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Technological start-ups in the innovation system: an actor-oriented perspective

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ABSTRACT
The functional approach of the Technological Innovation System (TIS) has become important in innovation theory to understand the dynamics of technological innovations. Until now, TIS has mainly been applied top-down from a policy perspective. The aim of this study was to investigate whether TIS can be used in the management domain, from an actor-oriented perspective, to explain the dynamics in which technological start-ups are involved when developing innovations. We interviewed the founders of 24 technological start-ups about their experiences with the developmental processes of their innovations. Our results highlight that the functions of TIS provide a useful framework to structure the interactions of technological start-ups. Especially the functions ‘Resource Mobilisation’ and ‘Legitimation’ appeared to be important functions for start-ups when developing an innovation. Our findings show that TIS is a promising framework for the strategic management domain that can offer guidance in the development of innovations.

1. Introduction
The Technological Innovation Systems (TIS) perspective has become a dominant approach in studying the dynamics of the development, utilisation, and diffusion of new products and technologies. TIS adopts a holistic perspective, in which a technological innovation is seen as a ‘network of agents interacting in a specific industrial area under a particular institutional infrastructure’ (Carlsson and Stankiewicz 1995, 49). These agents include diverse academic, economic and governmental actors that interact within networks (e.g. technology consortia, learning networks, and public–private partnerships), shaped by institutions (e.g. culture, norms, laws, and regulations) (Bergek, Jacobsson, Carlsson et al. 2008). Although TIS has shown its relevance in various empirical studies by contributing to the understanding of the development of different innovations, it is still in development (Suurs and Hekkert 2009).

In fact, several areas of TIS are rather underdeveloped. Firstly, TIS is primarily used as an analytical framework to inform policy-making. However, some scholars acknowledge that it might be useful for the management domain as well, as entrepreneurs play a pivotal role in the innovation processes and even might be able to overthrow and change structures around them (Hekkert et al. 2007; Planko et al. 2016). Secondly, TIS has mostly been used as a top-down approach, but as Markard and Truffer (2008a) have shown, a bottom-up approach from an actor-based perspective provides new and useful insights into the influence of a particular actor group on the innovation system. Thirdly,
the TIS literature leaves room for further specification of the interactional processes that shape technological innovations. Although these interactions are key to understand the innovation system, a detailed understanding of them remains underexplored (Bergek, Jacobsson, and Sandén 2008; Binz et al. 2016).

In order to further develop TIS as an analytical framework, the aim of this study is to investigate to what extent the functional approach of TIS is a useful framework to identify the interactional processes of technological start-ups involved in generating (technological) innovations. As technological innovations are increasingly initiated by creative enterprises (Groen and Walsh 2013) and technological start-ups play a key role in the economy (Maes and Sels 2014), this study focuses on this actor in the innovation system. In conclusion, we apply TIS in the strategic management domain, using an actor-oriented perspective.

1.1. Functional approach of TIS: from policy to strategic management

The functional approach of TIS emerged in the beginning of the twenty-first century and saw a rapid increase in attention since its specification by Bergek, Jacobsson, Carlsson et al. (2008). The functional approach aims to clarify the dynamics of the system in which the interactions take place and is used to identify (potential) factors that may hinder or promote the development of technological innovations (Wieczorek and Hekkert 2012). Within such a system, seven functions can be distinguished: resource mobilisation, market formation, legitimation, entrepreneurial experimentation, knowledge development, influence on the direction of search, and development of externalities (Hekkert et al. 2007; Bergek, Jacobsson, Carlsson et al. 2008). They have been mainly formulated on an abstract level, as they are used as heuristics to understand the dynamics of an individual innovation, rather than as guidelines that prescribe how a system optimally functions. An improved understanding of the functions in TIS is important, because of the consequences it can have for producers and, customers in a particular field, as well as for policy-makers and society at large (Markard and Truffer 2008b; Binz et al. 2016).

