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The technology transfer ecosystem in academia. An organizational design perspective☆

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ABSTRACT

University technology transfer has emerged as an important and standalone research field over the past few decades. Given the great challenges that are involved with transferring science to the market, many universities have established technology transfer offices, science parks, incubators, and university venture funds – an organizational assemblage labelled the technology transfer (TT) ecosystem. By reviewing the extant literature on the TT ecosystem and its components, this paper aims at providing an understanding of the organizational design of the TT ecosystem. Surprisingly, the results of this review show that research considering this ecosystem as a whole is largely lacking. Specifically, the literature on the topic can be typified as atomistic, with a wide range of studies on the various TT components and a dearth of research studying holistically the wider knowledge transfer ecosystem that reflects the evolution and impact of academic entrepreneurship. Consequently, this paper presents an organizational design framework that sets out a future research agenda for studies taking a holistic approach.

1. Introduction

This paper aims to address the following research question: "what is the current understanding of the Technology Transfer (TT) ecosystem in the literature, and how can future research systematically extend this understanding?" University science often forms the basis of new and innovative products and may even set the stage for the creation of entirely new industries, contributing significantly to economic development (Christensen, 2013). As a consequence, the commercialization of university research, hereafter referred to as technology transfer (TT), has been a major item on the agenda of university staff, researchers, practitioners, and governments seeking to stimulate TT and enhance national competitiveness (Grimaldi et al., 2011; Muscio, 2010). Subsequently, TT has become highly institutionalized within universities throughout the world (Ambos et al., 2008; Colyvas and Powell, 2007; Owen-Smith, 2003). The TT process is complex, requires significant resources, and involves high levels of uncertainty and risk (Bradley et al., 2013b). Consequently, a TT ecosystem has developed within or close to many research universities across the world in order to support TT (Siegel and Wright, 2007). This paper refers to the term "TT ecosystem" as the set of university affiliated intermediary organizations that are connected by directly supporting TT activities. The various core components of the TT ecosystem (i.e. TT offices, incubators, science parks and university venture funds) act as supporting organizational entities related to TT, and as boundary spanners between the academic environment of the university and the commercial environment of the market (Huyghe et al., 2014).

As the literature on these various components is fragmentary, there is a need to review existing studies in order to form a coherent understanding of the TT ecosystem as a whole including its components. While some of these components have existed from as early as the 1950s, it has only been since the 1980s that they have become prevalent (Atkinson, 1994; Campbell and Allen, 1987; Colyvas, 2007; Link and Scott, 2003). Since then, the TT ecosystem has evolved significantly including increased interdependencies between its components, making a structured synthesis of the knowledge on TT ecosystems timely. A particularly relevant theoretical perspective, namely the organizational design perspective, guides this synthesis and the core theoretical elements of organizational purpose, activities, structure, and people and organizational culture are used to structure the literature.

The literature review indicates that, despite the richness of the TT literature, it has largely focused on the TT components separately, and has rarely considered the ecosystem as a whole. The current state of the literature on the TT ecosystem is therefore typified as "atomistic", in

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which much knowledge has been generated on each of the different components of the TT ecosystem in isolation. Consequently, this paper presents an organizational design framework that sets out a future research agenda that takes a "holistic" ecosystem approach. It is argued that this will allow for novel insights into the inner-workings of TT ecosystems alongside deep insights into how the various components of such ecosystems communicate and collaborate. Such an approach is important as, recently, TT is considered to take place in what is commonly referred to as the "university ecosystem", comprising a wide range of interconnected actors (Siegel and Wright, 2015).

This paper contributes to the TT and academic entrepreneurship literatures. Specifically, this paper provides a detailed overview of the current understanding of the organizational design of the TT ecosystem and identifies important knowledge gaps in organizational design of TT ecosystem components. Since the current state of the TT ecosystem literature is typified as atomistic, an organizational design framework is offered for studies to move from an atomistic to a holistic approach. In doing so, a range of compelling research topics are presented which can guide future research. Alongside the implications for research, this paper offers implications for practitioners, including university and TT managers, amongst others.

This paper is structured as follows. The next section presents the organizational design perspective applied to synthesize the literature on the TT ecosystem and its components. Following this is a discussion of the methodology used to conduct the review of the literature. The findings of the literature review are then presented, followed by a discussion on the current understanding of its organizational design. Finally, a framework is presented for moving from an atomistic toward a holistic approach to studying the TT ecosystem, accompanied by a future research agenda.

2. Theoretical background: organizational design and the TT ecosystem

The term "ecosystem" originates from biology, and generally typifies a system in which diverse members share the fate of the ecosystem, and have mutually dependent relationships (Iansiti and Levien, 2004; Oh et al., 2016). The business and management literatures have identified different types of ecosystems including, amongst others, innovation and entrepreneurial ecosystems (Jackson, 2011; Spigel, 2017). The aim of this paper is to add to this literature by studying the TT ecosystem, defined as the set of university affiliated intermediary organizations that are connected by directly supporting TT activities. In what follows, the organizational design perspective used to structure the findings of this paper is presented.

2.1. Organizational design: general background

Organizational design is a framework that synthesizes insights and theories from organizational and management research. Building on the early academic work on organizational structure and design in the 1960s and 1970s (e.g., Chandler, 1962; Galbraith, 1974; Lawrence and Lorsch, 1967), the study of organizations and their design recently found renewed interest among management and organization scholars (e.g., Dunbar and Starbuck, 2006; Greenwood and Miller, 2010; Van de Ven et al., 2012). This resurgence of interest is fuelled by new, more complex types of organizing and by the emergence of new organizational properties, configurations, and ecosystems, as well as increasingly distributed forms of organizing that often span more than one organization. Knowledge-intensive sectors, such as the setting being studied, have particularly witnessed novel organizational complexities. Activities, goals, and tasks no longer reside within a single organization, but cut across organizational boundaries and include different types of organizations (Anteby et al., 2016; Grant and Parker, 2009; Powell and Soppe, 2015).

The organizational design perspective affords new light to be shed on such complex yet collective organizational structures and efforts. By appreciating a range of critical design elements, the approach allows for analysing and comparing different types of organizations, their configuration, capabilities, complementarities and their way of organizing in order to accomplish desired ends (Greenwood and Miller, 2010).

Organizations can be defined as "the pattern of communications and relations among a group of human beings, including the processes for making and implementing decisions" (Simon, 1947/1997, pp. 18–19). Organizational design thus allows for understanding and producing coherent organizational goals, patterns of division of labour, and effective organizational coordination and communication among the people that perform the work (Galbraith, 1977; Csaszar, 2013). Adopting the organizational design perspective is particularly relevant since this paper is concerned with shedding light on the organizational properties, challenges, and functioning of the TT ecosystem.

2.2. Organizational design: design elements

A number of authors have identified a range of design elements that enhance the understanding of how organizations are structured, how they process information and coordinate activities in order to pursue certain organizational goals. According to Scott (1998), there are five critical organizational design elements: goals, organizational technology, participants, social structure and environment. Burton et al. (2006) propose process, people, coordination and control as important design components. Daft et al. (2010) add size and culture, and focus on a more explicit set of structural properties including formalization, specialization, hierarchy of authority, centralization, professionalism, and personnel ratios. Nadler and Tushman (1997) include all of the previous elements, but also consider inputs (environment, resources, and history) and outputs (system, unit, and individual).

Despite using different terminology and levels of detail, there is a significant amount of overlap between these various conceptualizations. In particular, four elements of organizational design are consistently considered as important: organizational purpose, activities, structure, and the people and organizational culture that constitute the organization.

Organizational Purpose reflects the main reason for the organization's existence, and represents the conception of the desired ends (Nadler and Tushman, 1997; Scott, 1998) of the organization. Organizational purpose is the primary driving force behind the design of the rest of the organization and is therefore considered to constitute a central point of reference for organizational analysis (Scott, 1998). From the purpose, organizations identify necessary activities, derive a structure for these activities, and determine the type of people required to perform them.

Activities consist of the different tasks that employees members of an organization perform to fulfil its purpose (Nadler and Tushman, 1997; Scott, 1998). Activities can include a wide variety of tasks, ranging from routine tasks, such as basic accounting or administrative work, to unique and more complex tasks, such as providing consulting services (Nadler and Tushman, 1997; Scott, 1998). A well-designed organization has a structure that supports the performance of these activities and offers a supportive culture for its members to perform these activities.

