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Holistic ecosystems for enhancing innovative collaborations in university–industry consortia

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Abstract
University–industry (UI) consortia are gaining prominence as new organizational platforms that facilitate innovative learning, translation of basic research into applied R&D, and the formation of collaborations. Research has highlighted the benefits of collaborative knowledge-creation within consortia, yet little attention was given for a holistic approach to this platform and to the organizational design framework that is fruitful by participants. Given this research shortage, we interviewed consortia leaders and university/industry participants in order to study what platforms of collaborations are perceived fruitful and desired by consortia leaders and participants. The findings show that consortia managers and participants suggest establishing multiple types of platforms for different sub-clusters within the consortia and offering entry flexibility for new participants by need. These design suggestions depict consortia as holistic ecosystems that facilitate the creation of innovative UI technologies and products.

Keywords Consortia · Ecosystem · Holistic · Innovation · Platform · Technology transfer · University–industry collaborations

JEL Classification 031 · 032

1 Introduction

In order to innovate, knowledge based organizations need to learn from and collaborate with other knowledge organizations in relevant fields and transfer technologies (Chesbrough, 2006; Holmqvist, 2004; Oliver, 2009; Perkmann et al., 2013; Powell et al., 2005). The formation of various platforms of university–industry technology transfer collaborations is beneficial for both universities and firms. These forms include, for example, technology transfer offices (TTOs), incubators, science parks, university venture funds, and accelerators (Good et al., 2019). The main general advantages of such collaborative ecosystems for universities are the addition of funds for professors that provide flexibility and freedom of research; access to practice-focused research and open explorations to new

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fields of research and methods; access to updated research results; and access to knowledge from the industry and the market realities (Dan, 2013: 71). In addition, academics can gain access to industry data and equipment as well as faster feedback loops and research validation (Dooley & Kirk, 2007). Participation in various UI ecosystems facilitates the creation of new knowledge with practical applications and enables universities to show that they are contributing to the economy. Additional advantages for university scientists include acquiring new capabilities and expertise, enhancement of interdisciplinary knowledge, and the creation of learning environments for young scientists. Such collaborations also promote scientific research whose ultimate aim is commercialization while offering learning opportunities by presenting scientists with new problems that come from industry (Oliver, 2009).

For industry members, a key benefit of UI consortia is the opportunity to access new (tacit and explicit) knowledge and competence stemming from publicly funded academic research (Dan, 2013). In addition, the industry can benefit from speeding up the innovation process and a reduction of research stages, and joining a consortium with universities offers a division of the R&D costs as well as reducing uncertainty and related risks (Dan, 2013). These opportunities are particularly advantageous in areas of science where the industry may be weak. Moreover, consortia provide industrial scientists with the possibility to collaborate with leading scientists, working both in academia and in other firms that are competing in the same technological domain. Through these collaborations, the industrial scientist can gain exposure to new scientific methods and validation opportunities that can expedite R&D. These knowledge advantages can provide firms with a competitive edge (Dooley & Kirk, 2007; Perkmann & Schildt, 2015).

Such learning collaborations are important facilitators of knowledge-creation that enhance firms' and universities' ability to capture returns from innovative ideas, or in other words, to translate knowledge into commercial potential (Bruneel et al., 2010). We also know that innovation is most likely to occur within an entrepreneurial ecosystem involving a range of actors including firms and universities (Feldman et al., 2019). Another important aspect concerning UI technology transfer is that most studies focus on the formal technology transfer platforms, and there is little empirical evidence for informal technology transfer collaborations (Link et al.,2017).

A recent important line of re-thinking TT (Siegel & Wright, 2015) and theorizing TT ecosystems (Good et al., 2019) calls for a holistic approach that offers an organizational design framework for TT collaborations. Good et al. (2019) claim that the literature has rarely examined the ecosystem as a whole and is mostly typified as "atomistic" where knowledge is produced within isolated components. Their "organizational design framework" calls for a new agenda for a "holistic" ecosystem approach. Such holism is associated with insights into the identification of the ecosystem components and the collaborations they facilitate.

Following these new calls for holistic studies of TT ecosystems and the limited examination of UI consortia, this paper asks how UI consortia can be designed as holistic ecosystems that can maximize the learning and innovating potential. Organizational scholars have sought to identify platforms that facilitate fruitful learning collaborations (For example, Al-Tabbaa & Ankrah, 2016) but are not yet clear on the specific factors that promote success and what collaboration platforms are perceived as beneficial.

