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Managing technological uncertainty in science incubation: A prospective sensemaking perspective

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Abstract
This paper focuses on the adaption challenge that confronts the top management team (TMT) of science incubators in situations of substantial technological uncertainty. To do that, we draw on the three-year longitudinal analysis of a major bioscience catalyst in the UK. Through the lens of 'prospective sensemaking', we follow the TMT as they work with stakeholders in their ecosystem to make sense of a significant technological shift: the convergence of life sciences, IT and other sciences in the health care environment. Our analysis reveals how prospective sensemaking resulted in the launch of a new strategy to exploit these emerging opportunities. However, stakeholders' increasingly fragmented interpretation of the term convergence and the anticipation of legitimacy challenges in the wider ecosystem resulted in the repositioning of the incubator. Our findings contribute to extant research on science incubation. In particular, the paper sheds light on the complex interactions of incubator TMT's with stakeholders in situations of technological change and uncertainty. Moreover, responding to technological change does not only affect the structural conditions of an incubator. Rather, it may also require changes to the positioning of the incubator in order to maintain legitimacy in the wider ecosystem. The paper also suggests managerial as well as policy level implications.

Keywords: Incubators, Technological Change, Sensemaking, Legitimacy, Pharma, Healthcare, Ecosystems

1. Introduction

Science parks and incubators have become a growing area of research due to their implications for innovation and regional development (Ford et al., 2010; Siegel et al., 2003; Soetanto & Jack, 2016). Incubators are organizations, often backed by public and / or private funding, that can be defined as "property-based initiatives providing tenant firms with a portfolio of new venture support infrastructure […]" (Mian et al., 2016, 2). Such infrastructure may involve office space, skill development and access to networks and funding in order to nurture firm growth (Bruneel et al., 2012). While incubators are set up based on a specified mandate, often in a particular technological domain (e.g. pharmaceuticals, digital technologies etc.), incubators are also evolving, as managers respond to changing technological demands in their ecosystem (Koh et al., 2005; Phan et al., 2005). An incubator's ecosystem is comprised of its external relationships (Iyer et al., 2006), such as entrepreneurs, universities or venture capitalists. Yet, how the management of incubators responds to technological change, while addressing the demands of these multiple, interconnected organisations has received limited attention in extant research. Indeed, prior research has either taken an institutionalist perspective by tracing the evolution of incubation 'models' (Mian et al., 2016) or has remained conceptual without explaining the mechanisms through which science incubators adapt to technological change (Koh et al., 2005).

Incubators can only facilitate innovation if they are closely attuned to the needs of the entrepreneurial firms within them (McAdam & McAdam, 2008; Peters et al., 2004; van Weele et al., 2017). Significant technological changes potentially require incubators to adapt their incubation model in order to remain relevant and effective (Hsu et al., 2003). Thus, the challenge for the management teams of incubators is to anticipate changes in technology that would substantially affect their raison d'etre, the portfolio of tenants, as well as the activities and networks deployed in the process of incubation (Koh et al., 2005; Phan et al., 2005). Yet,

how incubators respond to technological change and the process through which incubator managers make decisions about such changes, has only received limited research attention (Bruneel et al., 2012).

We follow research on strategy practice and process (Balogun & Johnson, 2004; Gioia & Chittipeddi, 1991; Stensaker et al., 2008) and argue that understanding the evolution of science incubators requires us to investigate how the top management of incubators create meaning from uncertain technological change. An important theme in strategy practice and process research is how managers prospectively make sense of poorly understood events that are still unfolding (Stigliani & Ravasi, 2012; Weick et al., 2005). Such prospective sensemaking often occurs in collaboration with external stakeholders (Werle & Seidl, 2015). Based on this perspective we address the following research question: How does the collective prospective sensemaking of incubator managers and external stakeholders influence the adaptation of a science incubator to a new technological trend?

We draw on the longitudinal case analysis of Stevenage Bioscience Catalyst (SBC), an incubator jointly funded by GlaxoSmithKline, The Welcome Trust and the UK government. We analyse how SBC's top management team (TMT) engages with substantial technological uncertainty caused by what they termed 'Convergence': the coming together of multiple technologies and sciences including biotechnology, chemistry, information technology and mechanical engineering, as they collectively relate to the development and production of new drugs. Our paper follows SBC's TMT as they work 'with' stakeholders in their ecosystem over the 2013 to 2016 period, as they attempt to ensure that the incubator works 'for' the ecosystem in an environment of converging technologies.

Changes in SBC's ecosystem triggered prospective sensemaking regarding the meaning and implications of Convergence for the incubator. The term Convergence and the underlying health care opportunities were adopted as key pillars of SBC's strategy that was supposed to

ensure SBC's legitimacy as a leading incubator in the wider ecosystem. Yet, prospective sensemaking also resulted in two critical sensemaking outcomes: First, prospective sensemaking, in collaboration with a broad group of stakeholders, highlighted that Convergence had significantly different meanings for different stakeholder groups. Second, based on this fragmentation of meaning, the TMT anticipated legitimacy challenges within its ecosystem if the notion of Convergence was retained in its strategy. SBC responded by repositioning the incubator around the notion of 'Future Health', yet continued to align the incubator structurally, with the wider trend of Convergence. Our findings contribute to the growing debate on science incubation by providing insights into the inner workings of how incubators adapt to technological change and uncertainty.

2. Evolution of science incubators

2.1. Strategic change of science incubators: State of research

Science incubators form the empirical context for a growing body of research on innovation and entrepreneurship (Albort-Morant & Ribeiro-Soriano, 2016; Clarysse et al., 2005; Mian et al., 2016; Phan et al., 2005; Thierstein & Wilhelm, 2001). Extant research has investigated the influence of incubators on the regional, national and international economy (e.g. Albort-Morant & Ribeiro-Soriano, 2016; Hsu et al., 2003) and has also studied the incubation process. This includes the activities of incubation embedded in the tenant-incubator relationship (e.g. Ahmad, 2014; Becker & Gassmann, 2006; Markovitch et al., 2017; Mian, 1996; Soetanto & Jack, 2016) and the implications of networks for tenant companies' performance (Bøllingtoft & Ulhøi, 2005; Collinson & Gregson, 2003; Díez-Vial & Montoro-Sánchez, 2016; Ebbers, 2014; Sá & Lee, 2012). An emerging strand of research relates to the processes and mechanisms through which such organizations change over time. We differentiate between two distinct perspectives: institution level studies of incubation models and micro-level analyses of the dynamics of incubator change.

