks due to the multiple disciplines and industries they serve. Organisations with a low specialisation allow a wide range of actors to produce and use knowledge (Pertusa-Ortega, Zaragoza-Sáez, and Enrique 2010; Foss, Lyngsie, and Zahra 2015). A low specialisation is therefore best suited to searching for knowledge related to problems of low complexity that demand a trial-and-error search approach (Felin and Zenger 2014).

5.3. Centralisation

Centralisation refers to the locus of authority to make decisions (Dalton et al. 1980). This dimension, which Good et al. (2019) portrayed as important for TTOs, also varies between high and low. A TTO has a *high centralisation* when only few instances decide on how to support knowledge search in the ecosystem. Several studies have found that a high centralisation, such as a central R&D unit, tends to result in more complex innovation (Argyres and Silverman 2004). This implies that a central R&D unit is more likely to search for knowledge that is not part of a firm's knowledge base. Therefore, a high centralisation is useful under high problem complexity (Felin and Zenger 2014).

By contrast, a *low centralisation* is in place if any organisational unit has the authority to decide (Dalton et al. 1980); in the case of TTOs, this refers to how to support knowledge search. In line with Burns and Stalker (1961), several studies have found that a low centralisation is able to add familiar knowledge to an existing knowledge base (Damanpour 1991). Recent studies have confirmed this insight. For example, Jansen, Van Den Bosch, and Volberda (2006) showed that a high centralisation negatively influences incremental innovation.

5.4. Formalisation

Formalisation denotes the degree of documented organisational relationships (Dalton et al. 1980). Early scholarship recognised that not all behaviour can be formalised and considered informal structures as important (Burns and Stalker 1961; Donaldson 1996). In a similar vein, Foss, Husted, and Michailova (2010, 467) argued that examining 'both formal and informal organizational factors and antecedents has more potential to devise efficient organization for knowledge sharing', showing the relevance of formality for knowledge flows.

A *high formalisation* supports searching for knowledge that is not closely related to the existing knowledge base (Moenaert and Souder 1990; Meulman et al. 2018). Thus, a high formalisation is best suited for distant search (Rosenkopf and Nerkar 2001; Meulman et al. 2018). By contrast, a *low formalisation* refers to a low degree of documented and official organisational relationships, which is useful when organisations mainly search locally for knowledge related to the existing knowledge base (Järvi, Almpanopoulou, and Ritala 2018; Stuart and Podolny 1996).

6. Typology of TTO designs

We have shown that whether a TTO is part of an ecosystem in which participants mainly conduct a local search or a distant search matters. We have further shown that a TTO faces different demands when the dominant ecosystem search scope is to solve problems of high complexity or low complexity. We now integrate these insights to address the question how to align the design of a TTO – its structural dimensions and activities – with the ecosystem structure

As depicted in Figure 1, crossing a contingency and its two variations with each other results in a typology of four TTOs designs. A design details an archetypical configuration (Meyer, Tsui, and Hinings 1993) of both variations in a TTO's structural dimensions, namely, coupling, specialisation, centralisation, and formalisation, and selected activities in the domains of monitoring, membership, ownership, knowledge production control, knowledge diffusion, and identity (Perkmann 2017; Perkmann and Schildt 2015; O'Mahony and Bechky 2008; De Silva, Howells, and Meyer 2018). The label of each design – 'acquaint', 'broadcast', 'convene', and 'modify' – signals the basic way in which the interplay of the TTO structure and TTO activities supports knowledge search. This interplay also has implications for the knowledge base of the ecosystem and thus the governance aim that is characteristic for each design (Brenner 2007; Malmberg and Power 2005; Cohendet, Simon, and Mehouachi forthcoming; De Silva, Howells, and Meyer 2018). In what follows, we discuss the designs and their implications for the ecosystem knowledge base. Table 2 provides an overview. In this discussion, we provide further examples for how a TTO represents a generalist that fosters mutualism with respect to knowledge exchange (Mars, Bronstein, and Lusch 2012; Mars and Bronstein 2018; Shaw and Allen 2018).