This study is motivated by the growing interest in UI science and technology consortia. Aside from funding for collaborative research, we know little about the structures, formats, and experienced learning in the different innovative platforms established in these consortia. An inside view of the choices made within consortia is of interest both to science policymakers (Proskuryakova et al., 2017) and to academic and industry scientists—all interested in maximizing the benefits and outcomes of consortia. In addition, the paper examines "alternative pathways" for knowledge exchange. It follows the call of Hayter et al. (2020) to examine alternative practices, policies, and conceptualizations of knowledge exchange that go beyond what they term “the traditional linear, patent-based heuristics of technology transfer.”

The paper is organized as follows: First, we provide a theoretical background and literature review of UI consortia, their history, and the knowledge creation networks they host. Then, we present the method of the study where we describe the selection of the four consortia and the data we collected. Next, we characterize 12 different learning platforms mentioned by our interviewees. Finally, we offer a conclusion and discussion section where we highlight the importance of our findings and their relevance to theory and policy.

2 Theoretical background and literature review

In general, UI consortia are (typically) government-funded programs aimed at providing incentives for UI learning collaboration while offering assurances of protection. UI consortia are recognized as structures with the potential to provide rich knowledge-exchange opportunities to university and industry scientists (Carayannis, Alexander & Loannidis, 2000; Sydow et al., 2012). Consortia facilitate UI knowledge sharing and collaboration networks among the members (Valkokari et al., 2012) and they dissolve after a pre-defined time or objective (Sakakibara, 2002).

In what follows, we first provide basic context for the concept of UI consortia and subsequently discuss how the structure of a consortium has the potential to facilitate knowledge sharing and innovation. Next, we review the benefits that such platforms provide to university and industry members.

UI collaboration research focuses on the interaction between different stakeholders from universities and industries (Roelofsen et al., 2011). Such collaborations aim to facilitate knowledge and technology exchange (Ankrah & Omar, 2015; Siegel et al., 2003) and to create new knowledge and technologies. In a systematic review of UI collaborations, Ankrah and Omar (2015) identified five key factors reviewed in the research literature. The key themes are forms, motivations, formation and activities, enablers and inhibitors, and outcomes. This paper focuses on the key theme of the formation of activities within the context of a science and technology consortium and suggests a variety of platforms for increasing access to knowledge and enhancing the formation of UI collaborations.

2.1 UI consortia and related feature

Research about UI collaborations has been gaining momentum among organizational and policy scholars since the passage of the Bayh-Dole Act in 1980 in the US (Veugelers, 2014). The Bayh-Dole Act shifted the ownership of intellectual property (IP) resulting from publicly-funded research from the government to the research sector, mainly universities. This right to own IP resulting from publicly-funded research created incentives for universities to look for commercial applications of their research and to attempt to obtain patents for inventions produced by scientists who had used public funding. With the support of technology-transfer offices established in universities to appropriate the returns from academic knowledge and inventions and to reach the markets with their inventions, UI collaborations became an important and legitimate source of funding for universities.

Soon enough, governments began to acknowledge the economic potential of UI collaborations and to establish new models, platforms, and policy initiatives for supporting such collaborations on a national level (e.g., Etzkowitz et al., 2005; Hermans & Castiaux, 2017; Leydesdorff, 2013; Leydesdorff & Sun, 2009). Similarly, the notion of knowledge communities (e.g. communities of practice) began to be relevant for knowledge management, the development of social capital, and the facilitation of new knowledge creation and innovation in the reactions of the European Commission and the framework programs (Klein & Hirschheim, 2008; Draghici et al., 2008). New research aimed to identify innovative processes facilitated by new models such as the Quadruple Helix and Quintuple Helix (Carayannis & Campbell, 2010).

Government initiatives under the triple helix or community of practice models may range from funding one-on-one collaborations for several years (e.g., one academic group and one firm) to establishing larger-scale UI consortia. The consortia operate as an organizational form that fosters the organizing capacity of universities and industry actors to solve innovative complex problems in specific areas and reach the market faster (Aldrich & Sasaki, 1995; Mannak et al., 2019; Nakamura et al., 1997; Padilla-Meléndez et al., 2020).

