Initial and further business development: highlights from business model, open innovation, and knowledge management perspectives

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Abstract: In a technological spin-off, initial and further business development is a two-stage challenge of survival and growth. Spin-offs’ business development relies on the design and renewal of an adequate business model, effective open innovation, and advanced knowledge management. This study describes the initial and further business development of a successful spin-off, MEMS&Co, through a longitudinal case study. The business model benefited from specific revenue/investments streams from clients and was subsequently supplemented by new business models in novel applications. Open innovation offered a unique outside-in process from universities, suppliers, and research centres and then transformed into an advanced new process. Knowledge management focused on cross-technical knowledge modularity and subsequently on knowledge recombination.

Keywords: business development; survival; growth; entrepreneur; start-up; spin-off; business model; open innovation; knowledge management; case study; longitudinal; MEMS.

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1 Introduction

What is business development (BD)? For practitioners, BD entails increasing sales, creating partnerships, creating value for customers, organisational growth, geographical expansion into new markets, and development of new business models. From an academic perspective, the definition of BD remains unclear (Kind and Knyphausen-Aufseß, 2007; Daubenfeld et al., 2014), but may comprise ‘the tasks and processes concerning analytical preparation of potential growth opportunities [including] the support and monitoring of the implementation of growth opportunities’ [Sørensen, (2012), p.26]. The product-market matrix suggests four options for growth: market penetration, market development, product development, and diversification (Ansoff, 1965). As we argue that BD of a newly created venture and a mature firm differ, we study the distinction between initial business development (IBD) and further business development (FBD) for growth.

Those two stages of BD are especially challenging for start-ups having limited resources, funding, and market power, since these limitations may preclude them from conducting BD in a separate organisational unit (Kind and Knyphausen-Aufseß, 2007; Lorenzi and Sørensen, 2014; Daubenfeld et al., 2014). A start-up’s IBD and FBD are linked to entrepreneurial competences (Loué and Baronet, 2012) and the ability to develop and renew the business model (BM), open innovation (OI), and knowledge management (KM). During the IBD, start-ups design their first BM, mobilise external stakeholders through the OI outside-in process, and capture knowledge modules through compositeness. A mature start-up then has to pursue FBD to grow – to develop new BMs, continue mobilising external stakeholders through OI not only with outside-in processes but also with inside-out processes, and develop new technological applications through knowledge fungibility.

The BM is the realisation of strategy (Casadesus-Masanell and Ricart, 2010). BD may encompass one or multiple BMs. Consequently, we define BM as follows: “A business model is a rational and coherent activity system design and renewal, offering a flexible/viable revenue and cost structure to develop business, exploit business opportunities, span its boundaries, handle commercialisation, create, propose, and deliver product/service value to dedicated customers, and support organisational growth”.

BD is linked to OI because a firm requires both inputs and outputs relating to the external environment. OI is “the use of purposive inflows and outflows of knowledge to accelerate internal innovation, and expand the markets for external use of innovation, respectively” [Chesbrough, (2006), p.1]. OI is needed to keep pace with technological development, shorten innovation life cycles, manage technological convergence, increase product complexity, share R&D costs, and take advantage of the heterogeneity of demand.

To nurture IBD and FBD, firms benefit from various processes. The outside-in process allows IBD and survival through the sourcing of external knowledge. The inside-out process allows FBD and growth through the external exploitation of ideas in different markets. The coupled process allows both initial and further BD by linking outside-in and inside-out processes (Gassmann and Enkel 2004).

BD is linked to KM because knowledge is the most strategically significant resource in the knowledge-based view of the firm (Nonaka, 1994). In IBD and FBD, firms have to gather, generate, apply, and protect knowledge assets (Teece, 2000), and also assess the complementarity between internal and external sources of knowledge and between basic
and applied R&D (Cassiman and Veugelers, 2006). Entrepreneurs can foster IBD with knowledge compositeness to increase entrepreneurial actions (Smith and DeGregorio, 2002) and promote FBD by recombining and reusing existing knowledge (Kogut and Zander, 1992).

We are particularly interested in studying successful BD of spin-offs. The BM of spin-offs differs from that of regular start-ups (Chesbrough and Rosenbloom, 2002) since through incubation, spin-offs plan their BD and growth earlier than regular start-ups. While scholars have investigated corporate spin-offs (Chesbrough, 2010; Chesbrough and Rosenbloom, 2002) and university spin-offs (Lubik et al., 2013; Radu and Loué, 2008), research centre spin-offs have not been studied from a BM perspective.