Structure refers to ownership structure, governance structure, the internal organizational structure, the size of the organization, and the organization's physical location (Scott, 1998). Frequently studied elements of structure for instance comprise the level of centralization or formalization of an organization (Colquitt et al., 2009). An important feature of organizational structure is that it formally indicates how activities and tasks are divided between individuals and groups of individuals in the organization. Furthermore, organizational structure is commonly considered to have a significant impact on organizational performance.

People and Organizational Culture focuses on the key individuals

that belong to the organization, the internal incentive systems in place to encourage specific behaviour from those key individuals, and the internal culture of the organization (Scott, 1998). As to the latter, organizational internal culture is typically considered to be the shared social knowledge within the organization and includes the values, rules and norms of the organization, which, in turn, can shape employee behaviour (Colquitt et al., 2009).

These elements and their definitions are used as a framework for analysing the different components of the TT ecosystem. Every component can be broken down into these four basic organizational design elements allowing for comparison between the different TT ecosystem components while at the same time enabling a holistic perspective on the TT ecosystem to be taken.

2.3. Organizational design and the TT ecosystem

As Siegel and Wright (2015) indicate, organizational design offers an interesting theoretical perspective for deepening the understanding of TT. Specifically, as they point out, it is a highly appropriate perspective for studying organizational configurations for promoting academic entrepreneurship including organizational structure and managerial practices. Organizational design is concerned with different organizational levels (Shibayama et al., 2015; Van de Ven et al., 2012). The overall TT ecosystem is considered to be the higher-order level, composed of lower-level components represented by the intermediary organizations themselves. Accordingly, as a first step, it is important to identify the relevant lower-level units or components of the TT ecosystem. In order to do so, a range of literature reviews (e.g., Markman et al., 2008; Siegel and Wright, 2007; Rothaermel et al., 2007) alongside two recent papers (Siegel and Wright, 2015; Hayter, 2016) were built upon and used as a basis for identifying the core organizational components of the TT ecosystem. This resulted in the identification of four core components of the TT ecosystem: technology transfer offices (TTOs), incubators, science parks, and university venture funds.

TTOs are organizations that have been given the responsibility to facilitate the transfer of technology from a directly affiliated research institution (or multiple research institutions) to market by acting as a bridge between the two environments (Geuna and Muscio, 2009; Huyghe et al., 2014; Markman et al., 2005b; Siegel et al., 2003a).

Science parks are property-based organizations that are linked to a university environment, have identifiable administrative centres, focus on the mission of developing technology-based businesses, and provide services related to business development and TT (Link and Scott, 2003; Phan et al., 2005; Tan, 2006). Another identifying feature of science parks is that they host a wide variety of residents including research centres, divisions of large corporations, small and medium-sized enterprises, business support service providers, new technology-based ventures, incubators and/or TTOs (Benneworth and Ratinho, 2014; Chan and Lau, 2005; Phan et al., 2005; Siegel et al., 2003c; Zou and Zhao, 2014).

Incubators have a definition that is very similar to that of science parks in that they are property-based organizations that are linked to a university environment, have identifiable administrative centres, are focused on the mission of developing technology-based businesses, and provide services related to business development and TT (Aaboen, 2009; Bergek and Norrman, 2008). However, unlike science parks, incubators are populated only with early-stage science-based firms (Bergek and Norrman, 2008). Accelerators, proof of concept centres and entrepreneurship garages can all be considered a form of incubator since they all fit the incubator definition and are only labelled differently given their focus on, amongst others, particular physical infrastructure, short time frames, or particular types of companies (for instance those with high growth potential) (Bradley et al., 2013a; Siegel and Wright, 2015).

University venture funds are defined as “seed and early-stage funds that have a deliberate and explicit mission to make investments in [academic spin-offs] to support TT and the commercialization of both university and public research results” (Munari et al., 2015, p. 954). Additionally, these funds have, at a minimum, some form of formal or informal collaboration with a university.

While the TT literature identifies these four primary components of the TT ecosystem, recent literature points to the emergence of new modes for the facilitation of academic entrepreneurship, such as university-based entrepreneurial ecosystems and accelerators (Siegel and Wright, 2015). While the latter are integrated in the broad definition of incubators, which is applied in this paper, the first are excluded as they do not represent organizations and as the origin and activities of such ecosystems are largely region- and less university-dependent (Siegel and Wright, 2015). Along the same lines, this review excludes informal types of TT (Link et al., 2007) which do not rely on formal TT organizations nor an organizational structure.

3. Methodology

The review process consisted of multiple steps. First, an extensive search for scientific articles up to the end of 2017 was conducted using the Scopus database, which indexes journals across all disciplines including over 5000 journals within the social sciences. In order to conduct this search, keywords were generated for each of the four core components of the TT ecosystem and for the holistic concept of the TT ecosystem. Literature reviews on science parks (Phan et al., 2005), incubators (Bergek and Norrman, 2008), and TTOs (Siegel et al., 2007; Link et al., 2015) were consulted to generate keywords for each TT ecosystem component. Due to the lack of relevant literature reviews on university venture funds, keywords were instead generated based on two recent articles (Munari et al., 2015; Croce et al., 2014). To generate keywords for the holistic concept of the TT ecosystem, reviews were again referred to in the field of TT (e.g., Markman et al., 2008; Siegel and Wright, 2007; Rothaermel et al., 2007) and combined commonly used terms (i.e. “technology transfer”, “commercialization”, “entrepreneurship”, and “innovation”) with either “ecosystem”, “system”, “support system” or “infrastructure” and “university”. Keywords were searched for within the title, abstract, or keywords of articles. The search was limited to journals within the social sciences and included both journal articles and reviews. One major issue was encountered during this search process for articles related to incubators: the initial search into incubators returned well over 1000 articles. After reviewing the titles of some of these results, it was found that, even though the search was limited to social science journals, a large number of results were related to the natural science definition of an incubator and were therefore not relevant to this study. In order to exclude such articles, a secondary search was performed within the initial search using additional business and startup related keywords for incubators specifically. This “search within a search” function of the Scopus database allows for searching additional terms in every field of the article including the title, abstract, and keywords.

Table 1 details the keyword combinations that were used in the search and the results from these initial searches, including the additional keywords for the search for articles on incubators.

Second, all articles were screened for quality and relevance. Specifically, the initial results were further limited to only articles or reviews published within journals ranked within the first quartile of journals on the Scimago Journal and Country Rank system. Scimago is directly linked to the Scopus database and ranks journals based on the average number of weighted citations received in the selected year by the documents published in the selected journal in the three previous years. The reason for doing this was as an initial filter for quality. To ensure that this quality selection would not have eliminated relevant journals within this field due to its niche nature, the journals already represented in a range of literature reviews on TT and academic entrepreneurship were reviewed, including Markman et al. (2008), Perkmann et al. (2013), Rothaermel et al. (2007) and Siegel and Wright

Table 1
Overview of articles on the TT ecosystem.

Search Word Combinations	Number of articles from initial search	Number of articles after screening for quality and relevance
("technology transfer ecosystem" OR "technology transfer system" OR "technology transfer infrastructure" OR "innovation ecosystem" OR "entrepreneurship ecosystem" OR "entrepreneurship system" OR "entrepreneurship support system" OR "technology transfer support system" OR "commerciali*ation support" OR "commerciali*ation system" OR "commerciali*ation ecosystem" OR "commerciali*ation infrastructure") AND universit*	96	13
("technology transfer office*" OR "technology transfer cent*" OR "industry liaison office*") AND universit*	230	76
("science park*" OR "research park*" or "technology park*") AND universit*	275	94
("incubat*" OR "accelerator" OR "proof of concept cent*" OR "entrepreneurship garage") AND universit*	435	64
Additional filter keywords used: ("spinoff" OR "spin off" OR "spin-off" OR "business" OR "startup" OR "start-up" OR "start up" OR "entrepreneur*" OR "commerciali*ation" OR "technology transfer")		
("venture fund" OR "venture capital" OR "seed capital" OR "seed fund" OR "investment fund") AND universit*	331	9
TOTAL	1367	257

(2015). This procedure allowed verification of the appropriateness of the journals represented in this review (see Annex A for a list), which are largely consistent with those represented in these earlier reviews. Therefore, there is confidence that this review includes the vast majority of relevant studies related to the topic of interest. Furthermore, in order to make sure that only relevant articles from the initial search were included, the title and abstracts of each article were reviewed for relevance. An article was deemed relevant if it likely dealt with one of the elements of organizational design of the TT ecosystem or its components. In that case, it was flagged for detailed review. The third column of Table 1 indicates the number of articles that were kept after the quality and relevance screening and that were included in the literature review.

