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Evolving Toward an Ecosystem Perspective: Market Strategies for Science-based Ventures

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Abstract

Matching a new technology to an appropriate market is a major challenge for new firms. Selecting the wrong market not only means selecting unsuitable customers, but doing without the appropriate set of players to help commercialize innovative products. For generic science-based ventures, this a particularly difficult task, as the innovations they are established to commercialize often have a number of markets and applications open to them, each one carrying considerable technological and market uncertainty. By applying an ecosystem perspective to these ventures, we can better understand how their need for resources affects their strategic options in the context of their co-evolving innovation environment.

The study is based on dataset and case study research on UK advanced material university spin-outs (USOs). We find that, contrary to the recommendations dominant in academic and practitioner-oriented literature (notably the pursuit of a niche market strategy), the most commercially successful ventures in our sample were targeting mainstream markets by working closely with larger established competitors during early development. Rather than seeking strategies that protect them from the competitive actions of incumbent firms, science-based innovations, such as new materials, appear to require the presence and participation of established companies in order to create value. Our cases provide examples of how these ventures can overcome co-innovation and adoption risks, by creating an ecosystem in which they play a central part, and/or choosing an entry point to the value chain which requires no major changes for downstream players.

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Key words: Market selection, innovation ecosystems, advanced materials, university spin-outs, science-based ventures, value creation

1. Introduction

Companies and nations increasingly aim for economic renewal through innovation, but the model of innovation within a single vertically-integrated corporation is increasingly viewed as outdated (Pisano, 2006; Adner, 2012). New ventures and spin-outs are increasingly seen as more appropriate vehicles for pioneering innovation based on scientific advances (Rothaermel and Thursby, 2005). Unconstrained by earlier markets, investments or capabilities, these firms are free to pursue radical innovations with a focus and flexibility that may elude large firms. (Lieberman and Montgomery, 1988). However, these start-ups face a host of challenges unique to their situation and characteristics. Choice of market[1] is among the most significant of these challenges. It has not been well recognised in the literature on market selection that this choice implies the selection not only of a market but of an innovation ecosystem.

Flawed market selection can cost a new business countless man-hours, millions in funds and, not uncommonly, its future. Several dominant strategies have been proposed to guide the market-oriented strategy for new and emergent technologies; however, science-based[2] entrepreneurs must be careful about how and why they follow that guidance, as the proposed solutions do not fit all technologies, sizes of firm or technological paradigms. In particular, the challenges faced by these ventures, including the need for process innovations, need for complementary innovations, need for large amounts of financial and capital resources (such as manufacturing equipment) and long development times, often requires the management of a complex network of players in order to achieve successful commercialization (Maine and Garnsey, 2006; Lubik, 2010). For this reason, an ecosystem perspective is particularly useful for developing suitable market strategies.

In this paper, we first examine the commercialization challenges faced by advanced-material ventures (i.e. carbon nanotubes, polymer-based organic light-emitting polymers, etc.), as a prime example of science-based venture, and then discuss recommended market selection strategies in light of the challenges identified. We find a potential mismatch between recommendations and practice. From a dataset of new materials university spin-outs (USOs), we select and summarise evidence from two of the ventures that succeeded in creating above average economic value, measured by revenue over time, from a larger sample of new materials spin-outs. Both cases demonstrate a market strategy and ecosystem development strategy that differs from that favoured by conventional wisdom. We discuss these findings in relation to the relevant literature, applying and extending the innovation ecosystem perspective beyond the corporate setting to that of new science based ventures, with a focus

[1] By market, we refer to potential buyers (and existing sellers) in a unique industry segment with a particular set of desired product attributes (Maine et al., 2012)
[2] By science-based, we mean ventures formed to commercialize technologies based on new or developing, rather than accepted, scientific principles. While we accept that this is a large and highly heterogeneous group, we are focusing on science-based ventures with generic technologies, such as advanced materials.

on resource availability and dependency risks, namely adoption chain risk and co-innovation risk. We conclude with implications for management and future work.

2. Literature

The arena of advanced materials USOs provides a useful context in which to apply the ecosystem construct to science-based ventures, since these firms encounter particularly stringent constraints and require complex networks of players for successful commercialization. In what follows, we first discuss the particular market-oriented challenges faced by advanced material ventures. Second, we give an overview of the strategies currently recommended by the academic and practitioner communities, grouping them into four general categories to assist later analysis.