The functional approach of TIS has been mainly applied in the policy domain as an analytical framework. Jacobsson and Bergek (2011, 43) state that ‘the key contribution of the innovation system analyses is (…) that it provides policy-makers with a tool for identifying system weaknesses’. Furthermore, Markard and Truffer (2008b, 601) argue that the functional approach makes it possible to assess innovation systems, and ‘on the basis of system comparisons, scholars are finally able to arrive at policy recommendations’. By analysing the functions of TIS, policy-makers can identify key policy challenges, and assess whether inducement or blocking mechanisms should be applied.

Although far less explicit and elaborate than in the policy domain, a connection between TIS and the management domain was made in the same period as well. For example, Bergek, Jacobsson, and Sandén (2008) and Markard and Truffer (2008a) underline the importance of managerial perspective in the innovation system and relate literature on innovation systems to literature on business studies and innovation management. Only recently, a first conceptualisation of TIS as strategic management framework was made by Planko et al. (2016), who investigated to what extent entrepreneurs recognised the functions of TIS in the development and implementation of their technological innovation. Indeed, the entrepreneurs acknowledged the importance of all functions in their daily work, although the prominence of specific functions varied. However, Planko et al. (2016) only focused on one sector (smart grids), and did not systematically address the interactional processes involved in the functions. To further scrutinise the applicability of TIS in the management domain, these processes should be the starting point, rather than entrepreneurs’ recognition of the functions.

1.2. An actor-oriented perspective

Much progress has been made towards the identification of general conditions for good system performance at the macro- and meso-level of TIS. This includes the identification of various actors that
are involved in the generation and diffusion of technological innovations, such as firms along the whole value chain, universities and research institutes, public bodies, interest organisations, venture capitalists, and organisations deciding on standards (Bergek, Jacobsson, Carlsson et al. 2008). While the involvement of these actors is mostly described top-down, ‘considerably less effort has been devoted to systematically explore the link to the micro-level of innovation actors’ (Markard and Truffer 2008a, 444). Nonetheless, an actor-oriented analysis from a bottom-up perspective can provide insights into the role of different actor groups in the development of technological innovations (Markard and Truffer 2008a). Of the various actor groups included in TIS, especially the importance of entrepreneurs has been emphasised in innovation literature (Hekkert et al. 2007). According to Markard and Truffer (2008a), business units within larger companies, but also single-business companies which operate exclusively in the innovation field are a prime actor group in generating and diffusing innovations.

Several attempts have been made to identify the interactions that take place within a particular function (e.g. Bergek, Jacobsson, Carlsson et al. 2008; Bergek, Jacobsson, and Sandén 2008), but they have been described in an illustrative way and not systematically. The main reason for this is that most interactions and stakeholders are described top-down and from a holistic point of view in the TIS literature. Therefore, in this study we will investigate the interactional processes of technological start-ups in the innovation system from an actor-oriented perspective.

2. Method

2.1. Design and instrument

To unfold the interactional processes, in our study we used the qualitative empirical research cycle based on an inductive approach. As our research aims to further specify the interactional processes of one specific actor group, an inductive approach was most appropriate. To examine whether TIS indeed is applicable in the management domain we did not explicitly direct the interviewees towards (the seven functions of) TIS to avoid a bias. Instead we asked innovators about their experiences with the development of their product or technology, and about their interactions with various stakeholders during this process.

The interview scheme consisted of four parts. In the first part, we asked the interviewees to explain the technology or product they were developing or implementing, along with its possible applications. We also asked them about the possible impact of the innovation, as this may influence the interactional processes (Greenacre, Gross, and Speirs 2012; Dijk, Orsato, and Kemp 2013). Secondly, we showed interviewees four different developmental phases of a technological innovation (discovery, incubation, acceleration, and commercialisation), derived from the literature on new product development (Pullen et al. 2009; Story, O’Mally, and Hart 2011). These phases were useful, as they helped interviewees to describe the developmental process of their innovation step by step. We first asked the interviewees to describe in which phase they currently found themselves with their technological innovation, after which we asked them to describe how the innovation evolved through the different phases. Thirdly, we asked the interviewees to point out the stakeholders that were important for the development and implementation of the technological innovation. In order to do this, interviewees had to first write down the stakeholders per phase. We then showed them a list of possible stakeholders, derived from the TIS perspective (c.f. Bergek et al. 2008) and asked them if any stakeholders were missing. Subsequently, we asked the interviewees to explain why the various stakeholders were important, how they interacted with them, and how the stakeholders affected the developmental process of their technological innovation.