We therefore address the following research question: “How does a successful spin-off handle both initial business development survival and further business development growth from the business model, open-innovation, and knowledge perspectives?”

In the following sections, we review the literature linking BD with BM, OI, and KM, describe the methodology used to develop an in-depth case study, analyse the narrative biography of a spin-off we call MEMS&Co, and discuss the two stages of BD.

2 Literature review

The literature review presents the BD theoretical framework and discusses IBD and FBD from the perspectives of BM, OI, and KM.

2.1 BD theoretical framework

2.1.1 Business model during the BD

BD as a corporate entrepreneurial capability has been designated as extremely important for SMEs to identify business opportunities, co-create value with customers, develop and maintain partnerships, and guide the deployment of resources (Davis and Sun, 2006). Customers participate in BD by being involved in product development to ensure that their needs are well integrated into firms’ operations, as well as to create value, assess the alignment with inter-firm activities, and ensure positive financial returns (Hunter, 2014). The value proposition to customers is a central aspect of BM.

2.1.2 Open innovation during the BD

Knowledge management, absorptive capacity, and dynamic capabilities are linked in an integrated OI framework. Six knowledge capacities are needed to manage OI: inventive (internal exploration), absorptive (external exploration), transformative (internal retention), connective (external retention), innovative (internal exploitation), and desorative (external exploitation) (Lichtenthaler and Lichtenthaler 2009). In OI, outside-in thinking is needed, along with a greater market orientation (Lorenzi and Sørensen, 2014), more specifically with the involvement of customers (Daubenfeld et al., 2014). Spin-offs particularly benefit from outside-in OI during incubation. At that stage, networks are particularly important, providing benefits such as the ability to identify
opportunities outside of start-ups, access to local resources through an incubator, and the ability to move quickly and build trust (Nicolaou and Birley, 2003).

2.1.3 **Knowledge management during the BD**

The creation of value and revenue from the development of products and technologies may entail the contribution of partners, customers, and stakeholders. Spin-offs are adequately equipped with relevant technical knowledge that addresses a particular clearly identified market segment. BD often requires the recombination of resources, including knowledge, knowledge flow across organisational boundaries, and the creation of value (Kind and Knyphausen-Aufseß, 2007) as well as the creation of new knowledge (Madhavan and Grover, 1998). The creation of new knowledge needs to consider the business relatedness (knowledge diversity/similarity) of BD activities which affects innovative performance (Keil et al., 2008).

Overall, we argue that BD requires interaction between BM, OI, and KM stemming from corporate entrepreneurial BD and knowledge capabilities. BM and OI are connected to identify business opportunities, support co-creation with customers, and guide partnership development. OI and KM are connected through the six knowledge capacities needed to manage OI. KM and BM are connected to coordinate the deployment of resources, create value/innovation, and develop technologies. We developed Figure 1 which captures the interaction between BM, OI, and KM.

**Figure 1**  BD theoretical framework linking BM-OI-KM
2.2 Initial business development

2.2.1 Business model during the IBD

The BM design is of great importance to IBD. The first BM must represent a rational and coherent activity system (Zott and Amit, 2010) offering sufficient flexibility (Smith et al., 2010; Schreyogg and Sydow, 2011) and a viable revenue and cost structure (Chesbrough and Rosenbloom, 2002; Zott and Amit, 2010; Teece, 2010) to exploit business opportunities (Amit and Zott, 2001). Such an initial BM creates, proposes, and delivers product/service value to dedicated customers (Chesbrough and Rosenbloom, 2002; Amit and Zott, 2001; Osterwalder and Pigneur, 2010; Teece, 2010). The first commercialisation of innovation is vital to the support of the early BD (Chesbrough and Rosenbloom, 2002; Chesbrough, 2010; Teece, 2010). To survive during the first few years, new ventures must capture related revenues (Chesbrough, 2010; Teece, 2010) not only for stakeholders (Casadesus-Masanell and Ricart, 2010) but also for themselves (Sosna et al., 2010).

