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Nurturing entrepreneurs: How do technology transfer professionals bridge the Valley of Death in Japan?

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ABSTRACT

The study aims to clarify the behavioral patterns of technology transfer professionals (TTPs) required in university technology commercialization. In the past, TTPs simply transferred technology using functional skills and experience gained in specific science/business fields; however, now they are often required to be entrepreneurial in the process, as mentioned in the literature and manuals on the TTP's job. However, we know little about what type of behavioral patterns of entrepreneurship are required for TTPs. Through our explorative case studies of veteran TTPs in Japan, we found concrete behavioral patterns within the theoretical framework of effectuation. TTPs start with the means they can use, try to set temporary goals under high uncertainty, raise technological value using affordable resources, and get stakeholders' involvement. In performing these activities, they take control of emerging situations and iterate several trial-and-error processes to deal with contingencies to accomplish their technology transfer projects. We found that entrepreneurial universities require TTPs who possess not only functional skills but also an understanding of how TTPs act to bridge the Valley of Death.

1. Introduction

This study aims to clarify the behavioral patterns of technology transfer professionals (TTPs) that are required to effectively transfer technology from universities to firms. For universities to play an active role in innovation, TTPs need to play a central role in technology transfer (Etzkowitz, 2004; Etzkowitz and Leydesdorff, 2000; see also Son et al., 2020). In the past, TTPs performed simple patent management and licensing of technology, but they are now often required to nurture technology by obtaining funding, search for potential markets, and identify practitioners who want to be in charge of commercialization (Lundqvist, 2014; Perkmann et al., 2013; Phan and Siegel, 2006). This reflects that there is the Valley of Death (VoD) – the gap between the development of technology at universities and commercialization in industry (Auerswald and Branscomb, 2003; Biemans and Huizingh, 2020; Markham et al., 2010; Meyer et al., 2011). The problem is even more pronounced in countries where the technology transfer market is immature, such as Japan (Takata, 2017). TTPs are considered to take central roles in bridging the VoD (Alliance of Technology Transfer Professionals, 2018); however, we know little about what type of behavioral patterns is required for these roles. We analyze it through explorative case studies of veteran TTPs in Japan. Then, as a contribution, we show that the required behavioral patterns of the TTP to cross the VoD is a kind of entrepreneurial behavior called the "effectuation" (Sarasvathy, 2009).

The structure of this paper is as follows. First, we will review the literature in the next section, and we will discuss the changing roles and skills of TTPs and identify gaps in the literature. In addition, we will show that theory about the behavioral patterns of entrepreneurs is useful as an analytical framework to fill the gaps in existing research. Next, we will explain our method of empirical case analysis, and present our findings. Then, we will develop several propositions about the

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behavioral pattern required of TTPs. Finally, we are going to mention the contributions and limitations of our study and conclude with implications for the practitioners.

2. Literature review

2.1. Traditional perspective on the role of technology transfer professionals

We start by reviewing earlier research that analyzes the roles and competencies required in technology transfer. A basic assumption of this discussion is that universities should play a role in realizing innovation (Etzkowitz, 2004; Etzkowitz and Leydesdorff, 2000). Universities have great potential for innovation because they possess not only novel technologies with commercial potential but also large numbers of skillful and ambitious students. Following this logic, several universities set up technology transfer offices. However, universities as institutions of research and education did not have the function or ability to transfer technology to the business world, and therefore TTP became a new job in universities.

Early technology transfer models assumed some division of labor to achieve innovation from a university (Chakrabarti and Hauschildt, 1989; Maier and Brem, 2017; Perry-Smith and Mannucci, 2017). Commercialization of university technology involves several stages, each of which requires different activities. Meyer et al. (2011) proposed three stages that are required to take a university invention to a business venture. Once a potential scientific invention has been realized, the first step toward commercialization is to confirm its commercial feasibility by Proof of Concept (POC) or prototyping. Next, a convincing business plan is developed, including a specific product/service, marketing plan, and value chain design. The third stage is to establish a viable company, and build a credible management team and customer base to encourage investment in this company. Each of these stages requires different skills, hence the division of labor concept that was central to past studies. This simple and logical approach allocates responsibility to institutions with a relative advantage in each area. Because universities have an advantage in generating new technology and industry has more experience in developing businesses, the role of universities is to establish technology to a commercially feasible level and that of industrial corporations is to develop a business using that technology (Franklin et al., 2001; Lundqvist, 2014).

Based on this division of labor model, the conventional main responsibility of the TTP was to quickly transfer technology (knowledge) to industrial institutions that were willing to accept and use research output (Etzkowitz and Leydesdorff, 2000; Perkmann et al., 2013; Phan and Siegel, 2006). In such a case, the role of the TTP was only to connect two sectors (Debackere and Veugelers, 2005; Guston, 1999). In this role, the required skills included management of patents, negotiation skills, legal knowledge about licensing contracts, and technology marketing. Personality-wise, TTPs needed to be professional, open, inclusive, knowledgeable, dependable, altruistic, co-operative, passionate, enthusiastic, and authoritative (AUTM, 2008). To summarize, the TTP was expected to act as a professional mediator who connected university technology and industry.

2.2. Challenges and changes in recent years

The role required for TTPs has changed dramatically recently. The biggest reason is that universities should play an entrepreneurial role: the idea of entrepreneurial universities has become more important (Etzkowitz, 2003; Kalar and Antoncic, 2015). According to the former division of labor model, universities are responsible only for technological development and TTPs should license the resultant technology to industry, but this idea is becoming outdated. Universities are playing a more active role in the commercialization of technology, and it is now considered that they should be responsible for the examination of commercial possibilities and the construction of business models (D'Este and Perkmann, 2011).

To implement this change, universities are now required to help cross the VoD as their role (Meyer et al., 2011). Additionally, within such universities, which are characterized by shifting multiple institutional logics, TTPs have to explore the expected role and the new skills required from them (Schildt and Perkmann, 2017; see also Ellwood et al., 2020); that is, now TTPs not only play the past role of licensing established technologies to industry but also actively bridge the VoD by facilitating the development of technology and business.

Indeed, TTPs have begun to respond to some serious gaps in the steps of technology commercialization, as shown in Fig. 1 (Meyer et al., 2011). To fill all the gaps, the technology handed off from universities must first be validated, to some extent, for practicality and commerciality (Jensen and Thursby, 2001; Perkmann et al., 2013). To satisfy this condition, the focal technology must be sufficiently developed to convince industrial entrepreneurs of its commercial feasibility. It is rational for any potential entrepreneur to request investment-worthy, proven technology that can be incorporated into a product or service quickly. Thus, university researchers are challenged to establish the commercial feasibility of their technology, even though their primary expertise lies in generating new scientific knowledge (Jensen and Thursby, 2001; Perkmann et al., 2013). As a result, many technologies become stuck in this phase, regardless of their actual commercial potential (Etzkowitz and Leydesdorff, 2000; Rasmussen et al., 2006). This is the origin of the VoD metaphor (Auerswald and Branscomb, 2003; Markham et al., 2010; Meyer et al., 2011). The VoD problem exists because of the large capacity gap between scientific research and commercially feasible product development; a gap that has become wider than expected in recent years.