The interview scheme served as the general structure for the interviews, but as the interviews were semi-structured, other questions for clarification were asked as well. The interviews took between 40 and 90 minutes. All but two interviews were conducted in a face-to-face setting. The other two were conducted via Skype for logistical reasons. The interviews were recorded and transcribed.
interviewees, except for one, agreed with being recorded. In the exception, the interviewer made notes of the answers during the interview.

2.2. Participants

For the interviews, we selected founders of innovative technological start-ups. In order to get a clear picture of the interactional processes around a technological innovation, it was important to carefully select the start-ups. We cooperated with a consortium between a technical university, a university of applied sciences, a municipal board, and the provincial government in the eastern part of the Netherlands. This consortium was created to valorise and accelerate knowledge and innovations, and gave us access to nearly all spin-offs located in the region (a database with more than 900 spin-offs from both the Technical University and the University of Applied Sciences). We selected the most innovative spin-offs, based on database analysis and content analysis. To facilitate comparability, we made a first selection based on sector and type of technology (among others: nanotechnology, ICT, sensor technology, and membrane technology), and type of spin-off (research and patent-based). This narrowed down the sample to 142 start-ups. For these remaining 142 start-ups, we conducted a content analysis of the product information on their websites. We first examined whether these were actually working on their own product or technology. Subsequently, we examined whether the innovation included the development of a new technology or a new application of an existing technology. In total, 38 start-ups met these criteria.

Based on the area of application of the product or technology, we divided the start-ups into five categories: health, safety, sustainability, ICT, and other. We contacted these start-ups via the consortium’s managing director, by e-mail and phone. In total, 24 start-ups agreed to participate.

2.3. Analysis

Following the Grounded Theory approach (Corbin and Strauss 2008), we first inductively analysed the results by selecting the text parts in which any kind of interaction was mentioned. These text parts formed the units of analysis. They consisted of three to 20 lines and described one kind of interaction. After a first analysis, we used the seven functions of TIS to link them to the interactional processes, in a second round of coding. We found that the processes which seemed rather random and disorganised in the first round, showed a clear structure when we linked them to the seven functions.

Hence, the codebook consisted of the seven key processes of TIS: resource mobilisation, market formation, legitimacy, entrepreneurial experimentation, knowledge development, influence on the direction of search, and development of externalities (Table 1). Using these seven codes, we could

<table>
<thead>
<tr>
<th>Functions</th>
<th>Description</th>
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<tbody>
<tr>
<td>Resource mobilisation</td>
<td>Mobilisation of competence/human capital, financial capital, and complementary assets, such as investments, human resources, and changes in supply resources and infrastructure for the purpose of the development of the innovation</td>
</tr>
<tr>
<td>Legitimation</td>
<td>Getting social and institutional acceptance of a product/technology by counteracting resistance to an innovation and creating incentives</td>
</tr>
<tr>
<td>Entrepreneurial experimentation</td>
<td>Finding and trying new applications and markets for a product/technology, including the social learning process people working on the innovation go through</td>
</tr>
<tr>
<td>Market formation</td>
<td>Development of the market around a product/technology and how innovators approach it</td>
</tr>
<tr>
<td>Knowledge development</td>
<td>Development of scientific, technological, production, market, and design knowledge of an innovation by creating knowledge through R&amp;D programmes and exchanging knowledge through networks</td>
</tr>
<tr>
<td>Influence of direction of search</td>
<td>Influence of visions, expectations, and beliefs in growth potential and relevance of the product/technology on the development of it</td>
</tr>
<tr>
<td>Development of externalities</td>
<td>External developments in society that can possibly influence the technology, such as crises, structural political developments, and demographic developments</td>
</tr>
</tbody>
</table>
code a large majority of the transcribed interviews (most introductory parts could not be coded, as they explained the technical features of the product or technology). After coding 10% of the text units, a second coder independently coded the same units using the codebook. This resulted in a Cohen’s kappa of 0.65, which is considered to be a good agreement since the codes are rather abstract and include various topics. Based on the codebook, one coder analysed the remaining text parts.