Clearly, UI collaborations aim to facilitate knowledge and technology exchange (Ankrah & Omar, 2015; Siegel et al., 2003) and to create new knowledge and related products and technologies. However, they entail various complexities including multiple actors with different knowledge and interests as well as the need for establishing trust in the collaborations (Laursen & Salter, 2014; Kalish & Oliver, 2021; Oliver, 2004, 2009; Oliver & Kalish, 2012; Oliver et al., 2019).

The proposed holistic perspective on the TT ecosystem approach proposed by Good et al. (2019) offers four main components: purpose, activity, structure, and organizational culture. A holistic approach for the 'purpose' component includes a focus on knowledge transfer and on wide societal impact, and for the 'activity' component includes collaborative and complementary activities, boundary spanning between the TT ecosystem and the related environment, and a focus on a process perspective of TT. The 'structure' of a holistic TT ecosystem involves an understanding of the needs of the TT ecosystem, allowing for the engagement of new members and structures as well as additional needs of the universities and facilitating the flow of digitized databases. Finally, for 'organizational culture', the focus is on allowing for different compositions of TT ecosystem teams, both heterogeneous and homogeneous, paying attention to the entrepreneurial culture of the TT ecosystem and to the important role of leaders in the evolution of the ecosystem. From an ecosystem design perspective, we depict two main components underlying knowledge creation: multiple channels of interactions and nested networks.

Channels of interactions: There are three stages of UI interactions: drivers, channels of interactions, and benefits (De Fuentes & Dutréni, 2012). Drivers and benefits were discussed above. Here we focus on alternative channels of interactions for knowledge transfer. The literature review by DeFuentes and Dutreni suggests the existence of multiple channels for interactions and that academic researchers value different channels from those valued by industry scientists. Academic researchers prefer meetings and conferences, training, and consultancy, while industry scientists prefer joint R&D projects and networking meetings. The channels are grouped into different categories including formal and informal interactions, collaborative research leading to publications, or contractual R&D projects. In all channels, tacit knowledge can be transmitted (Perkmann & Walsh, 2009), and the co-existence of multiple types of channels can increase motivation to interact and employ different knowledge interactions. In the holistic approach, multiple channels of interactions between actors with different capabilities and interests are a key element of the ecosystem design.

Nested networks: Many scholars have discussed the benefits of knowledge-sharing systems for enhancing innovation (Al-Tabbaa & Ankrah, 2016; Carayannis et al., 2000). A classic study in this domain is the exploratory work of Dyer and Nobeoka (2000), who examined knowledge-sharing networks in Toyota and produced important insights. Their investigation suggested that Toyota's innovation capacities were largely attributable to the novel institutional features that facilitated the creation of a high-performance interorganizational learning network including the establishment of a supplier association, and the formation of "jishuken" (e.g. smaller working groups). These small groups constituted networks that were "nested" within the larger network of suppliers; the members of a particular group shared strong ("embedded") ties with multiple other suppliers with whom they were able to exchange particularly relevant knowledge.

In effect, UI consortia are knowledge-sharing systems that rely on a "nested network" approach, in that they provide incentives for small groups of university and industry networks within the larger consortium, as a means of promoting innovation. Carayannis et al., (2000:477) highlight the benefits of such a knowledge-sharing structure that promotes the formation of trust and builds social capital needed for further cooperation. Such platforms are a vehicle for accelerating organizational learning in UI collaborations where learning takes place through shared knowledge. A more recent study, by Al-Tabbaa and Ankrah, (2016), follows the work of Nahapiet and Ghoshal (1998) and Tsai and Ghoshal (1998) who identify three dimensions of social capital: structural, relational, and cognitive, and claim that the value of social capital can be moderated by the interaction among these dimensions. Al-Tabbaa and Ankrah (2016) highlight the importance of these dimensions of social capital in platforms that create and maintain social capital in UI collaborations; they further argue that social capital does not develop linearly but through a continuous complex interaction among the three dimensions. In addition, they claim that it is important to facilitate both the relational and the cognitive dimensions of social capital.