2.2.2 Open innovation during the IBD

An open-innovation outside-in process is important in IBD. Of the three OI basic processes (Gassmann and Enkel, 2004), the outside-in process has sparked the greatest interest because organisations cannot achieve most of their goals alone within time constraints. New ventures in particular do not rely solely on internal knowledge to cope with limited resources and time, but collaborate with external partners (Lambe and Spekman, 1997; Swan and Allred, 2003). Firms increase the diversity of knowledge dynamics from external organisations (Tether, 2002) such as universities, governments, firms’ research and development departments, equipment suppliers, materials suppliers, downstream users, competitors, and public and commercial research institutions (Enkel et al., 2009; Gassmann and Enkel, 2004). As a first outcome of IBD, external knowledge combined with internal knowledge (Von Hippel, 1988; Pisano, 1990; Lane and Lubatkin, 1998) is transformed into product and service innovation (Christensen et al., 2005).

2.2.3 Knowledge management during the IBD

Knowledge compositeness refers to innovation and complexity as a result of combining several knowledge modules. The design and reconfiguration of modules within an original hierarchy simplify new product development (NPD) complexity (Hargadon and Eisenhardt, 2000; Baldwin and Clark, 2000b) and increase modular innovation (Clark, 1985; Henderson and Clark, 1990). Modularisation allows faster modular product innovation (Sanchez, 1999), which is important because of resource constraints of new ventures. Modularity is especially needed in the development of complex products. For example, product innovation in the computer industry mainly results from the management of smaller subsystems’ opening of new avenues for experimentation and value creation (Baldwin and Clark, 2000). Modularity allows firms “to make complexity manageable; to enable parallel work; and to accommodate future uncertainty” [Eisenhardt and Tabrizi, (1995), p.175].
2.3 Further business development

2.3.1 Business model during the FBD

The BM is also important to guide FBD and support organisational growth (Denicolai et al., 2014; Wei et al., 2014). Firms have to rethink (Doz and Kosonen, 2010), develop, and adapt (Wirtz et al., 2010) their BMs frequently and continuously, especially in uncertain and fast-moving environments (McGrath, 2010). A new BD is business activity outside the firm’s existing boundaries that explores the opportunities for growth beyond the existing technology base, product, market, and customers (Karol et al., 2002), requiring firms to innovate and change their position by using new BMs (Govindarajan and Trimble, 2005). As successful BD ensures a continuous stream of innovation (Sørensen, 2012), the strategic renewal of the BM is key to adapting to changing sources of value creation (Schneider et al., 2013). Firms engaging in FBD often face barriers to change (Chesbrough, 2010).

2.3.2 Open innovation during the FBD

Firms seek FBD and sustainable growth through multi-stakeholder governance mechanisms (Midtkandal and Sörvik, 2012) based not only on the outside-in process but also on the inside-out process. The inside-out process focuses on externalising the company’s knowledge and innovation to bring to the market ideas that do not fit the firm’s current BM. It enables companies to bring ideas to market faster than through internal development (Chesbrough, 2000, 2003; Maine, 2008), as well as to generate additional revenues by licensing IP and/or multiplying technology by transferring ideas to other companies (Gassmann and Enkel, 2004). BD and licensing in the biopharmaceutical industry represents an inside-out OI in which firms generate incomes from licensing their technologies because of rising costs of R&D: “all pharmaceutical companies these days require external collaborations to obtain products to supplement internal R&D” [Davies, (2013), p.52].

Outside-in and inside-out processes together constitute the coupled OI process. As the locus of innovation shifts from dyadic relationships to ecosystems, networks, and communities, demand is growing for research on collaborative mechanisms within multi-stakeholder partnerships (Vanhaverbeke et al., 2014).

2.3.3 Knowledge management during the FBD

Thanks to the transferability (Starr, 1965) of product modularity (Lau et al., 2011), in FBD firms may reuse knowledge modules in another product without much additional effort (Starr, 1965), and can explore domains far from their initial domain to multiply opportunities for innovation (Hipkin and Naude, 2006). Fungibility entails development of a basic module of knowledge within a broader product or different field of scientific development (Antonelli, 2003). The aim of developing fungible knowledge is to maximise the number of subsequent applications in FBD to spread quasi-fixed costs, benefit from economies of scale, and obtain a higher rent from general technology (Gambardella and McGahan, 2010).
2.4 Summary

We have argued that BM, OI, and KM are strongly embedded in BD and that IBD differs from FBD in several respects (Table 1).