As new scientific knowledge is discovered, it is necessary to invest a large amount of resources to make it commercially feasible. However, researchers who prioritize scientific discoveries have little incentive for commercialization, and entrepreneurs lack motivation to invest in technologies for which commercial feasibility is unconfirmed. Additional difficulties in crossing the VoD arise from uncertainty in the process that links scientific discovery and practical use (Barr et al., 2009; Murphy and Edwards, 2003). Previously, the relationship between technologies and business opportunities was simple. A TTP could easily set a clear goal and process of commercialization, and define the roles of all players in advance. However, increasing volatility and uncertainty in social and business environments challenge this approach. It has also become important to pursue innovations, that is, those that arise from unforeseen combinations of technology and opportunity. This requires TTPs to take a more proactive role in commercializing technology (Bozeman, 2000; Markman et al., 2005). In this process, a simple linear model from university to industry is not always suitable. Instead, the technology transfer job often involves exploration and experimentation to determine an appropriate application for novel technology.

To summarize, the current division of labor model of technology transfer from universities seems promising but incomplete because the circumstances around technology transfer are changing from relatively stable to more uncertain (Table 1).

2.3. Emerging role of TTPs

In response to the aforementioned challenges and changes, for universities to contribute to society, the idea that they must be able to act more entrepreneurially is spreading. Universities that manage uncertainty and actively transfer technology are conceptualized as entrepreneurial universities, and the requirements for doing so and their consequences are beginning to be analyzed (Etzkowitz, 2003; Kalar and Antoncic, 2015).

Along with this conceptual change in the role of universities, TTPs are required to take initiatives to transfer technology while managing uncertainty (Fitzgerald and Cunningham, 2016). TTPs can no longer be

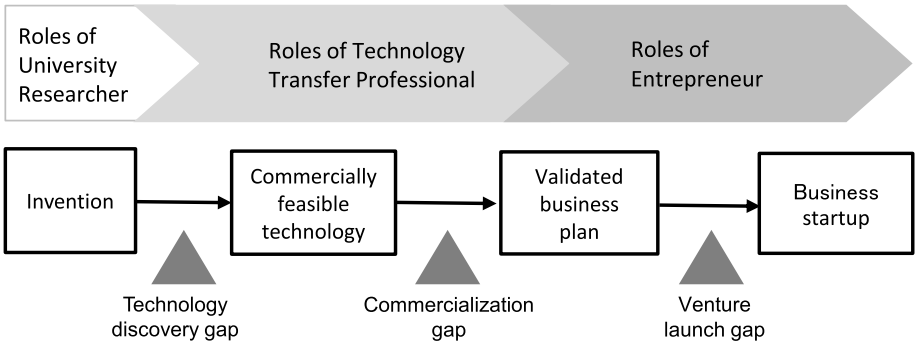

Fig. 1. Technology commercialization process: stages, roles, and capability gaps.

Table 1
Comparison of changing perspectives of technology transfer work.

	Technology transfer in the past: An agent between academia and industry	Technology transfer today: A bridge over the VoD
Technology	Ready for commercial use	Incomplete for commercial use, it must be improved and proven
Potential markets	In existence	Unknown
Technology transfer recipient	Recipients approach the university	The university seeks out recipients or start-ups
Time needed for technology transfer	Short	Long
Resources	Sufficient to sell the technology	Insufficient to nurture the technology

passive agents, but should behave like entrepreneurs who intend to bridge the VoD using their own skills and efforts (Gianiodis et al., 2016). TTPs are expected to be actively involved in the advancement and proof of technology, and must gather various resources to achieve this. Simultaneously, TTPs must work on identifying promising customers and potential markets. Finally, TTPs must respond to several uncertainties.

Entrepreneurial skills and mindsets are required for TTPs. TTPs can no longer simply mediate between university researchers and business practitioners. Instead, they must actively tackle the task of filling the capability gap between them. They must take a role in developing technology to be commercially feasible, while simultaneously analyzing its market potential. To execute this, they need to collect the required resources from their surroundings (Bessant and Rush, 1995; Meyer et al., 2011). In addition to these tasks, the search for potential entrepreneurs is becoming increasingly important (Lundqvist, 2014).

We analyze the situation in more detail. First, determining a potential market is a key task of TTPs, but this is also typically the task of entrepreneurs. Like entrepreneurs, TTPs must hypothesize about potential markets and conduct market searches while gathering additional information. In the course of that process, they must interact with inventors and explore different fields (Bessant and Rush, 1995). Sometimes, they may explore the market through events such as student education programs and showcases of technology (Nakagawa et al., 2017; Ollila and Williams-Middleton, 2011). These efforts may involve multiple trials and dead ends.

Even when a potential market is identified, the technology may still not satisfy market needs. Therefore, TTPs must verify the technology's feasibility, often using POC and gap funding (McAdam et al., 2009; Munari et al., 2016). This may involve motivating researchers to help with POC efforts or finding a company that is interested in the focal technology and willing to cooperate on a POC effort. While comparing these options side by side, TTPs advance technology feasibility research. In unfortunate situations when the technology is inadequate, TTPs must restart their market search efforts.

Another task of TTPs is to find recipients or industrial entrepreneurs for technologies. Sometimes, a company that collaborated on research might want to acquire commercial development rights. Another option may be an existing company that sees technological synergies with a related field. Occasionally, university stakeholders might prefer commercialization through a new company formed for this effort. At other times, the TTP has to locate another talented entrepreneur from industry or a university who is ready to build a new technology-based business (Franklin et al., 2001; Lundqvist, 2014).

To summarize, the technology transfer office and TTPs are the organization and personnel, respectively, that play a central role in a university being entrepreneurial. The technology transfer office is the first trigger to transform scientific and technological value into commercial value, it ignites and involves stakeholders, and it fills the gap of the VoD in the commercialization process. Additionally, the new tasks of TTPs at the technology transfer office are (1) to explore the potential need for technology, (2) to identify the specific segment for first market entry, (3) to develop the hypothesis of a business model and the value chain, (4) to support technological development and validation to a level where a company can have incentives to be involved, and (5) to assist with further product development or technology introduction (Alliance of Technology Transfer Professionals, 2018; Takata, 2017). Additionally, such activities are performed under high uncertainty. Tony Raven, CEO of Cambridge Enterprise, the organization responsible for Cambridge University's industry-academia collaboration, has emphasized this point: "We are not administrators, we have to be entrepreneurs! We proactively work on our ecosystem, and initiate innovation!" (Raven, 2018). At the present time, TTPs must take the initiative to develop premature technologies, find markets, and hand verified technologies over to industrial entrepreneurs.

However, one question remains: What specific behavioral patterns facilitate technology transfer in such uncertain situations to bridge the VoD? When we look at the document for the Registered Technology Transfer Professional (RTTP), the international standard for TTPs working in universities or research labs defined by the Alliance of Technology Transfer Professionals (2018), it emphasizes entrepreneurial mindsets and skills. However, neither that document nor other literature has provided sufficient discussions about what type of entrepreneurial behaviors facilitate technology transfer. Furthermore, even if they contain a list of required behavioral patterns, most of them has shown no evidence that those patterns really work for successful technology transfer.

2.4. Theoretical framework: entrepreneurial behavioral patterns and the idea of effectuation

In the previous section, we confirmed that TTPs have been required to behave entrepreneurially in recent years, but what is that "entrepreneurial behavior"? Existing studies on entrepreneurship are useful

for theorizing this.

Stevenson and Jarillo (1990) performed one of the first trials to conceptualize entrepreneurial behavioral patterns, which resulted in the finding that entrepreneurs mainly behave in an opportunity-based manner. They found that entrepreneurs continuously pursue new opportunities and move quickly to benefit from them. Lumpkin and Dess (1996) extended this idea and conceptualized the entrepreneurial orientation of personnel. They highlighted autonomy, innovativeness, risk taking, proactiveness, and aggressiveness as the chief characteristics of entrepreneurs, and discussed the method of measuring them and their relationship with firm performance. These previous studies provided a fundamental understanding of the nature of entrepreneurial behaviors (Welter, 2011).