6.1. Acquaint

A TTO designed to *acquaint* is best suited when distant search is the ecosystem search scope and when participants mainly seek knowledge to address problems of high complexity. A TTO designed to acquaint encourages non-binding collaborations and interactions between producers of knowledge that is not part of an organisation's current

		Ecosystem search scope	
		Distant search	Local search
Problem complexity	High	**Acquaint** (nurture interdisciplinary and interindustry ecosystem knowledge base)	**Convene** (extend ecosystem knowledge base)
	Low	**Broadcast** (revitalise ecosystem knowledge base)	**Modify** (refine ecosystem knowledge base)

Figure 1. TTO designs.

Table 2. Configurations of the structural dimensions and activities for each TTO design.

TTO design	Coupling	Specialisation	Centralisation	Formalisation	Activities (Activity domain)
Acquaint	Loose	High	High	High	Ensure pluralistic control (Monitoring) Enact a space within which to pursue multiple goals at the same time (Knowledge diffusion) Mediate knowledge revealing (Knowledge diffusion) Create a cosmopolitan interpretative scheme (Identity)
Broadcast	Loose	Low	Low	High	Observe the ecosystem structure and participants (Monitoring) Sponsor contributions to the ecosystem (Membership) Manage technical directions (Knowledge production control) Span knowledge (Knowledge diffusion) Manage and maintain social boundaries (Identity)
Convene	Tight	High	High	Low	Establish ecosystem participant representation (Monitoring) Manage surplus contributions (Ownership) Develop contribution agreements (Ownership) Manage the ecosystem participant control of contributions (Knowledge production control)
Modify	Tight	Low	Low	Low	Define the rights of ecosystem participants (Membership) Capitalise on knowledge (Ownership) Obtain task assignment rights (Ownership) Advance knowledge (Knowledge production control)

knowledge base. Thus, a TTO with this design follows the governance aim to nurture an interdisciplinary and/or interindustry ecosystem knowledge base. An example is a TTO dedicated to foster research and teaching on quantum mechanics and its societal implications.

To support knowledge search, a loose coupling with ecosystem participants such as research units from various disciplines and firms from different industries is sought, as this allows loose interactions. When a TTO fosters loose coupling, participants can interact on an ad-hoc basis and move on if the exchanged knowledge does not fit their needs. Moreover, a TTO designed to acquaint is highly specialised, highly centralised, and highly formalised. These structural configurations reflect the necessity that tackling problems of high complexity requires theory-guided search.

In particular, a TTO designed to acquaint should offer four activities identified by prior research. First, high specialisation, high centralisation, and high formalisation require ensuring pluralistic control, which is crucial to of the activity domain of monitoring. Second, being part of the knowledge diffusion domain, the acquainting TTO provides a space within which to pursue multiple goals at the same time, which allows heterogeneous ecosystem participants to engage in distant search. Third, and again part of the domain of knowledge diffusion, emphasis is placed on mediating knowledge revealing due to the high complexity of the problems to be solved. Finally, a TTO that acquaints creates a cosmopolitan interpretative scheme to foster a shared understanding among ecosystem participants, an activity that falls into the activity domain of identity. Overall, we propose:

Proposition 1: When a TTO is part of an ecosystem in which distant search is the dominant search scope and knowledge is sought to mainly address problems of high complexity, 'acquaint' – a configuration of loose coupling, high specialisation, high centralisation, and high formalisation as well as selected activities from the domains of monitoring, knowledge diffusion, and identity – would be the most effective design.

6.2. Broadcast

The *broadcast* design is favourable for a TTO when ecosystem participants are mainly conducting distant search and when they address problems of low complexity. The notion of broadcasting signals that a TTO designed this way provides steady small impulses to support knowledge search akin to a radio broadcasting station. In terms of ecosystem governance, the aim of a broadcasting TTO is to revitalise the ecosystem knowledge base. Consider the example of a TTO dedicated to a technology that has reached its productivity limit.