<table>
<thead>
<tr>
<th>IBD</th>
<th>FBD</th>
</tr>
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<tbody>
<tr>
<td><strong>Single</strong></td>
<td><strong>Multiple</strong></td>
</tr>
<tr>
<td>BM design</td>
<td>BM renewal</td>
</tr>
<tr>
<td>Limited resources</td>
<td>Barriers to change</td>
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<tr>
<td>BM</td>
<td>Flexible/viable revenue and cost structure</td>
</tr>
<tr>
<td>Exploit initial business opportunities</td>
<td>Exploit further business opportunities</td>
</tr>
<tr>
<td>Creates, delivers product/service value</td>
<td>Creates, delivers product/service value</td>
</tr>
<tr>
<td>Captures the related revenues</td>
<td>Captures the related revenues</td>
</tr>
<tr>
<td><strong>Outside-in</strong></td>
<td><strong>Coupled</strong></td>
</tr>
<tr>
<td>Inflows of knowledge</td>
<td>Inflows and outflows of knowledge</td>
</tr>
<tr>
<td>Sourcing of external knowledge</td>
<td>Exploitation in different markets</td>
</tr>
<tr>
<td>Diversity of knowledge dynamics</td>
<td>Multi-stakeholder governance</td>
</tr>
<tr>
<td>Technological convergence</td>
<td>Technological leverage</td>
</tr>
<tr>
<td>Brings products/services to market</td>
<td>Brings ideas to market</td>
</tr>
<tr>
<td>Revenues from innovation</td>
<td>Revenues from IP licensing</td>
</tr>
<tr>
<td><strong>Compositeness</strong></td>
<td><strong>Fungibility</strong></td>
</tr>
<tr>
<td>Recombines knowledge modules</td>
<td>Reuses existing knowledge</td>
</tr>
<tr>
<td>Creates something innovative</td>
<td>Maximises applications</td>
</tr>
<tr>
<td>Modular innovation</td>
<td>Innovation multipliers</td>
</tr>
<tr>
<td>Shares R&amp;D costs</td>
<td>Spreads quasi-fixed costs</td>
</tr>
<tr>
<td>Faster pace of innovation</td>
<td>Broader innovation</td>
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IBD requires:

1. the design of a single BM in a flexible/viable revenue and cost structure, exploitation of initial business opportunities, creation/delivery of product/service value, and capture of related revenues

2. development of the outside-in OI process, access to external and diverse knowledge, technological convergence, and monetisation from innovative products/services sold on the market

3. the recombination of composite knowledge modules, quick creation of modular innovation, and sharing of R&D costs.

FBD requires:

1. the renewal of multiple BMs in a flexible/viable revenue and cost structure, exploitation of further business opportunities, creation/delivery of product/service value, and capture of related revenues
the development of the coupled OI process, exploitation of technology with different stakeholders in different markets, technological leverage, and monetisation from ideas and IP licensed on the market.

3 the reuse of fungible existing knowledge modules, broad maximisation and multiplication of applications, and the spread of quasi-fixed costs.

Managing IBD and FBD by maintaining a coherent alignment between BM, OI, and KM is a challenge for start-ups. Many start-ups fail during IBD (limited revenue, insufficient resources/knowledge, high costs, time constraints). Many more start-ups fail during FBD (increasing cost structure, identifying/exploiting business opportunities, leveraging technologies/getting value from IP licensing).

3 Methodology

The qualitative case study is used mainly to examine BM, OI, and KM (Amit and Zott, 2001; Chesbrough and Rosenbloom, 2002). We used an inductive approach to gain an in-depth understanding of issues, stakes, and influences to allow the theory to emerge from the data (Strauss and Corbin, 1998) collected through a single longitudinal case study at MEMS&Co.

This case was selected because of its richness (Neuman, 1997) and because the company experienced a successful IBD and FBD. The company has been able to move from a simple to a more complex BM, from an outside-in OI process to a coupled OI process, and from knowledge compositeness to knowledge fungibility. In addition, MEMS&Co has been very successful in a short period of time.