By taking an institutionalist view, Mian et al. (2016) trace how science incubation as a particular form of economic activity has changed since the 'first-wave' before the 1980s, compared to the complex and multi-faceted incubation models of today. This suggests that incubation models are contingent on particular technological and economic contexts, which are dynamic and subject to change (Phan et al., 2005; Shepard, 2017). Indeed, Koh et al. (2005) point out that "if a science park or technology district is unable to renew itself through new sources of growth, decline will set in" (p. 225). They argue that it is crucial for incubators to be able to embrace new, emerging technologies and incorporate these into their incubation practice. Similarly, Phan and colleagues (2005) raise the question of whether science incubators can actually develop dynamic capabilities (Eisenhardt & Martin, 2000; Teece et al., 1997): processes or routines that would allow them to transform their incubation approach as times change, whilst retaining their legitimacy in relation to key stakeholders.

Yet, despite calls for empirically investigating the dynamic nature of incubators (Koh et al., 2005; Phan et al., 2005), the micro-level mechanisms through which incubators deal with changes in technology have only received limited research attention. One of the most substantial empirical studies is Bruneel et al.'s (2012) comparative study of incubators, which proposes a model of ideal-typical incubation approaches and their evolution. This study does not trace the underlying dynamics within an incubator but does point out how different incubation models evolved with regard to infrastructure, business support and access to networks. Hsu and colleagues (2003) show how the evolution of a science incubator in Taiwan is linked to the development of a wider technology cluster in which it was embedded.

Rather than tracing the evolution of incubators at the institutional level, we follow calls in prior research and investigate how such evolution may actually occur through activities at the micro-level (Bruneel et al., 2012; Koh et al., 2005; Phan et al., 2005). Research on strategy and organization highlights how the evolution of firms is influenced by how management teams

interpret events. These interpretations may give rise to strategic transformation (Dutton, 1993; Laamanen & Wallin, 2009) or may also underpin inertia and difficulties for change (Staw et al., 1981; Tripsas & Gavetti, 2000). Thus, an important avenue to understanding the evolution of science incubators is to investigate managers' interpretations of the future implications of technological change.

2.2. Theoretical perspective

A core tenet of strategy practice and process research is to explore macro-level phenomena (such as the evolution of science incubators), by investigating the micro-level activities that give rise to these phenomena (Johnson et al., 2007; Johnson et al., 2003; Whittington, 2006). Strategy practice and process research often explains organizational change by investigating how managers make sense of events (Balogun & Johnson, 2004; Gioia & Chittipeddi, 1991; Stensaker et al., 2008). The notion of sensemaking describes the complex, inter-personal process through which actors create or change meaning in an uncertain world (Balogun & Johnson, 2004; Weick, 1995). Sensemaking is usually considered a retrospective process, triggered by, for instance, crises and break-downs of practice that render existing meaning systems obsolete (Maitlis, 2005). A classic example of such a study is Weick's reinterpretation of the Mann Gulch fire disaster (Weick, 1993).

However, recent research argues that sensemaking does not only happen retrospectively, but may also occur prospectively; as actors aim to understand events as they unfold in order to develop a suitable response (Güttel et al., fc; Jacobs et al., 2013; Sandberg & Aarikka-Stenroos, 2014; Stigliani & Ravasi, 2012). Prospective sensemaking involves the sharing of 'provisional' and 'tentative' understandings amongst actors, often with external stakeholders (Werle & Seidl, 2015). This may require multiple interactions over time, through which these understandings are refined (Stigliani & Ravasi, 2012; Weick et al., 2005). As prospective sensemaking involves actors' engagement with yet uncharted and unfamiliar trends, it *"provides the*

opportunity for the prolonged and conscious articulation and elaboration of tentative interpretations." (Stigliani & Ravasi, 2012, 1250) Managers rely on these interpretations when making decisions about the future of organizations (Gephart et al., 2010).

Prospective sensemaking is of particular importance in innovation and high technology contexts, where information about new technologies and their evolutionary paths is, by definition, incomplete. Technologies are often only vaguely defined, and their meanings for particular user groups are not obvious (Daft et al., 1987; Schneckenberg et al., 2017). The uptake of technologies (as portrayed in the media) is always subject to political agendas and may thus be hyperbolic (Rosenberg, 1994; Swanson & Ramiller, 1997). As Berente et al. (2011, 686) argue *"individuals construct the future of equivocal technologies rather than simply apply them (Daft et al. 1987; Weick 1990)."* For instance, Jacobs and colleagues (2013) draw on prospective sensemaking to study how designers envisage potential uses of a technology. Moreover, the involvement of external stakeholders as part of prospective sensemaking is highly likely in the case of science incubators due to their strong network and ecosystem embeddedness (Phan et al., 2005).

Thus, in this paper we focus on the collaborative, prospective sensemaking of incubator managers and external stakeholders in the context of significant technological change and uncertainty and thus aim to answer the following research question: How does the collective prospective sensemaking of incubator managers and external stakeholders influence the adaptation of a science incubator to a new technological trend?

3. Methodology

We draw on the longitudinal, inductive analysis of a single case (Easterby-Smith et al., 2008; Langley et al., 2013; Yin, 2009). The single case design allows us to follow the sensemaking of actors at SBC over time (Maitlis, 2005). Below we describe the research context as well as our approach to data collection and data analysis.

3.1 Research context

Addressing our research question required a context characterized by substantial technological changes; changes that are still unfolding with unclear consequences for incubators. This paper is based on the three-year study of Stevenage Bioscience Catalyst (SBC). GlaxoSmithKline (GSK), The Welcome Trust, and the UK government set up SBC in 2011 as a not-for-profit incubator, by. SBC's main strategic priority is to use principles of open innovation to nurture next generation bioscience companies. Thus, the TMT focused on maximizing collaboration in as many areas of the organization as possible. By 2013, a trend called 'Convergence' has become increasingly salient: the coming together of sciences such as information technology and mechanical engineering in the bioscience innovation sphere. Technology convergence has since also been the object of innovation research (e.g. Maine et al., 2014).