The current study draws from field data in four science and technology consortia in Israel. The goal of this study was to identify innovation platforms that could facilitate collaborations and knowledge creation in consortia. A consortium platform is "*a multi-actor configuration deliberately set up to facilitate and undertake various activities around identified … innovation challenges and opportunities*" (Kilelu et al., 2013:66). Thus, it is a space for formal and informal learning among individuals who represent organizations with different research and development backgrounds and interests. Within consortia, members coordinate R&D activities through diagnosing problems, identifying opportunities, and sharing knowledge and technologies. Prior studies on the topic have offered suggestions for improving collaborations within consortia (e.g.,Thune & Gulbrandsen, 2011), yet a comprehensive list of potential platforms has yet to be developed. In addition, the concept of knowledge management is multifaceted (Firestone, 2008) and in the context of UI innovation platforms is associated with group learning and knowledge sharing. Based on the elements of the holistic perspective to the TT ecosystem, we examined insights offered by UI consortia ecosystems and acknowledged elements that support the model proposed by Good et al. (2019).

3 Research method

3.1 Context and sampling

The study is based on four state-funded UI science and technology consortia in Israel that operated between the years 2013 and 2018. A government program, titled Magnet, initiated these consortia, and they are described as "…dedicated to the establishment of a technological infrastructure for the next generation, and the creation of a cooperative technological reservoir—containing a combination of knowledge from the industrial sector and the academic world".[1] The Magnet program offers a unique business model funded by the chief scientist of the Ministry of Economy and Industry. Under this model, participating firms receive 66% financing (not expected to be returned) in order to collaborate. Academic scientists receive 80% funding in order to collaborate with industry members, and industry collaborators pay the other 20%. This incentive system provides all participants with a strong financial motivation to collaborate. IP protection is another important aspect of knowledge exchange systems, and the contractual arrangements provided each consortium member with a clear contract regarding IP protection. The formal goal of the consortium was to develop generic knowledge that will be beneficial for all participating members, and thus, knowledge sharing and collaborations among participants were expected.

We carried out this research as part of a longitudinal study of collaborations within science consortia. We began by interviewing the government administrator in charge of funding and monitoring all UI science consortia. This administrator gave us background information and granted us an endorsement to interview consortia heads and their members. Then, we selected a sample of four consortia from a list of 11 active consortia. In selecting this sample, we targeted consortia that comprised more than 10 participating firms and universities, that were in their first or second year of operation, and that represented different scientific and technological areas (as a means of increasing diversity). Based on these sampling criteria, we chose the four consortia that focused on nanotechnology, biotechnology, new materials, and drug delivery. Rather than sampling interviewees, we interviewed all scientists involved in the four consortia (n = 58).

3.2 Data collection

Data were collected through several stages, and here we use the data that originated from the open-ended parts of the interviews. Table 1 explains the data collection analyses stages.

For each of the four science and technology consortia in our sample, we conducted face-to-face semi-structured interviews with the head of the consortium. Next, we conducted structured (both face-to-face and internet) interviews with all scientists (both university and industry) who participated in these consortia. As instructed by the Research Ethics Committee (REC) of our university, we assured all interviewees of anonymity and obtained their signed consent to participate.

The interviews included questions on the scientists' background and on their participation in the consortium in terms of the knowledge exchange activities they had conducted within the consortium. The first part of the questionnaire included closed-ended questions about the contribution of the consortium participants to knowledge exchanges, the

[1] http://www.consortia.org.il/.

Table 1 Data collection and analyses stages

Data collection stage	Data procedure	Description
Stage 1	Interview with government administrator who is in charge of funding and monitoring all UI science consortia—background information and endorsement to interview	Interview lasted about 2 h
Stage 2	Designing the sampling criteria, and sampling the four consortia for the study	Interviews lasted between 1.5 and 3 h and focused on the background information of the consortium head, the description of the participants and the procedures and practices by which the consortium was managed
	Based on background information given, the four consortia were selected	
Stage 3	Semi-structured interviews with the four scientific heads of the consortium	
Stage 4	Structured (face-to-face or through internet/phone) interviews with the 58 participants (both university and industry) who participated in the four consortia	Interviews lasted between 45 min to an hour. Each member was asked questions on his/her own consortium and some general questions on the knowledge exchange platforms they wish to benefit from
Stage 5	Analyses of qualitative data from all parts of open-ended interviews	Based on the qualitative parts of the interviews we searched and selected general themes and preferences about knowledge exchange platforms