When designed to broadcast, a TTO fosters loose couplings among ecosystem participants, as this type of coupling is beneficial for distant search. Likewise, distant search requires a high formalisation. This is important given the high number of different participants, thereby requiring documentation to continue the search over time. Moreover, a TTO that broadcasts need be less specialised and centralised, as these features are most appropriate to support the search for knowledge to solve problems of low complexity.

Five activities seem particularly important for a broadcasting TTO. First, a TTO observes the ecosystem structure and participants (part of the monitoring domain). This is important given the high number of various ecosystem participants. Second, a broadcasting TTO sponsors contributions (part of the membership domain) to observe the ecosystem structure and participants, again given the large number of the latter. Third, a broadcasting TTO manages technical directions to control knowledge production. This is a crucial activity to avoid high coordination costs among participants, as a low problem complexity suggests rather unguided trial-and-error search. Fourth, as part of the knowledge diffusion domain and resulting from a focus on distant search, a broadcasting TTO spans knowledge, which enhances the chances of a mutual understanding of knowledge that is not yet familiar to participants' knowledge bases. Fifth, such a TTO manages and maintains social boundaries to accommodate the identity of diverse ecosystem participants. We thus propose:

Proposition 2: When a TTO is part of an ecosystem in which distant search is the dominant search scope and knowledge is sought to mainly address problems of low complexity, 'broadcast' – a configuration of loose coupling, low specialisation, low centralisation, and high formalisation as well as selected activities from the domains of monitoring, membership, knowledge production control, knowledge diffusion, and identity – would be the most effective design.

6.3. Convene

A TTO designed to *convene* is most suitable when the dominant ecosystem search scope is local search and when participants primarily seek knowledge to solve problems of high complexity. As the label indicates, this design connects participants in a focused way akin to a specialised convention. Supporting the knowledge search of participants in this way allows a TTO to meet the governance aim to extend the ecosystem knowledge base. An example is a TTO with a focus on computational science, a field that connects natural sciences with computer science and mathematics.

A convening TTO suggests a tight coupling with organisations in the ecosystem, as this feature is beneficial for local search. In addition, a convening TTO is characterised by a high specialisation and high centralisation, as these configurations best support the search for knowledge to solve problems of high complexity. Given that local search is the dominant ecosystem scope, a convening TTO is also hardly formalised.

To support knowledge search, a convening TTO offers four activities. First, as part of the monitoring domain, such a TTO establishes ecosystem participant representation. This is important because the theory-guided search resulting from high problem complexity benefits from a clear positioning of ecosystem participants with respect to their knowledge bases. Second, a convening TTO manages surplus contributions, an activity part of the domain of ownership. This is an important activity to encourage finding knowledge to solve problems of high complexity, as organisations often struggle to find such knowledge. The third activity, which is also part of the ownership domain, is to develop contribution agreements. Such agreements are important for a problem of high complexity. Fourth, a convening TTO manages the ecosystem participant control of contributions, an activity of the knowledge production control domain. This activity backs the activities in the domain of ownership, manages surplus contributions, and develops contribution agreements. In sum, we propose:

Proposition 3: When a TTO is part of an ecosystem in which local search is the dominant search scope and knowledge is sought to mainly address problems of high complexity, 'convene' – a configuration of tight coupling, high specialisation, high centralisation, and low formalisation as well as selected activities from the domains of monitoring, ownership, and knowledge production control – would be the most effective design.

6.4. Modify

A TTO designed to *modify* is suitable for an ecosystem in which participants are searching locally and for the knowledge required to solve problems of low complexity. As the label indicates, the governance aim of a modifying TTO is to refine the ecosystem knowledge base. An example is a research-oriented TTO to foster knowledge search in an established ICT sub-discipline such as social media. Due to the affordances of searching for knowledge to solve simple problems, this TTO is characterised by a tight coupling with other organisations that enables frequent exchanges on a trial-and-error basis. Moreover, seeking knowledge for simple problems requires a low specialisation and low centralisation. As organisations engage in local search, a low formalisation is also suggested.

