Paper to be presented at: DRUID17
NYU Stern School of Business, New York, June 12-14, 2017

Creation and Orchestration of an Innovation Ecosystem: Strategies and processes of an entrepreneurial firm in a emergent industry

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Abstract
This paper investigates the strategic approach employed by a small entrepreneurial firm to create and orchestrate an ecosystem in the context of breakthrough technologies. Drawing on the innovation ecosystem literature, we employ a single case study of a publicly listed small Norwegian company with core competencies in printed rewritable memory. We find that enrolling actors and defining boundaries when creating an innovation ecosystem are necessary but not sufficient conditions for capturing value. We propose a conceptual framework of inter-organizational and intra-organizational routines to analyze the dynamics and processes underlying value co-creation in an entrepreneurial ecosystem.

Jelcodes: O32.M10
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ABSTRACT
This paper investigates the strategic approach employed by a small entrepreneurial firm to create and orchestrate an ecosystem in the context of breakthrough technologies. Drawing on the innovation ecosystem literature, we employ a single case study of a publicly listed small Norwegian company with core competencies in printed rewritable memory. We find that enrolling actors and defining boundaries when creating an innovation ecosystem are necessary but not sufficient conditions for capturing value. We propose a conceptual framework of inter-organizational and intra-organizational routines to analyze the dynamics and processes underlying value co-creation in an entrepreneurial ecosystem.

Keywords: Entrepreneurial ecosystem; Emerging technologies; Routines, Printed Electronics
INTRODUCTION

The innovation literature has clearly recognized that knowledge has become more distributed and complex over time (Coombs and Metcalfe, 2000; Rothwell, 1992), especially in the context of rapidly evolving technologies. The increasing technological specialization and complementarity associated with recent rapid technological progress makes it particularly difficult for a single firm to develop the required capabilities to innovate and this requires shifting the locus of innovation from a central firm or organization to ecologies (Dougherty and Dunne 2011). Innovation success therefore does not depend solely on strategies adopted by a single firm, but it largely depends on the number and intensity of inter-organizational collaborations and the differential ability of the firms to manage them. The design of these new organizational forms presents substantial challenges and requires understanding the processes that facilitate coordination, governance, alignment of incentives and knowledge flows among heterogeneous organizations under conditions of ambiguity and uncertainty (Dougherty and Dunne 2011; Fjeldstad et al. 2012). One perspective of new inter-organizational forms that has recently gained considerable traction in the academic literature is that of ‘Ecosystem’. Ecosystems have been defined by varying, overlapping terms such as ‘business ecosystem’ (Iansiti and Levien 2004; Moore 1993), innovation ecosystem (Adner 2006, 2012; Adner and Kapoor 2010), and technological ecosystem (Gawer and Cusumano 2002).

While empirical research on innovation ecosystems is growing (e.g., Autio and Thomas, 2014; Nambisan and Baron, 2013; Zahra and Nambisan, 2012), the context has been mainly on information and digital technologies, telecommunication, and manufacturing. Furthermore, the discussion is populated by success stories of large hub firms or system integrators such as Walmart, Microsoft, and Apple that act as a platform provider which provide niche opportunities for new ventures and small companies. However, scant attention has been given to the emergence and creation of ecosystems (Autio and Thomas 2014; Sharapov, Thomas, and Autio 2013) and even less to ecosystems orchestrated by small firms.
and in a nascent market, with only a few exception (see Lubik and Garnsey, 2014; Santos and Eisenhardt, 2009).

Entrepreneurial firms, though important for emerging and disruptive innovation, suffer from the liability of newness (Stinchcombe, 1965), encounter difficulties related to define a business model, especially market selection (Lubik and Garnsey, 2014), face challenges for commercialization of emerging technologies due to limited resources (financial, human and relational) and lack of adequate market and product knowledge (Maine and Garney, 2006), and have low survival rates (Song et al., 2008; Yu and Hang, 2010). Nascent markets based on emerging technologies, though characterised by uncertainty, offer numerous benefits for entrepreneurial ventures (Santos and Eisenhardt, 2009) and this necessitates understanding the factors that facilitate value creation and growth of new technology ventures and expedite commercialisation. However, extant discussion is mainly focused on the challenges confronted by incumbents (Ansari et al., 2015) and there is still a need for “shifting the focus of study away from how to prevent the failure of large incumbent firms towards how to reduce the barriers to new technology-based firms” (Spencer and Kirchhoff, 2006, p.154).

The importance of innovation ecosystems in an entrepreneurial context has also been emphasized by Nambisan and Baron (2013), yet their main focus has been on the challenges offered by multiple and conflicting goals faced by entrepreneurial firms as they participate in an innovation ecosystem orchestrated by large hub firms.

Although founding a new venture is risky, for small ventures in the early formative years of a new industry, the nature of the challenges is compounded as they relate not only to survival and their embryonic state, but also to the need of legitimising the new venture, create new routines, “carve out new markets, raise capital from skeptical sources, [and] recruit untrained employees” (Aldrich, 1999, p.228).

In this paper, we study creation and orchestration of an entrepreneurial innovation ecosystem through an in-depth case study of a fast growing entrepreneurial firm, ‘Thin Film Electronics’ (TFE or Thinfilm) in an emerging science-based industry, printed electronics (PE). The research setting of emerging technology and entrepreneurial firm provides an ideal setting for extending the existing theories and developing novel insights (Santos and Eisenahrdt, 2009). PE is considered to be one of the enabling generic technologies with many potential applications that mostly require long period of process and systemic innovation before final adoption and commercialization (Maine and Garnsey, 2006). The promise of
growth potential within PE has resulted in the emergence of large number of entrepreneurial firms. TFE is a leader in development of component technology within PE, but it struggled to commercialize it and find end customers. It then changed its business model from licensing the technology to product development, adopted a hub-based model and keystone strategy, mindfully orchestrated the development of the innovation ecosystem, and created value through symbiosis and interdependencies. To capture the dynamics of value co-creation and tension related to the TFE ecosystem, and how the entrepreneurial firm balances individual and collective level strategies to orchestrate the innovation ecosystem, we focus on the following interrelated research questions: ‘How does an entrepreneurial firm orchestrate the development of an ecosystem?’ and ‘what are the strategies adopted by an entrepreneurial firm at both individual and collective level to create a new market?’

In the next section we briefly revise the literature on innovation ecosystems and emerging technologies, and issues about creating and orchestrating innovation ecosystems. This is followed by a section illustrating the context of Printed Electronics where the empirical study is grounded, and a methodology section which details the company chosen for case study, the research design and the data collected through interviews. Then there follows a section reporting the finding and analysing the results. The paper closes with a discussion and conclusions section.

INNOVATION ECOSYSTEMS AND EMERGING TECHNOLOGIES

Innovation ecosystem in the context of Emerging technologies

The notion of ‘ecosystem’ was initially proposed in the practitioner literature by Moore (1993) and since its introduction the construct has gained considerable importance in different contexts and rapid adoption in strategic management and entrepreneurship (Adner, 2006, Adner and Kapoor, 2010, Gulati et al., 2012, Nambisan and Baron, 2013, Zahra and Nambisan, 2012). The idea of business ecosystem highlights that there exists an opportunity space that cannot be explored by individual firms but requires collective action and convergence of vision within the market. Innovation ecosystem in particular consists of interdependent heterogeneous actors bounded by either cooperative or competitive relationship who depend on each other for their survival and success (Iansiti and Levien, 2002). The key defining characteristics of an ecosystem are value creation, coordination mechanisms and symbiotic partnerships (Thomas and Autio, 2012). Co-specialisation
(bilateral dependencies) provides required interfaces among participants and ensures
distribution of roles and division of labour (Jacobides et al., 2006) whereas complementarities
ensure symbiosis.

The importance of building an ecosystem, or, in general, collaborative networks and
value networks, varies across industries; however, it tends to be critical for emerging
technologies because of higher market and technological uncertainty, dynamism, the
complexity and distributed nature of knowledge, and increased interdependence with
complementors (Moore, 1996; Rosenkopf and Schilling, 2007). Furthermore, the challenges
for creating ecosystems around new emerging technologies tend to be different from those
around stable or incremental technologies (Möller and Rajala, 2007).