2.1 Getting advanced materials to market

The commercialization of advanced materials has not received extensive academic attention and existing literature focuses mainly on incumbent firms (Hounshell, 1988; Hagedoorn and Schakenraad, 1991; Wield and Roy, 1995; Maine, 2008). This is not surprising as Wield and Roy (1995) and Hagedoorn and Schakenraad (1991) show that large and multi-national firms are increasingly recognizing the importance of advances in material science and taking them into account in strategic decisions. Within this prior work a recurring theme is the importance of other players, including alliance partners (Wield and Roy, 1995; Peters et al., 1998; Heidrick et al., 2005), investors (Maine and Ashby, 2002; Maine et al., 2005; Maine, 2008), policy-makers (Wield and Roy, 1995). Despite the focus on incumbents, the importance of commercializing university research in areas such as materials, often through spin-outs, is increasingly recognized (BERR, 2009), and the small amount of work specifically on these ventures also clearly reveals the partnership theme (Maine and Garnsey, 2006; Lubik et al., 2011; Maine et al., 2012).

Maine and Garnsey (2006) have proposed a model which lays out the challenges facing advanced materials ventures as they attempt to get their products to market and generate revenue. These include the radical nature of the technology, need for process innovations, need for complementary innovations, lack of continuity with prior technologies, multiple potential markets and up-stream value chain position, together with competition from established substitutes. These factors all impact the market and technological risk and uncertainty faced by the firm, affecting the venture’s ability to demonstrate value and to create and capture value. While most of these factors directly or indirectly influence each other, Maine and Garnsey's model proposes that, in particular, value chain position; lack of continuity, observability and trialability; need for complementary innovations; and number of potential markets influence market uncertainty. The farther upstream in the value chain a new technology is, the more difficult it is for the enabled product to be observed and trialled by the consumer increasing market uncertainty (Maine, Lubik et al., 2012). Most have substantial need for complementary innovations by other players which also increases uncertainty, as it increases the investment in time, effort and resources required by other players in the value network before the product can be fully commercialized. Market uncertainty is also reduced if the enabled product does not require the customer or next player in the value chain to learn new skills or change their routines in order to adopt the innovation, but that can be difficult for ventures launching innovations from upstream in the value chain, far from the final customer (Rogers, 1995). New advanced materials are also often generic, having potential application in many markets, and the number of markets targeted also influences market uncertainty; though what the effect will be is in question, as discussed in the next section. Given all of the above variables intensifying market uncertainty, the substantial need for external resources and complex network of suppliers, downstream players, complementors and final customers, the selection of market is often a difficult decision. Moreover, there is a variety of competing advice for how such ventures should proceed.

2.2 Market-oriented strategies for science-based business

A wide variety of strategies have been proposed for new technologies and new technology ventures. In the following, we discuss frequently cited works and those that have become popular in business teaching and with entrepreneurs, such as *The Innovator's Dilemma* (Christensen, 1997) and *Crossing the Chasm* (Moore, 2002). Table 1 provides an overview of these works.

Table 1: Market Strategies Recommended for Commercialization of New Technologies

	Theory/ Empirical	Industry/ Context	Level(s) of Analysis	Recommended strategy for market selection and entry
Davidow (1986)	Theory	Marketing High Tech Products	Product and Firm	Pursue a niche market strategy the expand into mass market
Teece (1986)	Theory	Capturing profit from Innovation	Innovation & Firm	License widely if IP is strong and specialized resources not required. If specialized resources are required, those who own those resources will capture the most value.
Hagedoorn and Schkenraad (1991)	Theory & Empirical	Advanced Material Firms	Sector	Ventures should focus on niche markets
Gans and Stern (1993)	Theory	Product Market vs. the Market for Ideas	Firm	Align commercialization strategy with firm's commercialization environment (whether a firm has a strong IP position relative to control of specialized complementary assets)
Christensen (1997)	Theory & Exemplars	Market Selection for Disruptive Technologies	Disruptive Technologies	Start in a niche market where customers value new performance attributes enough to accept lower performance in current main attributes
Arora, Fosfuri and Gambardella (2001)	Theory & Empirical	Markets for Technology	Technology sector & Firm	Remain upstream and license downstream into multiple markets
Moore (2002)	Theory & Exemplars	Marketing High Tech Products	Firm	Pursue a niche market strategy then expand into mass market
Nerkar and Shane (2003)	Theory and case	University Spin-outs	Firm	Commercialize in multiple markets to spread risk
Christensen (2004)	Theory	Value Chain Position	Firm	Forward integrate to decoupling point
Shane (2004)	Theory & Empirical	University start-ups	Technology & Firm	Commercialize in Multiple Markets
Utterback and Acee (2005)	Theory & Exemplars	Market Selection for Disruptive Technologies	Disruptive Technologies	Launch in high-value markets and move toward lower end markets
Maine and Garnsey (2006)	Theory & case studies	Advanced Materials Ventures	Technology & Firm	Limit number of markets, choose near term substitution markets with lower hurdles in terms of regulations, complementary innovation, and process innovation
Adner (2012)	Theory and Exemplars	Innovation Ecosystems	Innovation Ecosystem & Firm Strategy	Select an ecosystem where all necessary co-innovations will be available when the focus innovation is ready

The above recommended strategies can be grouped into four broad categories: niche markets, multiple markets, market for technology (licensing) and, more recently, market selection with reference to the firm's potential innovation ecosystem.