Importantly, a scarcity of studies were found that have considered the TT ecosystem as a whole (first row of Table 1). Of the 96 papers found in the initial search, only 24 were published in Q1 journals. Of these 24 articles, 22 considered the TT ecosystem from a regional or national perspective, considering the TT process at an abstract level, studied the role external actors take within innovation ecosystems, or looked at a single component of the ecosystem. The first remaining paper, by Heinzl et al. (2013), provides a set of recommendations for implementing effective "technology innovation commercialization infrastructures" at universities of applied sciences in Austria. Specifically, they recommend that such infrastructures require "interrelated cognitive, cultural and structural embeddedness" (p. 636). However, the paper does not go into detail about how different universities in Austria organize the various components of the TT ecosystem to achieve these different forms of embeddedness. The second paper, by Hayter (2016), identifies the existence of such an ecosystem and the different components, which is in line with our definition, but looks at it from the perspective of a spinoff company and networks and is not concerned with how ecosystems are designed. Important to further note is the significant reduction after screening in results related to university venture funds. This was due to the fact that the majority of the initial results were either related to traditional types of funds that were not linked to a university or studied university-linked funds at an aggregate level with little organizational detail and were therefore outside of the scope of this study.

Third, in the detailed review, each paper was read and information was extracted relevant to the previously identified organizational design elements of each component of the TT ecosystem. Using a qualitative analysis of the resulting set of articles, the extracted information on each component of the TT ecosystem was organized into the four different categories of the organizational design framework described above. The results of the review were then used to conceptualize and understand the organizational design of the holistic TT ecosystem and to identify areas for future research.

4. Findings

Our first finding is that papers discussing the TT ecosystem as a whole are scarce and those that do mention it typically take a regional or national perspective rather than an organizational or management perspective. This finding is surprising given recent trends that consider academic entrepreneurship and TT within the context of university ecosystems consisting of a range of interconnected actors (Siegel and Wright, 2015). Further, despite the fact that each component of the TT ecosystem plays a role in TT, the majority of studies only focus on a single component. Indeed, there is a dearth of research that discusses more than one of these components together in the same study (with the exception of science parks and incubators due to definitional issues), which leads to typifying the current state of the literature on the TT ecosystem as an atomistic one. Each "atom" represents a stream of literature that separately considers a different component of the TT ecosystem.

Notwithstanding this separation, each literature stream does provide important insights into the organizational design of each component of the TT ecosystem, which is useful in understanding the TT ecosystem as a whole. These insights are presented in a comprehensive fashion below using the building blocks of the organizational design perspective (i.e. purpose, activities, structure, people and organizational culture) as a guideline. These findings indicate that, even when the components of the TT ecosystem are considered separately, the interest by researchers in the organizational design of these components has been distributed rather unequally. In what follows, the synthesis of the literature on each of the elements of organizational design is presented (in tables), followed by an analysis in which important research gaps are identified.

4.1. Purpose

Table 2 summarizes the findings from the literature related to the organizational purpose of each component of the TT ecosystem.

Overall, the organizational purpose of TTOs, science parks, and incubators appears to be well understood and received significant scholarly attention.

Taking a holistic perspective, strong commonalities are found between the purposes of the different TT ecosystem components, with all components striving at supporting the commercialization of technology from universities and enhancing regional economic development. At the same time, each component also has its own emphasis in terms of purpose, for instance in terms of their focus on different stages of the

Table 2
Organizational purpose of TT ecosystem components.

Component	Findings	References
TTOs	Act as a **bridge** between university and market environments	Geuna and Muscio (2009); Huyghe et al. (2014); Markman et al. (2005b); Schaeffer and Matt (2016); Siegel et al. (2003a)
	Protect university **proprietary rights in order to generate returns**	Geuna and Muscio (2009); Jefferson et al. (2017); Schaeffer and Matt (2016)
	Support **pre-commercialization of inventions**	Fitzgerald and Cunningham (2016); Jefferson et al. (2017); Siegel and Wright (2007)
	Support local or regional **economic development**	Fitzgerald and Cunningham (2016); Jefferson et al. (2017); O'Gorman et al. (2008); Siegel and Wright (2007); Schaeffer and Matt (2016); Siegel et al. (2003b)
Science Parks	**Support the development of technology-based firms**	Chan and Lau (2005); Diez-Vial and Fernandez-Olmos (2015); Hansson et al. (2005); Lofsten and Lindelof (2005); Phan et al. (2005); Siegel et al. (2003c)
	Support local **economic development**	Hansson et al. (2005); Phillimore (1999); Zou and Zhao (2014)
Incubators	**Support** the formation and development of technology-based **startup companies**	Bergek and Norrman (2008); Bollingtoft and Ulhoi (2005); Chan and Lau (2005); Colombo and Delmastro (2002); Hackett and Dilts (2004); Lofsten and Lindelof (2002); M'Chirgui et al. (2016); Phillips (2002); Ratinho and Henriques (2010); Rothschild and Darr (2005)
	Support local or regional **economic development**	Bergek and Norrman (2008); Ratinho and Henriques (2010)
	Generate **profit** for its owners	Bergek and Norrman (2008); Bollingtoft and Ulhoi (2005); Clarysse et al. (2005)
University Venture Funds	Provide **financing** to early stage technologies or firms emerging from affiliated universities	Atkinson (1994); Croce et al. (2014); Heughebaert and Manigart (2012); Lerner (2004); Munari et al. (2015)
	Generate additional **revenues** which can then be used by the **university** to speed up TT activities	Croce et al. (2014)
	Enhance the university's reputation and sustain local **economic development**	Heughebaert and Manigart (2012); Pierrakis and Saridakis (2017)

entrepreneurial process. Furthermore, differences between these components arise in terms of the goals related to profit generation, which seem most prevalent with incubators and university venture funds. In addition, TTOs, incubators and science parks are more oriented towards generating awareness within the community of researchers and supporting them in pre-commercialization and early stage commercialization efforts than university venture funds. Both these commonalities and complementarities call for considering the TT ecosystem holistically, as they can give rise to potential synergies or conflicts. For instance, the fact that all components focus on enhancing regional economic development raises the question on how efficient they are in achieving their purpose and how economies of scale can be obtained, for example in their contacts with regional development partners. Further, as different components focus on different stages of technological development this is likely to give rise to important synergies if the different components collaborate. Indeed, while TTOs tend to focus either on licensing technology or forming a company around a technology (Bozeman et al., 2015), science parks, incubators and university venture funds are more concerned with ensuring that the company formed around university technologies successfully builds commercial products based on that technology. Together these purposes are likely to provide a complete coverage of the different stages of commercialization and are more likely to have successful outcomes, on the condition that efforts are coordinated. At the same time, special attention is needed for the secondary purposes of the different components. For instance, as TTOs strive to provide universities with substantial ownership rights on the developed technologies, they may jeopardize the incubator and university venture fund's goals of obtaining additional funding for the firm, and generating the (social or financial) returns their stakeholders require.

4.2. Activities

Table 3 summarizes the findings from the literature related to the activities of each component of the TT ecosystem.

This table indicates that extant research has studied the activities of the TT ecosystem components, particularly focusing on TTOs, science parks and incubators. Specifically, it shows that TTOs typically engage in activities related to awareness creation, opportunity identification, technology commercialization strategy and internal and external networking activities. Science parks and incubators are less concerned with the earlier stages of TT, such as opportunity identification, but engage in similar activities as TTOs in terms of internal and external networking, but seem more active in providing post-founding support. Further, the review shows that understanding of university venture fund activities has remained limited, with the few existing studies pointing to activities related to deal flow generation, the search for syndicate partners, support to portfolio companies and determination of the fund strategy. While one could presume that, in general, university venture fund activities are similar to activities of traditional venture capital funds, the origin, purpose and governance of such funds is likely to affect the type and nature of activities, making further research into the activities highly warranted.