Nascent markets and new industry creation based on emerging technologies offer
numerous benefits for entrepreneurial ventures (Santos and Eisenhardt, 2009). However,
they are characterized by high technological, market and environmental uncertainty,
complexity, nonlinearity in their development, long period of gestation, absence of dominant
design, initial hype, promises, and lofty expectations (Rosenberg, 1995). Furthermore,
moving from research to market for the initially low performing technology may take
decades.

Technological progress within emerging technological fields is mostly attributed to
small entrepreneurial technology-based firms (Schumpeter, 1934). Entrants have the potential
to disrupt and displace incumbents (Carayannopoulos, 2009; Markman and Waldron, 2014)
due to their smaller size, flexibility, shorter path dependencies and limited commitment to
existing networks (Yu and Hang, 2010). However, it has been documented that de novo
startups face considerable challenges in commercializing disruptive innovation and typically
have low survival rates (Song et al., 2008; O’Reilly and Tushman, 2011; Maine, Lubik and
Garnsey, 2012). The radical nature of the technology, the need for process innovation and the
potential application in multiple markets contribute to high technological uncertainty. The
need for complementary innovation and the lack of continuity, observability, trialability and
multiple markets further contribute to market uncertainty. Technology-Market matching
(Maine and Garnsey, 2006), gain of complementary assets (Teece, 1986), access to financial
and human resources and strategic alliances (Lee, Lee and Pennings, 2001; Hill and
Rothaermel, 2003), establishing credibility and acquiring support of ecosystem partners
(Aarikka-Stenroos and Lehtimäki, 2014) are some of the factors that are deemed vital for their development and commercialization.

Success within an emerging technology landscape therefore does not depend on an organization’s innovative activity alone but on a co-evolutionary and interdependent set of heterogeneous actors/players within the space who provide the required symbiotic, commensalist as well as competitive interdependencies (Eisenhardt and Galunic, 2000).

Ecosystem Creation and Orchestration

The orchestration of an ecosystem consists of ‘deliberate, purposeful actions undertaken by the hub firm as it seeks to create value (expand the pie) and extract value (gain a larger slice of the pie) from the network’ (Dhanaraj and Parkhe 2006, p.659). The hub firm in an ecosystem needs to develop processes and practices to enhance receptivity and utilization of network resources to be able to leverage or exploit the available resources from partner organizations which are characterized by knowledge heterogeneity (Gulati et al., 2012; Autio and Thomas, 2016). Previous empirical and conceptual studies have suggested various mechanisms orchestrated by hub firms for managing and creating ecosystem. Dhanaraj and Parkhe (2006) emphasized knowledge mobility, knowledge appropriation and network stability while establishing legitimacy, engagement, connection and co-development were the actions deemed important by Paquin and Howard-Grenville (2013). For Gulati et al. (2012), boundary management related to enrolment, stratification, redundancy and exclusivity impact the governance of an ecosystem.

However, much of the progress in understanding how this happens in practice is mostly discussed with the perspective of large firms such as Walmart, Apple, Microsoft acting as an orchestrator (Clarysse et al., 2014), often focusing on structures and relations rather than processes, (Nambisan and Sawhney, 2011), or the design of new organizational forms necessary for the development of organizational capabilities and processes and the exploitation of accrued benefits (Fjeldstad et al., 2012).

Participation in an ecosystem offers several advantages to resource constrained start-up firms such as access to complementary assets, capabilities, reciprocal commitments from other members, shared vision, distributed cost and common fate (Zahra and Nambisan, 2012). By developing relationship among complementary actors, the hub firm facilitates synergies and systemic impact, and achieves goal convergence, lock-ins and investment by partners,
which results in reducing uncertainty, sharing risks and accelerating time to market. Ecosystem creation thus aims at increasing the size of the pie and creates a win-win situation for all the partners rather than redistributing value (Pitelis and Pitsa, 2012).

Specific to the context of emerging technologies, lack of demand articulation, not yet established or developing value chains, unclear technological development paths and performance requirements on the supply side result in numerous challenges for creating and orchestrating an ecosystem. High expectations and lofty promises provide incentives for actors to remain in the game, but the combination of supply and demand side uncertainties refrains potential stakeholders from making concrete commitments thus offering a paradoxical situation (Parandian et al., 2012), where incumbent large organizations are monitoring the progress in the early stages of industry emergence rather than making deep commitments and therefore often enter into waiting games and adopt a wait-and-see attitude. On the other hand, entrepreneurial firms are mainly resource constrained and cannot go alone (Pinkse and Groot, 2013) and at the same time are reluctant to make commitments due to the risks associated with innovation appropriability in the pre-commercialization phase and tend to opt for licensing strategy (Gans and Stern, 1993).

Ecosystem creation can provide an opportunity for technology push, demand creation and commercialization and breakthrough the impasse of waiting games, typical of science based industries (Lubik and Garnsey, 2014). However, it could be particularly challenging for an entrepreneurial venture to move beyond mere participation within the ecosystem to a keystone position and perform interrelated tasks and processes at different levels such as that related to ecosystem design (vision, enrolment and stratification), legitimacy and stability, knowledge mobility and absorption, mainly associated with large incumbent organizations. Overall, the challenges of acting as an orchestrator and hub firm implies are exacerbated for entrepreneurial firms that face the dual pressure of balancing the individual and collective interest (Ansari et al., 2015; Van de Ven et al., 2007) and power imbalances caused by presence of heterogeneous actors (Pinkse and Groot, 2013).

In the context of orchestrated networks, capabilities and processes, rather than structural embeddedness, determine firms’ robustness and success (Human and Provan, 2000; Paquin and Howard-Grenville, 2013). In order to have a fine grained understanding of the orchestration processes and explore the dynamics related to strategizing at individual and collective level (Barnett, 2006; Whittington et al., 2011), the paper adopts a routines lens,
distinguishing between intra- and inter-firm routines which support knowledge creation through variation, selection and retention (Lewin et al., 2011) in the hub firm and probes the early stages of ecosystem creation and capability development by an entrepreneurial firm in the context of an emerging technology.

CONTEXT

Printed Electronics: An Emerging Technology

To investigate the dynamics of ecosystem creation, we have selected the context of the emerging technology Printed Electronics (PE), and developed an in-depth case of the small entrepreneurial firm named Thin Film Electronics (TFE). Printed electronics has been referred to generally as ‘electronics beyond the classical approach’ (OE-A, 2011). It is considered to be a paradigmatic shift from the conventional silicon-based manufacturing that tends to require expensive vacuum-based equipment and is produced in batches to be printed continuously at ambient temperatures, using fewer and simpler processing steps. The advantages offered by PE as compared to traditional silicon-based electronics are: low cost, for example costs for setting up manufacturing for silicon chips are approximately $2 billion compared with printing chips that may cost up to $10 million (Frost and Sullivan, 2013); a variety of additive manufacturing techniques such as screen printing, gravure, inkjet, flexography among others; use of functional inks (organic and inorganic); and flexible, low-cost substrates such as glass, metal and polymers. It is considered to be one of the key enabling technologies with a high economic potential for numerous applications such as displays, lighting, photovoltaic, memory, sensors, batteries, and radio frequency identification (RFID), with significant broad societal implications.

The overall ecosystem of printed electronics is still evolving. At present there are approximately 3,000 organizations active in the field within three competing regions (United States, Europe, and Asia), which include universities, research institutes, and large organizations as well as start-ups (IDTechEx, 2011). The industry is mostly concentrated around developing individual components which can be integrated in existing innovative products rather than an integrated system and this has delayed its commercialization.
METHODOLOGY

Purposive sampling has been used for the selection of the TFE case from a rich data set of a large research project on printed electronics that also informs the findings of this paper. There was a large number of component providers within the space but very few integrators and, for the industry to succeed, the latter tend to be crucial. Thus, a firm level case that was particularly enlightening, information-rich and that allowed data access and diversity was selected. This selected single case study is revelatory (Eisenhardt and Graebner, 2007) as it provides the unique opportunity to analyze in depth (Siggelkow, 2007) the routines and processes underlying the orchestration of an ecosystem by a small firm for commercializing emerging technology.