While Convergence was already discussed at major conferences, the TMT was unsure how it would affect SBC. We trace the TMT's engagement with the phenomenon of Convergence over time. While Convergence was quickly adopted as a new 'agenda' for SBC in 2013, the term was ultimately abandoned in 2016. Thus, SBC is a revelatory case as it provides insights into prospective sense making and its implications for organisational change at a science incubator faced with technological uncertainty (Yin, 2009). Table 1 provides an overview of the development of SBC between 2013 and 2016.

INSERT TABLE 1 HERE

3.2 Data sources

This paper forms part of a larger, longitudinal study of bioscience incubation at SBC (Mason et al., fc, 2017). For the purpose of this paper, we only used those parts of the data set that

provide insights into prospective sensemaking regarding technology convergence and the background of SBC. We draw on the following data sources for our analysis:

INSERT TABLE 2 HERE

We draw on 34 semi-structured interviews (26 interviews with SBC management and 8 interviews with tenant firms) in order to understand the bioscience industry, the incubation process at SBC, and the TMT's interpretation of technology convergence. Interviews lasted between 30 minutes and 2 hours and were recorded and transcribed verbatim. In addition, we also collected data from two 'Convergence Workshops' and a conference on the theme of 'Future Health', all organized by SBC. These events were attended by the top management team as well as industry experts. The 2015 workshop was recorded and transcribed verbatim, and we were also provided with the workshop minutes. The 2013 workshop was recorded in contemporaneous hand written notes by the attending researchers, and we were provided with a whitepaper written as a summary by SBC staff after the event. These data sources provide in-depth insights into the prospective sensemaking of the TMT and other stakeholders. Finally, we also collected further documentation. This involves seven SBC strategy and planning documents outlining the objectives of the incubator as well as nine industry reports on technology convergence in the biosciences.

3.3 Data analysis

Drawing on a process approach, we reconstructed the TMT's collective prospective sensemaking with actors in their ecosystem, regarding the meaning and the implications of technology convergence (Langley, 1999; Langley & Tsoukas, 2010). We used NVivo to organize and analyse the data. In a first stage of analysis, we created a timeline of key events regarding SBC management team's engagement with technology convergence (for a summary

see Table 2). We used the two Convergence Workshops in 2013 and 2015 as well as interviews with SBC management in order to create three distinct phases. Phase 1 (2013-2014), is characterized by the initial sensemaking around the meaning of Convergence. Phase 2 (2015), in turn, sees a shift towards a more critical stance towards the implications of technology convergence. Finally, in phase 3 the notion of Convergence is abandoned.

In a second stage of analysis, we compiled a data set for each of the three phases and wrote up first order descriptions emphasizing key events. In a third stage of analysis, we focussed on the prospective sensemaking that took place in each of those phases. To do that, we looked at accounts in interviews, documents or workshop recordings that mentioned Convergence and in which actors discussed the term. Similar to prior studies on sensemaking (Gioia & Chittipeddi, 1991; Stigliani & Ravasi, 2012), we assigned descriptive themes that broadly described the objective of sensemaking, for instance 'bridging and blurring of disciplinary boundaries', 'Struggle to explain convergence to stakeholders' or 'change in composition of tenant portfolio' (see Figure 1).

In a fourth stage of analysis, we compared these themes in several iterations in order to develop aggregate, conceptual themes. Figure 1 provides the final data structure with first-order categories, second-order themes and aggregate dimensions and Table 3 includes supporting evidence for each of the conceptual themes. Moreover, the temporal sequencing of themes across phases 1-3 allowed us to theorize the dynamics of prospective sensemaking shown in Figure 2.

INSERT FIGURE 1 HERE

INSERT TABLE 3 HERE

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4. Making sense of technology convergence at SBC

Below we describe how SBC engaged in prospective sensemaking in order to engage with the trend of technological convergence that has the potential to revolutionize the provision of healthcare.

4.1 Phase 1: Convergence - making sense of an emerging trend (2013-2014)

Sensemaking triggers. In 2013, SBC's TMT was aware of an increasing discussion in the bioscience arena with regard to the potential future convergence of various technologies. Indeed, the notion of Convergence had been discussed for a few years and it had already formed the focus of an MIT report in 2011. This report calls Convergence the 'Third Revolution' and a radical shift in how research is conducted as different knowledge domains such as microbiology, computer sciences and engineering are combined (MIT, 2011). Leading scientific advisors to the National Science Foundation (NSF) also published a book in 2013 pointing out the implications of this phenomenon (Roco et al., 2013). Yet, in 2013 SBC was neither clear about the meaning of the term, nor the actual implications for them as a science incubator. Despite this ambiguity, however, it was perceived to be a significant enough opportunity for them to focus their annual Open Innovation Summit on this theme, giving it the title "Convergent Medical Technologies". During this period, Convergence also raised questions in the professional media with commentators pointing out that an increasing number of start-ups "*stretched over more than one category. They incorporated elements of a device and digital health or diagnostics*." (Combs, 2014).

Sensemaking around strategic implications of technology convergence. As a response to these early signals, and the apparent success of their 2013 event, the TMT invited a number of

industry experts to a workshop in order to discuss convergence as a future trend of potentially high significance for SBC. Workshop participants included experts from the NHS, research organizations, entrepreneurs as well as major pharmaceutical corporations. They agreed that Convergence is a wider phenomenon and discussed that firms in a number of industries were working on Convergence. There was also an initial assumption that different technology domains coming together had the potential to deliver against a number of important patient needs such as certain types of "*vaccines, diseases of the brain and early cancer detection.*" (SBC White Paper July 2013). SBC framed this as an opportunity to continue acting as a *"catalyst for innovation"* (SBC Workshop Minutes, June 2013).

Yet, the TMT as well as external participants also discussed potential challenges involved in realizing a '*Convergence Agenda*' as it came to be called. The big challenges were envisaged to be cultural and financial in nature. An important implication of the convergence of different scientific disciplines is the increased need for coordination across disciplinary boundaries. Bridging these cultural boundaries was considered a major challenge: there are *"different language in different disciplines – are we talking in digital code or patents? [there is a] lack of understanding at the upper echelons of companies"* (SBC Whitepaper, July 2013). At the same time, workshop participants also predicted a funding gap as convergent technologies would, by definition, fall in between any established ways of classifying and evaluating technologies. Thus, attracting venture capital funding could potentially be difficult due to a legitimacy void: "*People don't invest in early stages until you have something that everyone would invest in*" (SBC White Paper, July 2013).