Based on the aforementioned studies, Sarasvathy (2001) further clarified the characteristics of an entrepreneur's specific behavioral patterns—referred to as effectuation. By comparing senior managers of large corporations with successful entrepreneurs, Sarasvathy draws more concretely on how entrepreneurs think and act to make their business successful. Patterns observed in the behavior of such entrepreneurs are classified as: bird-in-hand, affordable loss, leveraging contingencies, co-creation with partners, and pilot-in-the-plane. Further, in the book that treats those five ideas in more depth (Sarasvathy, 2009), Sarasvathy proposes specific actions for entrepreneurs and illustrates them with giving rich examples. Although other research on entrepreneurial skills appears to be useful, it is theorized to ensure generality without describing a concrete course of action (e.g., Lumpkin and Dess, 1996). By contrast, Sarasvathy's research describes a concrete course of action to create a new business (Sarasvathy, 2001). Thus, we think that effectuation theory is useful because it enables us to describe concrete actions to realize successful technology transfer. Hence, we use the principles of effectuation as a framework for our study.

However, effectuation's nature of describing specific behavioral patterns poses serious doubts about generalizability (Arend et al., 2015; Grégoire and Cherchem, 2019). There are five major ideas for behavioral patterns in the theory of effectuation, and they are sometimes useful for creating new businesses under certain conditions; however, they may have the opposite effect under different conditions (Palmié et al., 2019). Even for a TTP, who operates in the unique environment of the commercialization of university-initiated technology, it is unlikely that all the effectual courses of action apply. Thus, we consider whether each of five principles can be used.

2.5. Bird-in-hand: start with a given means

The first principle of effectuation is that successful entrepreneurs do not start with a goal and detailed plan toward it, but start to act with what they have at hand. Entrepreneurs first explore what they can do with the given means because, under uncertainty, it is difficult to formulate suitable and unambiguous goals. For example, it is very difficult to define business opportunities or target customers that may only be defined *ex post* once someone buys the product or service. Goals change, are shaped and constructed over time, and are sometimes formed by chance (Fisher, 2012).

However, this principle has been considered to be debatable. Entrepreneurs sometimes have an unwavering vision from the beginning, and it is thought that the ability to have a strong will and the commitment to achieve it are required (Palmié et al., 2019; Baum et al., 1998).

Considering the situation of technology transfer under high uncertainty, the principle "start-by-means" seems to be beneficial because it is difficult for TTPs to draw clear goals. However, simultaneously, because technical commercialization requires a strong TTP's willingness to formulate suitable goal, the spirit and skills to develop strategy backward from the goal are also required (O'Shea et al., 2005). Based on these considerations, both "start-by-means" and "start-by-goals" are examined in our analysis.

2.6. Affordable loss

Studies of effectuation describe how successful entrepreneurs manage the risks associated with new challenges. Having the skill to manage risk is important in unpredictable, volatile settings. To continue to pursue as many challenges as possible, it is critical to avoid a fatal loss from any one opportunity (Sarasvathy, 2001; Dew et al., 2009). This proposition is crucially different from existing entrepreneurship research that emphasizes the risk-taking action applied to change the situation (Lumpkin and Dess, 1996). Indeed, both risk-taking challenges that bring something new and risk-avoidance to survive and keep challenging might be required to realize innovation (Bowers and Khorakian, 2014).

Given the TTP's situation, risk management does not seem to be so important. Even if a technology transfer project at a university fails, there is no risk of bankruptcy. Rather, to explore the applicability of technology, continuous actions are required. Thus, we need to investigate the TTP's attitude toward risk in more depth.

2.7. Leveraging contingencies

According to Sarasvathy (2001), expert entrepreneurs tend to acknowledge and appropriate contingency by leveraging surprises rather than trying to avoid, overcome, or adapt to surprises. By looking for advantageous opportunities that emerge from surprising events, entrepreneurs are more likely to gain business than when they try to avoid surprising events.

In subsequent studies, this behavioral feature was generalized as a trial-and-error process of seeking for answers, and relabeled as an "experiment" (Chandler et al., 2011). This is consistent with the results of existing research about entrepreneurs (Fisher, 2012) and has been frequently verified in subsequent research (Palmié et al., 2019). In an uncertain environment where the answer is not easily found, experimental exploration is considered to be very effective. This is also true for TTP situations. Because it is not easy to find an area where technology can be used effectively, TTPs are required to conduct extensive search activities and repeat the trial-and-error process.

2.8. Co-creation with partners

Another principle of effectuation emphasizes collaboration with stakeholders that are willing to make actual commitments to the project. Partnerships with self-selected stakeholders expand the set of existing resources that define "what can be done?" Simultaneously, because such stakeholders bring their own preferences and visions, the vision of the venture becomes transformed and co-created through collaboration, and eventually converges into a new product or new market (Sarasvathy, 2001). This principle was labeled "networking" after being linked to past research (Chandler et al., 2011). Considering the TTP's work of transferring technology together with obtaining information from venture capitalists (VCs) and external analysts, this principle may be considered to be quite applicable.

2.9. Pilot-in-the-plane

The last component of effectuation theory, "pilot-in-the-plane," addresses the mentality of the entrepreneur. It highlights the entrepreneurial attitude of taking control of the emerging situation. The traditional approach that is taken by senior managers in a large company is to attempt to analyze and predict the future, and then react to unforeseen changes. Such an approach would be suitable for developing a robust plan to achieve a pre-determined goal. Entrepreneurs, by contrast, recognize that such a prediction cannot work in the face of market and technology uncertainty. Instead, they focus on controlling the situation that they can affect significantly, like a pilot in a plane (Sarasvathy, 2009).

Generally, a TTP is an intermediary in technology transfer and is often not considered to be a protagonist (Debackere and Veugelers, 2005; Guston, 1999). In that sense, the idea of controlling the situation like a pilot would be different from the TTP image that was previously discussed. However, today's TTPs may be required to work on the project and find a pathway in an uncertain situation (Fitzgerald and Cunningham, 2016). Thus, it can be said that the degree to which a TTP is involved in the situation is an important consideration.

Drawing on the concept of effectuation, we would like to confirm its behavioral patterns in terms of the job of high-performing TTPs, and attempt to determine how they contribute to bridging the VoD, using an explorative case analysis.

3. Methodology

We reflected that the nature of our question is to ask "what?" Therefore, we believe that an explorative qualitative study that derives some propositions inductively is suitable (Eisenhardt, 1989; Yin, 1994).

From a comparative study of high-performing veteran TTPs and novice TTPs, we analyze the differences in their behavioral characteristics. First, we collected data through insider action research (Brannick and Coghlan, 2007; Roth et al., 2007). The insider action style fits well when it is extremely difficult to capture the situation precisely unless researchers become part of the setting. Because we need to know quite personal characteristics, such as entrepreneurship and entrepreneurial skills, we believe that insider action research is the most suitable approach for our study. Hence, we included some typical high-performing TTPs in our research team, and described their cases using interviews and mailing interactions. We obtained two cases from Osaka University (*Case 1 & 2*), one of the largest and highest-ranked research universities in Japan.

Furthermore, for validation, we collected two cases from a Japanese research university, the University of Tokyo, until the behavioral pattern converged (Yin, 1989). Thus, we obtained four cases of high performers. Simultaneously, two cases of newcomers that could serve as a comparison were collected from the same universities to clarify the behavioral patterns of high performers.