Davidow (1986) originally suggested that firms with new technologies should focus on carefully segmenting their potential market and then beginning in one where they were fairly likely to be able to capture around twenty percent of the market, usually a niche market. Hagedoorn and Schakenraad specifically suggest that in the arena of advanced materials, ventures may play a role but mainly in niche markets (1991) [3]. Christensen (1997) and Moore

[3] Although in their 1991 paper, they were specifically speaking of SMEs with <500 employees, far more than most USOs have in their early stages

(2002) also suggest the use of niche markets to introduce high-tech products. Niches provide a protected space for ventures to test and perfect their products with the input of lead users who are willing to accept inferior performance on attributes currently valued by most customers in exchange for high performance on new attributes, thus allowing a new technology to be refined before wider commercialization. However, according to Utterback and Acee (2005), in direct contrast with Christensen (1997), *if* a new technology improves or augments currently desired functionalities, it should be aimed initially at a high-end market.

A smaller group of researchers suggest that ventures can benefit from targeting several markets, either to achieve the flexibility to change markets if initial efforts prove unsuccessful (Shane, 2004) or because many distinct markets spread risk (Nerkar and Shane, 2003). However, specific research into science-based spin-outs uncovers evidence of circumstances incompatible with this strategy. Financial constraints early in the life of a USO often inhibit the use of pure licensing models in multiple markets, as they often require significant resources to get to a stage where their technologies are attractive for licensees (Minshall et al., 2008). Maine and Garnsey (2006) hold that for advanced materials, the resource requirements and time required to prepare such an innovation for each unique market would make it difficult for resource constrained ventures to successfully pursue multiple markets.

A third group of researchers advises firms with new technologies to participate in the market for technology (licensing), though often with caveats regarding resources. Teece (1986) suggests that a firm with a new technology can profit through licensing *if* the downstream resources required are not specialized and the firm can get its technology to market without investing in its own equipment. If specialized resources are required, whoever owns those resources is likely to capture greater profit. Gans and Stern (1993) make a similar point to Teece, suggesting that licensing is an option if the firm has strong IP relative to the control of specialized complementary assets. Arora et al. (2001) point out that licensing into multiple markets also increases the strategic space a firm can occupy. However, it may also increase the need for the firm to have the internal assets required for downstream differentiation.

The concept of complements also comes into the final category, which involves innovation ecosystems, whether or not this term is used. Christensen (who does not use ecosystem terminology) suggests that new entrants, particular those who developed the new technology, should forward integrate to the decoupling point “the point at which there is a modular interface with the next stage of the value chain” (2004, p.15). This is a way of assessing and reducing interdependency risks, such as the need for further innovations downstream in the value chain. According to Maine and Garnsey (2006), ventures commercializing generic technologies should choose markets where limited complementary innovations, process innovations and regulatory changes are required, again to reduce risks associated with co-innovation and downstream adoption. This approach is made more explicit through use of the ecosystem construct by Adner, who proposes that firms need to select their markets after considering the interdependence risks inherent to each related innovation ecosystem, i.e., the set of players required to produce a complete solution for the final customer. He advises that firms be aware of two key types of interdependence risk: co-innovation risk "the extent to which the success for [the focal] innovation depends on the successful commercialization of other innovations" and adoption chain risks "the extent to which partners will need to adopt [the focal] innovation before end consumers have a chance to assess the full value proposition" (2012, p.6) and evolve their strategies accordingly. This is in addition to allowing for such execution risks as are inherent in developing a working product. While Adner's work has largely focused on large firms, this perspective is also illuminating for innovative start-up firms, as will be shown in our case study evidence.

In the following section, we explain our methodology before delving into case studies to further explore which market (and thus ecosystem) selection strategies are most appropriate for science-based ventures. The cases involve the two advanced materials ventures in our dataset who have had above average commercial success.

3. Methodology

This research has been iterative in approach: a continual re-evaluation and refinement of literature as informed by evidence, and vice-versa (Garnsey and Leong, 2008). We use a case study method to highlight two examples which demonstrate an extreme with regard to the phenomena in question (Eisenhardt and Graebner, 2007), here, advanced materials ventures achieving unusually high commercial success. While case study research is not statistically generalizable, it can have *analytical* generalizability when it yields theoretical generalizations based on conceptually grounded empirical observation (Yin, 2003).