Outcome of phase 1: The vagueness of the term Convergence created issues for SBC's management team. It raised questions regarding appropriate responses that would enable SBC to embrace this trend and leverage it for its growth plans. As the discussions around the meaning and implications of Convergence had only just started, the CEO concluded that it was

too early for implementing any changes to the incubation model. He argued that the only thing SBC could really do in order to prepare was to be 'ready'; to embrace the change and remain alert by being *"unafraid of the unknown, comfortable with ambiguity."* (SBC White Paper, July 2013)

4.2 Phase 2: Fragmentation of meaning and anticipated legitimacy challenge (2015)

By 2015, the notion of convergence had gained substantial traction in the wider bioscience community with major conferences and industry reports devoted to this topic. SBC was keen to be at the forefront, and SBC staff routinely talked about the 'Convergence Agenda' as the future of the organization. In 2015, SBC also accepted a new tenant firm that tried to leverage the opportunity of delivering towards unmet patient needs by incorporating expertise in the manufacturing of semi-conductors into cell-therapy applications, a prime example of technology convergence. In a continued attempt to understand what Convergence meant and how SBC would have to change, SBC organized a second workshop attended by a number industry experts ranging from Pharma, Venture Capital, IT and Consulting in October 2015. The brief of the workshop was very simple: what is convergence and what do we need to do?

Fragmentation of meaning: Until this point SBC's sensemaking of Convergence mainly involved the coming together of IT, engineering and biosciences. Yet, throughout the workshop, this understanding was substantially challenged. The following examples show how, in the course of the workshop, the meanings started to fragment, as multiple interpretations reflected widely varying perspectives, agendas and expectations about what may, or may not, be converging. In an attempt to frame the discussion, one of the workshop participants started to map out a typology of convergence:

> "there's sort of almost two types of convergence and they might themselves be converging initially [….] One type of convergence is the data aspect and I think in terms of the patient journey [and] public health […] the second convergent strand […] was around microelectronics." (October 2015)

Thus, not only are there different types of convergence, these types are again assumed to converge thus creating an even more complex picture. Moreover, other experts, such as a technology consultant, started to even further expand what the term convergence actually meant:

> "Can I also just push the meaning of convergence a bit further? Wearables are one thing, it's a bit of tech sitting next to a patient but I think what really gets SBC excited is the technology that becomes part of the patient." (October 2015)

Also, while IT was still considered to be one of the key convergent sciences by SBC this was increasingly questioned by participants:

> "I agree that health IT is kind of all-pervasive but there are bits of convergence that I think are at the other end of the spectrum like regenerative medicine. Which is where there are lots of other strands that are converging like how you deliver it to the patient, how do you monitor it in the patient all these kinds of things. Obviously IT is going to be a component of it but it's not the most important component" (October 2015)

The result was an increasing fragmentation of meaning amongst stakeholders. We use the term fragmentation to describe the variance in interpretation across multiple stakeholders.

Anticipated legitimacy challenge: The fragmentation of meaning alerted the TMT to the danger of building its espoused strategy on such a fuzzy concept. Up to this point, the challenges of making Convergence happen were particularly seen on the level of collaboration and the acquisition of funding. In this workshop, the discussion shifted to SBC's legitimacy as a major UK science catalyst. Indeed, SBC had to make sure, that the ability to make Convergence happen could be credibly demonstrated to key stakeholders (such as government funding bodies and big pharma). This concern is expressed in the following quote in which SBC's Business Development Manager admitted that she refrained from using the phrase due to the lack of traction in the medical community: "*I haven't really badged things as convergent medical technologies, because it doesn't mean anything to the academic community*" (October 2015). In addition, workshop participants started to doubt whether the medical field as a whole would be receptive to such a complex development: "*Do the doctors really want this stuff to be shifted out of their laps?*" These anticipated challenges to the legitimacy of the notion of Convergence resulted in changes in how SBC's management continued to engage with this

phenomenon: Whilst the underlying trend of converging technologies was not in question, what became problematic was how SBC, as a science catalyst, should embrace it.

Organizational sensemaking outcome – Positioning and structural changes: The organizational implications of Convergence were now considered more serious for SBC than previously assumed. During the discussion it emerged that the existing ways of operating would probably not be sufficient in a scenario of converging sciences. Already before the workshop, the CEO envisaged a shift in the 'business model' of SBC as a science catalyst:

> "we don't want to reinvent the wheel. If it's good and it works we won't break it but we think open innovation and certainly convergence, and I'll come onto to explain why, requires new business models." (May 2015)

Rather than pure science incubation, involving the close work with fledgling businesses, technology convergence would require incubators to become mediators in a complex cross-industry value chain:

> "SBC could bring real value and attract companies in the space if we could find a way of orchestrating and catalysing activities, more than just brokering introductions but actively supporting the entrepreneurs and helping them to build their businesses." (Workshop Minutes, July 2015)

In order to fulfil this role, SBC would also have to alter the composition and diversity of its tenants, in order to reflect the various converging sciences. For example, in March 2015, SBC included two projects focused on manufacturing processes spear headed by UCL (University College London). Another initiative was the inclusion of the 'Cell Therapy Catapult' in 2015, an initiative to translate research into new forms of therapies. Linking SBC to the Cell Theory Catapult was *"one of [the] focus areas in the convergence space"*, as the CEO pointed out. In addition to these 'structural' adaptations, the TMT increasingly used the phrase 'convergence agenda' in slide decks that communicated the position of SBC in the wider ecosystem of firms as well as its objectives for the future.

4.3 Phase 3 – Repositioning: From convergence to 'Future Health' (2016)

By 2016, technology convergence was well established as a theme and substantial research budgets were made available. For instance, the NSF declared Convergence as one the top 10 themes for future investments (NSF, 2016). Moreover, professional service firms used the Convergence theme in their communications. Accenture, a major consultancy, published a blog post claiming an "*inflection point with healthcare and emerging technologies converging*" (Ural, 2016). Convergence was considered to be of major importance for future of health care. For instance, leading scientists at Massachusetts Institute of Technology (MIT) compiled a major report, which aimed to define what Convergence meant and map out the opportunities for health care. This report defined Convergence as: "*the integration of historically distinct disciplines and technologies into a unified whole that creates fundamentally new opportunities for life science and medical practice*." Yet, it also acknowledged the inherent practical challenges of bringing these domains together (Convergence – The future of health report, 2016, 17) In the same year, the NSF put a similar definition forward. It also reiterated the potential for solving some of the most challenging problems.