Table 2 Characteristics of participants in the four consortia

	Consortium 1	Consortium 2	Consortium 3	Consortium 4
Academia participants	5	6	7	9
Industry participants	5	6	10	10
Academic rank Professor (1), Dr. (2), none (0)	0 = 3 1 = 4 2 = 3	0 = 3 1 = 4 2 = 5	0 = 8 1 = 4 2 = 5	0 = 8 1 = 7 2 = 4
Total number of participants	10	12	17	19

management of the consortium, and the specific collaborations formed. After these questions, we posed an open-ended question asking the respondents to describe the knowledge exchange platforms in which they participated and benefitted from and other platforms within the consortium they perceived as important and valuable. In total, 4 consortia leaders and 58 university and industry scientists were interviewed (27 university scientists from 5 universities and 31 industry scientists). The interviews with the consortia leaders lasted between 1.5 and 3 h, and the interviews with the scientists lasted between 0.5 and 1 h). We transcribed the interviews with the consortia leaders and the open-ended questions of the interviews with the consortia participants. Table 2 describes the characteristics of participants in the four consortia.

3.3 Data analyses

Our goal was to offer a thematic analysis (Ritchie & Spencer, 2002; Silverman, 2019) of the qualitative data provided by the consortium leaders and participants concerning their experience with different UI innovation platforms. Using qualitative case methods on technology transfer issues is important for in-depth analysis of understanding distinctive themes (Cunningham et al., 2017). We sought to find out main themes about the different platforms they perceived to be appropriate for enhancing learning and knowledge sharing within consortia.

To analyze the qualitative data obtained through the interviews with the consortia leaders and the open-ended answers of the scientists, we began by creating a large text file that included all the comments offered by the consortia heads and participating scientists on the topic of alternative TT platforms within the consortium. Then, we categorized the various comments according to whether they dealt with issues regarding networking platforms that involved all members, issues regarding specialized platforms with clusters of members, or issues regarding additional needed platforms. We preferred to conduct the text analysis by ourselves rather than with software, due to our deep understanding of the materials and the limitations of computerized text analysis (Bright & O'Connor, 2007). The PI and an RA conducted the text analysis separately in order to increase inter-judge or inter-coder reliability (Campbell et al., 2013) and to explore as many directions as possible. We then reconstructed the comments and observations into central analytical distinctions of platforms. Our interviews led to insights regarding the value and context of the established platforms in the consortia that facilitated learning and collaboration.

4 Findings

With the aim to understand innovation holistic platforms for facilitating TT collaborations within consortia, the research question is: What platforms of collaborations are perceived as fruitful or desired by consortia leaders and participants? The classic format of a consortium is based on a structured platform with assigned formal results based on a "project governance perspective" (Österle & Otto, 2010; Rosemann & Vessey, 2008). However, our findings reveal that participants have expressed multiple expectations for sub-platforms, dealing with the consortium as a holistic ecosystem that can offer spaces for multiple interactions between different actors and also allow for external actors to be added and participate in certain clusters.

Based on the analysis of the aggregated text of the interviews, we identified 12 main platforms that were perceived by the consortia members to facilitate innovative collaborations by creating communication channels, supporting embedded networks, and generating new knowledge and innovation. These platforms were either established within the consortia or were suggested as needed by participants. We hereby describe these platforms, and for each one, we offer an indicative quote made by one of our interviewees.

Forming technological/scientific working sub-clusters—The average consortium included 12–20 participants. Many interviewees indicated that such a large group is at times too diverse for valuable learning sessions and that they do not want to disclose their knowledge to too many participants. Some consortium leaders established specific meetings and innovation platforms for creating clear clusters of specific shared interests in a technology or a scientific area. According to interviewees' perceptions, these smaller groups offered a better-focused platform for knowledge sharing and learning.

> It is hard to fit the needs and interests of all participants in the larger group and to protect our knowledge at the same time. Therefore, it is advantageous to create several technological clusters by area and interest where the members are committed to the protection of the knowledge exchanged. (Consortium #3, university professor)

Funding collaborative research within consortium clusters—The Magnet consortium model integrates the participants' intrinsic scientific/technological motivations with funding incentives. Interviewees suggested establishing, beyond the larger collaborative platform, a project-funding option for small project networks formed within the consortium. They expected that such monetary incentives would lead to greater emergence of successful intra-consortium collaborations.

> Although each consortium member gets funding for their participation in the consortium, I do not have the full motivation to form additional formal collaborative projects with the industry. If we could get additional funding for such collaborations… (Consortium #1, university professor)

Planning joint seminar days—Joint seminars offer opportunities for consortium members to present intra-consortium projects to other members of the consortium. In some cases, the consortium invited external university scientists or firms to present research that is relevant to consortium members. Interviewees considered such seminars as benefitting the whole network by generating platforms to further share ideas, discuss problems, and identify possible collaboration partners.