To enhance the theoretical generalizability of our findings, we have employed specific selection criteria for our cases (Gibbert et al., 2008).We started by identifying every recorded materials-based spin-out from the fourteen UK universities mostly likely to be involved in materials research commercialization, as shown by their researchers committing significant investment of time and resource in this field. Interviews with academics knowledgeable in the area and recent studies on technology transfer informed the selection of universities (Minshall and Wicksteed, 2005; Livesey et al., 2008). The resulting dataset comprised 67 advanced material USOs in the UK. From this dataset, seven in-depth case studies were conducted of ventures with different levels of commercial success in order to compare the strategies of the most successful with those having moderate, little or no commercial success. The two the most successful cases, in terms of revenue generation over time, are presented here[4]. While profitability would have been a useful alternative indicator for commercial success, most of the ventures in the sample had yet to reach profitability[5], during the interval of this research (2006-2010), so such data was unavailable. Also, many such ventures are acquired and integrated into other firms before reaching profitability, inhibiting further data collection.

Evidence was systematically coded to identify and compare important issues and constructs. We collected company development information, such as founding and parent university; market and partnership data, such as markets identified, markets selected and publicized partnerships; and resource and value creation metrics linked to framework presented by Lubik et al.(2011), such as annual revenue and patent growth. Much of the relevant information for the dataset was in the public domain, making it possible to draw data from secondary sources, including company websites, company databases, press releases, patent databases (UK PTO) and other case studies where available. Early in the life of many ventures, information is made available on their websites and in the public domain in order to increase their credibility with investors and potential customers. Once complete, this database guided the selection of the case study firms, who were then contacted for interviews. Detailed interviews were carried out with key personnel, generally founders, CEOs or other top management.[6] In the interest of brevity, not all case studies conducted are discussed here (see Lubik 2010 for full versions of all cases).

Below, we focus on the two companies in our sample achieving the highest level of value creation (measured by revenue over time)[7,8]. In each case, we looked for evidence relating to

[4] These ventures were also experiencing significant degrees of the market-oriented challenges identified by Maine and Garnsey (2006) in section 2.1.
[5] Advanced material ventures can take 10-15 years to reach revenue alone (Maine and Garnsey, 2006).
[6] The exception was CDT, a local success story in Cambridge, which has been the subject of many studies and articles, making it possible to base a detailed history on secondary sources alone.
[7] One company had higher overall value creation (revenue over time) than Metalysis but also went out of business during the course of the study.

the four broad strategies (niche markets, multiple markets, market for technology or ecosystem approach), which we discuss in section 5.

4. Evidence

The following cases shed light into the experiences of two of the sample's most commercially successful firms, both of which have the potential to drastically transform the value networks and industries they have entered. They serve to highlight reasons why the strategies that they evolved may be appropriate for advanced materials. They show the importance of taking ecosystem factors into account in devising a strategy.

4.1 Metalysis[9]

Metalysis (FFC Ltd until 2003) began in the Department of Materials Science and Metallurgy in the University of Cambridge, when researchers Fray (Cambridge), Fathering (former Cambridge student), and Chen (Cambridge) developed the Cambridge FFC Process. Using molten salt electrolysis to convert metal oxides directly into purified metals, the process offers significant advantages over conventional metal-processing techniques. By replacing significant portions of a previously complicated, expensive and polluting value-chain, the process has the potential to lower costs and add considerable value for other players in metal processing and end-markets. The process allows the production of near net shaped products, which reduces costs in machining and further production, as well as allowing the production of valuable, customized metal-alloys. Metalysis' process also significantly decreases environmental impact of materials processing because it works at much lower temperature, uses fewer toxic chemicals and avoids toxic by-products, (Metalysis, 2009).

Metals often have a many potential uses across a number of markets and industries; however, Metalysis' original market selection was on among the metals for which the process was suitable. Titanium was identified as a metal of high interest even before the company spun-out, but the rights for titanium were licensed by the university (through an intermediary called QinetiQ) to another spin-out called British Titanium. Titanium notwithstanding, Metalysis identified tantalum, chromium, tungsten, cobalt and silicon as highly attractive materials. The first metal selected was tantalum, a metal needed for cellular phone

[8] While profit may have been a preferable indicator of commercial success, most ventures in the sample had not reached the profit stage.

components (Process Engineering, 2003). Tantalum was only required in small amounts in comparison to other metals and very costly to produce, meaning that the FFC process could offer significant value-added by greatly reducing processing costs. According to Dr. Fray "it did not require huge quantities, it is more reasonable to be able to get a significant portion of the world's market" (interview, 2006). When the process was perfected and scaled up, the venture was confident that it could produce enough to serve a significant proportion of the world's market, roughly 2000 tonnes per year. As the firm's strategy evolved, Former CEO Graham Cooley would later explain that the easiest entry point appeared to be producing the metal powder that was already in common use instead of trying to introduce a completely new product (interview, 2006), which limited the need for complementary innovations by other players. This would also position the USO far from its products' end users, decreasing those final customers' ability to observe the value-added by the product; however, the value produced and costs lowered by the process, once-scaled up, would be clearly visible to those next in the value network. After legal proceedings, Metalysis later gained the full global rights to the processes for all metals, including Titanium, a market they quickly began working toward.