Furthermore, the different components engage in both complementary and substitutable activities. Consequently, considering them together as the TT ecosystem may provide ample opportunity to understand how efficiency and quality of activities across the entire ecosystem can be increased. This could lead to a more efficient division of effort in support in terms of type of support (e.g. technology-focused versus business-focused), markets (e.g. technology markets focused on licensing deals or idea markets focused on spin-off establishment) or technology domains. By consequence, services provided can become more complementary and less competitive in nature. In what follows, the most important commonalities and complementarities between the different components are identified and indications are provided into how considering them as part of the TT ecosystem could substantially enhance the understanding of the activities they engage in.

First, the different components of the TT ecosystem are complementary in terms of the stages of development they engage in. Indeed, some of the components engage in activities aimed at early-stage firm development, ranging from the earliest stages (e.g. support for research and intellectual property right application provided by TTOs) to later stages (e.g. business support, property management, network development engaged in by science parks and incubators). Considering the different components as part of an ecosystem may help in understanding how one component prepares a technology until it can be further nurtured by the next component, or to which extent collaboration between the different components and tuning of their activities may enhance the TT process. For instance, in order to be successful, university venture funds require high quality deal flow. TTOs, incubators and science parks all act as both a source of new potential investments and as a filter or proving grounds that help select out the technologies and start-ups that have the highest potential. From the perspective of TTOs, incubators, and science parks, university venture

Table 3
Activities of TT ecosystem components.

Component	Findings	References
TTOs	**Encourage** the participation of researchers in technology commercialization	Aragonés-Beltrán et al. (2017); Jefferson et al. (2017); Lach and Schankerman (2008); Link and Siegel, 2005; Macho-Stadler et al. (2007); Markman et al. (2005a); Rasmussen et al. 2006; Neves and Franco (2016); Siegel and Wright (2007); Villani et al. (2017)
	Build trust and relationships with researchers	Debackere and Veugelers (2005); Huyghe et al. (2014); Jefferson et al. (2017); Miller et al. (2009)
	Identify high potential technologies	Aragonés-Beltrán et al. (2017); Debackere and Veugelers (2005); Huyghe et al. (2014); Jefferson et al. (2017); Jensen et al. (2003); Markman et al. (2004); Siegel et al. (2004)
	Secure funding or other resources where more research is required	Gubatti et al. 2016; O'Gorman et al. (2008); Rasmussen (2008)
	Determine an **intellectual property** rights strategy and secure intellectual property rights for university-based inventions	Aragonés-Beltrán et al. (2017); Boh et al. (2016); Jefferson et al. (2017); Olcay and Bulu (2016); Siegel et al., 2003; Siegel and Wright (2007)
	Assess **commercialization potential** of technologies	Boh et al. (2016); Cartalos et al. (2016); Jefferson et al. (2017); Landry et al. (2013); Schaeffer and Matt (2016); Tello et al. (2010); Vohora et al. (2004)
	Determine the ideal **commercialization strategy relating to licensing, spinoffs and research contracts**	Aragonés-Beltrán et al. (2017); Berbegal-Mirabent et al. (2015b); Caldera and Debande (2010); Rasmussen et al., 2006; Siegel et al. (2004); Van Looy et al. (2011)
	Develop a **licensing strategy**: selling licenses in return for cash payments, equity in the receiving company, or in return for research sponsorship	Belenzon and Schankerman (2009); Bercovitz and Boh et al. (2016); Bray and Lee (2000); Feldman et al. (2002); Feldman, 2006; Jefferson et al. (2017); Markman et al. (2005b); Siegel et al. (2003a); Thursby and Thursby (2007)
	Develop a **licensing strategy** with a preference for licensing to local companies to support economic development	Belenzon and Schankerman (2009); Jefferson et al. (2017); Powers and McDougall (2005)
	Develop a **licensing strategy**: decide on exclusive vs. non-exclusive licensing strategy	Bercovitz and Feldman (2006); Jefferson et al. (2017); Thursby and Thursby (2007)
	Engage in **spinoff creation**: spinoffs are created when technologies are not easily codified and have a perceived high potential of commercial success	Jefferson et al. (2017); Lockett et al. (2005); Lockett and Wright (2005); Lockett et al. (2003)
	Engage in **spinoff creation**: TTO involvement depends on strategy, individual characteristics, and resources	Berbegal-Mirabent et al. (2015a); Jefferson et al. (2017); Markman et al. (2005b)
	Engage in **spinoff creation**: TTOs may provide business support services such as entrepreneurial training, mentoring, networking, or resource acquisition	Berbegal-Mirabent et al. (2015b); Clarysse et al. (2005); Jefferson et al. (2017); Lerner (2004)
	Engage in **spinoff creation**: TTOs may engage in activities related to structuring the spinoff firm and the venture creation process such as selecting a surrogate entrepreneur to lead the venture	Franklin et al. (2001); Jefferson et al. (2017); Lockett et al. (2003); Lundqvist (2014)
	Engage in both **internal and external network building**: connecting with industry actors, business support organizations, government representatives, and researchers	Comacchio et al. (2012); Hayter (2016); Jefferson et al. (2017); Miller et al. (2014); Neves and Franco (2016); Nicolaou and Birley (2003); O'Shea et al. (2005); O'Shea et al. (2008); Olcay and Bulu (2016); Schaeffer and Matt (2016); Villani et al. (2017)
	Simplifying bureaucratic processes and **facilitating connections** between stakeholders	Villani et al. (2017)
Science Parks	**Attract** technology-based startups, corporations of various size, public research groups, and relevant business service providers through marketing, referrals, or direct contact	Colombo and Delmastro (2002); Salvador (2011); Lai and Shyu (2005)
	Screen potential **residents** based on specific criteria	Bakouros et al. (2002); Baraldi and Ingemansson Havenvid (2016); Colombo and Delmastro (2002); Kocak and Can (2013); Ratinho and Henriques (2010)
	Enforce **graduation policies** related to how long companies are allowed to stay on the park	Baraldi and Ingemansson Havenvid (2016); Colombo and Delmastro (2002); Ratinho and Henriques (2010)
	Plan **networking events** during which residents can connect with other residents or with external parties	Cantu (2010); Chan and Lau (2005); Kocak and Can (2013); Yang et al. (2009); Zou and Zhao (2014)
	Build **formal and informal links with the university** to gain access to research and development resources, or promote research collaborations	Berbegal-Mirabent et al. (2015a); Colombo and Delmastro (2002); Diez-Vial and Montoro-Sanchez (2016); Fukugawa (2006); Hayter (2016); Lai and Shyu (2005); Liberati et al. (2015); Lofsten and Lindelof (2005); Salvador (2011); Bakouros et al. (2002); Lindelöf and Löfsten, 2004; Pilar Latorre et al. (2017); Vedovello (1997); Westhead and Storey (1995)
	Build **external networks** with local and international stakeholders to gain access to supportive resources for its residents and build legitimacy	Bigliardi et al. (2006); Diez-Vial and Fernandez-Olmos (2015); Edgington (2008); Hayter (2016); Olcay and Bulu (2016); Ratinho and Henriques (2010); Salvador (2011); Siegel et al. (2003c); Koh et al. (2005); McAdam and McAdam (2008); Phan et al. (2005); Pilar Latorre et al. (2017); Vohora et al. (2004); Zou and Zhao (2014)
	Provide **office space** and access to basic administrative resources	Montoro-Sanchez et al. (2011); Olcay and Bulu (2016); Vedovello (1997); Westhead and Storey (1995)
	Offer varying levels of business or financial **support services**	Benneworth and Ratinho (2014); Diez-Vial and Fernandez-Olmos (2015); Liberati et al. (2015)
	Engage with and balance the needs of **external stakeholders**. Through this engagement, managers work to acquire resources for residents and influence policy decisions that support the operation of the science park	Koh et al. (2005); Olcay and Bulu (2016); Phan et al. (2005); Vohora et al. (2004); Zou and Zhao (2014)

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Table 3 (*continued*)