We selected cases from Japan because it was easy for us to obtain data using insider action research; in addition, the positive reason for using Japanese observations is that the Japanese market of university technology is still immature (Nakagawa et al., 2017; Takata, 2017; Yamamoto, 2015). Compared with the United States (US), which has a somewhat established market for technology from universities, the probability of successful technology transfer in Japan is lower, and there is considerable uncertainty. In such a market environment, we thought that the actions to cross the VoD could be identified more clearly.

However, to check the validity of the findings from Japan, we also used data from US and European research universities. This was not to attempt to generalize our findings to the world, but to test whether the behavioral patterns observed in Japan are very specific to a Japanese situation. In order to do this, we asked two high-performing TTPs from Europe and the United States respectively to cooperate with our study. Those two were selected from our research members' personal connections. The data were obtained from online interviews and/or several email exchanges. A summary of the cases that we collected is presented in Table 2.

When collecting the data from high performers, we asked them to prepare a document that summarized their typical successful technology transfer experience. Then we conducted an interview that lasted about 1 h based on the document, which was followed up by several emails. When collecting the data from novice TTPs, we interviewed them for about 30 min to 1 h. Because they did not have remarkable technology transfer experience, we asked how they were usually involved in the technology transfer business.

The data were transcribed and a brief summary was created. Then, the actions that positively or negatively related to the five effectuation principles were selected from each case (Table 3). Based on these findings, we derived some propositions regarding the effect of effectual behavioral patterns.

Table 2
The list of our cases.

TTPs studied	High performer/ Novice	Nation	Interview date
Case 1. ***Matsuhashi***	High performer	Japan	(Insider action research)
Case 2. ***Kato***	High performer	Japan	(Insider action research)
Case 3. ***Yamamoto***	High performer	Japan	2018, May. 10 60 min
Case 4. ***Honda***	High performer	Japan	2019, Dec. 6 90 min
Case 5. ***Mr. A.***	Novice	Japan	2019, Nov. 6 60 min
Case 6. ***Mr. B.***	Novice	Japan	2019, Dec. 4 70 min
Case 7. ***Stevens***	High performer	The U·S.	(Insider action research)
Case 8 ***Ms. C.***	High performer	Ireland	2018, July. 24 Exchanging e-mails based on her demonstration of experience for RTTP applications

4. Case summaries

Case 1. Toshihiko Matsuhashi, Technology Transfer Professional, University-Industry Collaboration Office, Osaka University.

Osaka University is one of the top research institutes in Japan. It established the Office for University-Industry Collaboration (UIC) in 2011 and determined that the mission of that office was to establish joint research programs with industrial corporations and commercialize technology developed by Osaka University professors. Matsuhashi has worked at Osaka University from the inception of UIC and clearly succeeded in developing both start-ups and collaborative research programs.

When he was developing a successful start-up, he first considered the strategic plan to prepare for the market launch: "When I received one potential technology from a university researcher, I hypothetically developed a plan throughout commercialization from technological development to business start-up. Such a plan often was unsuccessful, but I thought it was an important process for making progress. While doing it over and over, in the course of accumulating failures, gradually we identified the unmet market need and the goal that we should aim for."

While he emphasized the importance of the trial-and-error process, he took care to ensure the survival of the project and technology: "It is important not to kill with failure, but to correct the logical flaws and get closer in the next iteration. I made steadfast progress in the direction of the technology. I utilized the personal connections cultivated through exploration in a certain direction, and the prototypes were created there, in the next search. I tried to learn something from every search. At the same time, I was keeping an eye on cash flow while thinking about the next step, to avoid the situation that it is no longer stuck and not financed."

Although Matsuhashi's central job was to create collaboration with industries, he did more than that. He pursues progress in commercialization by developing many programs, such as design thinking, technological assessment, business plan development, and funding for POCs by himself, and by making connections with other stakeholders, such as VCs and incubators. Then, through an education program about design thinking, successful technology ventures were launched by those who recognized the business opportunity.

Table 3
Observation status of five key elements of effectuation.

TTPs	Perfor -mance	Nation	start with given means	affordable loss	leveraging contingencies	co-creation with partners	pilot-in-the-plane
Case 1. ***Matsuhashi***	High	Japan	Hypothetically developed commercialization plan (tentative goal), after receiving technology from researcher	Utilized prototypes, got fund for POC, and kept an eye on cash flow to avoid being stuck and not financed	In the course of accumulating failures, he gradually identified the unmet market need and goal	Made connections to other stakeholders such as VCs and incubators	Pursued progress by using many programs such as design thinking, technological assessment, business plan development
Case 2. ***Kato***	High	Japan	At first, utilized university's education program for finding out the potential market and personal connection for getting prototype	Facilitated researchers to conduct the POC and prototyping using grants and subsidies	Even though the technology assessed not so well, he kept iterate trial and error process for commercialization	Gained collaborative research with a company in one usage, and utilized supports from government and VC for another usage	Further pursued the other opportunity of commercialization after the success in one usage
Case 3. ***Yamamoto***	High	Japan	Started to design several application ideas of technology, and sought potential partner		After learning from pharma company, he ruled out the idea of using it as a drug and refocused on applying it to cosmetics	Pointed out the importance of personal network to find new hint or support for commercialization	Eventually persuaded to conduct joint research with the cosmetics manufacturer, even the inventor was initially reluctant to do it
Case 4. ***Honda***	High	Japan	Started with pre-marketing of 5–6 company interviews for clarifying marketability	Pre-marketing activities before patenting (avoiding unnecessary patent cost)	If first plan was not right, changed the direction with hints from many interviewing	Talked with counterpart in company very persistently for successful licensing	Searched for customer iteratively and led to successful deal, though others thought it so difficult
Case 5. ***Mr. A.***	Novice	Japan	Did not have enough external channels or communication experiences	Not much support for immature technologies	Stopped action and wait, if customers did not get interested	Weak activation of surrounding people	Work motivation is not clarified, and keep aside if project is not active
Case 6. ***Mr. B.***	Novice	Japan	Concretely designed the target market and application				Focused on creating win-win structure between researcher and company
Case 7. ***Stevens***	High	The U·S.	Formed management committee and routinely developed mini-business plan	Gained funds which can be spent for translational purpose, and managed it		Experienced executives, management committee, and co-principal investigators	Active project management to ensure the projects
Case 8. ***Ms. C.***	High	Ireland	Discussed the project with existing contacts at various funding bodies, so she could shape the proposals	Actively helped to explore various POC funds, and finally obtained it after several rejections	Any comments or criticism in the grant application process were addressed in following iterations of the applications	Partnership with pharma for new IP creation, licensed to pharma & software providers, and formed a spin-out company	Brought 'investment' into the company and obtained the best deal after long and difficult negotiations

Case 2. Kosuke Kato, Technology Transfer Professional, University-Industry Collaboration Office, Osaka University.

Kosuke Kato also works as a TTP at Osaka University. We introduce one of the chief technology transfer cases, embedded circuit technology, conducted by Kato.

This technology had already been patented; however, it encountered difficulties regarding finding promising applications. Kato used the university's technology commercialization education program (Nakagawa et al., 2017) to take advantage of students' labor to determine the use of the technology. They found two possible applications: lighting and noise cancelling. Both uses have been assessed as "Conditional Kill/Kill" because the scale of the project is too small; however, they are in the process of being commercialized in an enterprise after Kato's iterated trial-and-error process as follows.