> I love the seminars – both the specialized and the general – that we have in the consortium. I learn a lot when external experts are invited beyond what we can learn from the members of the consortium. (Consortium #4, industry scientist)

Scheduling consortium progress-examination sessions—As a condition for continuing funding, the Ministry of Economy and Industry requires that consortia implement a formal mechanism to monitor members' progress. In practice, most consortia required collaborating teams to participate in progress-report sessions once every three months. Such sessions generate time pressures for progress and provide an opportunity to learn from the work accomplished by different teams in the consortium.

> The progress examination sessions create tensions on the one hand, yet force us to make progress and also allow us to learn from other projects. This is a positive competition within the consortium that facilitates learning. (Consortium #1, industry scientist)

Establishing a joint internal database—A collaborative database for consortium members enables project teams to share and access information about their research and the progress of their projects. The consortia in our sample adopted such resources, in different forms; these databases included different scientific and technological materials, including research papers, progress reports, technology reviews, patent listings, and the specifications for all projects in the consortium.

> We established an internet database with access to only consortium members. It allowed access to related articles, work in progress of clusters, data from experiments, technologies, and information about funding opportunities. It also helped us better understand what each member works on in case we wanted to form new collaborations. This was a very helpful and highly successful initiative. (Consortium #2, industry scientist)

Enhancing contacts with the Ministry of Economy and Industry—Interviewees claimed that it is important to have frequent contacts with the ministries involved. They felt that frequent contacts with funding government agencies facilitate routine exchanges and information gathering on other related projects, and may give rise to additional funding opportunities. Opening up R&D projects to further funding opportunities generates new energy for possible collaborations and new research directions.

> Through the consortium, we had more knowledge and higher accessibility to additional funding opportunities from the Ministry of Science in other streams relevant to our research. (Consortium #4, industry scientist)

Designing cross-cluster demonstration sessions—Even though many interviewees felt that dividing the consortium into sub-clusters led to high efficiency, more committed collaborations, and to higher protection of their IP, they also expressed a need for platforms for demonstration sessions across clusters within the consortium. Such sessions are important because they allow consortium members to learn about the advancements made by each sub-cluster and possible cross-cluster collaborative opportunities. This design offers structural support for a process of concentration and focus within clusters, coupled with diffusion and expansion of collaboration across clusters.

> My main learning and added valuable knowledge in the consortium resulted from my participation in sessions where other groups presented their work. This gave me some new ideas for my projects. (Consortium #3, industry scientist)

Establishing industry priorities for the collaborative projects—As discussed above, cultural differences between university and industry researchers constitute a key hurdle in UI collaborations. Indeed, interviewees in our study mentioned this as an issue. As a result, some recommended establishing clear R&D priorities specified by industry members, with the expectation that the university partners adapt to these priorities. This approach, which ensures that the collaborative platform is in harmony with the needs of the industrial partners, can expedite firms' in-house innovation processes and lead them to express stronger commitment toward the consortium partners.

> Most collaborations are with the academic partners, but the industry members have to set the priority for this synergy and decide first what is best for them. After all, the industry needs to come out with new products and this is the priority. This is why we needed an exclusive platform for industry members to discuss issues that are important for us – this includes for example, who we want to invite to join the consortium and what experts we need to invite to give a talk. (Consortium #2, industry scientist)

Adding new collaboration partners based on need as the consortium develops over time—During the initiation stage of the consortium, relevant firms and university laboratories are listed as members. These members share complementarities in their R&D interests and capabilities and in their relevance to the main subject goal. They are also all subject to binding contractual arrangements that describe their rights and the expectations from them. Yet, interviewees indicated that there are cases in which the membership boundaries need to retain some level of flexibility. It is important to have such flexibility when members are not meeting expectations, or when a need arises for new members with different knowledge or technological capabilities as the projects advance. Adding such new members, from either industry or university groups, is perceived to generate new opportunities for emerging collaborations.