Component	Findings	References
Incubators	Actively search for and **attract university startups** and spinoffs	Grimaldi and Grandi (2005); Clarysse et al. (2005)
	Define **selection criteria** to target companies	Baraldi and Ingemansson Havenvid (2016); Carayannis and von Zedtwitz (2005); Clarysse et al. (2005); Rothaermel and Thursby (2005); Schwartz and Hornych (2010)
	Define **graduation requirements** which can be time-based or performance-based	Baraldi and Ingemansson Havenvid (2016); Bollingtoft and Ulhoi (2005); Mian (1997); Patton et al. (2009); Phillips (2002); Rothaermel and Thursby (2005)
	Provide **physical resources**	Baraldi and Ingemansson Havenvid (2016); Lee and Osteryoung (2004); M'Chirgui et al. (2016); McAdam et al. (2016); Mian (1996); Patton and Marlow (2011); Rothschild and Darr (2005); Xiao and North (2017)
	Facilitate access to **financial resources**	Baraldi and Ingemansson Havenvid (2016); Clarysse et al. (2005); Etzkowitz (2003)
	Provide **competency building activities**	Aerts et al. (2007); Bergek and Norrman (2008); M'Chirgui et al. (2016); Peters et al. (2004); Soetanto and Jack (2016); Villani et al. (2017); Xiao and North (2017)
	Provide or facilitate access to **consulting services**	Bollingtoft and Ulhoi (2005); Chan and Lau (2005); M'Chirgui et al. (2016);
	Enable **proof of concept tests**	Chan and Lau (2005); Hayter and Link (2015); Maia and Claro (2013); Mian (1994); Mian (1996)
	Enable relationships between tenants and the university or other research environments	Bradley et al. (2013a); Hayter (2016); Hayter and Link (2015); Lasrado et al. (2016); Maia and Claro (2013); McAdam et al. (2010); McAdam et al. (2009); McAdam et al. (2016); Hackett and Dilts (2004); Rothaermel and Thursby (2005); Rothschild and Darr (2005); Soetanto and Jack (2016); Villani et al. (2017)
	Support **internal network development** within the incubator	Aernoudt (2004); Ebbers (2014); Soetanto and Jack (2013)
	Build **relationships with industry actors** and external business service providers	Aernoudt (2004); Chan and Lau (2005); Rothschild and Darr (2005); Soetanto and Jack (2013); Soetanto and Jack (2016); Villani et al. (2017)
	Maintain **alumni networks** to provide advice and guidance to current tenants	Aernoudt (2004); Hayter (2016); Patton et al. (2009); Rubin et al. (2015)
University Venture Funds	**Acquire funds** from a range of public and private actors	Atkinson (1994); Croce et al. (2014)
	Build relationships with potential investors and syndicate partners	Croce et al. (2014)
	Build relationships with local innovation actor such as universities, incubators, and others	Pierrakis and Saridakis (2017)
	Decide upon **investment strategies** and targets	Croce et al. (2014); Munari et al. (2015)
	Provide advice, guidance, and contacts to the firms	Croce et al. (2014); Heughebaert and Manigart (2012); Munari et al. (2015)
	Monitor and assess the performance of each company	Croce et al. (2014); Munari et al. (2015); Swamidass (2012); Wright et al. (2006)

funds are considered a reliable source of funds for the entrepreneurs they support.

Second, each ecosystem component engages in activities that show high levels of overlap with those conducted by other ecosystem components. Specifically, TTOs, incubators and science parks engage to a large extent in internal and external networking activities with the purpose of supporting the commercialization of technology. The question then arises to which extent these boundary spanning or networking activities are redundant or complementary and how a better tuning of who engages in networking with which parties could improve the efficiency of the TT process. Such tuning could avoid different components from becoming competitive service providers instead of partners in reaching their goals of effective university technology commercialization.

4.3. Structure

Table 4 summarizes the findings from the literature related to the structural dimensions of each component of the TT ecosystem.

As the table shows, the study of the organizational structure of the TT ecosystem components has received a lot of attention. At the same time, it points to a number of unexplored areas. First, scholarly attention has been distributed rather unequally over the different TT components. Indeed, whereas the organizational structure of TTOs has been frequently studied, and the structure of science parks and incubators has received some attention, the structure of university venture funds has rarely been studied. Specifically, TTO studies point to diversity in terms of ownership and governance, with TTOs differing in terms of their integration within the university, their degree of centralization, their size and location. The literature on science parks has extensively focused on the location of science parks, has documented the diversity of science parks in terms of size, but has covered governance and ownership issues to a much lower extent. Similarly, studies into incubators have provided limited insights into their governance and ownership, but do elaborate on the diversity among incubators in terms of size and location. Further, as only a limited number of studies has focused on the organizational structure of university venture funds, insights into their ownership, governance and size are lacking. Second, there appears to be an unequal distribution in the attention toward the different themes of organizational structure, with particularly little attention attributed to the study of the internal organizational structure of the different components of the TT ecosystem. Furthermore, while the internal organizational structure of one particular element, namely the TTO, has been studied, research in this domain has been largely case-based (e.g., Bercovitz et al., 2001; Huyghe et al., 2014), as such presenting a rather fragmented view on how TTOs are internally structured.

Despite the lack of understanding on some of the elements of structure, the literature indicates that structural overlaps between the components of the TT ecosystem are common, particularly in terms of ownership, governance and physical location. Research that considers the TT ecosystem holistically could reveal the advantages and disadvantages related to such structural overlaps, as indicated in what follows.

First, unity in terms of ownership seems to be prevailing, with many components in the TT ecosystem owned by the same organization such

Table 4
Organizational Structure of TT Ecosystem Components.