Regarding the first use of lighting, Kato contributed to the situation significantly. He introduced the technology to a professor at another institute. That professor recognized that it was interesting and developed a prototype based on the technology. The prototype was exhibited at the big technology conference called Innovation Japan and Kato succeeded in gaining collaborative research for business development with a company for an amusement use. In parallel, Kato contacted a lighting design start-up that he saw on a TV program, and organized a collaborative project and obtained a national government's subsidy.

Kato further pursued the commercialization of the other use: noise cancelling in a medical device. After securing funds for further technology development by taking advantage of several grants and subsidies, he helped the researchers to conduct POC and prototyping. Seeing this progress, Kato continued to contact VCs and companies. Most of them had a negative attitude toward commercialization, but Kato finally found a VC that recognized the potential of the technology and they started working together toward business development. The technology is under development for clinical use with support from a university gap fund, and a start-up company will be launched.

Case 3. Takafumi Yamamoto, Chief Executive of the Technology Licensing Office, the University of Tokyo.

Next, we examine Takafumi Yamamoto, who is another high-performing TTP. Yamamoto is a pioneer in the field of university technology transfer in Japan. He has been active in technology licensing since the mid-1990s and has been the chief executive of the Technology Licensing Office (TLO) of the University of Tokyo since 2000. Among his many works, Yamamoto's well-known commercialization of γ-Oryzanol eloquently demonstrates how he went beyond the traditional role of a technology transfer manager.

In 2005, Ozaki and Ushio at the University of Tokyo found that γ-Oryzanol performed better in relieving early stage allergic reactions than traditional alternatives. To achieve its practical use, Ozaki contacted the TLO and discussed options with Yamamoto and other

licensing associates of the TLO. They intuitively recognized its potential for anti-allergy treatments and proposed several approaches to apply this chemical substance: orally available drugs, eye drops, nasal sprays, cosmetics, nutritional supplements, and health foods. They even proposed a possible commercialization as a pet medicine.

Drawing on these diverse ideas, they started seeking potential partners for the commercialization of γ-Oryzanol. First, they met an R&D manager of a promising partner: a Japanese pharmaceutical company that had already developed and sold anti-allergy drugs. Although this meeting concluded that γ-Oryzanol could not be used as a drug because of its chemical properties, Yamamoto learned much more about the substance. Using the information from this meeting, he eliminated the idea of using it as a drug and refocused on applying it to the other areas that had been suggested. When in discussion with a woman who was involved in advertising for cosmetic companies, he proposed the idea that γ-Oryzanol could be used as a skin care product for people with sensitive skin. She told Yamamoto that people with sensitive skin used products made by either Natural Science Co. or French cosmetics companies.

Yamamoto contacted Natural Science Co. and proposed partnering on the commercialization of γ-Oryzanol for this application. Yamamoto met Osaki, the CEO of Natural Science Co. and learned that the company had been established to treat the founder's son and daughter, who suffered from atopic dermatitis, so its founders were very interested in pursuing the commercialization of γ-Oryzanol in cosmetics. Ozaki was initially reluctant to conduct joint research with the cosmetics manufacturer; however, he was eventually persuaded to collaborate because Yamamoto and his team members emphasized how γ-Oryzanol could improve the quality of life of people suffering from skin allergies. Eventually, product development was successfully completed and the resultant products are sold all over the world.

Looking back at his achievements, Yamamoto highlighted the importance of a personal network for finding new information or support to commercialize the technology, and the spirit of trying to accomplish things on your own. Because only TTPs are in charge of technology commercialization, the key to achieving it is to be able to continue various challenges using that network.

Case 4. Satoshi Honda., Technology Transfer Professional, Technology Licensing Office, the University of Tokyo.

Satoshi Honda has over 10 years of experience at the University of Tokyo TLO, and has achieved many technology transfers. He talked about a typical experience.

In this case, Honda's work started with patenting technology. First, through pre-marketing activities, he clarified that a marketable patent was possible. "I usually listen to five to six companies to check the market potential of the technology. Then, I often recognize that it may be surprisingly marketable."

During this pre-marketing interview, Honda often discusses with the interviewees how to proceed with the introduction of the technology. In this case, he also talked with the counterpart very persistently about how the company would introduce the technology, which led to licensing.

The University of Tokyo TLO has groups that evaluate the marketability and novelty of technologies, and decide which technologies to sell at a regular weekly meeting. At this meeting, Honda believed in his own evaluation. At one meeting, most of the members thought that it was difficult to license the technology, but he decided to do it. His conviction and responsible actions led to a successful licensing deal as a result of making efforts to identify potential customers and continuous discussion with a principal investigator to further validate the patent.

Honda emphasized that the most effective way to find license customers was corporate interviews. In particular, he said that he got very useful information from talking to a company that was not interested in the technology. The idea of the commercialization starts from negative information such as which aspects of the technology are not good and what the expected manufacturing cost will be. If the plan that Honda made at first was not correct, he changed the direction using a hint from an interview and went to other companies in a different industry. Finally, he found a suitable industry to which the focal technology could apply. "I changed direction while running."

Case 5. (Novice). Mr. A, Technology Transfer Professional, University-Industry Collaboration Office, Osaka University.

Mr. A was still in his first year and had three to four licensing experiences. Previously, he had worked in genetics at a pharmaceutical company and moved to the University-Industry Collaboration Office at Osaka University. Using his current experience, his task was to achieve licensing in the pharmaceutical area.

At the beginning of his licensing job, Mr. A started by communicating well with the researcher, selected the technology that the researcher was strongly interested in commercializing, and intensively discussed with the researcher how to transfer the technology. He thought that the researcher's enthusiasm was important, and he should facilitate and motivate it. At that time, he tried to deepen his own knowledge by studying the researcher and the researcher's technical fields.

Mr. A did not have many channels to access external resources; thus, he did not experience communication with and utilization of external partners. "Compared with experienced people, I feel that the way to involve the stakeholder is weak, and I do not have enough knowledge of how to do it."

When Mr. A started marketing the technology, he emphasized licensing customers. If customers were not interested, he temporarily stopped the action for that technology and waited for another opportunity to transfer it in a different direction.

Mr. A did not support immature technologies; he focused on licensing mature technologies. Additionally, he focused on the projects which are already active and easy to handle, rather than making efforts to activate them.

At the time of the interview, he didn't have a strong work motivation as a TTP. "The motivation to work has not yet been clarified. Social installation of the technology is a dream, but first I need to be able to do the job at hand."

Case 6. (Novice). Mr. B, Technology Transfer Professional, Technology Licensing Office, the University of Tokyo.

Mr. B has been working at the TLO for about one year and eight months, since graduating from university.

Mr. B's technology transfer work began when researchers submitted an invention report to his organization. He then contacted the researchers to talk about how they wanted to apply their technology to society. Before that meeting, he conducted brief literature and patent reviews for preparation. He also performed pre-marketing and a search for a few potential customers.

At this time, he did not expect big market prospects because he thought that it was sufficient to obtain licensing income with a reasonable fee from at least one company. "Instead of higher license income, my objective is to make progress as soon as possible, by creating a win-win structure between the licensor and the licensee."

In the marketing of the technology, Mr. B concretely designed the possible market application to explain how that technology is useful for customers. Simultaneously, he searched for about 10 target companies, usually using a web database. Then he started to license the patent to them.

After a company had shown interest and Mr. B made an appointment with it, he set up a meeting with the university researchers and that company. He thought his role was to connect the researchers and the company.