Four activities seem particularly relevant for a TTO with the modify design. First, defining rights is important. As part of the domain of membership, this activity supports local search, as the returns of this search are secured despite similar knowledge bases among participants. In a similar vein, second, a modifying TTO capitalises on knowledge, an activity of the ownership domain. Capitalising on knowledge ensures that participants receive their returns as defined. Third, a modifying TTO obtains task assignment rights, an activity that also falls into the ownership domain. Doing so is important, as it enables a focused support of local search as tasks are clearly divided, thereby best supporting ecosystem participants in their local search. Fourth, a modifying TTO advances

knowledge, an activity of the knowledge production control domain. Doing so avoids the knowledge bases of ecosystem participants becoming path-dependent, which is a likely for local search and problems of low complexity. We thus propose:

Proposition 4: When a TTO is part of an ecosystem in which local search is the dominant search scope and knowledge is sought to mainly address problems of low complexity, 'modify' – a configuration of tight coupling, low specialisation, low centralisation, and low formalisation as well as selected activities from the domains of membership, ownership, and knowledge production control – would be the most effective design.

7. Discussion

In this paper, we argued that our understanding of the role of TTOs in supporting knowledge search in ecosystems is limited with respect to ecosystem-level contingencies, the structural dimensions of a TTO, and how to align the design of a TTO – the interplay of its structural dimensions and activities – with the ecosystem. By addressing each of these gaps, our paper contributes to research on and the policy-making practice of ecosystems.

7.1. Implications for research

Our paper adds to three lines of research. First, our theorising contributes to scholarship on the *open governance of ecosystems* in two ways. The first way is that we address the issue of how organisations can purposefully support ecosystems. As we argue, such purposeful support can be achieved through TTOs that are designed to either 'acquaint', 'broadcast', 'convene', or 'modify'. Each of these designs suggests different bundles of TTO structural dimensions and TTO activities support knowledge search in an ecosystem and thus different ways of shaping the ecosystem knowledge base. We thus make the case that the design of a TTO that supports knowledge search with specific designs is key for a successful open governance of ecosystems (Filatotchev, Aguilera, and Wright 2020; Leten et al. 2013). This is an important insight, as studies of how to leverage TTOs for open ecosystem governance are fragmented and hardly go beyond the notion that TTOs matter (Van Lente et al. 2003; Kant and Kanda 2019; Howells 2006). Likewise, while TTO activities are found to support knowledge search in ecosystems (Perkmann 2017; Perkmann and Schildt 2015; O'Mahony and Bechky 2008; De Silva, Howells, and Meyer 2018), these insights are hardly related to findings on how TTO structure supports knowledge search (Dalton et al. 1980; Schoen, van Pottelsberghe de la Potterie, and Henkel 2014; Debackere and Veugelers 2005). Overall, we demonstrate that an integrated organisational perspective that accounts for the interplay of TTO activities and the TTO structure (Foss, Lyngsie, and Zahra 2015; Foss 2007; Schüßler, Decker, and Lerch 2013) offers a systematic understanding of how to leverage TTOs as an open governance mechanism in ecosystems.

We further contribute to research on the open governance of ecosystems by enhancing our understanding of the role of specific ecosystem actors that the specific interaction types they foster. A TTO represents a generalist that accounts for mutualism with respect to knowledge exchange (Mars, Bronstein, and Lusch 2012; Mars and Bronstein 2018). We

enrich these important insights grounded in the innovation ecosystem literature with insights from the knowledge ecosystem approach. As we show, TTO activities in the domains 'monitoring, 'membership', 'ownership', 'knowledge production control', 'knowledge diffusion', and 'identity' support knowledge search in different ways. These combined insights showcase the richness of governing in an open way (Filatotchev, Aguilera, and Wright 2020; Leten et al. 2013) that reflects the evolutionary nature of ecosystems that is characteristic for both, the innovation ecosystem approach and knowledge ecosystem approach (Järvi, Almpanopoulou, and Ritala 2018; Mars and Bronstein 2018; Thomas and Autio 2020). With this careful synthesis, our paper follows the call by Clarysse et al. 2014 to cross the chasm between these two ecosystem approaches and to specify the inner workings of a TTO as a 'mechanism that reinforces convergent interests while allowing divergent ones to persist' (O'Mahony and Bechky 2008, 426).