Anticipated legitimacy challenge: In line with these developments at industry level, the TMT's sensemaking was no longer restricted to the meaning or opportunities of Convergence. By 2016, these were taken as a given. In contrast, an important outcome of prospective sensemaking and the increasing fragmentation of meaning regarding the term Convergence triggered growing concerns of legitimacy and the risk involved in shifting away from SBC's current business model (which was proving to be successful), to a yet unproven idea.

> "Our stakeholders are so complimentary about how we have delivered an open innovation campus focussing on biotech, [with a] portfolio of 50 [organizations], with a mix of business and academia, corporates and small firms. And now you say, we are gonna expand the business model. And all of a sudden you are adding on something and you have to convince them that this is a natural extension [of SBC]" (CEO, February 2016)

Still, engaging with Convergence as a trend was inevitable and there remained no doubt that this would be an important element in the future of healthcare.

Organizational sensemaking outcome - Repositioning: The CEO and the COO realized that they had to divorce the underlying industry level trend of different technologies and sciences coming together from the label Convergence. While the former proved to be crucial the latter became problematic. They realized that in order to create legitimacy amongst healthcare professionals in the UK they would have to reposition themselves. This legitimacy was key to ensuring that SBC could continue with its successful incubation model and tenant groups, while progressively building capabilities in the convergent technologies space. As a result, despite the wide spread use of the term in science media, SBC decided to move away from the phrase Convergence as expressed in the following quote of SBC's COO in June 2016: *"We move away from this term convergence. Because it's…it's confusing people. We now actually talk about Future Health."* This new phrase was launched at SBC's annual Open Innovation Summit 2016, which brought together industry experts, academics and major stakeholders. While SBC continued to consider technology convergence in managing and expanding its tenant portfolio (in particular by engaging with the Cell Therapy Catapult), the notion of 'Future Health' allowed them to engage with their key stakeholders in a more constructive way. In particular, they avoided the need to alter their now-well-established business model, and continue to seek potential tenants that contributed to the Future of Health through more widely recognised and established channels.

5. Discussion

Our analysis traces the process and outcomes of prospective sensemaking of the management team of an incubator faced with substantial technological uncertainty. Below we provide a conceptual interpretation of the longitudinal case analysis and discuss theoretical contributions of our findings.

5.1 Prospective sensemaking and technological change in science incubation: a process model

The recent advances in strategy process and practice research highlight the need to study individual or group level dynamics in order understand organization level change (Vaara & Whittington, 2012). Following SBC's TMT as they aimed to understand an emerging technological transformation provides deep insights into the dynamics underpinning the evolution of science incubators faced with technological change. By bringing together both internal and external stakeholders (such as scientists, venture capitalists and consultants), SBC engaged in collective, prospective sensemaking. This was an attempt to create a shared understanding of the characteristics of technological transformation ('what does Convergence mean') and the opportunities and threats involved but also how this technological shift would affect the very process of incubation. Our analysis highlights three main findings (Figure 2).

INSERT FIGURE 2 HERE

The ecosystem of an incubator is both a trigger and resource for collaborative sensemaking: The trend for converging technologies had been discussed in the wider innovation ecosystem for some time. This ecosystem, comprising of multiple stakeholders such as scientists, venture capitalists, consultants, universities and pharmaceutical companies, became both a trigger and a resource for collaborative sensemaking. The TMT's discussions with stakeholders highlighted the need to investigate the implications of this particular trend for SBC's incubation practice. The process of prospective sensemaking that followed drew on this ecosystem as a resource for collective meaning making. This process allowed the management team to create multiple interpretations of a particular phenomenon (in this case technology convergence) and, through these, to identify opportunities and potential organizational challenges.

Collective prospective sensemaking informs incubator strategy to maintain legitimacy within the ecosystem: Prospective sensemaking centred on the strategic implications for SBC, triggered by the potential for delivering unmet patient needs through the practical application of Convergence. In other words, SBC's TMT was working 'with' the ecosystem to make sure that the incubator was working 'for' the ecosystem by continuing to be perceived as a legitimate incubator. In line with prior research, we use the notion of legitimacy in order to describe whether it is appropriate for an organizations to operate in a particular way in a specific domain (Suchman, 1995). Prospective sensemaking quickly affected the positioning of SBC. Members of the TMT used the phrase 'convergence agenda' to describe the future direction of the incubator. This positioning was also manifest in structural changes towards convergent medical technologies; for instance, through the recruitment of tenant firms but also the formation of new alliances.

Collective prospective sensemaking may result in critical sensemaking outcomes (fragmentation of meaning and the anticipation of legitimacy challenges). We use the notion of 'critical sensemaking outcomes' to describe the emergence of differences in stakeholder interpretations that affect the positioning of the incubator. As SBC engaged in further prospective sensemaking by collaborating with stakeholders in the wider ecosystem, they saw that stakeholders' understandings of Convergence did not align. In contrast, the term seemed to be adopted in ever widening circles, and its meaning became ever more fragmented. Over time fragmentation of meaning increased to the point where it became very opaque as to what the phenomenon actually was. This fragmentation of meaning and the fact that SBC used the phrase 'convergence agenda' to communicate its positioning resulted in the anticipation of a legitimacy challenge: How could SBC credibly portray its strategy to their ecosystem if they were unsure what Convergence actually was? The maintenance of legitimacy is crucial as science incubators and catalysts are often founded based on a particular agenda, which becomes

the mechanism to attract funding (Hsu et al., 2003; Phan et al., 2005). Their mission is hard-wired into the tenants they recruit, their founding investors and shareholders, as well as the capabilities and processes through which incubation is actually delivered. Prospective sensemaking is thus a means to anticipate issues, such as legitimacy challenges in the wider ecosystem, prior to the need for significant structural realignment of the organisation. This is an important finding, as the very structure of science catalysts, which often involves public-private partnerships, requires the delicate maintenance of legitimacy in order to secure financial and political support and to be regarded as a suitable host for fledgling innovations by leading scientists.