Through those licensing activities, Mr. B did not use external agents, such as a VC. He took advantage of the rich resources within his TLO. "Technology assessment and marketing activity could be made only by our staff."

Case 7. Ashley J. Stevens, former Executive Director, Technology Transfer, Office of Technology Development, Boston University and Past President, AUTM.

Boston University was selected as one of 10 US universities to receive grants as part of the Wallace H. Coulter Foundation's first cohort of the Translational Partnership Awards in Biomedical Engineering.[1] This is a transformational program that provides financial and management support to professors seeking to commercialize novel medical devices. The Coulter program has been exceptionally successful, achieving a licensing success rate that is almost double that reported in the AUTM Annual Licensing Activity Survey. In addition to the high success rate, the Coulter program is notable for having 80% of its commercialization achieved through start-up companies compared with 15–20% of commercialization reported in the AUTM Annual Licensing Activity Survey.

A reason for the success rate is the design of the program, which was developed by Ashley J. Stevens and his colleagues. The program is characterized by the following.

1) an experienced executive from the medical device industry overseeing the program;
2) a management committee that selects and manages projects that comprises a majority of individuals from the local innovation economy – for example, entrepreneurs, investors, corporate and intellectual property attorneys, and corporate technology scouts – and individuals from within the university – for example, the technology transfer office, biomedical engineering department, entrepreneurship center, incubator, and venture capital fund;
3) co-principal investigators – a basic scientist or biomedical engineer partnered with a managing director whose specialty includes the uses of the proposed device;
4) active project management to ensure that projects remain on schedule and budget via quarterly reviews;
5) strong administrative support to schedule meetings, distribute documents, and monitor budgets; and
6) existing intellectual property that undergoes technological evaluation prior to the program's round of project evaluations. After all basic discovery research has been completed, funds can only be spent on translational projects.

Another reason for its success is the diversity of entrepreneurial commercialization skills represented in the management committee, of which Stevens was a member. Sitting around the table at committee meetings were clinical end-user experts, product development experts, clinical development experts, marketing experts, intellectual property specialists, VCs, manufacturing experts, and joint venture specialists. Thus, the management committee was a self-contained entrepreneurial team that was able to co-create and collaboratively guide successive projects (typically, four to six projects were receiving funding and development at any time). A "mini-business plan" was routinely developed for each project, thereby preparing the project for its transition to an entrepreneur (Stevens and Kato, 2013).

Case 8. Business development manager C, in a university in Europe.

Ms. C was in charge of business development based on life science-related university technology. She worked closely with researchers to advise and help them with various technology transfer matters.

In 2009, during a session with a professor, Ms. C discussed the development of an algorithm for evolutionary drug design optimization. This algorithm was being developed as a part of a Ph.D. studentship under the supervision of that professor. Ms. C and the professor recognized the commercial potential of what appeared to be game-changing, cutting-edge technology.

Ms. C initiated activity for the development and commercialization of the algorithm, but she faced some challenges from the outset. In that country, funding for POC was not readily available for the type of technology under development, and the novelty of the technology made funders skeptical about its market value. Ms. C actively helped to explore various POC funds by discussing the project with her existing contacts at various funding bodies so that she could shape the proposals for the funding bodies. In particular, she worked closely with the professor to ensure that any comments about or criticism of the grant application reviews/rejections were addressed in the following iterations of the applications. After some rejections, they finally obtained a grant for POC, and this led to the successful receipt of further follow-on funding and further development of the technology.

Through this exploration and development process, Ms. C identified mechanisms by which the technology could demonstrate its real potential and simultaneously reduce its reliance on traditional methods of academic funding for research and development (R&D). These mechanisms included a partnership with pharmaceutical companies to use the novel technology for the creation of new IP for the partners, licensing the technology to pharmaceutical companies and software providers, and/or forming a spin-out company. She explored these ideas, which were further explored through discussions with pharmaceutical company representatives and VCs. After brainstorming with the professor, Ms. C started a series of negotiations with pharmaceutical companies to create deals that would bring in much needed funding for the technology but without giving up control of the technology. These negotiations envisioned that deals would be signed when a spin-out company was incorporated using the technology. Through this process, Ms. C brought investment into the company without compromising the IP developed during POC. The negotiations were long and difficult, but, finally, her resolve to protect the technology and obtain the best deal for the university stakeholders paid off. These efforts resulted in multi-million-dollar revenues from deals with pharmaceutical companies in 2012. At present, the spin-out is a multi-award-winning thriving company that has attracted investment from additional pharmaceutical companies.

5. Analysis

In this section, we synthesize the data from the case studies into propositions to verify whether technology transfer from universities to industry can be explained by effectuation. Table 3 shows an overview of the four cases of high-performing TTPs and two cases of novice TTPs in Japan. It also contains two high-performing TTPs from Europe and the US, which have relatively established technology transfer markets, for comparative analysis. It can be said that this research achieved literal replication (Yin, 1994) because the findings from the observations were highly convergent in (Table 3), which means that our findings fall within the allowable level of reliability (Yin, 1989).

Our case study observations provide insights into the differences in TTPs' behavioral characteristics in technology transfer. First, we analyzed the effect of the "starting with given means" approach on technology transfer. We found that most of the TTPs studied confronted a noticeable lack of information and uncertainty at the early stage of technology commercialization. They could not develop a definite image of the market application of the technology at that stage. Therefore, they needed to start using their existing knowledge and personal connections in industry and academia. This is, in particular, a behavioral pattern commonly observed in high-performing TTPs. For example, when Matsuhashi in Case 1 obtained technical information from the inventor, he first contacted his personal network to obtain the information necessary for describing the hypothetical goal of technology commercialization. Kato in Case 2 used potential market information that students found in educational programs and asked a close friend to build a prototype.

[1] http://whcf.org/coulter-foundation-programs/translational-research/coulter-translational-partnership-tp-and-research-awards-ctra/coulter-translational-partnership-award-in-biomedical-engineering-tp/, searched 7/30/18.

Honda in Case 4 started with pre-marketing, which consisted of interviews with multiple companies, to confirm the marketability of his technology. Ms. C in Case 7 in Europe, had similar behavior. Thus, the series of actions in which high-performing TTPs make the best use of their personal networks match the phrase "Knowledge transfer is a contact sport" (Minshall, 2009).

By contrast, in the case of the two novice TTPs, they had limited personal contacts, and they did not have much external communication experience; hence, they could not take actions as quickly as veteran TTPs. The novice Mr. A in Case 5 tried to deepen his knowledge by studying the technology rather than contacting external resources.

As described above, the interaction with a broad range of parties by making full use of one's own personal connections in a situation where the goal is unclear corresponds to "starting with given means" in effectuation. However, simultaneously, the early stages of commercialization are characterized by dynamically changing goals that emerge in response to personal connections or new information. Under such conditions, many of the TTPs studied used their financial, physical, and human resources to determine a goal that could be shared by stakeholders, and tried to obtain resources for commercialization in a goal-oriented manner. This includes Matsuhashi's hypothetical commercialization plan and Yamamoto's quick shift of focus from pharmaceuticals to skin care products. In the case of Europe and the US, Stevens's development of a mini-business plan and Ms. C's shaping of proposals through various contacts illustrate the same behavior. In particular, in the pharmaceutical and medical device industry where regulatory requirements are clear, and in licensing to start-ups that must meet the VC's investment requirements, technology transfer activities must be designed backward from the goal (Matsuhashi et al., 2018); therefore, setting goals quickly is important for technology transfer. This tendency was partially observed in the novice TTP in Case 6. Behind these actions, there is the fact that the resources necessary for commercialization cannot be provided by the university alone, and it is essential to obtain industry cooperation and its resource provision. Therefore, the behaviors of setting goals and involving stakeholders outside the university are definitely observed in the activities of TTPs, and they are very effective tools for successful technology transfer.