3. Results

In this section, the results of the interviews are discussed, following the seven functions of TIS. The order of the functions is based on how frequently they were mentioned by the interviewees.

3.1. Resource mobilisation

Most interviewees considered resource mobilisation to be an important function in the development of technological innovations. Of all 1136 text parts that were coded, 351 parts were about resource mobilisation. The resources the interviewees discussed can be divided into the categories money and manpower.

3.1.1. Money

Money was by far the most frequently mentioned resource. Most interviewees emphasised the importance of money as a precondition for the development of a technological innovation. Money can be collected through public funding in the form of subsidies and public loans, or through private investments. Many interviewees mentioned the difficulties and obstacles in the process of getting money.

Firstly, finding the right subsidy programme or attracting the right investor was an issue. Due to a fragmented subsidy system that is divided into different layers (regional, national, and EU), programmes and themes, and offered at different times, interviewees found it hard to figure out which programme fits their innovation best. Interviewees who collaborated closely with the university and had a network with officials in regional and national politics mentioned that these actors were important sources of information for upcoming programmes. This is exemplified in the following quote: ‘It is just important that you find the right subsidies at the right moment and that you know the right people. Due to our network, we often know about a subsidy program before it even is publicly announced’ (Interviewee16, Energy). When attracting private investors, finding the right one was an issue as well. This is mainly because innovators were not looking for an investor solely for money, but also for advice and coaching. They emphasised the importance of having an investor with knowledge about the potential markets and entrepreneurial processes. For example, a respondent stated: ‘They had found us. And yes, we immediately felt good about it; they knew the market. We did not just want money, we wanted money from people who really knew the market’ (Interviewee 7, ICT). Furthermore, a number of interviewees mentioned that there are many ‘wrong’ private investors who only focus on short-term profits; not taking any risks and demanding too much influence on the decision-making process. This would not benefit their innovation.

Secondly, almost all interviewees were very critical about the application procedure for subsidies which they found bureaucratic and time-consuming. The process was time-consuming, because they had to fill out many forms to explain the technological features and possible applications. Having the right communication skills to explain the technology in an understandable way is crucial. Often, members of the screening committee do not have any knowledge about the technological details of the innovation, and are focused on the problems in a specific sector or area. In practice, this means that innovators should not elaborate on technological features, but instead, write the application from a problem-based perspective. This is the other way around for private investors, who are especially interested in the solutions.
Finally, even when the right programme was found and the application criteria were met, the problem occurred that innovators still depended on public officials who were responsible for the screening process. Interviewees emphasised the importance of having a large network and getting media attention, because being top of mind among public officials or knowing someone of the screening committee was important to get approval for the subsidy. For example, one of the interviewees stated that ‘knowing people from the screening committee is very important. They often look at the name of the consigner; at the applicant and his partners’ (Interviewee 23, Safety). Another interviewee said: ‘We only got approval for the public financial and business support for innovative start-ups, because we had some media attention. Without this media attention, we would probably never have gotten approved for the program’ (Interviewee 12, ICT).

3.1.2. Manpower
Besides money, the team involved in the development of the innovation is crucial for its success. All interviewees explicitly mentioned the importance of attracting the right people to work with and for them. This is not only essential for the development of the innovation, but also for attracting investors, and later on, for communicating with the market. Finding skilled employees that fit the team, both on a management and on a lower level, was seen as a challenge by quite some interviewees. They mostly found them through their own network.

Besides having the right managing team, manpower was needed for the development of the product. Many interviewees emphasised the usefulness of being located in a region with a technical university, where students could be recruited to work for them. Having a good connection with professors and student associations gave them the opportunity to find the best students.