The markets for these types of metals are dominated by a number of large, global firms, and in 2006, Metalysis announced partnerships with two major players that would help them commercialize the new technology. Under the first partnership agreement, Rolls-Royce would provide funding for the R&D activities and scale-up as part of its offset programme in Malaysia (The Star Online, 2006; Metalysis, 2009)[10]. Rolls-Royce may also become an even more formidable ally and customer once the process can produce commercial quantities of its target metals. BHP Billington was the venture's next significant partnership. Metalysis acquired BHP's polar process, an alternative method for processing titanium and BHP took a minority stake in the new joint venture: Metalysis Titanium Inc. This venture has helped to accelerate the development of strategic alliances which could lead to other joint ventures and licenses for rapid market penetration while concurrently enabling the production of titanium and bulk titanium alloy products (Metalysis, 2009). For each metal, Metalysis is currently scaling up and providing samples to select partners. Revenue has been generated from sales of samples, though at the time of this study, the company's focus was more on quality scale-up to commercial quantities (Pepper, interview, 2009). By producing these metals in powder

[10] In exchange for the government's procurement of several jet plane engines, Rolls Royce would help bring Metalysis' scale-up facility to the country, providing manufacturing jobs and technical training

form and in a variety of grades, Metalysis' customers could use them in a variety markets and applications from electronics, biotechnology, chemical reaction vessels and jet engines (tantalum) to special alloys engines, air-frames, pressure vessels, fasteners, medical implants, automotive components, jewellery, marine and sports equipment (titanium) (Metalysis, 2011).

4.2 Cambridge Display Technology[11]

In 1989, Dr Richard Friend, Jeremy Burroughes and Andrew Holmes of the University of Cambridge's Cavendish Laboratory discovered organic electroluminescence from polymers (CTD, 2010). Three years later, Cambridge Display Technology (CDT) was born. Their innovation would allow light-emitting diodes (LEDs) to be made of conductive polymers, rather than traditional semiconductors. By changing the composition of the polymer and the structure of the device, the team achieved efficiencies above those of traditional LEDs (Seldon et al., 2005). These new polymer organic light-emitting diodes (P-OLEDs) could be printed using ink-jet techniques, a new and less costly production method, and did not restrict the size of the displays.

It was clear to the team from the beginning that the end market for this technology was in electronics, most notably displays. A strategy was required which would allow them to enter and work within the electronics market, which was dominated by well-established global players. Early in its life, CDT realized that producing an entire product was unlikely. Burroughes explained "it was clear from [his work with IBM] that millions of pounds were required to develop new products. This was something CDT didn't have" (Seldon, Probert et al., 2005, p7). Instead the venture focused further up the value chain, developing the fundamental technology and licensing it to larger firms, like Philips, who could devote the capital necessary to develop and integrate the technology into their own components and products. The partnerships increased the company's credibility, gave the company a route to market for their technology, sped adoption and buy-in and generated revenue. In exchange, the partners gained access to technology that had could potentially offer substantial benefits to their customers. While they originally tried to work with partners in a variety of market sizes, CDT realized that did not have the processes necessary provide full solutions to smaller licensees in niche markets, limiting the value that could be created through such licensing

[11] This case study is based on secondary information including past case studies, press releases and company websites which are cited where appropriate.

(Seldon, Probert et al., 2005). In 1999, after the US acquisition, the company stopped focus on any niche applications and chose to focus on six key areas: material deposition, device physics, P-OLED materials, optics enhancements, device electronics and process equipment. Within each area, the firm identified two or three (often large) key partners who would both collaborate with CDT and compete with each to reach market faster (Minshall et al., 2007). This crafting of relationships in all identified key fields, coupled with development and manufacturing services allowed CDT to offer a 'one-stop' value proposition for partners. To prove viability of scale-up and assist partners/licensees with the development of their complementary technologies and processes, then CDT built their Technology Development Centre (Maine and Garnsey, 2006). This would also improve trialability and observability of their materials. Moreover, it would provide development revenues for the small firm. Later, CDT's business model would evolve again, further integrating its activities with those of its partners and licensees by attempting to deliver a comprehensive package to interested parties including hardware, printers, processes, devices and service. In 2005, it began selling these packages internationally (Hall, 2006).