The case study

TFE is a leader in the development of printed memories and integrated systems. It is among the few companies within the PE space that are acting as an integrator with major strides in commercial product development, thus creating the necessary market pull long awaited by the industry. This success has been the major driver for the selection of this single case of TFE within the printed electronics industry.

TFE is a publicly listed company on the Oslo Stock Exchange, therefore events are well documented, which also provides a unique opportunity to collect secondary data and validate and triangulate primary data. TFE’s history can be divided into three phases. The first phase was from 1997–2006, when Thinfilm was still a subsidiary of a Swedish high tech company, Opticom active in developing polymer-based multi-layer memory. Founded in 1994 by Hans Gude Gudesen, Opticom had been active in researching polymer-based multi-layer memory, which had the potential to disrupt the flash memory market. During 1995-1998, Opticom concentrated on developing printed roll-to-roll memory and developed prototypes with collaborative partners. Memory technology progress and its business potential created lofty expectations resulting in a joint development research agreement and attracting investments from Intel in 1999 and the formation of Thin Film Electronics ASA (Intel’s initial investment was 6%). In 2001 Intel increased its investment to 13% and also entered into a licensing and production agreement. In 2003, Opticom hybrid memories were hit by manufacturing problems and technological hurdles and this resulted in the cancelling of the collaboration between Intel and Opticom in 2005. Opticom was acquired by FAST (Fast Search and Transfer) in 2006 and it then transferred the old business (Thin Film ASA) to a new
incorporated company Thin Film Electronics. 2006–2010 constituted the second phase during which efforts were devoted to developing the non-volatile fully printed ferroelectric memory; and in the third phase, from 2010 onwards, TFE changed its orientation from a licensing to a product company and worked towards the development of the ecosystem for smart integrated systems. The TFE ecosystem configuration comprises a variety of partners: technology partners, upstream material partners as well as downstream commercial partners, and external stakeholders such as industry associations and policy makers.

Data Collection

The rich empirical data was collected from the focal firm as well as its ecosystem partners between 2012 and 2013. The primary data collection method involved using semi-structured interview protocols and observations during the field-configuring events organized by the Organic and Printed Electronics Association (the main industry association in PE).

At the time the data collection started in 2012, TFE had only 16 employees and the ecosystem was in its early stage of development. (TFE grew to 24 employees in 2013 and more than 100 by 2015). The data collection involved visiting the TFE’s head office in Oslo and their technology development centre in Linkoping, as well as using other electronic means such as Skype. The main informants were the members of TFE’s top management team and the key decision makers for the ecosystem partners. In total, 10 interviews were conducted, 6 within TFE, and 4 with TFE ecosystem members. The duration of the interviews ranged between 25 minutes to more than two hours. In addition, extensive secondary data and updated market information, collected as part of the larger research project on inter-organizational routines for knowledge creation in an emerging industry, contributed to our understanding. The sources of secondary data include Plastic Electronics Magazine, Frost and Sullivan reports, and the IDTechEx report on ‘Printed, Organic & Flexible Electronics Forecasts, Players & Opportunities 2011–2021.’ We also collected a large amount of data from TFE annual reports, websites (TFE and their partners), and TFE Annual General Meetings podcasts. Thus, this entrepreneurial setting and the early emergence of industries provided an ideal opportunity to study mechanisms related to ecosystem orchestration and capability development.
Data Analysis

The analysis of the extensive data was based on template analysis (King, 2004) which allows the development of a codebook based on the interpretation of emerging themes, in addition to the a priori themes discussed in the literature. Data analysis was carried out in three steps. The initial step comprised of reading transcripts, assigning a priori themes to obtain descriptive themes. At this stage the coding software NVivo 10 was used with the aim of organizing the large amounts of textual data, development of structure and identification of categories. A few emergent themes related to importance of ecosystem were identified from the data. The emergent themes required further probing around ecosystem creation, legitimacy, and two follow-up interviews with the CEO were conducted. Thus the analysis and data collection was an iterative process. Writing the descriptive case based on secondary data as well as identified categories formed the second step. The final round of analysis aimed at moving away from the flat description generated at stage two to more in-depth interpretation of the findings and the formulation of a routine based model of entrepreneurial ecosystems. This required moving back and forth between raw data and theoretical explanations.

FINDINGS: ORCHESTRATING AN ECOSYSTEM - A ROUTINE BASED MODEL

In this section, we present the main findings of the TFE case study. We first show the pre-ecosystem development phase that enabled TFE to move from the collaborative model prevalent at that time in the PE industry to an ecosystem approach. We adopt the routines lens to elucidate the processes underlying the orchestration of the ecosystem and identify the inter-organizational and intra-organizational routines that were mobilized by TFE for (1) creating the ecosystem creation (2) developing absorptive capacity (3) building legitimacy (see Figure 1). Intra-organizational routines are defined at the hub firm level while inter-organizational routines comprised those developed in dyadic relationships between the ecosystem hub firm and an individual partner, and those developed at the collective level in the ecosystem to achieve shared logic and cognitive framework at industry level and to build socio-political legitimacy.
Pre-Development Phase of an Ecosystem

The TFE case demonstrates the importance of iterative and staged process for the ecosystem expansion in the context of emerging technologies (Adner, 2012; Sharapov et al., 2013). TFE followed the strategy of ‘innovation from below’ focusing on smart packaging and finding out sweet spots in existing markets where the technology could be disruptive. TFE initially focused on improving the functionality of its printed memory while lowering the cost of the memory. With these aims, it then adopted an exploratory market strategy to target cost-sensitive market segments and flanks, that is, opportunities unnoticed and underexploited by established companies. Such ‘Trojan horse’ moves are considered performance enhancing for entrepreneurial firms (Katila et al., 2012). Their first target was the toys and games market, with the goal to demonstrate the technological possibilities based on a simple value proposition in a highly demanding industry.

[...] People have been working on things for 10 to 12, 15 years; and people are becoming more realistic—they’re not saying, “We’re going to do an entire RFID tag immediately.” They’re dividing the different addressable markets into segments and saying, “We’re going to go after the easy ones first, then the next ones, and so forth. That’s why we’re starting with toys and games. That’s why, you know, this is what we make, because this is doable with today’s technology. (Respondent DST)

However, when TFE decided to approach the toys and games industry, they had to learn the rules for playing the game within this industry. The initial screening or filtering of ideas through the inventor relations department requires a demonstrator that looks like the final toy. At that time, TFE only had the technology, not a product. TFE came up with the idea of a ‘toy development kit’ and reduced the bill of materials to $5 from the previous $12. The prototype was made available to the world’s top toy companies’ engineering teams for evaluation. Close interaction, feedback and incremental improvements enabled an accelerated learning curve and offered a unique value proposition for printed electronics as compared to that of silicon.

So our first shock was we didn’t have a complete toy. And so the toy company says, ‘Well, we’re not used to dealing with technology [...] we don’t go to Intel and specify a chip; we just go to an inventor and the inventor buys some chips and makes a toy and we either like it or we don’t.’ (Respondent DST).

The desired customer-pull proved to be an important milestone in TFE’s success. TFE’s efforts to establish their identity as a product company, matching market demand with technological possibilities, signaled their quality and leadership, further paved the way for
integrated systems, and established a strong relationship with PARC, a Xerox company with 15 years of experience and the world leader in developing thin film transistors (TFT). The collaboration, initiated in 2010, had been able to achieve fundamental milestones such as demonstration of Thinfilm’s competences in addressable memory.

TFE established relationships with other component providers such as Acreo (electrochromic displays), PST Sensors (thermistor), Imprint Energy (batteries) and Polyera (n-type semiconductors) and an undisclosed collaborator (p-type semiconductor). In addition to that, existing relationships with InkTec (a leader in manufacturing printed electronics headquartered in Kyungki-do Korea) and Solvay (material supplier to enhance the performance of its memory and optimise the ferroelectric material) were further strengthened and deepened. TFE’s top management was very aware of the importance of building an ecosystem to be able to commercialize their products.

So the idea of ecosystems, the fundamental one, is that anything that shortens your time to market is something you want to do; and anything that guarantees that you have world-best technology, and a way to diffuse that technology into market, are the other pillars of why you want to build an ecosystem.

Building an ecosystem, on the one hand, can save you money because other people do some of the heavy lifting. And publicly I often refer to that as an important asset. Well, in fact, they call it off-balance sheet assets.