> The highest risk is with regard to the organization of teams is in the first year. It takes time to understand what we need to do and who is relevant to each cluster. Then, some university scientists moved to other clusters and we recruited new scientists who worked on related and needed research to the consortium. It is important to retain such flexibility for achieving the needed knowledge integration. (Consortium #3, university professor)

Encouraging the evolution of teams comprising only university or industry members—Interviewees indicated that although the basic premise of UI science consortia is to enhance cross-sector collaborations, more flexibility in team formation is important. In such consortia, there is also an opportunity to establish collaborations among different university scientists that can contribute new basic or applied knowledge. In cases in which new scientific outcomes emerge from these collaborations, they can contribute to other industry members or teams within the consortium. Here, again, flexibility is valuable. Scientists expressed an interest in forming exclusive specialized research groups comprising university scientists only or industry scientists only, following the specific needs that emerge at the consortium.

> The consortium is based on heterogeneous clusters with both university and industry participants. This is important, but there is also a need to build homogeneous teams. The industry participants compete and try to protect their IP. Therefore, it is important to force them to talk among themselves. The university participants are interested in conducting basic research-driven toward publications and conferences and these should also be encouraged. (Consortium #1, industry scientist)

Table 3 Types of contextual collaboration-facilitating platforms in UI science and technology consortia

Type of potential collaborations	Contextual collaboration facilitating platforms
UU collaborations	Funding collaborative research within clusters; consortium progress examination sessions; joint internal database; contacts with the Ministry of Economy and Industry
UI collaborations	Forming technological/scientific clusters; designing cross clusters demonstrations; identifying industry priorities and expected time tables for collaborative projects; adding new collaboration partners; evolution of university teams across clusters; joint seminar days; industry only meetings; consortium progress examination sessions; joint internal data-base; contacts with the Ministry of Economy and Industry
II collaborations	Adding new collaboration partners; joint seminar days for only industry scientists; consortium progress examination sessions; joint internal data-base; contacts with the Ministry of Economy and Industry
Consortium—external collaborations	Adding new collaboration partners; joint seminar days with external speakers; contacts with the Ministry of Economy and Industry; information on international collaborative research projects—EU, US, Canada

Planning industry-only meetings—Despite efforts to enhance UI collaborations in the consortia, interviewees emphasized the importance of having sessions that are exclusive to industry scientists. They viewed these as important towards dealing with issues that are specific to applied and commercially oriented research that takes place in the industry; such issues included commercial policies and constraints that all industry partners need both to be aware of and to develop strategies to face.

> The industry members are not willing to share freely their knowledge, even if there is an IP protection contract. Yet, it is important to have technological and commercial understanding for all industry members. Therefore, in smaller groups of only industry members, it is possible to restrict sharing sensitive information and focus on the joint commercial challenges. (Consortium #4, industry scientist)

Providing information on international collaborative research projects in the European Union, US, Canada, or other countries—Consortium members specified the importance of learning from R&D projects that are external to the consortium on the international level. Since each consortium includes scientists who are interested in similar research and technological issues, there was an expectation to learn about and jointly explore international research groups and funding opportunities. Such information opened up new avenues for establishing collaborations outside the consortium with international firms from the same industry or with international university research teams. Designating people who are responsible for collecting and distributing information about international research and inviting speakers who are experts on international funding opportunities can enhance access to these opportunities.

> The consortium is also a platform for facilitating international collaborations. We invited a few international scientists and industry representatives to talk to us,

and these led to the formation of some international collaborations with firms from Florida and Canada. (Consortium #2, industry scientist)

To summarize the different suggestions offered by the interviewees, Table 3 combines the collaboration-facilitating platforms that were perceived as valuable by consortia participants in the UI consortia into four types of sub-platforms, where each constitutes a different part of the consortia ecosystem.

5 Conclusion and discussion

This study follows the claim that "innovation is most likely to occur within an entrepreneurial ecosystem that typically involves a set of agents, institutions, activities or processes, and surrounding culture" (Feldman et al., 2019:817). The current study follows the search for a holistic examination of TT ecosystems (Good et al., 2019). Rather than atomistic analysis of TT collaborations, Good et al. (2019) assert that studies should examine ecosystems as a whole. The "organizational design framework" they propose calls for a new agenda where collaborative ecosystems are examined by a holistic approach. Such holism is associated with insights into the identification of the ecosystem components and the collaborations they facilitate.