Critical sensemaking outcomes result in repositioning of espoused strategy to maintain legitimacy: In the initial phase of our inquiry, SBC's espoused strategy used the phrase 'Convergence Agenda'. This phrase was used in multiple meetings in which authors were present and it was also included in slide decks shown at presentations to stakeholders and investors. When legitimacy challenges were anticipated, SBC did not dismiss the relevance of technology convergence. Rather, anticipated legitimacy challenges resulted in a process of realignment of the 'espoused' incubator strategy and the underlying organizational capabilities, processes and networks that they developed and maintained. Prospective sensemaking also resulted in the anticipation of potential future capability shifts. This involved the questioning of SBC's current business model, the composition of tenants, and other aspects. While these changes were considered inevitable, resolving the legitimacy challenge required abandoning the term 'Convergence' as a key communicating device of SBC's espoused strategy. Adopting the term 'Future Health' as espoused strategy allowed the incubator to frame their activities to the market more credibly, while organizationally embracing the opportunities of the underlying trend of technology convergence.

5.2 Theoretical implications

In this paper, we show the importance of prospective sensemaking as a means by which the management team of a science incubator engages with technological uncertainty. This provides new insight into the ways in which incubators anticipate technological and industry level change and offers the following theoretical contributions to the literature on science incubation:

First, this paper contributes to extant research on the complex relationship between science incubators and the wider innovation ecosystem in which they operate. Indeed, incubators are often considered an important vehicle that connects entrepreneurs located within the incubator with other actors in the ecosystem (Hsu et al., 2003). Prior research has already started to describe more complex, synergistic interactions between incubators and other actors (Bøllingtoft & Ulhøi, 2005). This also involves the role of sensemaking as a way to explore changes in a particular technological field (Möller, 2010). This paper adds to this debate by highlighting the role of an incubator's TMT, as a particular group of actors, through which such interactions unfold. In particular, we show that the TMT acts as an orchestrator of collective, prospective sensemaking and thus becomes a mediator between the stakeholders in the wider ecosystem and an incubator's positioning and structure over time. Providing a more nuanced, micro-level perspective on the role of the TMT as they seek to address technological ambiguity, opens the black box of incubation management. It contributes to extant studies that focused on the 'delivery' of science incubation (Bergek & Norrman, 2008; Markovitch et al., 2017), the relationship between the business environment and incubation models (e.g. Chandra & Chao, 2016; Hsu et al., 2003), and how 'incubation' as a particular form of economic activity has changed over time (Mian et al., 2016).

Second, our findings reveal that responding to technological change is not only about adapting the structural conditions of an incubator. Rather, it is about changing the positioning such that the incubator maintains legitimacy in the wider ecosystem. These findings contribute

to prior research on science incubators that particularly addresses the stakeholder dynamics involved in these organizations (McAdam et al., 2016; Nicolopoulou et al., 2017; Sá & Lee, 2012). Indeed, SBC was co-funded by a big-pharma company, a charity, and government, and thus needed to not only respond to the demands of these stakeholders, but also remain attuned to its positioning as an 'incubator of choice' for leading scientists. Incubators often combine the interests of private business with contributions to the public good (Nicolopoulou et al., 2017; Sentana et al., 2017). The SBC case demonstrates two instances in which prospective sensemaking resulted in a legitimacy maintaining repositioning. Initially, SBC described its positon by using the phrase 'convergence agenda', this was later repositioned as 'Future Health'. While the first positioning set in motion structural changes to the incubator (such as the formation of an alliance, seeking of new tenants, and decisions about resource allocations to deliver certain events and workshops), the second reposition maintained the strategic trajectory but (by repositioning) aimed to maintain the incubator's legitimacy as the notion of convergence became problematic.

Third, our findings suggest that collective prospective sensemaking may result in, what we call, critical sensemaking outcomes: the fragmentation (rather than alignment) of meaning regarding a particular trend and based on that the perceived challenge to the incubator's legitimacy. While the involvement of stakeholders from the wider ecosystem of firms was intentional in order to explore 'Convergence' as a phenomenon, our analysis reveals that the fragmentation of meaning that emerged in phase 2 was also a result of the multiplicity of perspectives. Maitlis (2005) already highlights how such fragmentation might arise through multiple, individualistic accounts. However, while her study foregrounds the positive implication of fragmentation (the potential of new insights) the SBC case suggests that the fragmentation of meaning was an important trigger for the anticipation of legitimacy challenges. This is in line with Gephart et. al. (2010), who already highlight the relationship

between sensemaking and legitimacy. Thus, the SBC case demonstrates that prospective sensemaking is an important political activity that allows an organisation to anticipate responses to uncertainty-driven change *before* a course of action becomes embedded to such an extent, that organisational legitimacy and thus the future of the organization are placed in doubt.

7. Conclusions

As technologies advance the role of incubators as orchestrators of entrepreneurship and innovation becomes ever more challenging. Located at the intersection of academia, entrepreneurship, big-pharma and government, incubators must not only anticipate technological changes but also incorporate them into the very fabric of the incubator, if they wish to remain relevant and valuable members of their ecosystem. Yet, remaining relevant is a delicate balancing act of prospective sensemaking. It requires incubators to respond to anticipated change in collaboration with members from their ecosystem, without damaging their legitimacy within that very ecosystem of stakeholders.

The findings presented in this paper are subject to limitations. While the longitudinal, single case design sheds light on the processes and outcomes of collaborative sensemaking over time, it does not allow us to make inferences about the conditions under which critical sensemaking outcomes are more or less likely. Therefore, we encourage future comparative studies to investigate the role of stakeholder diversity as well as other contextual characteristics for how incubators evolve (such as the speed of technological change).

Our findings also have implications for the management of science incubators as well as policy. Managers of science incubators benefit from deep insights into the process and outcomes of SBC's engagement with stakeholders in their particular ecosystem. We illustrates how collective, prospective sensemaking enables the identification of strategic options in the face of technological uncertainty, whilst ensuring legitimacy by embedding stakeholders into

the decision making process. Moreover, our findings are also of relevance for policy makers seeking to design governance regimes that support long-term incubator viability. While incubators are often established through a collaboration between multiple public and / or private organizations, our findings suggest that incubators should take an ecosystem view when constructing supervisory boards. This internalizes the prospective sensemaking dynamics described above, ensures continuous sensitivity to legitimacy challenges, and thus supports the evolution of the incubator in line with changing environments.