Component	Findings	References
TTOs	**OWNERSHIP STRUCTURE**	
	Internally integrated into university administration, fully-owned **external** organization, or **an external organization owned by multiple universities**	Battaglia et al. 2017; Brescia et al., 2014; Schaeffer and Matt, 2016
	GOVERNANCE STRUCTURE	
	Internal TTOs **integrated** into the university structure, receiving their budgets directly from the university	Brescia et al., 2014; Jefferson et al. 2017, Markman et al., 2005b; Markman et al., 2008; Schoen et al., 2014
	External TTOs are separate organizations with their own board and management team and can take on either a non-profit or a for-profit focus, typically funded by their stakeholders and proceeds from licenses and spinoffs	Brescia et al., 2014; Markman et al., 2005b
	May act as a member of a greater **alliance of TTOs** through either a network structure or the creation of a central hub where some resources are pooled	Battaglia et al. 2017; Brescia et al., 2014; Park et al. 2010; Schaeffer and Matt, 2016; Schoen et al., 2014
	INTERNAL ORGANIZATIONAL STUCTURE	
	Centralized TTOs characterized by a strong central office	Bercovitz et al., 2001; Brescia et al., 2014; Fisher and Atkinson-Grosjean, 2002; Jones-Evans et al., 1999; Siegel and Wright, 2007
	Fully **decentralized TTOs** place technology officers within faculties or specific research centres	Debackere and Veugelers, 2005
	Hybrid centralized/decentralized **TTOs** involve TT officers located in close geographical proximity to researchers and supported by services delivered by the central organization	Brescia et al., 2014; Fisher and Atkinson-Grosjean, 2002; Huyghe et al., 2014; Jones-Evans et al., 1999; Siegel and Wright, 2007
	Can take on **various structural forms** including unitary (U-form), matrix (MX-form), divisional (M-form), or holding company (H-form) forms	Bercovitz et al., 2001
	SIZE	
	Ranges from less than 5 to well over 100 employees	Clarysse et al., 2011; Siegel and Wright, 2007
	PHYSICAL LOCATION	
	Diverse locations. May be located within the university administration building, within a science park in a separate location away from campus, or even in an entirely different region,	Brescia et al., 2014; Chapple et al., 2005; Lai and Shyu, 2005; Markman et al., 2005b; Schoen et al., 2014
Science Parks	**OWNERSHIP STRUCTURE**	
	Shared ownership may include universities, government agencies, non-profit foundations or private entities	Albahari et al. 2017; Colombo and Delmastro, 2002; Lai and Shyu, 2005; Lofsten and Lindelof, 2003; Phan et al., 2005
	GOVERNANCE STRUCTURE	
	Integrated part of the university's organizational structure or a **separate** organization	Bigliardi et al., 2006
	May consist of multiple separate legal entities	Bigliardi et al., 2006; Hansson et al., 2005
	Can take on a for-profit or a not-for-profit orientation	Bigliardi et al., 2006
	Typically, **different stakeholders** participate on the science park board	Phan et al., 2005; Ratinho and Henriques, 2010
	SIZE	
	Ranges from less than 1,000 **square meters** and hosting only a few companies to areas consisting of well over 500,000 square meters.	IASP, 2016
	Varies from fewer than 50 **companies** to well over 1,000 with the majority hosting between 50 and 400 companies	IASP, 2016
	The administrative **staff** of a science park **varies** from 0 to over 250 employees	Colombo and Delmastro, 2002; Liberati et al., 2015
	PHYSICAL LOCATION	
	Can be located at **varying distances** from the affiliated institution(s)	Link and Scott, 2005; Link and Scott, 2006; Salvador, 2011
	Science parks located further away from universities tend to less frequently connect with the university	Dettwiler et al., 2006; Hu, 2008; Lindelof and Lofsten, 2004; Vedovello, 1997
Incubators	**OWNERSHIP STRUCTURE**	
	Typically owned by a **range of actors**	Bergek and Norrman, 2008; Hackett and Dilts, 2004; McAdam et al. 2016; Ratinho and Henriques, 2010
	GOVERNANCE STRUCTURE	
	Typically governed as **separate legal entities** with a separate management team and board of directors	Bollingtoft and Ulhoi, 2005; Peters et al., 2004
	Depending on stakeholder characteristics can have a for-profit or a non-profit orientation	Bollingtoft and Ulhoi, 2005; Peters et al., 2004
	INTERNAL ORGANIZATIONAL STRUCTURE	
	Many incubators have a **light, organic structure** whereas others rely on a heavier, hierarchical structure	Autio and Klofsten, 1998; Mian, 1997; Schwartz and Hornych, 2010
	SIZE	
	Great variation in number of employees and specialized functions offered	Aerts et al., 2007; Clarysse et al., 2005
	Often rely on **external service providers**, board members, and other stakeholders to provide additional resources	McAdam et al. 2016; Mian, 1997; Patton et al., 2009; Schwartz and Hornych, 2010
	The **number of tenants** hosted **varies** significantly	Aerts et al., 2007; Clarysse et al., 2005
	PHYSICAL LOCATION	
	Typically located **within** a university affiliated **science park**	Chan and Lau, 2005; Phan and Siegel, 2006
	Occasionally located near specific **research departments** or **off campus**	McAdam et al. 2016; Salvador, 2011
	In some cases housed within the university's **TTO**	Clarysse et al., 2005; McAdam et al. 2016;

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Table 4 (*continued*)

Component	Findings	References
University Venture Funds	**OWNERSHIP STRUCTURE**	
	Can be owned by a **combination of actors**	Atkinson, 1994; Munari et al., 2015
	GOVERNANCE STRUCTURE	
	Can be either **internal** to the university, **externally** managed by another component of the TT ecosystem, or a **standalone** organization	Croce et al., 2014; Gubitta et al. 2016; Munari et al., 2015; Munari et al. 2016; Westhead and Batstone, 1999
	Funds that are separate organizations typically resemble traditional limited partnerships managed by a team of **experienced professionals** with a formal advisory board	Croce et al., 2014; Munari et al., 2015
	SIZE	
	Internally managed funds typically **smaller than external**ly managed funds	Munari et al., 2015
	Internally managed funds have further been shown to employ **on average 4 executives** while information on staff of externally managed funds is largely lacking	Croce et al., 2014

as the university. Considering the ecosystem as a whole could shed light on the extent to which such joint ownership helps in balancing the purposes and activities the different components have or engage in, or the extent to which they can reap the benefits from approaching stakeholders or external parties as a unity.

Second, it is also quite common for one TT ecosystem component to own the other. While such ownership relation may enhance information flows, it may also give rise to inequality or hierarchy in the TT process, and as such affect the activities and impact of the different components.

Third, large differences are identified in terms of the size and

Table 5
People and Organizational Culture of TT Ecosystem Components.

Component	Findings	References
TTOs	**PEOPLE**	
	Possess business and marketing skills or prior entrepreneurial **experience**	Jefferson et al. 2017; Lockett and Wright, 2005; Siegel et al., 2003b
	Have the **capability to understand complex technologies**	Berbegal-Mirabent et al., 2015a; Di Gregorio and Shane, 2003; Jefferson et al. 2017; Lockett and Wright, 2005; Markman et al., 2005b; Neves and Franco, 2016
	Often have experience in **intellectual property rights** (i.e., lawyers, patent attorneys)	Feldman et al., 2002; Jefferson et al. 2017
	Have an understanding of the **academic** environment and how **research** is conducted	Bercovitz et al., 2001; Debackere and Veugelers, 2005; Huyghe et al., 2014; Jefferson et al. 2017
	Have hybrid backgrounds (e.g. technical combined with business skills)	Villani et al. 2017
	Have the capability of **developing networks** with either industry, academia, or business support organizations	Berbegal-Mirabent et al., 2015a; Lockett and Wright, 2005
	INCENTIVES	
	Provision of **higher salaries or bonuses** to TTO staff	Belenzon and Schankerman, 2009; Markman et al., 2004; Siegel et al., 2003a
	CULTURE	
	Typically described as **risk averse** and **bureaucratic**ally inflexible	Siegel et al., 2003b
Science Parks	**PEOPLE**	
	Have the ability to recognize and **attract high potential residents**	Hansson et al., 2005; Ratinho and Henriques, 2010; Westhead and Batstone, 1999
	Have the ability to develop and manage **relationships** with a range of relevant stakeholders	Hansson et al., 2005; McAdam et al., 2005; Ratinho and Henriques, 2010; Westhead and Batstone, 1999
	Have extensive **industry experience** combined with large networks and excellent network building capabilities	Hansson et al., 2005; Ratinho and Henriques, 2010; Westhead and Batstone, 1999
	Have relevant **business experience** to act as advisors and **mentors** to on-park firms	Hansson et al., 2005; Ratinho and Henriques, 2010; Westhead and Batstone, 1999
Incubators	**PEOPLE**	
	Have the capability of providing **advice** and guidance to spinoff companies	Bollingtoft and Ulhoi, 2005; Chan and Lau, 2005; Moray and Clarysse, 2005; Patton et al., 2009; Ratinho and Henriques, 2010; Rothschild and Darr, 2005; Schwartz and Hornych, 2008
	Have the ability to **connect** the spinoff companies with relevant **resource providers**	Bollingtoft and Ulhoi, 2005; Moray and Clarysse, 2005; Rothschild and Darr, 2005
	Are increasingly required to have **collaborative, project management, and networking skills**	Bollingtoft and Ulhoi, 2005; Chan and Lau, 2005; Patton et al., 2009; Ratinho and Henriques, 2010
	Have specialized knowledge in **technical fields** that are relevant to the incubator	Schwartz and Hornych, 2008
	CULTURE	
	Have **cultures vary**ing from highly collaborative and supportive to secretive and isolated.	Cooper et al., 2012; Patton and Marlow, 2011; Rubin et al., 2015; Schwartz and Hornych, 2008; Soetanto and Jack, 2013
	Some have an **open culture** with significant amounts of interaction, support, collaboration and cooperation, while others have a closed culture with tenants protecting their knowledge from others or choosing not to spend their limited time on interaction	Cooper et al., 2012; Schwartz and Hornych, 2010
University Venture Funds	**PEOPLE**	
	Have a lower level of experience managing investment funds compared to traditional venture capital funds and may **lack "value-adding" capabilities**	Croce et al., 2014; Pierrakis and Saridakis, 2017; Wright et al., 2006
	Try to **involve co-investors** with greater levels of experience to mitigate a lower level of internal experience	Croce et al., 2014

Table 6
From an atomistic to holistic perspective on the TT ecosystem.