CDT has established and maintained a number of partnerships, using a licensing model and collaborations for the development of necessary complementary innovations, IP and integration into the value chain (Davis, 1997). Among those who directly assisted with market access, co-innovation and downstream adoption were Seiko-Epson, Dow Chemical, Uniax, Phillips, Covion, Bayer, Delta Optoelectronics, DuPont, Eastgate, Mark IV Electronics, Osram Opto Semiconductors and Kolon Industries[12]. Seiko-Epson entered a joint venture focusing on ink jet printing, and Dow Chemical, who would help create new materials that were more efficient and easier to manufacture. In 2001, CDT and Sumitomo Chemical established a licensee and technical assistance agreement based on the patents for LEP materials, speeding up the development of LEP displays and leading to an equity investment by Sumitomo (CDT, 2010). Two years after forming a joint venture in 2005, Sumitomo acquired CDT and soon announced significant improvements in technological performance (ElectonicsWeekly.com, 2007; CDT, 2010). Licensing by partners has contributed to revenue generation of by the firm thus far. Ian Chao, CDT's general manager of Asia Business Development, also explains that the company's broad and comprehensive

[12] CDT has over 35 publicized partners. This case study focuses on those most publicized and with the most influence over ecosystem and business model evolution. Full list of partners and the resources they provide can be found in Lubik (2010) p.181.

strategic partnerships with the other companies in its ecosystem "has helped the players to shorten their learning curve" (Hall, 2006).

5. Discussion

Of the four strategic categories identified above (niche market, multiple markets, market for technology (licensing) and ecosystem matching), the last seems to best reflect the strategic choices of the high-value creating cases. A perspective which views innovation as taking place across an ecosystem of players clarifies and integrates core issues in strategy development. This view is suited to understanding science-based ventures that must operate in complex, interdependent ecosystems. However, there are features of other strategies that remain relevant to the domain of science-based ventures. Table 2 gives an overview of the strategies used by our high-value creators, contrasted with the strategies proposed in the literature reviewed.

Table 2: Contrasting strategies of case firms

Advice	**Metalysis**	**CDT**
Pursue a niche strategy (Davidow, 1986; Moore, 2002)	Pursue a mass market strategy with assistance of partners	Pursue a mass market strategy with assistance of partners
Commercialize in multiple markets (Shane, 2004)	Commercialize to single process focused on a small number of high-end mass markets	Focus on demonstrating value to large partners within the electronics market.
License into multiple markets with strong IP, depending on resources (Teece, 1986; Arora, Fosfuri et al., 2001)	Carefully protect IP but develop manufacturing in-house (this also avoided delay: the technology required additional work before licensing would be feasible)	Cross license with big players in a single large market
Match strategy to ecosystem (Maine and Garnsey, 2006; Adner, 2012)	Select a position in the value chain where process innovations are not required by others	Create manufacturing facility to demonstrate value to and assist adoption by appropriate partners who can assist with complements and adoption.

Both ventures identified the need to pioneer in manufacturing in order to secure IP and prepare for any subsequent licensing. Noted scholars recommend niche construction as a preferred start-up strategy because it offers protection from competition as the firm develops its offering; many of whom are concerned with IT rather than science based ventures (Christensen, 1997; Moore, 2002). Our evidence suggests that a niche market may not provide the resources required for the commercialization of science-based innovations in general and advanced materials in particular. Moreover, niche building is not always an option for science-based ventures, as it can be highly time and resource intensive and does not diminish interdependency risks..

Both our case study firms formed alliances with industry leaders in mainstream markets early in the development process and both added value to existing products, one by reducing cost and one through enhancing performance. However, where CDT is creating a new ecosystem of firms working on the new P-OLED technology and altering the old value chain, Metalysis' technology, if successful, could transform the existing ecosystem, by-passing nearly all of the established upstream value chain for metal refinery[13]. A related finding has been discussed by Utterback and Acee (2005) who suggest a distinctive strategy for technologies which even from the start offer performance benefits for the top end of the market. They argue that if it offers better performance than existing products, a new technology may find it advantageous to enter the higher and more demanding price segments of a mass market and then move toward volume production for the lower price segments. While the firms in this study have yet to reach a their full commercial potential,, our examples suggest that entry to markets of this kind is possible by way of alliances or significant involvement with established key players.

While neither of the ventures in question pursued a number of disparate markets to spread the risk, as advised by Nerkar and Shane (2003), Metalysis was developing a single process that they choose to apply to a small number of high-value mass markets, echoing the advice of Maine and Garnsey (2006) and Utterback and Acee (2005). Similarly, CDT decided to focus on a single sector: electronics, from a position far upstream in the value chain.

Licensing, in the traditional sense of allowing downstream partners to commercialize the new technology, was not a core feature of the strategy of either young firm. Given the need for further development and the desire to minimize adoption risks by reducing the need for complementary process innovation by downstream players in their ecosystem, Metalysis carefully protected their IP, but focused on proving the technology and scaling-up. Their partners thus far have mostly facilitated the process of attracting investment and network creation. CDT developed an impressive portfolio of patents with the close collaboration of a large number of partners, co-applying for several patents with key partners, demonstrating value to those partners and speeding up learning in the innovation ecosystem. The IP may attract also future partners. This is also consistent with the findings of Ajuha (2000), that ventures can benefit from alliances with large firms if their technology and IP are sufficiently valuable.