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Tables

Table 1. Overview of data sources

Data sources	Data description	Use for data analysis
Interviews	▪ Total of 34 interviews ▪ 26 interviews with SBC management (CEO, COO, Marketing Manager, Entrepreneur in Residence) ▪ 8 Interviews with directors of tenant companies	▪ Background information on bioscience industry ▪ Background information on SBC ▪ Reflective accounts of technology convergence and implications for SBC
Workshops	▪ Documentation of convergence workshop in 2013 ▪ Full transcript of half day convergence workshop in October 2015 ▪ Protocol of convergence workshop 2015 ▪ Observation and documentation of Health Future event 2016	▪ Insight into prospective sensemaking as it unfolded in the interaction of SBC staff and industry experts
SBC Documentation	▪ 7 SBC Strategy and Planning Documents	▪ Background information on SBC ▪ Insight into SBC top management prospective sensemaking on technology convergence
Industry reports	▪ 9 Industry reports on technology convergence in the biosciences	▪ Insights into industry wide discussion on the definition of convergence and the implications for the biosciences as a whole

Table 2. Timeline of events

Phase	Key events	Implications
Phase 1: Convergence – making sense of an emerging trend (2013-2014)	▪ SBC organizes workshop as part of the annual Open Innovation Summit devoted to technology convergence: "Convergent Medical Technologies" ▪ Invitation of multiple stakeholders and industry experts	▪ Whitepaper on the strategic implications of technology convergence for science incubation at SBC ▪ Alertness of SBC management to engage with the organizational changes necessary to leverage convergence ▪ Convergence integrated in SBC strategy: 'Convergence agenda'
Phase 2: Fragmentation of meaning and anticipated legitimacy challenge (2015)	▪ The notion of technology convergence gains traction in the wider environment with major conferences devoted to the topic ▪ SBC continues to make sense of the implications of convergence by inviting stakeholders to a workshop intended to further clarify the strategic implications for SBC ▪ SBC starts to accept additional tenant firms that represent convergent technologies ▪ Formation of alliance with Cell Therapy Catapult	▪ Experts agree that convergence is an important phenomenon with major implications for health care ▪ The boundaries of the phenomenon become increasingly blurred ▪ Increasing concerns about ability to communicate 'convergence' to health sector in UK
Phase 3: Repositioning: From convergence to 'Future Health' (2016)	▪ The trend of convergent technologies is firmly established in scientific circles ▪ The terminology of convergence seen as incompatible with health stakeholders in UK ▪ Use of Open Innovation Summit to further commit to convergent technologies yet under the new positioning of 'future health'	▪ Repositioning of 'convergence agenda' as 'The Future of Health'. ▪ Continued engagement with Cell Therapy Catapult alliance