	Current Atomistic Approach	Proposed Holistic Research Agenda
Purpose	Commercialize faculty research Technology transfer Generate intellectual property rights	Wide societal and economic impact Knowledge transfer Purpose adapted to individual university contexts
Activities	Isolated efforts by TT ecosystem components Closed networking activities within the TT ecosystem components	Collaborative and complementary activities by various types of TT intermediaries Boundary spanning between the TT ecosystem and its environment A process perspective into TT
Structure	Standalone structures of TTOs, incubators, science parks and university venture funds	Holistic structure and understanding of the TT ecosystem New emerging structures such as enterprise labs and garages, offices of engagement University ecosystem approaches Information flows and the role of digitalization
People and Organizational Culture	Demographical and human capital perspective into the TT ecosystem components	Composition of, and evolution in, the TT ecosystem teams Role distribution and identity Entrepreneurial culture of the TT ecosystem Intra- and inter-individual micro-processes Role of leaders and champions in the evolution of the ecosystem

location of the different TT components. Indeed, whereas some TT ecosystem components are fully integrated into the university location, others reside outside of the university. Considering the TT ecosystem as a whole would allow for assessing the advantages and disadvantages of geographical proximity alongside equality in terms of size between the different components.

4.4. People and organizational culture

Table 5 summarizes the findings from the literature related to the people, incentives and organizational culture of each component of the TT ecosystem.

As the table shows, knowledge about the people who work in each of the components of the TT ecosystem and particularly their incentive systems and organizational cultures has largely remained undocumented and future research into this area is highly warranted. Studies that have dealt with the human component within the TT ecosystem have, as the table shows, largely considered knowledge, skills and abilities of people involved in the different components. While these human capital-related elements are of interest, the people component of organizational design is by no means limited to human capital, and can also include, amongst others, task allocation between people (Csaszar, 2013; Shibayama et al., 2015) and identity (Foss et al., 2015). As such, it is clear that the literature, which has considered the people and organizational culture elements of organizational design, shows important shortcomings. While this holds for all TT ecosystem components, this is particularly true for university venture funds, where only two papers that dealt with the human aspects were identified.

Despite the limited attention that has been given to these aspects, a number of areas for which a holistic approach towards the TT ecosystem may be beneficial can be identified.

First, people within each of the TT ecosystem components seem to have specific human capital and are particularly knowledgeable in terms of technological development, intellectual property and commercialization. By consequence, teams of people in these components often have a wide range of backgrounds (entrepreneurial experience, industry experience, experience in law and intellectual property rights, …) and networks in industry. Considering the TT ecosystem as a whole may give rise to a better understanding of whether complementarity in terms of skills, background and networks is to be achieved within each component separately, or in the TT ecosystem as a whole, and under which circumstances knowledge gaps in one component could be filled with people active in another component.

Second, little research has been conducted on the culture that prevails within each of the TT ecosystem components. Considering the TT ecosystem as a whole may however be more fruitful in this regard, in which the culture of the entire ecosystem is likely to affect the TT process.

Importantly, while working through the current state of the literature on TT, a remarkable degree of overlap and complementarity between the organizational design elements of each component was identified. This significant degree of overlap and complementarity indicates that treating the components of the ecosystem separately misses important aspects of how these organizations jointly organize for TT. For this reason, there is a strong argument for a more "holistic" approach in the literature instead of an "atomistic" approach. In what follows, an elaboration of a future research agenda that moves from an atomistic toward a holistic understanding of the TT ecosystem is presented.

5. Organizational design of the TT ecosystem: a HOLISTIC research agenda

The purpose of this paper is to provide a synthesis of the current understanding of the TT ecosystem and to develop a framework for future research. In doing so, the TT ecosystem is considered as a whole alongside its components. Building on the findings that prior research has taken an atomistic approach to studying the TT ecosystem and that there exists extensive overlaps and commonalities between the components of a TT ecosystem, a future research agenda is outlined for a holistic approach to understanding the TT ecosystem based on the elements of the organizational design framework. Specifically, the research agenda is organized along the core themes of "purpose", "activities", "structure" and "people and organizational culture". In presenting the research agenda, it is indicated how considering the TT ecosystem holistically is likely to significantly progress the literature, which has taken an atomistic perspective into TT. The evolution from an atomistic into a holistic perspective along with the emerging themes is summarized in Table 6.

5.1. Purpose

As the literature review showed, different TT ecosystem components have different purposes, but are, at the same time, similar in striving to support regional development through commercialization of faculty research typically through technology transfer of formal IP by patenting, licensing and spin-offs. Partly in response to the oftentimes disappointing financial returns from such direct TT, more recent policy debate is evolving to emphasize the *wider societal and economic purpose* and resultant impact of universities (Siegel and Wright, 2015; Wright, 2014). Accordingly, there is a need for future research to approach the TT ecosystem holistically in order to shed light on the extended scope of

TT activities. In such an extended scope, TT is no longer reserved for the commercialization of research executed by university staff, but is extended towards *knowledge transfer* in general, comprising, amongst others, non-proprietary knowledge transfer, entrepreneurial activities by students and alumni as well as a range of outreach activities with industry and the wider community. Specifically, future research in this direction could focus on studying how the purpose of the TT ecosystem has shifted over time and the effect this has had on TT activities, management and performance measurement.

Further, while there is some understanding of the different configurations of TT ecosystem components in *different contexts* (e.g. Clarysse et al., 2005; Wright et al., 2008), there is a lack of insights into the relationship between purpose and the variation in university contexts. These different contexts, such as whether a university is research-leading, mid-range, science-based or arts-oriented, likely have implications for the nature of purpose. Each may be appropriate for a particular context, whereas attempts to adopt a particular purpose in an inappropriate context may create dysfunctional holistic approaches. Future research in this direction could investigate the conflicts that arise between ecosystem components due to misaligned purposes and how that relates to the overall purpose of the TT ecosystem. For instance, how does the choice of a particular purpose by one component affect the ability of other components to achieve their purpose? Alternatively, how do the different components of the TT ecosystem adapt their purposes to the local context and what impact does that have on the purpose of the ecosystem as a whole?

5.2. Activities

So far, the TT literature has documented isolated efforts by different TT ecosystem components. Considering the TT ecosystem holistically will allow for understanding the impact of *collaborative* efforts by different components in the TT ecosystem. Further, the holistic perspective will also allow for considering *boundary spanning activities* between the TT ecosystem and the ecosystem's environment (including stakeholders and other universities), including the roles and nature of a wider range of intermediaries (Wright et al., 2008). This is in contrast to much of the prior research that has considered each component of the TT ecosystem and their interactions with the environment in isolation. Future research into the collaboration between ecosystem components could investigate the different types of collaborations, whether formal or informal, that typically occur in these ecosystems, the antecedents of these collaborations, and their impact on TT and university outcomes. In line with the boundary spanning perspective, researchers could study how, why, and when the TT ecosystem facilitates cognitive, organizational, or geographical proximity between industry and academic actors (Boschma, 2005; Villani et al., 2017).

Finally, as research moves toward a holistic approach, it will allow for a much better understanding of the facilitators and constraints relating to the *TT process*, in which knowledge flows through the different stages of transfer, and is supported by the different elements of the TT ecosystem. Research in this direction could, for instance, follow the transfer of technological developments from the university to market and identify the role the various components play in supporting (or hindering) their transfer.

5.3. Structure

Whereas the literature review revealed that the structure of the different components in the TT ecosystem is relatively well understood, future research could study *structural design* of the TT ecosystem as a whole, as such shedding light on ownership, governance, internal organizational structure, critical mass and physical location and its impact on the TT process. Such future research could also work towards building a typology of different approaches towards organizing the TT ecosystem and highlighting the benefits and challenges of each approach, particularly in terms of the fit between the structure and other design elements such as activities, people and culture and organizational goals.

Considering the TT ecosystem holistically should further unlock attention for *new emerging organizations* within the ecosystem, beyond the traditional TT elements reviewed here. Specifically, it can give rise to the inclusion of *university ecosystem approaches* in future research. Indeed, whereas the four traditional TT components have been considered as core to the TT ecosystem, recent developments in policy and practice at various governmental, market and university levels point to the emergence of new actors in the TT ecosystem, which have so far largely remained undocumented. Such new actors include enterprise labs and garages, pre-accelerators, offices of engagement, knowledge transfer consortia, crowdfunding platforms and alumni angels, which are not only targeted at supporting faculty and researchers in commercializing their technology, but also at supporting students, alumni or multiple universities simultaneously (e.g. Pauwels et al., 2016; Wright, Siegel and Mustar, 2017). As such, the shift from technology transfer stricto sensu to knowledge transfer in general is likely to give rise to new components and beneficiaries in the TT ecosystem, which future research is urged to take into consideration.