3.2. Legitimation
The second function that was frequently mentioned (227 times) was the process of ‘Legitimation’. When interviewees talked about legitimation, they either mentioned creating incentives for the development of an innovation or counteracting resistance that might hinder it. Creating incentives or ‘enthusiasm for the technology’ in society or among public policy-makers was important, as it could help in the process of resource mobilisation and market formation. Resistance mostly involved legal barriers, negative attitudes towards the technology in society, or among potential end users. Interviewees mentioned various interactional processes to create incentives or counteract resistance.

Choosing the right applications of the technological innovation is one way to create positive incentives. By choosing applications that fit the needs of society and policy-makers, it is easier to mobilise means (see Resource Mobilisation) and get support for the innovation process. As one interviewee stated: ‘In the beginning, we focused on cooling, but we soon changed to heating (…) because heating has a much larger market in Western Europe. It might be more complex on a technological level, but you’ve got more parties that are interested … it is easier to get subsidies’ (Interviewee 16, Sustainability).

Other founders changed their product and production process to become more sustainable. They did not do this to improve technical features of the product, but to get access to other subsidy programmes and to get societal approval. As one respondent explained: ‘We chose to make [the product] of a material that is formally approved by the European Commission (…). With these elements, we answer societal needs and we try to fit in the circular economy program’ (Interviewee 21, Sustainability). However, only finding the right application was often not enough for creating legitimation. Interviewees underlined the importance of generating awareness of the positive features and/or problems that could be solved with the technology. This was especially the case for start-ups in the health, safety, and sustainability sector. Through positive media attention, networking events, and company visits, attempts were made to create this awareness. This was done on a societal, client, or public-official level.
Several interviewees mentioned the regulations around certification of the products as a resistance to counteract. In several sectors (e.g. health, energy, and safety), certification or compliance with established rules is necessary to bring the product to the market. However, several interviewees argued that their product was too innovative to meet these rules. One of them mentioned: ‘The only thing that we are doing is getting our technology included in the regulations. We have to get included in the regulations, so people can use our product legally’ (Interviewee 17, Other). When this was the case, the innovators tried to change the legislation around the technology by themselves. They sometimes did this by trying to get invited to governmental advising committees when a new certification standard was drawn up, or by lobbying among public officials in order to change the regulations. Several interviewees mentioned that it was important to already start such lobbying activities in the early phases of the developmental process. An illustrative phrase mentioned by one of the interviewees:

I think we were too late with influencing the government, way too late. (...) I’ve joked around, but I do think that there’s a truth in it, that I should have hired a PR person in The Hague [where the Dutch government is located]. (Interviewee 1, Safety)

The main reason was that it is easier to get legitimacy of a technology in the beginning of its development than of a product that has already been commercialised. It is harder for public administrators to modify regulations for organisations that are already operating on the market than for organisations that are still developing an innovation, since helping the former would influence their competitiveness.

Another resistance mentioned was created by potential end users. Some innovations in the health, ICT, sustainability, and safety sector required a different way of working by the end user. Examples of different end users are farmers, accountants, building experts, people working at water-treatment companies, energy distributors, and telecom companies. These groups had to be convinced of the benefits of working with the new technology. One way to do so was through education, by providing workshops or lectures for the target group. Another way was by having ambassadors (e.g. important clients, professors, or experts) support the innovation and spread the word. Cooperating with third parties or branch organisations helped as well. One of the interviewees worked with veterinarians to convince farmers of the added value of the innovation. Media attention or winning awards also helped to get legitimation among end users. A typical quote of one of the interviewees:

At one point, we won an award. The people then thought: ‘These guys have won an award, how is that possible? The technology must work then’. We then won another award after which they definitely believed our product would work. (Interviewee 21, Sustainability)

### 3.3. Entrepreneurial experimentation

The third function that was frequently mentioned (215 times) was ‘entrepreneurial experimentation’. This function includes finding and trying new applications and markets for the technology. The interviewees often mentioned two points of interests in this process. The first was that for every development within a technological innovation, the innovator goes through the same entrepreneurial process. The second characteristic was avoiding tunnel vision during the developmental process, which could be devastating for the innovation.