To summarize, the relationship between the means and goals that are outstanding for high performers is as follows; each time, they formulate a tentative goal from the resources at hand and move toward that goal.

Proposition 1. *In an uncertain environment, a TTP starts with the means he/she can use. However, simultaneously, he/she tries to define a commercialization goal for stakeholders and take goal-oriented action.*

The cycle of TTPs determining a goal from means is frequently repeated in technology commercialization. The process, with high uncertainty, tends to result in many contingencies and failures. Therefore, we analyzed the effect of the "leveraging contingencies" approach on technology transfer. In the technological development process, unexpected technical problems occur and competing technologies emerge, so uncertainty and risk are high. Additionally, market-related problems, such as misunderstanding the needs of potential customers, often occur. These are typical uncertainties in the technology commercialization process, particularly in the early stages. However, the failures and misconceptions encountered in the process also have the benefit of enabling the TTP to discover "new facts" that were not initially known. In the cases that we analyzed, we observed that TTPs adapted positively to such unexpected situations and failures. A typical example can be seen in Case 3. Yamamoto first considered that γ-Oryzanol could be a drug, but that idea was found to be wrong in the meeting with a pharmaceutical company. However, he thought that this was a clear advance to commercialization because he thought that it indicated that γ-Oryzanol should be sold somewhere other than the pharmaceutical market. Finally, he proposed the idea that γ-Oryzanol could become a skin care product. In Case 1, Matsuhashi mentioned that the development plan was often unsuccessful, but it was important to identify the real goal from accumulating failures. In Case 4, the plan that was formulated by Honda was initially not correct, but he changed the direction using hints obtained from many types of interviews. Such behavior was also observed in European Case 7, in which Ms. C used comments and criticism from the grant application process in the following iteration.

By contrast, in the case of a novice TTP, the behavior of repeating the trial-and-error process was not substantially observed. Mr. A, in Case 5, temporarily stopped his activities when customers did not become interested in the technology and waited for another opportunity.

From this, we conclude that, in the early stages of commercialization, the goal is not fixed and the theme of "you never know until you try" dominates; that is, pivots occur repeatedly because of small mistakes and misconceptions in the commercialization process; even failures or obstacles help TTPs to determine the potential of a business opportunity.

Proposition 2. TTPs use minor failure experiences in transferring technology as a sign to pivot to another market, or use obstacles in a positive manner to develop new ideas to overcome them.

In these trial-and-error activities, TTPs use their personal networks actively to carry out activities that supplement what they cannot do themselves. Therefore, we analyzed the effect of the "co-creation with partners" approach on technology transfer. In the case of university technology commercialization, it is indispensable to describe the entire value chain before developing products, and to involve stakeholders who will cooperate. In the case analysis, high-performing TTPs actively engaged potential partners who were likely to be interested in commercializing projects by presenting their commercialization goals and the economic returns or social impacts that would arise. They were taking significant steps to make up for the lack of resources for commercialization. Each TTP studied obtained information from external specialists, such as lawyers, industrial practitioners, successful entrepreneurs, and VCs. Such a network of external members contributes to determining a potential market, adequate use of technology, and the desirable form of the contract. It supplements the TTP's own thoughts and search efforts, and expands the possibility of achieving a suitable technology commercialization. It also helps to identify a potential entrepreneur. Potential entrepreneurs may be included in the partner network directly or may be accessed using the connections of people within the network. Furthermore, the network often provides financial or knowledge resources to develop the technology itself. When the technology is premature and requires further development for commercial use, a knowledgeable and engaged partner may help to improve the technology.

Particularly in the early stages of the technology commercialization process, the goals of commercialization are ambiguous, so the competitive analysis frequently used in the ordinary business process is not very useful. Rather, the competitive advantage greatly depends on who TTPs partner with. Therefore, high-performing TTPs played a role in engaging and actively involving potential stakeholders in moving the commercialization process forward. In contrast, the novice TTPs have insufficient external connections and therefore rarely involve others. Thus, enriching the partner network has become very important in technology transfer.

Proposition 3. External partners involved by TTPs help to determine the market, potential entrepreneurs, investments, and new opportunities to further develop the technology.

Among these trial-and-error activities, how do TTPs act on risk? We analyzed the effect of the "affordable loss" in effectuation and how TTPs behave toward risk in the technology transfer process. In the process of finding a promising market opportunity for technology, it is necessary to verify whether technical specifications can be fitted to market benefits, and to clarify the value proposition of the technology. For this reason, TTPs support inventors to obtain a small amount of POC funding/gap funding to collect additional data or develop prototypes, and actively show them to potential partners and obtain feedback from them. In the

case analysis, we observed that Matsuhashi and Kato were engaged in discovering the potential value of the technology through prototyping and acquiring POC funding. This was also noticed in the European and the US cases. In contrast, novice TTPs were weak in nurturing immature technologies.

At first glance, this seems to be in line with the principle of "affordable loss" in effectuation. However, in the process of commercializing university-initiated technology, the risk for universities was not high enough to create a crisis situation. Even if the commercialization is not successful, the university's loss is only the cost of initial patent applications, small gap fund costs, and TTP labor costs. Rather, the risks in the commercialization process belong to companies/start-ups that create new businesses based on the technology transferred from the university. The technology transfer activities of universities are within the range of affordable loss for universities.

Based on our analysis, TTPs show stakeholders the goal of expected economic return and social impact based on the information obtained using, for example, POC funding, and take actions to encourage stakeholders to contribute resources to the project; that is, they cause industry to bear the risk in exchange for expected returns from commercialization. In the case analysis, veteran TTPs, such as Matsuhashi and Kato, acquired external POC funding and supported inventors' prototyping to demonstrate the technological value. This allowed them to raise stakeholders' awareness of the business value and extract commitment.

To summarize, rather than the affordable loss principle, which is to continue activities while avoiding fatal losses, TTPs try to describe expected returns by acting quickly within a lower risk, and get stakeholders' commitment to commercialization projects.

Proposition 4. At the early stages of the technology transfer process, TTPs' activities involve only limited risk; they present expected returns and encourage stakeholders to take risks instead.

The last component of effectuation is the mindset of "pilot-in-the-plane". Because of the characteristics of TTPs analyzed so far, high-performing TTPs are not just passive agents entrusted with specific tasks, but develop the goal of commercializing technology with strong initiatives. For example, Matsuhashi in Case 1 used a variety of techniques, including design thinking and technology assessment programs, to try to portray the potential value of technology. In Case 2, Kato was not content with one technology transfer contract and continued to search for other uses, thus successfully transferring technology for multiple applications. Yamamoto in Case 3 worked with an inventor who was initially reluctant to commercialize the idea, and reached a joint research agreement with a partner company. In Case 4, Honda, whose team members did not believe in his commercialization plan, searched for a technology transfer opportunity and reached a successful deal. Such strong initiative was also observed in the European and the US cases. These high-performing TTPs' behaviors illustrate the principle of "pilot-in-the-plane" in effectuation.

In contrast, for novice TTP Mr. A in Case 5, the motivation for working was not clear, and he paused the project when it did not proceed well. Mr. B in Case 6 played the role of a mediator with the aim of establishing a win-win relationship between researchers and companies, and there were few actions to strongly control the situation.