Further, from a holistic perspective, these new actors add to the need identified in the previous section to understand more fully the processes of interaction between the different elements. Finally, future research could purposefully assess how the structure of the TT ecosystem could be optimized in order to facilitate *information flows* and how *digitalization* (Autio et al., 2017) could play a role in a TT ecosystem approach.

5.4. People and organizational culture

So far, research into the atomistic perspective has largely considered the demographical and human capital aspects of each of the TT ecosystem components. In considering the TT ecosystem holistically, new research themes will emerge. Specifically, *team composition* within the TT ecosystem is an important research subject. Teams within the TT ecosystem are typically composed of individuals with diverse backgrounds (e.g. industry versus academic experience). A holistic approach recognizes that such diversity is likely to be greater and more complex as new and emerging elements of the ecosystem attempt to interact more closely. Future research could study the impact of heterogeneous teams versus homogeneous teams (in terms of social, human capital, cognition, micro-processes and the roles team members assume) on the TT process. There is limited research on team *formation, evolution and functioning* in an atomized context (Nikiforou et al., Forthcoming) and a holistic approach likely increases the complexity of creating complementary and functional teams that further research can shed light on. It could further assess the extent to which the establishment of heterogeneous teams in the TT ecosystem gives rise to faultline formation and how this is addressed. Faultlines are hypothetical dividing lines splitting a group into relatively homogeneous subgroups, based on the alignment of individuals along multiple characteristics, possibly leading to conflicts (Lau and Murnighan, 1998). In this context, faultlines may originate from (mis)alignment of individuals in terms of human and social capital, and intra- and inter-individual micro-processes between individuals. There is limited work on these micro-processes within ecosystem components (Waldman and Siegel, Forthcoming) and even less across them. Future research could purposefully assess the circumstances under which faultlines within the TT ecosystem team are strong, potentially leading to (task-related) conflicts (Lau and Murnighan, 2005; Li and Hambrick, 2005) and how faultline origination in a TT context can be mitigated.

Future research could further investigate to what extent individuals within the TT ecosystem have *diverse roles* and how they differ in terms of *role and personal identity*. The latter identifies the extent to which an individual's identity synergizes with the identity of the organization in

which they work and how that might evolve (in this case, the TT ecosystem) (Stryker and Burke, 2000; Stets and Burke, 2000), and is particularly important to understand where purpose involves a wider societal social as well as an economic impact.

Finally, future research could consider the *organizational culture* within the TT ecosystem, and the extent to which the different subcultures of each element can be developed and optimized in line with the wider organizational purpose of the TT ecosystem. Specifically, research could investigate the role leaders or champions within the TT ecosystem play in defining the overall purpose of the TT ecosystem and developing a supportive organizational culture.

6. Conclusions, managerial implications and limitations

Due to the institutionalization of the TT process in the university context, a wide array of organizational components dedicated to support this process has emerged. This literature review aimed at providing an understanding of the current state of the literature on the TT ecosystem and its components by using an organizational design perspective. Surprisingly, many studies were found that have focused on either TTOs, science parks, incubators or university venture funds, but almost no studies could be traced that had considered the TT ecosystem holistically. Furthermore, while the purpose and activities of the TT ecosystem components have been well documented, the understanding of ownership and governance structures, alongside the "people" aspect of TT ecosystem components remains understudied. Finally, this review points to a dearth of research on the organizational design of university venture funds. At the same time, this review also points to overlaps in, and differences between, the different TT ecosystem components, urging future studies to apply a holistic approach toward the TT ecosystem. Subsequently, in Section 5, a research agenda was developed for moving from the current atomistic approach towards a holistic approach to understanding TT ecosystems. Future studies in line with this research agenda can have important implications to the science of TT.

In addition to the implications for academia, which were elaborated on in Section 5, this paper has important implications for TT management since it suggests that, in order to be effective, managers need to devote efforts to move to a holistic TT ecosystem concerned with the alignment of purposes, activities, structure, and people across its different elements.

Due to the evolving nature of the purpose of the TT ecosystem towards broader societal and economic goals and knowledge transfer in general, managers within the ecosystem must be prepared to adapt to new demands and maintain alignment with the other components within the ecosystem. Managers must also be aware of their local context and its influence on purpose both for individual components and for the ecosystem as a whole. As such, TT and university managers will have an important role in building a university ecosystem, in which broader knowledge transfer and wider societal impact can be achieved. To do so, managers not only need to be aware of how their activities fit into the TT ecosystem as a whole but also how they can collaborate with other actors within the TT ecosystem such as through joint events, projects, and service provision. In addition to collaborative activities, managers need to understand how they can effectively support the boundary spanning role of the TT ecosystem by identifying opportunities for connecting academic and industry actors and facilitating communication between them.

Managers will need to address the challenges associated with restructuring existing atomized arrangements into holistic arrangements involving both existing and new elements. These challenges involve decisions about whether coordination of the approach is centralized or decentralized, which new elements should be incorporated, creative approaches to designing new ecosystem components that suit the local context, how best to facilitate information flow within the TT ecosystem, and dealing with potential conflicts and resistance from existing elements.

Beyond restructuring, managers will also have to ensure they can recruit individuals with a diversity of skills, industry and academic experience, and human and social capital. Beyond simply recruiting individuals, managers must be able to build well-functioning teams both within specific components but also across the TT ecosystem. Critical to this will be the design of appropriate incentive mechanisms that encourage the development of an organizational culture that is supportive of knowledge transfer both within and between components.

Finally, this study has several limitations that can be addressed in future studies. First, in order to make the literature review tractable four main components of the TT ecosystem were focused on. Future research might usefully address other components discussed above. Second, given the nature of the study, primary field research was not undertaken but the research agenda presented above provides pointers in this direction. As in the existing literature, a number of methodological approaches might be adopted but study of TT ecosystems may particularly lend itself to qualitative process methods in order to chart their evolution. Third, the focus of this paper is on the TT ecosystem related to the promotion of faculty entrepreneurship rather than student entrepreneurship. However, as TT ecosystems begin to get more involved in student entrepreneurship further research will be needed to incorporate this aspect.

Despite these limitations, this study contributed by providing a synthesis of the TT ecosystem literature and by developing a framework for future research considering the TT ecosystem holistically.

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Annexure A. Journals included in this review

#	Journal Title in Alphabetical Order
1.	Cambridge Journal of Economics
2.	Economic Development Quarterly
3.	Entrepreneurship and Regional Development
4.	Entrepreneurship Theory and Practice
5.	Environment and Planning A
6.	Environment and Planning C: Government and Policy
7.	European Planning Studies
8.	European Urban and Regional Studies
9.	Foundations and Trends in Entrepreneurship

10.	Gender and Society
11.	Health Affairs
12.	Higher Education
13.	IEEE Transactions on Engineering Management
14.	Industrial and Corporate Change
15.	Industrial Marketing Management
16.	International Journal of Entrepreneurial Behaviour and Research
17.	International Journal of Industrial Organization
18.	International Small Business Journal
19.	Journal of Business Finance and Accounting
20.	Journal of Business Research
21.	Journal of Business Venturing
22.	Journal of Economic Behaviour and Organization
23.	Journal of Economics and Management Strategy
24.	Journal of Engineering and Technology Management
25.	Journal of Intellectual Capital
26.	Journal of Knowledge Management
27.	Journal of Management Studies
28.	Journal of Product Innovation Management
29.	Journal of Productivity Analysis
30.	Journal of Small Business Management
31.	Journal of Technology Transfer
32.	Long Range Planning
33.	Management Decision
34.	Management Science
35.	Omega
36.	Oxford Review of Economic Policy
37.	Papers in Regional Science
38.	Progress in Planning
39.	Public Administration Review
40.	R and D Management
41.	Regional Studies
42.	Research Policy
43.	Scientometrics
44.	Small Business Economics
45.	Social Science and Medicine
46.	Technological Forecasting and Social Change
47.	Technovation
48.	Urban Geography
49.	Urban Studies

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