Since there is a similar entrepreneurial process for every innovation development, experience with and knowledge about the process is extremely useful. However, most innovators had neither the entrepreneurial skills nor the experience required to smoothly manage the development of the innovation. Therefore, it was crucial to bring in help from others. This was most often done by either consulting other innovators from the network, or by attracting a managing partner (see Resource Mobilisation). Furthermore, gaining support through coaching programmes from universities or regional administrations that try to valorise knowledge into viable products was mentioned as
helpful. Respondents also mentioned that it was important to constantly review the entrepreneurial process and approach other parties for advice.

Another important aspect mentioned by interviewees about the entrepreneurial process is that being flexible and being informed about what is happening in the environment is essential for good entrepreneurship. Flexibility is important for getting resources (especially money, see Resource Mobilisation), but also for developing the technology. This is exemplified in the following quote:

For a start-up to be successful, you have to be good in the entrepreneurial process, which means that you cannot merely focus on the technology. I always say entrepreneurship is a managed coincidence. You come across things that you have to fit in your developmental process. It is impossible to set out the whole path in advance. It requires a certain degree of flexibility. (Interviewee 18, Sustainability)

### 3.4. Market formation

Answers regarding ‘market formation’ were mentioned less often (168 times). When interviewees discussed market formation, they mainly talked about how to approach the market and not about its characteristics and developments. Approaching the market with a new technology, which in most cases involved a rather radical innovation, is a difficult process. Having a large network of potential clients, collaboration partners, or investors, and advanced communication skills to sell the unfamiliar innovation were of utmost importance. This was illustrated by one of the interviewees as follows: ‘Not having a network of potential customers or investors is something that often goes wrong. You see, the product does not sell itself’ (Interviewee 16, Sustainability). Three strategies were mentioned to enter the market: approaching the market on their own; developing the technology as far as possible and then selling it to a dominant player in the market; and collaborating with a larger partner.

The majority of the interviewees planned to approach the market themselves. All of them explained the importance of giving a clear explanation of the technology and its working principles. Additionally, many of them stated that, in order to be able to tell a convincing story, a clear focus with regard to the application of the technology was needed. One interviewee explained, for example: ‘You can actually apply the technology in various ways, but you have to start with one thing. Focus is very important for technological small businesses, especially for start-ups’ (Interviewee 1, Safety). Furthermore, the interviewees who intended to bring the product to the market on their own emphasised the importance of having a large network.

Some of interviewees, especially in the health and sustainability sector, did not have the intention to bring the innovation to the market themselves. They thought it was too hard to enter a market where a couple of large players are dominant. Instead, they tried to develop the innovation as far as possible and then sell it to a large competitor. One interviewee illustrated it as follows:

The final goal is to have an exit and to sell our product to a large company. Why? Because in these times, you can’t do it on your own anymore. It all goes too fast to approach the market yourself. (Interviewee 3, Health)

There were also innovators who wanted to take part in the commercialisation phase, but recognised they could not do it alone, as they lacked a large network of potential clients. Therefore, they collaborated with larger partners who did have this network, such as distributors. Mostly, these partners had already been attracted in an early phase of the developmental process. As these partners had a clear perspective on the needs of the potential clients, they could influence how the innovation was being developed. Attracting partners for collaboration was comparable to attracting private investors (see Resource Mobilisation): Both the innovation and the innovator had to be presented convincingly.

### 3.5. Knowledge development

Another function that was mentioned less often (107 times) is ‘knowledge development’. This function concerns developing and sharing knowledge, either about the technology or about
entrepreneurship. For knowledge development on both subjects, knowledge institutes (e.g. universities and thematic campuses) and regional administrators were seen as important.

An aspect that was often mentioned was how the knowledge about the ‘idea’ of the technology had evolved. Many technologies started as a theory or idea in PhD trajectories at the university. These were then patented and further developed into a commercialised product. Motivated PhD students or entrepreneurs valorised these innovations by trying to develop them into a working product. However, the interviewees stated that many innovations that got patented had not been developed further due to a lack of motivated people.