Ecosystem-oriented strategies appear to be ideally suited to science-based ventures with generic technologies to address the particular challenges they face. By choosing to enter the value chain at the point where no further complementary innovations or adoption was required, Metalysis was unknowingly following Christensen's (2004) advice of reducing risk by integrating to the decoupling point (by a manufacturing metal powders). In this way they were able to deliver a powder that fit seamlessly with existing technologies and were freed of dependence on downstream players who did not have to alter their own production processes to adopt the innovation. CDT also recognised dependency risks, those of adoption and co-evolution, and had to weigh these against the initiation risks involved in getting their advanced technology to work, in a necessarily costly and drawn out development process. Their solution was to establish a central position in the emerging ecosystem of P-OLEDs by developing close partnerships with a wide network of all players identified as necessary to get their innovation to market (Adner, 2012). They were able to attract leading development partners through the offer of shared intellectual property and potentially lucrative co-innovation. Both these USOs were able to show that their pioneering technologies offered potential value sufficient to convince the larger partners to provide significant resources toward the commercialization of the new technology. Identifying and creating relationships with key partners without become overly dependent was in itself a key challenge. Being at the apex of current ecosystem, their partners had to see sufficient value in order to support the emergence of a new ecosystem which could undermine the existing value chain in which they had previously invested.

While it is clear from both cases that complementarities, complexity and cooperation underpin ecosystem-based strategies, our evidence also clearly shows the need to examine the availability of resources, as discussed by Teece (1986) and Maine and Garnsey (2006). Advanced materials ventures often require external capital and resources in amounts that may be unavailable in most niche contexts where well-resourced incumbent firms are absent. Collaborators with the requisite resources for co-development and scale-up are unlikely to contribute financing and assets over a lengthy lead time unless the resulting process or product can be targeted at a large and/or sufficiently lucrative market. They are likely to prefer to remain in mainstream markets and those where they have already invested in gaining an ample market share (Christensen and Bower, 1996; King and Tucci, 2002). Therefore those markets which offer advanced material USOs sufficient opportunity to access resources are also markets in which they are in a weaker position to compete independently. This is consistent with findings by Rogers (1983), whose early work greatly influenced Moore's *Crossing the Chasm (1991)*, to the effect that early adopters will be those with close connections to the science-base, sufficient financial liquidity and the risk tolerance that comes with financial resources. Science-based ventures may find it advantageous to identify markets where their innovation has the potential to contribute considerable value added for dominant players in the related ecosystem, few of whom are likely to be the end customer. Leading firms of this kind tend to shape their business environment; enabling the ventures to influence ecosystem evolution indirectly as innovative partner to platform leaders (Gawer and Cusumano, 2002). As in the case of CDT, these partnerships can also lead to eventual acquisition.

However, it should be noted that such partnerships are neither easy to secure nor to maintain. While steps can be taken, as by Metalysis, to minimize need for dependence on complementary and process innovations, management of such alliances by science-based ventures is likely to involve further development, complementary innovation and downstream adoption by partners. The venture will also need IP to protect the investment even before the firm can secure their first commercial partnership. There is a danger that dependence on incumbent firms may impair the venture's focus on other, potentially lucrative, markets or partners. Such arrangements could make the USO heavily dependent on a partner with whom a continued relationship is not guaranteed, a vulnerable position that Tidd et al. (1998) have cautioned against. Additionally, there may be a danger that the new firm could become less valuable/powerful over time if their partners gain too much strength in the new ecosystem or gain control over subsequently developed IP. This points to the importance of the venture developing a strong IP portfolio and keeping control of fundamental IP. The experience of both case study firms suggests that it may be wise to maintain multiple partnerships and to continue independent opportunity identification. This may be required in order to reduce the risk of partner dependence, known to be detrimental to a venture if conditions change (Mitchell and Singh, 1996). CDT managers carefully protected their IP and made themselves pivotal in a large ecosystem of partners, thus creating a fairly secure central position.. Metalysis also built a strong patent portfolio around their technology.

6. Conclusions

In conclusion we highlight three contributions and some of their implications for management. First, based on case study evidence from two advanced materials ventures that achieved an outstanding level of value creation over the period of the study, we have identified market-oriented strategies appropriate for science-based ventures from among those found in the literature. We note that both of these firms carefully matched their strategy to their ecosystem, one limiting the need for downstream process innovations, and the other offering sufficient value to attract appropriate partners to help develop those complements and drive downstream adoption. Their strategies also showed evidence of ventures targeting high-value, mainstream markets as advocated by Utterback and Acee (2005) for high value innovations, rather than aiming at niche markets (Christensen, 1997). Second, we have applied and extended the ecosystem perspective to science-based ventures. We find this concept particularly useful for analysing these innovators in their business environment, concluding that science-based ventures need to identify the complements required by their ecosystem, but adding they must also carefully select suitable participants with whom to partner, and to attract the resources they need via those partnerships. Moreover the warning against interdependency risks of co-innovation and downstream adoption in recent ecosystem literature (Adner, 2012) applies in large measure to these ventures, as much as or perhaps even more so than in corporate environments. This has also led to recommendations for science-based entrepreneurs and managers. Thirdly, it is implicit in our study that resource based analysis of the firm can be fruitfully combined with ecosystem analysis, since resource availability was a key issue for these entrepreneurial innovators (Garnsey, 1998).