Based on the holistic approach for examining TT collaborations in consortia, our research question was, "What platforms of collaborations are perceived fruitful or desired by consortia leaders and participants?" The evidence presented in this study suggests that by integrating a broad range of innovation platforms into expansive collaboration initiatives such as consortia, it is possible to offer a holistic design for TT consortia. The different innovation platforms suggested in this study, create an entrepreneurial ecosystem that involves different sets of agents, institutions, activities, or processes (Feldman et al., 2019).

The two concepts of "multiple channels of interactions" (De Fuentes & Dutréni, 2012) and "nested networks" (Al-Tabbaa & Ankrah, 2016) are key to our understanding of the organizational design of the consortium as a holistic ecosystem. The 12 main innovation platforms, identified by this study, offer a quest for both multiple channels of interactions and participation in nested networks sub-clusters. These design elements lead to a higher level of ecosystem holism and flexibility for consortia members that fit their interests and motivations. In addition, specialized and smaller clusters can fit more specific overlapping interests and create embedded networks within the consortium ecosystem. Consortium members can co-participate in various platforms simultaneously and thus make the best use of the consortium ecosystem. This holistic approach has the nature of the Ba for knowledge creation (Nonaka & Konno, 1998; Nonaka et al., 2000).

The study contributes to the efforts of organizational and policy scholars to understand the platforms that can improve UI collaborations and learning. Platforms of collaboration can take many different forms: Academic involvement in industry-relevant research (referred to as "academic engagement") can manifest in a wide range of individual, organizational, and institutional activities. (For a literature review, see Perkmann et al., 2013.) Likewise, there are numerous modes of industry involvement in UI research, and when collaborations are established, the transfer of knowledge within them is moderated by different factors related to the type of alliance (Khamseh & Jolly, 2014) and levels of formality (Kreiner & Schultz, 1993). Thus, there is a need for new holistic insights with regard to platforms that can accommodate complexities to enhance different forms of collaboration. Based on information collected from key actors in UI consortia, including government administrators, scientific heads of consortia, and consortium participants from academia and industry, we identified 12 platforms that can promote learning and collaborations in UI science consortia.

A key observation that emerges from our data is that collaboration-facilitating platforms are not "one-size-fits-all". Rather, consortium leaders and participants should be attentive to the needs of specific individuals and groups/projects/clusters within the consortium and select the platforms that are most appropriate for the circumstances they face. It is important to note, however, that, across consortia, the availability of multiple learning structures—including large heterogeneous groups, small specialized and/or homogeneous clusters, and exclusive learning sessions for only university or only industry scientists—were perceived as enhancing successful learning and collaborations. The important role of diverse learning structures reflects the need to accommodate the different characteristics of basic and applied research in UI collaborations. In particular, as Perkmann et al. (2009) observe, basic research projects are more likely than applied projects to yield academically valuable knowledge. As a result, university and industry scientists are less likely to show interdependence in basic research than in applied research. Yet, because applied research projects show higher degrees of partner interdependence, they encourage scientists to engage in exploratory learning, leading to new ideas and projects.

Our conclusions are in line with Ponomariov (2013) and Good et al. (2019), who emphasizes the importance of establishing innovative holistic ecosystem platforms that promote collaborative engagement of university and industry partners (Kruger & Steyn, 2020). Such platforms enhance scientists' ability to generate joint enterprises and shared repertoires, and these have important roles in facilitating additional successful collaborations. These platforms should be used by policymakers designing R&D (Proskuryakova et al., 2017), and our findings show the need for collaboration-specific platforms.

With regard to the evidence of conflict and lack of trust between the university and industry scientists and barriers inhibiting industry from collaborating with academics (Hall et al., 2001), our findings suggest that it is valuable to be explicit about the priorities and expectations of collaboration partners, and particularly with industry scientists. The consortium heads were aware of potential conflicts of interest and the fragile trust over IP rights (Kalish & Oliver, 2021; Rossi, 2010). They claimed that the contractual arrangements in the state-funded consortia had clear specifications that modified such problems, yet did not prevent them altogether. Finally, our findings point to the importance of being willing to open up the consortium to additional, external actors (both local and international) as the need for new sources of scientific and technological knowledge arises.

There are also limitations to our study. The findings come from only four consortia within one country. The four consortia provide an important, yet limited research context, and the country-level TT collaborative culture may be different from the culture in other countries. Future studies should aim to compare different types of consortia and in different countries to account for technological and cultural effects. However, the large number of interviewees in our study gave us access to a wider range of opinions and preferences, and these helped detect the different knowledge integration platforms.

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