So, the entire idea of creating an ecosystem is that allows you to become world class [...] before you make commitments of capital to make a particular product. So, our idea about creating an ecosystem is on the one side to figure out what is technologically possible in printed electronics; we’ll learn from our partners and create a win-win business model, and then get business partners. (Respondent DST)

These early technological achievements resulted in demonstrating the potential of the technology to brand owners and created the required traction. TFE pursued not only technological partnership, as is the case with most of the technology and component developers in the OPE space, but is also working towards the development of a broad range of commercial opportunities. TFE has established strategic relationships with Fortune 500 companies such as Bemis (a packaging company), Brady (a printer and labels company) and Hasbro (a toy company company) to enable commercialisation and reduce the speed to market.
Creation and Orchestration of an Ecosystem

Ecosystem Creation

The routines for creation of an ecosystem operate in two distinct domains those related to shaping the structure of ecosystem and to build the relational capability. Strategic decisions regarding structure require setting boundaries in the context of ecosystem creation. These decisions are mostly dealt with conceptually and include issues such as enrollment, stratification, exclusivity, and redundancy (Gulati et al., 2012). The enrollment strategies of the hub firm impact the structure, size, and diversity of an ecosystem (Dhanaraj and Parkhe, 2006). TFE’s approach to enrolling partners within the ecosystem is a closed partnership arrangement, rather than the open membership, that is more common within IT platforms. According to TFE’s CEO, ‘You need to have a club where membership is a virtue.’ TFE engages with members of the ecosystem in varied forms, such as licensing, research agreement, consortia and supplier-buyer relationship, but, from the perspective of intent, the focus is more towards exploitation and commercialization. This has resulted in a reduced emphasis on direct collaborations with universities, which tend to focus more on basic research, and increasing collaborations with Fortune 500 companies, who not only understand their market space, but also possess ultra-high scale manufacturing capabilities. Thus the change in business model from licensing to product mix also resulted in a change in the relationship mix within the ecosystem.

The selection of brownfield sites is an important theme that emerged from the interviews; that is, collaborating with partners who bring with them relevant experience because it tends to reduce uncertainty when developing new processes, decrease the development times for new products, and also contribute to capability development by improvisation (see Section A in Table 1). Over time, TFE preferred manufacturing partners such as InkTec over earlier production partners like PolyIC and Soligie who were more research oriented.

*So there’s a lot of technologies out there, right? [...] when I look at the history, when we created Renewable Energy Corporation we went to brownfield sites, not greenfield sites. We went to sites where the building’s already where they are, where the piping infrastructure was already there; and then you create a new process and a new product.*

*We’re doing the same in printed electronics. We’re going and leveraging... we’re standing on the shoulders of giants. We’re going to InkTec that already has a production line, that already has inks, that already has PET, and we’re saying, ‘Modify this a bit to create a new product.’ (Respondent DST)*
In addition to market orientation, that formed the initial membership criteria preference, and the brownfield sites, that reduced the uncertainty associated with manufacturing partner selection, other important factors influencing the tie formation at TFE are the need for complementary resources (manufacturing, complementary technology), amount of technological leverage the partnership offers, that is, to what extent the resources brought by different partners are comparable when measured in terms of commitment. In this regard, a partner’s patenting activity is considered as an indicator of its technological expertise and commitment.

Best partnerships are where they leverage our effort 5 to 1 or 10 to 1. (Respondent DST).

The TFE’s ecosystem shows some degree of stratification (see Section A Table 1). Collaborations vary in their scope depending on what is considered to be core or peripheral for technological platform development and commercialization by the hub company. Core collaborations tend to be more intense, transparent, reciprocal, and multiplex thus creating higher interdependencies. They tend to act as ‘glue’, maintaining the stability of an ecosystem as a result of partner interaction, while in the case of peripheral collaborations; replacements can take place if partners are unable to meet the ecosystem’s hub firm’s expectation. Because of interdependencies, both types of collaboration offer challenges for the stability and robustness of the ecosystem.

But the difficulty that’s going to happen, when we get to a position where we actually are making a specific product and one of our existing partners doesn’t cut it anymore and we have to switch them out, that’ll be hard.

It'll be hard on two fronts. Kicking them out will be just... you know, it'll be a hard half hour, but it'll be done. The harder part is finding somebody else to bring on-board instead, because all of a sudden we're signaling we need somebody new.

Well, that gives them a bunch of aces in their cards that they hold in their hand, because they know that we need them. When we built the original ecosystem that wasn’t the case. (Respondent DST)

TFE established exclusivity with some partners (e.g., PARC and Polyera) depending on their experience and expertise within the technological field. Exclusivity is a differentiator for a collaborating partner, reduces the free rider problem, and points towards partner commitment to the hub firm’s vision thus contributing to the ecosystem’s stability.

The ties thus created by TFE with collaborating partners within the ecosystem are heterogeneous and evolving. They may be classified as strong, weak, and latent. The nature
of ties (strong, weak or latent) is often dictated by the organizational strategy and complexity of the technological development rather than by technological capabilities or interpersonal relationship alone. For instance, the collaboration with PARC can be described as strong or intense with frequent interactions and close coordination resulting in co-developments and participation in multiple projects, while that with Solvay (TFE’s material provider collaborator) is marked by periods of intense to latent interaction, though both partners are classified as leaders within their respective technological field. However, the relationships with suppliers that provide more generic and readily available components can be characterized as more infrequent and therefore weak.

Another important criterion for boundary decision in the creation of an ecosystem, and closely related to tie heterogeneity and exclusivity, is that of redundancy. High redundancy in an ecosystem decreases interdependence and allows parallel processing and lower risks in circumstances when a member organization fails to innovate, but maintaining higher redundancy may be discouraging for some partners as they may see themselves not valued and replaceable, and therefore they may be hesitant to co-invest. It ultimately results in providing the hub firm more bargaining power. However, achieving high redundancy may not be possible in all areas where the focal company is searching for potential partners, even though it may be desirable for countering risk, because in new emerging fields where the technology is still developing and rudimentary finding more than one partner with similar skill sets is not always possible.

If you could do a search of the entire world there were probably only four places that we know of that could have built our memories roll-to-roll the way that InkTec does.
(Respondent DST)

Absorptive Capacity

The case demonstrates that TFE developed a repertoire of routines mainly aimed at identifying external technical and market knowledge, developing knowledge internally, knowledge assimilation, and transformation to improves its absorptive capacity (Cohen and Levinthal, 1990) and maintains its bargaining position as a hub firm. In technology intensive industries, where relevant knowledge tends to be distributed across multiple organizations, competitive advantage results from the core capability of an organization to access external sources of knowledge and complement it with its internal knowledge to facilitate innovation.
TFE’s external routines aimed at both scanning the technological environment and identifying commercialization opportunities and ‘sweet spots’ where ubiquity associated with printed electronics offered advantage as compared to silicon. They relied on weak signals (see Section B in Table 1) and developed elaborate mechanisms and processes such as the appointment of a technical advisory council (TAC) and participation in divergent conferences (e.g., those in packaging and cold supply chains) and international networks. The technical advisory council members appointed by TFE were highly respected in the industry and their expertise in relevant processes was deemed important for commercialization of TFE products. The case shows that the engagement of specialist knowledge providers is instrumental for radical innovation and complements firms’ internal knowledge; it enabled TFE to capitalize on social capital as well as providing a fresh perspective and critical feedback on their technological roadmaps. (See Section C in Table 1)

TFE participates actively in conferences not only within the technological domain of PE, but also in less related areas where they look for early commercialization, such as in toys and games, temperature sensor markets, or brand authentication. The process for identifying the target market is iterative and involves analyzing trends through market reports such as Frost and Sullivan, IDC, and Gartner, probing customers, and discussing with leaders of conventional technology and industry experts.