Regarding TTPs, it also required them to be proactive because they are no longer just agents for technology sales, but are truly key players in technology commercialization. This mental change toward taking control of an emerging situation is critical for TTPs to act as entrepreneurs (Cai et al., 2017; Sarasvathy, 2009; O'Shea et al., 2005). In developing and transferring technology, TTPs cannot be passive in a changing situation but should be proactive players to make changes. We could see such an attitude of TTPs in all cases.

Proposition 5. To move the technology transfer project forward, it is essential that TTPs take control of the emerging situation.

5.1. Model of the nurturing entrepreneur

Based on these propositions, in Fig. 2, we show a comprehensive model of TTPs that promotes technology transfer with entrepreneurial behavior. After receiving technology from researchers, high-performing TTPs start with the means they can use and try to set temporary goals under high uncertainty (Proposition 1). Subsequently, they increase value using affordable resources and present expected returns to stakeholders (Proposition 4), involve external partners (Proposition 3), and finally transfer the project to industrial entrepreneurs. Across the entire process, high-performing TTPs initiate technology commercialization by taking control of the emerging situation (Proposition 5) and iterate several trial-and-error processes to deal with contingencies (Proposition 2). From these characteristic behaviors, we define this type of entrepreneurship for TTPs as the nurturing entrepreneur, which is exerted to bridge the VoD between the major roles of the university researcher and that of the industrial entrepreneur through a heuristic and iterative opportunity-finding process.

6. Contributions and limitations

This study contributes to research on the commercialization of technology developed in universities, that is, research on bridging the VoD that exists between universities and industry (Auerswald and Branscomb, 2003; Markham et al., 2010; Meyer et al., 2011). Previous studies found that entrepreneurial spirit, skills, and behaviors are required for TTPs to respond to emerging situations around universities (Etzkowitz, 2003; Kalar and Antoncic, 2015; Schildt and Perkmann, 2017). However, few studies have investigated what type of entrepreneurial behavior affects how this occurs. Based on the exploratory case analysis with the theoretical framework of effectuation (Sarasvathy, 2009), we identified the specific behavioral patterns that are required to facilitate technology transfer. Drawing on our findings, we presented precise discussions about the required skills and roles of TTPs in the context of an entrepreneurial university that pursues the mission of achieving innovation for society (Etzkowitz, 2003, 2004; Fitzgerald and Cunningham, 2016; Kalar and Antoncic, 2015). Although the existing literature or manuals on the TTP's job have stated that an entrepreneurial mind and skills are required, they have not fully discussed how these appear in the actual work of technology transfer (ATTP, 2018; AUTM 2008). Furthermore, some of the actions are described in those manuals, but it is not explained why these actions should work. Thus, our study contributes to filling those gaps, to provide how and why TTPs behave entrepreneurially throughout the technology transfer process.

Based on such an academic contribution of this paper, we note that conventional styles of the TTP job of managing and transferring intellectual property are not sufficient if we expect the university to play a key role in industrial innovation. An entrepreneurial university requires TTPs who possess not functional skills, such as legal management, licensing, negotiation, start-up foundation, acquiring public grants, project management, and experience in specific science or business fields, but also an understanding of how TTPs act to bridge the VoD. This means that a fundamental change is required in the evaluation and human resource development system of TTPs; that is, universities that want to be entrepreneurial should assess TTPs' ability to perform entrepreneurial behavior and provide programs to foster it (Lundqvist and Williams-Middleton, 2013, Matsuhashi et al., 2018; Meyer et al., 2011, Nakagawa et al., 2017). A nationwide, governmental campaign since the late 1990s to enlighten the university-led innovations in Japan, this new role of TTPs would also contribute to improving the situation (Kim, 2016).

However, it should be noted that TTPs can perform well in technology transfer only when the organization supports them. The senior management of licensing offices, or even that of the overall university, need to understand this emerging role of TTPs to be an entrepreneurial university (Lumpkin and Dess, 1996). The organization may support

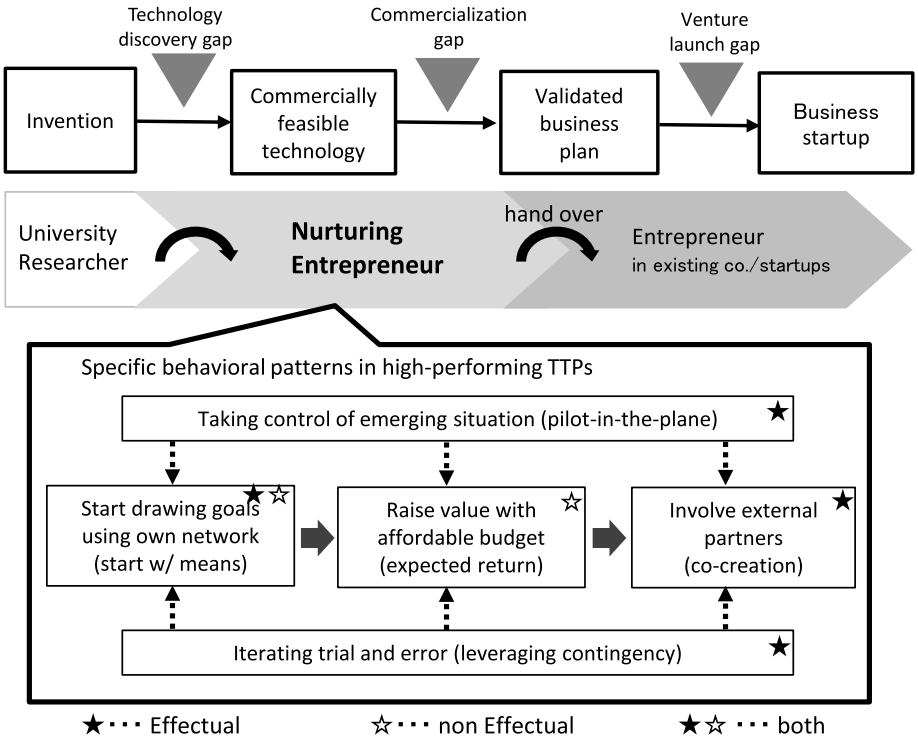

Fig. 2. Roles and characteristics of a nurturing entrepreneur in the technology commercialization process.

TTPs to build networks internally and externally, and to make decisions in the context of uncertainty. Giving TTPs the wide range of authority to make decisions may also facilitate their performance in technology transfer because they can behave like a "pilot-in-the-plane." Therefore, we suggest that organizational support can accelerate their actions. Identifying what type of organization is needed to support TTPs' entrepreneurial behavior is future work.

There are also limitations to our study. One limitation is that our study adopts a case-based approach that uses a limited number of observations. Although we aimed to ensure the logical validity of the discussion using several related papers and theories, further studies are required to empirically validate our findings. In particular, what is most important and effective in TTPs' behavior in nurturing technology is not yet clear. It is also not clear whether there are other important behaviors or characteristics that are not part of effectuation. Additionally, there is much room for research on the potential requirements for TTPs such as background and past experiences to acquire such behavioral patterns, and also the co-relations between individual TTPs and organizational entrepreneurial orientation, including decision-making authority, collaborative action with other TTPs, and budgeting systems in universities. Further qualitative investigations could provide a rich, in-depth understanding of the new entrepreneurship of TTPs, and quantitative studies could contribute to the verification of those discussions. We suggest future empirical work that builds on insights from this study that can lead to a new role for TTPs in the technology transfer process where the VoD is no longer a concern.

Declaration of competing interest

None.

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