The university, together with the regional government, played a vital role in the process of knowledge sharing between technological start-ups. Many interviewees embraced the cooperation between university, valorisation organisations, and regional administrations. They also explained that this often led to the specialisation of a particular technology or area, which resulted in various regional clusters in the Netherlands (e.g. energy, water, High Tech Systems and Materials). Although most interviewees agreed that these clusters may help to get legitimacy within a region, some were also critical of it. They criticised the lack of collaboration between the clusters, as the prime goal of focusing on a cluster is getting legitimacy and resources from the national and European government, instead of creating a framework of knowledge sharing.

Besides the need of sharing knowledge about the innovation with others, almost all interviewees underlined the importance of exchanging information about the entrepreneurial process (see Entrepreneurial experimentation). In this regard, the university and regional administration again played an important role by offering valorisation programmes and creating network events. Additionally, informal networks were mentioned as an important aspect for knowledge development: ‘We go to various network events, where you can meet other entrepreneurs. You talk with them about your own business and get feedback from them, which is very useful’ (Interviewee 6, ICT).

3.6. Influence of direction of search and development of externalities

Two functions that were mentioned far less often than the others were ‘development of externalities’ (32 times) and ‘influence of direction of search’ (41 times). Both are external processes that may hardly be influenced by the entrepreneurs.

Externalities can be developments in society or sectors that have a direct or indirect influence on the innovation process. Changes in policy were often mentioned as an external influence. References to particular changes varied between the interviewees, depending on the technology and the sector. One interviewee explained, for example, how new regulations had tightened the budget of hospitals,
which impacted on the potential market. Another interviewee emphasised that budget cuts have caused retrenchments in the innovation climate in the Netherlands since the economic crisis. The lack of a clear vision of Dutch politics on sustainable energy was also mentioned as a negative externality that influenced the innovation process. Nevertheless, several interviewees did mention the rapid growth of innovations in the world and the mutation of the organisation around it. They emphasised that whereas a few large companies were mostly responsible for the development of technological innovations in the twentieth century, small and medium-sized enterprises (SMEs) are nowadays involved in the development. One interviewee said: ‘Small businesses, that’s where the new technologies are coming from. They can take risks and they are innovative’ (Interviewee 18, Sustainability).

Where externalities mostly have an influence in the later developmental phases of an innovation, the process of ‘influence of the direction of search’ impacts the development in its early phases. This was mostly mentioned as an explanation of how the interviewees came to the idea and business proposal for the technological innovation. Influence of direction of search includes factors such as challenges in society (e.g. pollution of drinking water), demands from clients or the market, and possibilities of technological features (e.g. the lab-on-a-chip technology).

4. Conclusions

In this study the aim was to explore whether TIS is a useful framework to identify and understand the interactional processes that are important for technological start-ups involved in the development of technological innovations. Our findings show that TIS indeed is a useful framework for the strategic management domain. The functions of TIS provide a clear structure to understand the dynamics in which technological start-ups are involved in the process of generating a technological innovation.

‘Resource Mobilisation’ was the most prominent function in the development of a technological innovation. The interviewees especially emphasised the attainment of subsidies and investments in this regard. Without money an idea can never be developed into a product or technology. Moreover, interviewees mentioned that several great patented ideas or technologies could not be further developed due to a lack of funding. Additionally, ‘Legitimation’ was seen as an important function. On the one hand, to create incentives that advance the process of resource mobilisation, on the other hand, to remove barriers and shape the institutional framework in a positive way. ‘Entrepreneurial Experimentation’ was frequently mentioned as well. The interviewees emphasised how a learning curve could be developed by experience and trial and error in this regard. Furthermore, they stated that flexibility in the development and application of the technology was essential.