TFE, benefits from experienced top management to bring to the table diverse and complementary skills, knowledge sets, and capabilities. Jennifer Ernst, VP in US, has a notable 15 years’ experience of working in PARC; the CTO has been with the company since the time of Intel and therefore is aware of developments in memory. The CEO brought with him the entrepreneurial experience that set TFE apart from other academic start-ups. The heterogeneity in experience not only contributed to cognitive variation, but also established TFE legitimacy (see Section D in Table 1)

For effective knowledge absorption, externally acquired or accessed knowledge requires assimilation, transformation and recombining with the existing knowledge. Being an integrator and a product-oriented company, TFE differs from other players and academic start-ups. They have established engagement with market players such as Bemis, Hasbro, Brady, among others. These early interactions with customers, developing prototypes and not limiting themselves to demonstrators served as a vehicle to learn about potential market segments and their requirements that later translated into technological specification to be
incorporated into TFE’s organizational roadmaps. Thus there is a continuous feedback loop at both inter-organizational as well as intra-organizational level that is mandatory for assimilation and integration. While working with customers in the toy and game industry for commercialization of their memory, TFE were able to get input from the toy industry about its working practices, standards, bill of materials, and technical requirements and assimilate and transform that knowledge to produce a working prototype of their product, a game. The prototype was distributed among major customers to get the required feedback and thus improve further. These prototypes in turn facilitated assimilation of new knowledge from customers.

Prototypes thus provide an iterative cycle of improvement in the product and technology through mutual adaptation and adjusting of the procedures and processes (see Section E in Table 1). In addition to developing prototypes, other routines for assimilation and transformation of external knowledge were sharing knowledge internally within the growing organization through regular brain storming meetings, internal presentations, and training.

Knowledge Mobility

Along with developing absorptive capacity at the firm level, leveraging from the distributed knowledge residing in an ecosystem necessitates knowledge mobility among ecosystem partners through inter-organizational routines. Interdependencies between the hub firm and partners require developing coordinating mechanisms within an ecosystem, which in turn requires aligning actions by specialized partners, mobilizing and recombining distant scientific knowledge. Failure to coordinate distributed tasks is common when the partners are interdependent, distant and may lack mutual knowledge that restricts synchronization in joint efforts. This may hamper technology commercialization and demotivate partners of an ecosystem, even when the appropriability strategies such as contracting and IP issues are clearly defined and non-conflicting. We found that TFE used three mechanisms: (i) ongoing communication, (ii) modular communication through Copy Exact, and (iii) tacit coordination mechanism to facilitate development of a shared space for exchanges among partners and ensure alignment, and common understandings.

Ongoing Communication is necessary within an ecosystem because of the increased geographic separation among members, location in different time zones, and diversity in nationalities and culture. The use of information and communication technology (ICT)
communication tools such as email, telephonic conversation, Skype, and video conferencing that enable continuous feedback and ensure knowledge sharing was the norm in TFE.

Modular Communication through Copy Exact: TFE also replicated routines from their past partnership with Intel. One of these was Copy Exact (Burgelman, 2000), a routine that was dominant in Intel and became part of TFE. Every experiment is documented at TFE; they developed a standard way to record the results and also implemented the same ‘process of records’ (POR) at their partners’ premises (see section F in Table 1). Developing standard interfaces such as POR or employing similar testing mechanisms helps coordination when partners are geographically separated and tasks are more modular and interdependent.

Tacit coordination mechanism: In complex environments such as that of emerging radical innovations, where the pattern of interdependent changes is difficult to anticipate ex ante, coordination through ongoing communications and modularization may not be sufficient. In such situations, tacit coordination mechanisms are used to achieve common ground, that is ‘shared information that allows participants to anticipate each other’s actions and correctly interpret their communication’ (Srikanth, 2007, p.46). TFE as the hub firm in the ecosystem stresses the importance of co-development in an ecosystem, therefore visiting other members’ sites in addition to the frequent face-to-face communication is a norm (see Section F in Table 1).

In addition to the early experiments that resulted in knowledge exchanges with technology partners, TFE’s active participation in fora, such as those organized by PARC, IDTechEx¹, OE-A and FlexTech Alliance, facilitated further socialization, informal exchanges, and knowledge mobility among partners.

Legitimacy

Legitimacy facilitates identity creation for entrepreneurs in nascent markets (Santos and Eisenhardt, 2009). At the initial stage, before gaining credibility, entrepreneurial ventures seek to attract attention and indulge in sense giving activities, for example through broad communication process related to the new emerging field. TFE sense giving activities aimed at establishing legitimacy for heterogeneous audiences such as investors, shareholders, and ecosystem partners, both technological and commercial. TFE participated and presented at a

¹ Market Consultant
large number of conferences and fora that enhanced their visibility and established them as a key player in the field that should be followed. Participation was not limited to the dedicated Printed Electronics conferences, such as Large Area Organic and Printed Electronics Convention (LOPEC), but also to other diverse forums related to markets such as toys and games or smart packaging. TFE employed impression management tactics and used a variety of communication channels, both generic as well as industry specific, and frequently reported on their ecosystem achievements via press releases in the general media, as well as industry-related media. In addition to formal media channels, they also used social networking sites such as Twitter and LinkedIn to announce their achievements and establish themselves as reputable cognitive referents that enabled attracting potential ecosystem partners.

And what’s happening now—it’s actually been kind of an interesting shift for us—is we had the first set of partnerships. We have definitely leveraged... we're showing what can be done. We've started to demonstrate that the world is not against us, the laws of physics are possible to make real printed devices. And now people are coming to us. So I have more and more people... we basically created a magnet, and we have more and more people coming to us to say, "Have you looked at...?" "I have a novel technique for x, y, and z – would it be of interest to you (Respondent JET).

The perception of the young organization’s success and its reliability was also influenced by affiliations and inter-organizational relationship. TFE signaled leadership by establishing contacts with well-regarded established organizations, such as PARC, very early on, and disseminated stories of their success in toys and games. TFE built their identity around bringing intelligence to everyday objects and adopted motivational framing for their ecosystem vision, comparing it with the success of Apple (Battilana et al., 2009).

‘And then we found that there were two things that were happening: there was the Apple effect and the Walmart effect. And we published this in September 2010. When we raised the money, this was our pitch’ (Respondent DST).

As a result of the intense and diverse sense giving activities, TFE was able to attract attention in the press and was nominated for various technology awards. For instance, in 2012 they were the recipient of the most prestigious and esteemed OPE industry awards such as the FlexTech Alliance FLEXI Innovation Award and IDTechEx’s Best Product Development Award. TFE together with PARC were also named as runners-up for the Wall Street Journal Technology Innovation Awards. GigOM picked TFE as one of the most innovative company. The increased credibility of TFE also contributed to increasing its bargaining power. In the
absence of formal authority, higher status and reputation result in asymmetries and are a source of informal authority for the ecosystem orchestrator (Gulati et al., 2012).

While increasing legitimacy at firm level facilitate identity creation (Santos and Eisenhardt, 2009), in the context of emerging technologies the legitimacy of the industry also needs to be established. PE was initially considered the domain of large area electronics and therefore the focus was on displays, lighting, and photovoltaics, whereas TFE’s vision was “innovation from below”. One of the initial challenge for TFE was to establish the ubiquitous potential for PE as compared to silicon for applications related to temperature sensing, brand authentication and smart packaging and thus to enroll actors and influence the institutional logic (Gawer and Phillips, 2013). TFE ensured its leadership position with the industry associations such as Organic and Printed Electronics Association (OE-A) in Germany and FlexTech Alliance in United States and made significant changes at the institutional level, thus acting as the institutional entrepreneur (Battilana et al., 2009). Being at the board level position at OE-A and the FlexTech Alliance enabled TFE to actively participate in the standardization efforts, shaping the conference or events organized so that the topics, such as memory or smart packaging, most relevant for progress and resolving challenges associated with TFE platforms, were included in the conference programs (see Section B in Table 1). For instance, the focus of LOPEC² was modified to include a business conference in addition to the technical and scientific sessions, which brought practitioners and researchers/academics together.

An ecosystem perspective was new at the time and the industry was dominated by a silo approach to development of components, also due to the absence of firms acting as integrators; it therefore required a radical change in the dominant logic. TFE, through their marketing and public relation activities, attributed their early commercialization success to multiple alliance development and partners, thereby influencing the perception and shared vision of existing and potential partners and advocating importance of ecosystem creation for market creation at various other related forums. For instance, while TFE was announced as winner at World technology Network Forum³ their CEO commented:

² Large Area Organic and Printed Electronics Convention organized yearly by OE-A
³ The World Technology Network is a global association of over 1,000 peer-nominated, peer-elected most innovative people in science and technology elected annually through the World Technology Awards.
Thinfilm is delighted to win this award as it reflects the importance of our product vision and its role in catalyzing the Internet of Things. This recognition further confirms the significance of our work with Thinfilm's ecosystem partners, especially PARC and Inktec.