Conventional wisdom embodied in current academic and practitioner literature recommends that ventures commercializing high-tech innovations begin by targeting a niche market where they can establish a customer base and grow to dominate that niche without having to compete with from leading firms and attack incumbent firms in a wider market (Davidow, 1986; Christensen, 1997; Moore, 2002), to compete in multiple markets (Shane, 2004) or to compete in the market for technology (Teece, 1986; Arora, Fosfuri et al., 2001). However our evidence shows that these may not be an appropriate or realistic strategies for early, stage, resource-intensive, science-based innovators, such as advanced materials ventures. Advanced materials USOs often require significant external capital and resources such as scale-up facilities, complementary assets and wider market knowledge that are absent in most niches. They may also require significant co-development of innovations and IP for which large corporate incumbents are the most likely providers. Those partners are likely to prefer mainstream markets with many customers and are in better position than young ventures to compete in them directly. Partners with sufficient resources for co-development and scale-up are unlikely to contribute finance and assets over the required lead time unless the resulting process or product can be targeted at a large and/or sufficiently lucrative market. However, in order to secure such partnerships, the USO must demonstrate the potential for their innovation to generate sufficient commercial value, which is no small task, often requiring significant early stage finance. Another factor to take into account (not investigated here) is that it is well known that venture capitalists typically seek to support technologies with major market potential.

This has important implications for science-based entrepreneurs and managers. What we have shown in our case examples is that a niche strategy may not be viable for resource-intensive science-based ventures and that targeting one or a small number of closely related large markets where their innovations can add or augment performance for market leaders may be a more attractive alternative for value creation. To say that it may be necessary to target a broad market is not to say that this is easily achieved nor to overlook the dangers of dependence on powerful partners. Our cases also show that there are ways of mitigating interdependency risks by creating a network of partnerships and/or aiming to reduce reliance on complementary innovations. Where ventures have the resources and capability to integrate to the point where no further complementary innovation is required by other players in the ecosystem, this could decrease their dependency risks (Christensen, 2004; Adner 1012). The above evidence also shows that significant effort needs to be spent on identifying key players and complementors and on demonstrating the value creation potential of their technology in order to secure the commitment of other players in the innovation ecosystem (Maine and Garnsey, 2006; Adner, 2012) and speed up learning. However, with these types of strategies, the importance of developing and maintaining control of a strong IP portfolio central to the development of the ecosystem cannot be underemphasized.

While not the key focus of this paper, we have observed another key strategic consideration for these firms. The involvement and significant contributions of these partners and investors also has implications for the eventual exit strategy of these firms. Because of the long lead times and often millions of dollars in partner and financier investment, the short time to return promised by IT or service firms is unlikely to be realized by science-based firms, either through Initial Public Offering (IPO) or dividends. Instead, these collaborations may lead to acquisitions that may be one of the few attractive exits current available to founders and investors in this type of venture, which should be considered by founders and managers of science-based USOs. It also suggests that universities should take into account the extent to which any stake they have in a USO may be diluted by equity arrangements with partners and acquirers. Universities should work towards ensuring a fair return on their research input into the venture in conditions of acquisition and to promote partnerships with corporate players who have a good record in managing such acquisitions to the benefit of founders and employees.

In the course of this research, future areas for study have been identified. Further thinking could be devoted to ways to integrate resource-based theory of the firm with ecosystem analysis, for which space did not allow here, as both theories are concerned with value creation through resource building (Penrose, 1995) and resource attraction (Adner, 2012). The strategies found to be effective in our cases could be tested for statistical generalizability with a larger sample. As most firms in this sample had not yet reached profitability and wide-spread adoption of their technologies, future studies which re-evaluate the success of these strategies over longer time frames could be useful, following how power dynamics between firms evolve. Case studies which follow up the acquired unit after acquisition could also be very informative. The ecosystem perspective could also be usefully adapted and applied to science-based ventures which many face lower development costs, such as those involving clean-tech or photovoltaic materials and those effecting global healthcare. These ventures may provide solutions for mass-markets in emerging and developing economies, which may require entirely different strategies and partnerships with different players such NGOs, foundations and governments. In addition, it would be useful to investigate whether to compare our findings with evidence from life science ventures (in drug discovery, development and delivery) which currently have a lengthy and structured commercialization process.

In this paper, we have looked into the selection of market for science-based ventures and shown that this involves selection of an entire ecosystem. This decision is crucial, as such ventures are often heavily dependent on their environment to survive, let alone thrive. Further work on this topic is needed to improve understanding of a group of firms on which hopes of economic revival are pinned.

Resources

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