Second, our paper adds to research on *ecosystem structures* (Järvi, Almpanopoulou, and Ritala 2018; Cohendet, Simon, and Mehouachi forthcoming) by offering two key ecosystem-level contingencies for knowledge search: (1) ecosystem search scope that varies between distant research and local search (Stuart and Podolny 1996; Katila and Ahuja 2002; Rosenkopf and Nerkar 2001; Cyert and March 1963) and (2) problem complexity that oscillates between high and low (Felin and Zenger 2014; Nickerson and Zenger 2004; Cyert and March 1963). Both factors have been identified as important contingencies at the level of the knowledge-seeking organisation. As our synthesis with the knowledge ecosystem literature demonstrates, they are also important contingencies at the ecosystem level to explain different outcomes at the organisational level. Identifying ecosystem-level contingencies is of uppermost importance for ecosystem research given that the increasing complexity of knowledge search requires approaches that consider the specifics of ecosystems (Cohendet, Grandadam, and Simon 2010; Cohendet, Simon, and Mehouachi forthcoming; Gifford, McKelvey, and Saemundsson forthcoming).

Third, we add to research on the *relationship between the ecosystem structure and intermediary organisations*. So far, scholars have paid scant attention to the effects of the ecosystem structure on supporting knowledge search by intermediaries in general and TTOs specifically (Good et al. 2019; Howells 2006; Perkmann 2017). By carefully linking the key insights from organisation design and ecosystem studies, we provide a nuanced view of how the structure of an ecosystem influences the design of a TTO that is pivotal for how support in knowledge search is enacted. For example, two designs – 'acquaint' and 'broadcast' – suggest activities related to the activity domain of identity. As both designs are suitable when distant search is the dominant ecosystem search scope, this implies that a TTO should only attempt to manage the identity of ecosystem participants when this search scope is at hand. For the same reason, knowledge diffusion activities are suitable only for the 'acquaint' and 'broadcast' designs; it is the condition of distant search that prompts a TTO to spread knowledge. Moreover, activities that fall into the domain of knowledge production control are especially suitable for a TTO designed to broadcast, convene, or modify, but not for a TTO designed to acquaint. This indicates that given distant search and high problem complexity, the conditions that best work for the design 'acquaint', knowledge production control is better pursued by ecosystem participants other than a TTO. In addition, when a TTO is designed to modify, it does not include activities that fall into the monitoring domain. We can thus infer that a low

problem complexity and local search that is characteristic of the 'modify' design do not require strong monitoring efforts from TTOs. Overall, our theorising of the relationship between the ecosystem structure and intermediary organisations with a focus on TTOs resonates with the observation by Cohendet, Simon, and Mehouachi (forthcoming) that sustainable ecosystems require a 'middle ground', a structure 'to make creative material technologically feasible, economically marketable and viable, and to facilitate the codification and sharing of new knowledge' (p. 6). Put differently, a 'middle ground' represents a common forum that inspires the production of and search for knowledge in an ecosystem. A TTO whose design reflects ecosystem-level contingencies can ensure such a 'middle ground' and thereby act as example of 'common platforms of knowledge necessary for the knowledge transmission and learning that precedes innovation' (Cohendet, Grandadam, and Simon 2010, 92).

Our insights also provide a fertile ground for future research. To advance our understanding of the role of TTOs in open ecosystem governance, future studies should test our propositions empirically. Moreover, it would be interesting to apply our contingency theorising approach to other forms of intermediary organisations such as innovation consultancies (Van Lente et al. 2003; Kant and Kanda 2019; Howells 2006) and develop organisation designs that consider their specific support of knowledge search. This would be an important endeavour, as different intermediaries tend to co-exist in the same ecosystem. Moreover, reflecting that ecosystem structures change over time (Järvi, Almpanopoulou, and Ritala 2018; Clarysse et al. 2014; Cohendet, Simon, and Mehouachi forthcoming), we suggest examining the change in TTO designs with respect to ecosystem evolution. Such studies might identify change patterns linked to ecosystem lifecycles. Relatedly, it would be interesting to examine whether specific TTO designs come with specific degrees of nestedness (Shaw and Allen 2018; Mars, Bronstein, and Lusch 2012).