These efforts, supported by their positive outcomes, contributed to build trust and enhanced network stability. The case study finds support for the synergistic impact of both prior histories and expectation of continuity as an important determinant for developing trust in ecosystem within emerging industries. Both dimensions contributed to attracting and retaining partners. TFE had a long history since the time of Intel in the 1990s. The strong sense of expectation of continuity underlining the evolution of collaboration membership in the ecosystem is a critical element. In the context of PE there is a handful of players that had a product orientation or strong vision of the future, as is evident from the quotes below from the one of the ecosystem member, and this contributed to the stability of TFE ecosystem

 [...] When we first talked with Thinfilm was just trying to understand whether there was something that made sense for both of us to do together and started off with one version of what was happening and it's sort of grown into a much stronger relationship. So when we started out, it wasn't, 'Are we going to put all our eggs in the Thinfilm basket in this technology?' It was, 'We think these are very interesting people to work with.' We put together a deal that we think works well for both of us. (Respondent RBP)

Parallel to strategies of shaping perceptions, influencing shared vision and establishing cognitive legitimacy among its stakeholders; TFE also made efforts to establish technical instrumentality of PE technology by developing prototypes and demonstrating the potential of its low cost as compared to existing technologies. These strategies thus contributed to socio-political legitimacy of the technology as is evident from the following quote.

The key is cost per functionality. There are existing markets where conventional electronics are just too expensive or do not meet flexibility and ubiquity needs. For example, there are pharma and logistics applications that still use 20-year-old chemistries in color-change labels for time-temperature tracking. The integrated temperature sensor we are currently designing with our customers will provide quantitative actionable information at the same price point as these qualitative technologies, and potentially at a lower cost as well. Currently, up to 1 billion such tags are used at price points from 10 U.S. cents to 40 U.S. cents, and we believe that we can successfully compete in this market (Savastano, 2012)

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4 ww.printedelectronicsnow.com/contents/view_online-exclusives/2012-03-14/thinfilm-acreo-and-imprint-energy-are-buildin
DISCUSSION AND CONCLUDING REMARKS

This paper focuses explicitly on processes related to the creation of a new entrepreneurial ecosystem (Paquin and Howard-Grenville, 2013). While the discussion on innovation ecosystems is growing, its main emphasis has been on coordination and competition within an established ecosystem (Adner and Kapoor, 2010) and is populated around success stories of large hub firms such as Walmart, Microsoft and Apple that act as a platform provider and thus provide niche opportunities for new ventures and small companies. In this paper, we demonstrate the usefulness of combining the institutional perspectives that contribute to legitimacy and ecosystem stability (Autio and Thomas, 2016) with consideration of design elements such as enrolment criteria, stratification exclusivity and redundancy. Value creation within this context is associated not solely with developing the technological capabilities or relying on existing patents but is dependent on establishing logic of co-creation, enhancing knowledge mobility, developing norms of trust, reciprocity and transparency. In particular we identify three important factors underlying the creation and orchestration by an entrepreneurial firm: complementarities of inter- and intra-organizational routines in the ecosystem; building legitimacy for the emerging technology and hub firm; changing the business model to shift from licensing to commercialization.

Our analysis focuses on processes and routines for creation and orchestration of an ecosystem and contributes to the discourse on microfoundation of capabilities. It also provides empirical insights into the intra-organizational as well as inter-organizational routines, both dyadic and collective, adopted by the small hub firm to facilitate innovation and commercialization of the emerging technology. Routines are multi-actor phenomena and contribute to shared understanding and connection among organisational members (Cohen and Bacdayan, 1994; Feldman and Rafaeli, 2002; Becker, 2004). The collective nature of routines points towards another important attribute associated with routines – distributedness. Routines are carried out by multiple actors distributed across the different business units of the same organisation, thus intra-organisational, or belong to different organisations and are inter-organisational.

Small entrepreneurial firms do not build their internal processes and routines on long standing experience; therefore an important challenge is to understand how they develop such processes. Often in new firms these routines are not particularly sophisticated but simple processes that take the form of heuristics or rules of thumb, that seem appropriate in the uncertain, time and resource constrained context (Bingham and Eisenhardt, 2011; Aldrich
and Yang, 2014). These mental shortcuts are sometimes related to opportunity identification through the use of weak signals and sometimes form selection criteria as is evident from the use of brown field sites for selection of partners.

Our case firm was able to develop a repertoire of inter-organizational and intra-organizational routines and practices, including a number of routines at the collective, ecosystem level, through mindful routines and strategies of its top management members based on their own prior experience (Aldrich and Yang 2014). Timing and speed are important considerations in dynamic settings. Developing a large number of routines enabled faster learning in such a resource constrained environment by an entrepreneurial firm. Furthermore, for young firms, the top management team’s previous experiences facilitate the development of routines. Other sources of routines are “learning by doing” and external networks (Miner et al., 2011). Selective importation of routines from previous experiences of the top management team was dominant in the case and in addition these routines were combined with existing routines embedded in the organisation since the time of Intel. This perspective is interesting as it points towards the continuity of existing routines despite their inactivity or embeddedness in other organizational contexts. The case study highlights the role of top management team experience and cognition in developing capabilities in entrepreneurial ventures thus contributing also to the recent and growing academic research on microfoundations of organizational and managerial cognition (Eggers and Kaplan, 2013, Gavetti, 2005).

The case firm benefitted from the complementarities among those routines, which, in turn, resulted in competitive advantage and innovative performance (Lewin et al., 2011). The intra-organizational routines enabled the ecosystem orchestrator to identify opportunities and develop internal practices for variation, assimilation and transformation of internal knowledge. The case study provides evidence that the bundle of routines and their complementarities contributed to focal firm’s first mover advantage in the printed electronics industry. TFE identified and developed effective routines that would lead to their ecosystem momentum and success as the industry evolves, competition intensifies as new ecosystems and imitators enter the fray.

In uncertain and ambiguous environments endogenous strategies adopted by managers for manipulation of micro-institutional logics facilitate the ecosystem legitimacy (Autio and Thomas, 2016), and in turn increased legitimacy facilitates identity creation for entrepreneurs in nascent markets (Santos and Eisenhardt, 2009). Legitimacy is a crucial resource for new
ventures (Zimmerman and Zeitz, 2002), which enables entrepreneurial new ventures to overcome their liability of newness through acquisition of resources such as financial capital and trained and skilled human resources. Different perspectives on legitimation offered by institutional, cultural, ecological, impression management, and social movements converge on the need for new ventures to acquire, maintain, or restore legitimacy and this tends to be even more important in the context of new industries in high velocity environments.

However, building legitimacy in new markets can be extremely challenging (Navis and Glynn, 2010). In the case of new industries devoid of institutional context and characterized by higher uncertainty, entrepreneurs need to build legitimacy not only at organizational level but also at intra-industry, inter-industry and institutional levels (Aldrich and Fiol, 1994) and for heterogeneous stakeholders such as investors, ecosystem partners, potential customers and policy makers which may have conflicting legitimacy criteria (Überbacher, 2014).

Furthermore, we found that the cognitive and sociopolitical processes related to legitimacy need to be orchestrated simultaneously rather than sequentially in the early stages of ecosystem to facilitate stability, momentum and growth of venture, ecosystem and emerging industry thus contributing to the discussion of legitimacy within an ecosystem (Autio and Thomas, 2016; Paquin and Howard-Grenville, 2013; Sharapov et al., 2013) and extending the argument that legitimacy concerns for ecosystems need to be dealt differently than that related to dyadic relationship (Human and Provan, 2000).