Figure 1. Data structure

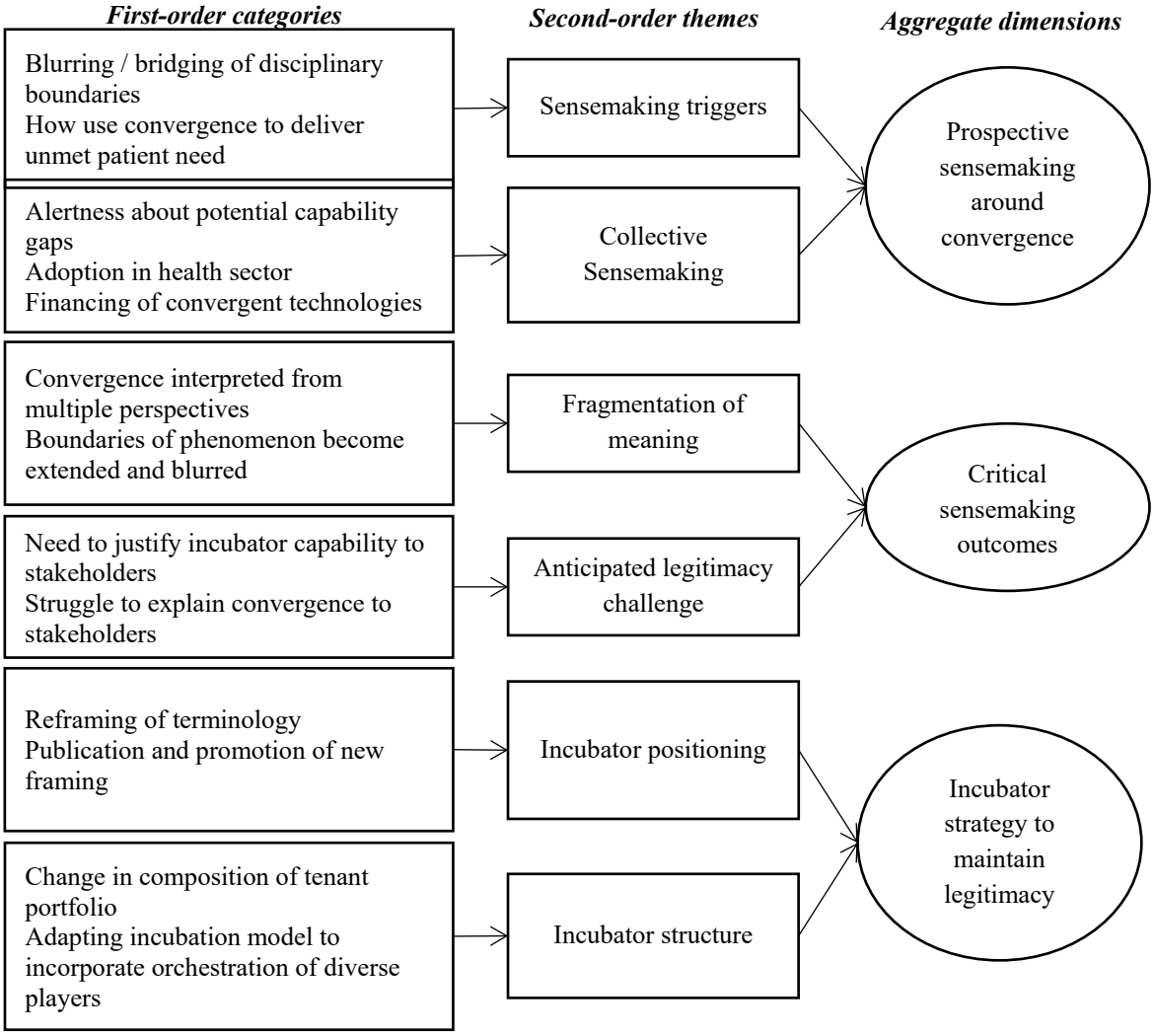

Table 3. Additional supporting evidence

Second-order themes	First-order themes and supporting evidence
Prospective sensemaking around convergence	
Sensemaking triggers	*Blurring / bridging of disciplinary boundaries* "Explore "unmet need" in healthcare to identify potential opportunities for SBC and reinforce SBC's role as a Catalyst for innovation" (SBC Meeting Minutes) *"*Stevenage Bioscience Catalyst will be defining convergent medical technologies as those bridging the gap between pharmaceuticals and medical technology, a mining of synergistic technologies." (Workshop Minutes)
	Deliver unmet patient need "There are people outside pharma and biotech who are working on convergence - future events should include these communities as well" (Workshop Participant) "innovation in terms of devices or diagnostics or drugs or technology. For example, one of our tenants, […] is looking to apply what they've learnt about manufacturing semiconductors and translate that into cell therapies" (Entrepreneur-in-Residence)
Collective sensemaking of strategic implications	*Alertness about potential capability gaps* "Bring in expertise from outside healthcare to catalyse organisational change" (SBC White paper) "Move away from the NHS as the (only) endpoint" (SBC Whitepaper)
	Adoption in health sector *"*Some middle management comfortable with technology innovation, but senior management only marginally engaged due to lack of ROI data*"* (SBC White Paper) "Working out how to divide incremental value between the various players" (SBC White Paper) "Few in healthcare understand customer experience and have a product view of life" (SBC White Paper)
	Financing of convergent technologies "People are starting to specialise in areas for investing meaning it may be difficult to find investors for CMT [Convergent Medical Technologies] as it covers multiple areas. In this case it may only make sense to the customer to invest." (SBC Whitepaper) "Many investors follow 'invest in what you know', making CMT less appealing to them" (SBC Whitepaper)
Critical sensemaking outcomes	
Fragmentation of meaning	*Convergence interpreted from multiple perspectives* "So anyway that was one of my convergent strands, the second convergent strand before we diverge was around microelectronics. And I think that's where the whole convergence of science between optics, electronics and physics to try to create… well particularly things that impact with neuroscience has massive opportunity where you could replace drug treatments with microelectronics in effect ultimately. I think that's a different level again and that's probably more one that the likes of GSK will be investing in for long term." (Workshop participant)
	Boundaries of phenomenon become extended and blurred *"*There is a whole spectrum which runs from wellness through prevention and on to maintenance/monitoring of patients after disease diagnosis." (Workshop participant) "Just the last piece of this convergence issue is we've talked about the technologies, the patients but there's this spectrum between wellness and health that is increasingly emerging as well, and diabetes is a particular one." (Workshop participant)

Table 3.continued

Second-order themes	First-order themes and supporting evidence
Anticipated legitimacy challenge	*Need to justify incubator capability to stakeholders* "It's that kind of cross-industry thinking. […] GSK collaborates a lot with McLaren […] You think, "Why is GSK collaborating with McLaren? […]" GSK does a lot of manufacturing drugs […] and McLaren does manufacturing. […] So we're always slightly having to prove ourselves […]" (Entrepreneur-in Residence) "here's the question about the convergence and you were talking about this earlier. […] It's a very awkward conversation about "I get paid by the patients and by outcomes and I can do these five tasks and I know I have a guaranteed revenue" (Workshop Participant) "it's about what do you do […] and then how do you do it so it's not just okay we have tools but it's also how do I deliver it and how do I ensure there's patient traction in that process?" (Workshop Participant)
	Lack of ability to explain convergence to stakeholders Interviewer: Was there the worry that you do spread yourself too thinly? "It's partly that. And also this philosophical, you are doing this so well why do you want to do this? Our business intelligence and our insight into the future of healthcare says we don't do this none of this will be relevant in 5 to 10 years". (CEO)
Incubator strategy to maintain legitimacy	
Incubator (re-) positioning	*(Re-) framing of terminology* "The definition is still the same whether it's called convergence or 'Future Health'. It's about bringing IT, electronics and engineering together to solve the next generation of biological problems." (CEO)
	Publication and promotion of framing "And the question and the debate for me is, would it be enough to use the same models that we have used so far, or do we have to put a new flavour or a new shade, and build on our model in order to really enhance the prospects for this industry ecosystem creation. And importantly, how do we make it Stevenage Plus. How do we show that we capitalize on innovation in the Cell and Gene Therapy space across the UK" (CEO)
Incubator structure	*Change in tenant portfolio* "Diversity was emphasised as being needed on the SBC CMT campus - in terms of the kinds of companies attracted, both 'cornerstone' and smaller tenants. the kinds of people involved etc. - to cover such a broad and rapidly / chaotically evolving space and place bets in many areas, e.g. in devices field, in genomics area etc. (Workshop protocol) "But then what we'll do is have focus, we've got this antibody company in little cluster so what we can do with them? We've got a start-up community of regen-med companies with GE, GSK and Cell Therapy Catapult coming so there's got to be something to do there with that cluster. So what else can we do, who do we need in the picture and we're ready to go. That's a whole supply chain that you can look at". (CEO)
	Change in incubation model "It's how you look for us going forward, what skills are needed and particularly because we're going into campus, science park whatever you want to call it […] Because as we grow we're not going to be able to say bring in two, three more buildings on board in the next three years that are going to have an extra ten, 15 staff. It just isn't going to happen, we'll have two or three maybe." (COO) "So actually if you get your head round this very, very few of those companies are actually covering all of these areas and what we were trying to tell Martino was basically the role of the SBC is to sink itself in the middle and say come and join us because we're going to be… we can join up the dots." (Workshop participant)

Figure 2: Prospective sensemaking in situations of technological change in science incubation