Table 2 presents the interactional processes and stakeholders that could be linked to the different functions. Five of the seven functions contained interactional processes that could be related to them, of which ‘networking’ was mentioned most often. In the TIS literature the components of a system are identified as actors, networks, and institutions. From this research it becomes clear that technological start-ups actively try to be part of various networks in order to advance the development of their innovation.

Furthermore, ‘framing and explaining technology’ and ‘approaching the media’ can be related to both resource mobilisation and legitimation. This is in accordance with the findings of Petkova, Rindova, and Gupta (2013), who found that start-ups try to get media attention through sense-making activities in order to gain legitimation for their innovation. Subsequently, this legitimation process helps them to get investments from Venture Capitalists. The interviewees emphasised that framing and explaining a technology should be different to different stakeholders. For public officials, a technology should be explained from a problem-based perspective, but for investors, it should be explained from a solution-based perspective. Additionally, it is important to prove the reliability and the working principles of a technology for potential clients, and the newsworthiness for the media. Nevertheless, in all frames, an innovation should be explained straightforwardly and understandably for the layman.
Another interactional process that appeared multiple times is ‘collaborating with other parties’. This collaboration is needed in order to gain legitimation, develop knowledge, and learn from entrepreneurial experimentation. In various earlier studies the importance of collaboration was also underlined. Bergek, Jacobsson, and Sandén (2008), for example, concluded that entrepreneurs should form broader coalitions in order to obtain legitimacy for their innovations. Furthermore, Bouncken and Kraus (2013) underlined how collaboration is crucial for SMEs to obtain technological progress. Through collaboration SMEs gain access to additional resources and benefit from knowledge spill overs.

No interactional processes could be linked to the functions ‘Influence of direction of search’ and ‘development of positive externalities’. Even though interviewees sometimes mentioned these functions as important for the context in which they were operating, they did not refer to concrete interactions in this regard. The main reason for this is that both are external processes that cannot be directly influenced by the innovators themselves.

Besides the interactional processes, interviewees also mentioned the stakeholders they were interacting with (see Table 2). The government, investors, partner organisations (e.g. distributors, knowledge institutes), and clients or potential end users were mentioned as important stakeholders. Remarkably, the role of stakeholders can differ between processes. The government, for example, on the one hand, distributes financial resources that are necessary for the development of a technological innovation (through subsidies, both on a regional and a national level), but on the other hand, serves as a gatekeeper and might hinder technological innovations with its regulations. Additionally, regional governments are an important catalyst for knowledge sharing. This finding is in accordance with Story et al. (2011), who found that actors involved in the development of technological innovations perform various roles.

In conclusion, TIS appears to be a promising framework for the strategic management domain. Though interviewees were not directly asked about the seven functions, the answers they gave could be directly linked to them. By applying an actor-oriented perspective we were able to get a clear picture of the interactional processes start-ups are involved in when generating a technological innovation. With our study, a next step is made in embedding TIS in the management domain. Whereas Planko et al. (2016) found that TIS provides useful insights for the entrepreneurs, we found the value of TIS as a managerial analytical instrument for a great variety of sectors. Furthermore, with our focus on the interactional processes that take place within the functions of TIS, we were able to go beyond the retrospective contribution of TIS and develop a practical instrument for entrepreneurs.

Some limitations of this study should be acknowledged. Firstly, we used the seven functions of TIS as separate codes. Within the TIS literature, these functions are less independent and show some overlap. Sometimes, interactional processes matched multiple functions, but we were always able to detect the leading function by looking at the goal of the interactional process. Secondly, due to our focus on technological start-ups, it is hard to make generalisations to other types of entrepreneurs in this regards. One might expect that for large businesses ‘Resource Mobilisation’, is of less concern. Instead, ‘Legitimation’ might be more important.

Finally, as the actor-oriented perspective on TIS turns out to be promising, other relevant actors could be included in future research as well as the prominence and the nature of the functions of TIS might considerably differ among these actors. As shown in this study, taking an entrepreneurial perspective, several stakeholders play a pivotal role within the functions. Especially the perspectives of these stakeholders could be taken into account.

Disclosure statement

No potential conflict of interest was reported by the authors.
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