The absence of cognitive and socio political legitimacy, among the many factors, hinders the commercialization of emerging technologies and creating the desired customer pull. Consequently, ventures success is in turn associated to commercialization success of emerging technologies. According to Deeds et al. (2004, p.10) “The value of technology ventures resides in difficult to understand, intangible and complex scientific and technical capabilities, which are of value only if their emerging industry achieves its promise.” In emerging industries, the “rules of game” are still in flux and are being negotiated by the actors. TFE at the firm level mobilised routines for sense giving thus establishing its credibility and identity. Consequently, at the inter-organisational level TFE manipulated institutional logics by employing various proactive mechanisms that enticed other actors to share and adhere to its vision of “Memory Everywhere” and enabled the creation and momentum of an ecosystem. These inter-organisational routines in turn impacted the
expectation formation for the technology in general and ecosystem in particular and thus enabled creation of constituency around PE that is important for emerging technologies.

However, achieving legitimacy at different levels is a strong challenge for resource constrained, small entrepreneurial firms and necessitates mobilizing both intra-organizational and inter-organizational routines. As shown in the case, diverse and intense sense giving communication strategies, affiliation with and endorsement from high status actors, changing the dominant logic of silo working, establishing technological instrumentality all contributed to achieving legitimacy for TFE, its ecosystem and printed electronics.

The role of entrepreneurial firms in the development of radical or discontinuous innovation or Schumpeter’s creative destruction has been discussed in the literature on advancements in industries such as biotechnology and computers (e.g., Whitley, 2002). In the context of emerging technologies they are considered as initiators and stimulators for widespread interest in the potential of breakthrough technologies (Acs and Audretsch, 1987). Autio (1997, p.263) referred to them as “bundles of technological resources.” However, they face challenges when it comes to commercialising and becoming industry leaders such as longer development times, limited resources (financial, human and relational) and lack of adequate market and product knowledge. They have high failure rates (Song et al., 2008) and suffer from the liability of newness (Stinchcombe, 1965). “While entrepreneurial firms may initiate innovation, the firms that begin commercialising radical or disruptive technologies are not necessarily the ones that profit from them” (Lubik et al., 2013).

According to Dmitriev et al. (2014) commercialization of an innovation is related to firm business model development. Among the strategies suggested in the literature for entrepreneurial ventures to ensure value creation with their novel technologies is the development of licensing business model. Licensing model has been increasingly used by entrepreneurs (Haeussler, 2010) as it enables entrepreneurial ventures to capture value by building a strong portfolio of patents without the need for developing complementary innovations that are fundamental for commercialization (Arora et al., 2001; Lubik and Garnsey, 2016). Our case demonstrates that building of an ecosystem is a dynamic capability that facilitates success for entrepreneurs in creating and shaping new markets. The shift from a patenting and licensing business model to product based orientation has allowed the focal firm to develop routines that put the technology from being more upstream to being downstream and closer to the market thus making the whole process of developing an
emerging technology more effective. We therefore contend that product orientation enabled
the entrepreneurial firm to overcome most of the risk associated identified in the literature
(Hsu, 2006) for leveraging from collaborative relationship such as (1) higher costs associated
with searching and evaluating the right partners (2) risk of appropriation.

To conclude, this paper has focused on analyzing organizational processes and routines for
orchestrating an entrepreneurial ecosystem in the context of an emerging breakthrough
technology. The contributions of the original case lies on the uniqueness of the small
entrepreneurial firm acting as an orchestrator of an ecosystem and industry shaper, rather than
a follower or niche player, as discussed often in the literature (Zahra and Nambisan, 2012;
Nambisan and Baron, 2013).

Like all case studies on small firms we were constrained by the limited number of people to
interview within the case firm, however we integrated this with a few interviews to other
members of the ecosystem and using extensive secondary and archival data.

Finally, the study identified the change in the business model, from licensing to
commercialization which impacted the position of the firm from upstream to downstream
thus affecting the configuration of partners and overall competitive advantage as crucial for
the success of the entrepreneurial hub firm. The findings of the effective strategies could be
further tested using large samples for generalizability.

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technological interdependence affects firm performance in new technology generations.


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Figure 1: Orchestration of an ecosystem - a routine based model

<table>
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<th>Ecosystem Creation</th>
<th>Meta-routines</th>
<th>Practiced routines</th>
<th>Level</th>
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<td></td>
<td>Structure</td>
<td>• Closed Membership</td>
<td>Intra-Organizational</td>
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<td></td>
<td>Relational</td>
<td>• Intent</td>
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<td>• Resource alignment</td>
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<td>• Redundancy</td>
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<tr>
<td>Absorptive Capacity</td>
<td>Identification, and Accessing External technical and Market Knowledge</td>
<td>• Technical advisory council</td>
<td>Intra-Organizational</td>
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<td></td>
<td></td>
<td>• Participation in PE related international networks such as industry associations OE-A, FlexTech Alliance</td>
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<td></td>
<td></td>
<td>• Attending conferences related to printed electronics as well as other divergent markets such as smart packaging, mobile communication</td>
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<td></td>
<td></td>
<td>• Relying on weak signals</td>
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<td>• Scouting</td>
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<td>• Internationalization</td>
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<td></td>
<td>Facilitating variation, selection and retention</td>
<td>• Top management team diversity and experiences</td>
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<td></td>
<td>Aggregating, Assimilation, transformation</td>
<td>• Prototype development</td>
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<td>• Sharing knowledge across organization</td>
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<tr>
<td>Knowledge Mobility</td>
<td>Coordination routines</td>
<td>• Ongoing communication</td>
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<td></td>
<td>• Modular communication</td>
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<td></td>
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<td>• Tacit coordination mechanism</td>
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<tr>
<td>Legitimacy</td>
<td>Venture (Micro)</td>
<td>• Sense giving activities (diverse and intense)</td>
<td>Intra-Organizational</td>
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<td></td>
<td>Ecosystem (Meso)</td>
<td>• Enhancing shadows of future and expectation of continuity</td>
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<td></td>
<td></td>
<td>• Social coordination mechanisms for trust, reciprocity and goodwill</td>
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<td></td>
<td>Industry (Macro)</td>
<td>• Shaping the conference at the level of industry associations.</td>
<td>Inter-organizational (Collective)</td>
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</table>
### Table 1 Illustrative Quotes

<table>
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<tr>
<th>Practiced Routines</th>
<th>Illustrative Quotes</th>
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<tr>
<td><strong>A. Ecosystem Creation</strong></td>
<td>Enrolment</td>
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<tr>
<td>What’s most important is they already had a brownfield site with the roll-to-roll equipment there that was custom designed by InkTec […] And that equipment was competent to make our memories. If you could do a search of the entire world there were probably only four places that we know of that could have built our memories roll-to-roll the way that InkTec does. (Respondent DST)</td>
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<td>We’re going to Polyera who has worked on n-type semiconductors for many years and we’re saying, ‘Modify your inks for gravure printing.’</td>
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<td>I think that each company should bring something important to the table. What we bring to the table is $100 million of investment in printed memory technology. And the patent family is all across the globe that protects… and the initiative to make product, and the DNA that is associated with that.</td>
<td></td>
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<tr>
<td>But one without the other is not enough. What we want from our partners is the same DNA and their own IP that complements ours. Polyera, with IP on the n-type semiconductor; PARC, IP that we now have an exclusive license on, background IP in printed transistors; InkTec, unique IP in silver inks and a DNA to make printed products. (Respondent DST)</td>
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<td>Stratification</td>
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<td>We have a design, polymer, making polymer analysis evaluation phase. Then we select something, then, in order to fully evaluate it in a roll-to-roll line typically takes a while, like several months. So, then, that is more on and off. (Respondent CKT)</td>
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<td>Yes, but actually with Polyera we are more intense. But that is, I guess, a maturity thing. Memories… of course you can always improve, but we are reasonably happy with the current situation, while with Polyera that is still a lot under development. So, much more intense (Respondent CKT)</td>
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<tr>
<td>Exclusivity and Redundancy</td>
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<tr>
<td>And then, with each of the other technology partners, we looked at their state of maturity. If they looked mature […] we wanted exclusivity for something. (Respondent DST)</td>
<td></td>
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<tr>
<td>What we get in return is exclusivity so that we’re not just a system integrator, we’re the only people that you can get the platform from. (Respondent DST)</td>
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<tr>
<td>What’s most important is they already had a brownfield site with the roll-to-roll equipment there that was custom designed by InkTec. And that equipment was competent to make our memories. If you could do a search of the entire world there were probably only four places that we know of that could have build our memories roll-to-roll the way that InkTec does</td>
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<tr>
<td>It means two things. We’ve got world’s best technology, and we saved years in bringing that technology in for products—because now that we want to buy a roll-to-roll machine ourselves… but if we had tried to do that three years ago, we would have...</td>
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We did our cost analysis. We then looked at what are all the vendor options available to us, and then what were the criteria that were important—so for the display technology we definitely had to think about supply chain, because we were seeing companies go broke in the space. In the case of the sensor, we looked at the sensing technologies, for both their cost competitiveness… there wasn't really a great match. To be honest, we didn't find exactly what we were looking for. (Respondent DST)