7.2. Implications for policymakers

Our study also has implications for policy makers. Foremost, we provide policymakers with guidance on how to set up and shape a TTO. Specifically, by giving insights into which structural dimensions shape a TTO's support of knowledge search, how to configure these dimensions, and how to align a TTO structure and activities with the structural affordances of an ecosystem, we provide a systematic yet focused overview of how to align a TTO with the ecosystem it should shape. Given that entrepreneurial incentives of knowledge ecosystem are strengthened by a higher degree of policy experimentation (Gifford, McKelvey, and Saemundsson forthcoming), such insights are of great relevance.

An important question for policymakers is whether to align the design of a TTO with the city level (Heimstädt and Reischauer 2019), regional level (Rong et al. forthcoming), or national level (Audretsch et al. 2019). We propose a three-step procedure to address this question. First, as Cohendet, Simon, and Mehouachi (forthcoming) suggest, it is important to identify the current capabilities, resources, and TTOs that a policymaker has available to govern knowledge ecosystems. Doing so sets an important boundary condition. For example, nations that have multiple innovation-promoting institutions such as business agencies and a wide range of clusters might find it easier to design or setup TTOs that also shape multiple knowledge ecosystems at different levels. By contrast, cities or regions with

a strong focus on specific industries might attempt to create a TTO that governs specific knowledge ecosystems. Second, and mirroring the fact that knowledge ecosystems emerge in pre-commercialisation settings, around emerging technologies, and around societal challenges (Perkmann and Schildt 2015; Järvi, Almpanopoulou, and Ritala 2018), policymakers should clarify the focus of future knowledge flows – which technologies, innovations, or challenges – they attempt to govern. In a third step, actors relevant for the identified future focus of knowledge flows can be mapped. Citation analysis is a useful tool for that endeavour, especially to map global knowledge flows (Bhupatiraju et al. 2012). Combining these insights with the capabilities, resources, and TTOs identified in the first step, policymakers can reflect upon which ecosystems they aim for by leveraging the governance mechanism TTO. For example, resourceful policymakers at the national level might decide to establish a TTO with a national scope together with other ecosystem participants to shape national knowledge ecosystems on an emerging technology such as blockchain. This is the case for the Austrian Blockchain Centre established with the resources from and in cooperation with multiple federal ministries, firms, and universities.

Moreover, our synthesis in the form of a typology provides policymakers with the opportunity to reflect on the extent to which established TTOs 'fit' their ecosystem. In doing so, we follow the call by Filatotchev, Aguilera, and Wright (2020, 175) to develop a framework that 'explicitly examines the alignment between organizations and their broader environment, and the firm's co-evolution towards a sustainable, win-win relationship with stakeholders'. As the popular typology proposed by Miles et al. (1978) on the archetypical innovation strategies of firms illustrates, typologies are highly suitable to reflect strategic issues and make adjustments in practice.

8. Conclusion

The governance of ecosystems is a topic of uppermost importance. By developing theory that incorporates both the organisational specifics of TTOs (as a distinct mechanism for open ecosystem governance) and key ecosystem-level contingences, we offer insights into how to align the design of TTOs with the ecosystem. This theorising is one step further towards a more comprehensive understanding of ecosystem governance and providing a possible solution to what Baldwin (2012) identified as 'the key problem for organization design [...] the management of distributed innovation in such dynamic ecosystems'.

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ORCID

Georg Reischauer http://orcid.org/0000-0001-7041-6106
Wolfgang H. Güttel http://orcid.org/0000-0002-0957-6378
Elke Schüssler http://orcid.org/0000-0002-7505-4148

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