**B: Attending conferences and relying on weak signals**

What I mean by that is, when you're in large companies there's a tendency to have to prove that something is a market or to prove that something is a good idea. I don't have enough data to be able to do that, but what we can do is we go to the conferences, we see… you look at the people that register—is it the same…? There are always a few packaging people at the conferences, there are always a few security printing people, there are a few of the labeling people, there's always Avery Dennison. So you start seeing some patterns about… the people that are paying attention to printed electronics are in certain blocs, and out of that you can begin feeling through what is it that really resonates? What is it that they're looking for? Why are they here? There's something that brings these same kinds of people back to these conferences year after year. So what is it that's the essence of what they're looking for…? (Respondent JET)

So we go to the printed electronics conferences and we see that… Procter and Gamble in the chemical area gave a few of these talks from a consumer goods perspective. They'd say, 'We're not a display company. You show me a display without any electronics to support it, I don't know what to do with it.' (Respondent JET)

You need to do both some proprietary data gathering, meaning you need to talk to industry experts, kind of existing silicon players that provide the products... to actually get the level of granularity you need in order to say, 'Well, if we develop kind of this with certain kind of price functionality, we will be able to compete in kind of this and that segment of the market.' So, I mean, there are kind of bottom-up type of analysis, just reading existing reports on markets; and then you need to do the... bottom-up analysis in terms of speaking to potential customers, speaking to existing manufacturers of the products, and so forth. (Respondent TTT)

**C: Technical Advisory Council**

...we're trying to fill gaps and potentially there are gaps we fill in areas that are non-core to Thinfilm... So there is the idea that here is a nucleus, a core technical strength of the company, and the TAC is an outer ring that has a broader set of experiences. (Respondent DLT)

Then they brought in competence in areas where Thinfilm didn't have it, like TFTs, LEDs, what have you. So, very useful now, particularly when it comes to... on a high level, giving some direction and selecting a technology. Not so much when it comes to details, of course, or detail roadmapping and stuff like that. So, more partner finding—OK, we need a display technology; who is out there? Some feedback... (Respondent CKT)

The reason is that we wanted to get input for the team, the development team in Linköping, a fresh set of eyes on the milestone plan that we develop.

But after we've drafted that (milestone), the technical advisory council was called in to critique the milestone plan, to give feedback on the feasibility and about the technical risk and about any opportunities they saw from modifying the plan to improve either the efficiency or reduce the risk—so, really, a technical critique of the milestones themselves and the plans, the
<table>
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<th>D: Top management team diversity and experiences</th>
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<td>What's really interesting about Thinfilm is we have experience from other industries. Torgrim, from management consulting [...] he knows a lot about technology acquisition, you know, the consolidation of industries. So we think that we bring to the table different industry experiences. Because we have different industry experiences, our view on how to organize a business conference, our view on how to organize a roadmap, may be different than somebody who's worked in a large company for 40 years. (Respondent DST) I had been in and around printed electronics for almost a decade in some way, shape or form, so it gave me two things: it gave me credibility at the table, because people do know PARC — so it was reasonable to use those contacts. (Respondent JET) I think this is a place where Torgrim and I complement each other, because there were definitely times when he was... he'll do the spreadsheet version and be an hour or so, and say, &quot;This is where the market is, so it looks like requirements are that we... we don't really know — let's verify.&quot; I'd go out and I'd have conversations with five or... a few people in the market. I'd reach out to some of my network. We'd try to test the idea. (Respondent JET)</td>
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<td>A lot of the performance requirements do not come from research organizations. They come from products. So they are developed together with design and product thinking rather than technical research-oriented. Then... when you develop a roadmap that includes design rules such as line width, spacing, registration accuracy, we... also consider all our input we have from equipment vendors, and what is possible to do within a given time frame when it comes to printing processes. So, equally important as just coming up with ad-hoc or product-inspired requirements is knowing the practical limitations of the processes and equipment you intend to use. (Respondent CKT) It's had a significant impact on requirements that we give our technical ecosystem. So it allows us to say, 'Here are the things that matter, these things that don't.' When we talk about the battery, do we care more about it being really small, and it can be thick? Or do we care more about it being thin? And those kinds of decisions are significantly informed by having a customer engagement. And that's actually why the early adopters, early customers, are so critically important to a technology company. We can design in a void, but the chances... if we don't have a customer with whom we are co-developing the spec, the specification, it's far too easy to get to market, say, 'I've got a device — it's all ready to produce — and nobody wants it because if you'd made a different design decision 12 months earlier you'd have ended up in a better spot. (Respondent JET) If you ask about what is best practice for the toy and game industry, first you have to understand the structure of the industry: you have to understand the cost dynamics of the industry, and then you have to have a platform that you can use as a starting point for exchanging information with the engineering teams. They give us feedback. 'This prototype failed' — that's the first thing they say. And then we work on those few items that they think need improvement. Some people were worried about electrostatic discharge; some people were worried about tape testing; some people were worrying about a ballpoint pen — you know, what is known as scratch testing or indentation testing. So we now have our standard spec sheet of what our 20 bit memory does. (Respondent DST)</td>
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<td>F: Ongoing communication</td>
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| Modular communication     | 1. So, where we did things, and we were happy, Intel tried to make copy-exact, everything in detail should be the same—[...] equipment, materials, temperature, relative humidity.  
2. So that we also try to do, so during initial phases, for example with Imprint Energy, battery testing, we bought a tester that was as identical to theirs—so first thing I asked was what type of tester they had—so that we actually have the same baseline, and then used the same script.  
3. Particularly evaluation protocols, test protocols, they should be copy-exact. Even a tiny change in a measurement protocol typically results in quite different results coming out on a measurement. (Respondent CKT) |
| Tacit coordination mechanism | 1. InkTec and ThinFilm have an excellent relationship in that context. They are so transparent, and we are that, too. So, actually, key to make a memory work was that we spent enormous amounts of time over there, with them, doing trials together, in a totally transparent fashion. (Respondent CKT)  
2. But we work closely with people: [...] we are in Korea once a month. And their staff have been at Linkoping and they’ve gotten training on how to test the memories, and we have delivered equipment to them; and we have made joint investments in upgrading their line—we are partners. (Respondent JET) |

| G: Shaping the conference at the level of industry associations | One of the things is it gives me access to a really large knowledge base. So it’s not just the reports that they have out there, but the network…we see proposals from all sorts of organizations. So I now know about people who are starting to do things at the edges or who are coming up with some new, interesting stuff that I would never have seen if I were just heads-down, working, my day job in ThinFilm. So it’s really about building up that network. (Respondent JET)  
2. But it’s much more than that: it’s the work on standards, getting the IEC to create printed electronics standards that are favorable to the OE-A: figuring out how to have the right mix of program material at LOPEC is very important. (Respondent DST)  
3. I mean, until we started being active there was no session on memory and logic. So Jennifer is organizing a session at FlexTech in Phoenix on memory and logic. There was no session on that last year.  
4. So how are we going to get funding or awareness of our product markets unless we lead that? Nobody’s going to do that for us. And in order to get the opportunity to do that leadership you have to be part of the organization that has the conferences. So I was elected to the OE-A; Jennifer was elected to FlexTech; we’re the only company in the world that has board members in both organizations. And we have 16 employees. And both have been chosen to organize a symposium, a session, based on their own strategic intent. So if you’re in charge of the business conference you can influence the strategy of the entire organization, in my opinion—in a positive way, to become more business focused and less academic, as we evolve. (Respondent DST) |