MEMS&Co develops and manufactures custom micro-electro-mechanical systems (MEMS) components and microsystems for specific applications of clients. With 44 employees and over €11 M of turnover (20% of exports), MEMS&Co plays an important role in the supply chains for MEMS components. We particularly explore the NPD of a captor that provides three-dimensional maps of the seabed, replacing conventional traditional mechanical seismic captors.

Initially, we adopted a retrospective approach aimed at becoming more familiar with the project, which started prior to our investigation (Miller et al., 1997). Interviews and written reports prevented us from distorting past facts. We then conducted periodic interviews to collect longitudinal data in real time (Pettigrew, 1990). The selection of interviewees was initially determined by the project leader.

In total, we conducted 15 interviews with ten researchers from CEA-LETI, research centres, engineering schools, and universities (Technical coordinator in electronics; Program manager of 'micro capture' product development; Specification of micro- and nano-technology-based product; Researcher in MEMS development; director of research; Research director of a joint laboratory; Former director of the Grenoble National Engineering School of Physics; Director of the Grenoble National Engineering School of Physics; Dean of engineering school at Grenoble INP; Director of Institut Néel), the founder and CEO of Tronics, three engineers/managers from Tronics (Chief Operating Officer, Production and R&D manager, Manager in charge of product testing), one supplier (Sales manager of Williams product in France). Interviews lasted on average
1 hour and 30 minutes (from 1 h to 2 h 25 min) and were recorded with informants’ permission. To avoid observer bias, a transcript of each interview was sent to interviewees for approval and eventual modification (Lincoln and Guba, 1985).

The data were collected in French on site over four years (2007–2010). To meet construct and internal validity, observations, documents, press articles, meetings minutes, communications, letters, memoranda, reports to shareholders, chief executives’ speeches and interviews with key informants were cross-checked through triangulation, which was very useful when comparing the point of view of various stakeholders (Easton, 1995; Miles and Huberman, 1994) and when assessing the internal validity of the study (Rosenthal and Rosnow, 1991; Dane, 1990). Observations conducted at both the research centre CEA-LETI and MEMS&Co provided data on how researchers and engineers collaborated and conducted tests on various products. Field notes described the participants, the specific task completed, and participants’ social behaviour. Triangulation revealed no significant discrepancies.

The unit for the content analysis of recorded data was the sentence (Insch et al., 1997). As we were not able to rely on existing ‘assumed categories’ (Insch et al., 1997) from dictionaries, we determined mutually exclusive categories (Weber, 1990). Coding, clustering, and reduction were done to obtain a code scheme developed after the first three interviews with project managers with the influence of the literature in the field (Strauss and Corbin, 1990; Araujo, 1995; Coffey and Atkinson, 1996). Although the EU-funded project EURODITE guided our large data collection, that project explores various research questions that are not addressed in the present article. The narrative biography of the case produced a patchwork or a global picture composed of a set of interviews, also called ‘components’ or ‘building blocks’ (Kwan, 2004; Strauss and Corbin, 1990; Wengraf, 2001; Yin, 2003). The veracity of the data depends on humanist criteria within case studies to increase the quality: credibility, transferability, dependability and conformability (Hirschman, 1986).

4 Analysis: narrative biography

The narrative biography focuses on geophones, which are extremely precise seismic sensors used to create three-dimensional maps of the seabed to locate oil deposits for further oil nape exploitations. We studied this NPD through four periods: traditional captor industry and MEMS emergence, combination of knowledge bits as a cumulative process, industrialisation of a composite-based product, and valorisation of vacuum technologies for new captor applications. IBD occurs in the first three periods and FBD in the last period.

4.1 Traditional captor industry and MEMS emergence (1994–1995)

In the 1990s, the captor industry was producing conventional electromagnetic mechanical captors built over time on a cumulative basis. In 1994, Sercel – a specialist in vibration captors for oil prospection – discerned that microelectronics and more precisely MEMS would lead to breakthrough innovation in replacement of electromagnetic vibration captors.
“Sercel didn’t know exactly what name to put on the next stage of technological progress, but they could sense it.... The customers were looking for the same thing as before. The only change is the need for more accurate and more precise device.”

Some background about the technology principle is in order. Before an off-shore platform is built, the prospection aims to determine where oil napes are located in the soil under the sea. Seismic captors are thrown into the sea and sink to the sea bottom. Once a great many captors are in place, heavy tooling on the coast is used to hammer the earth, creating a wave in the earth resembling a mini-earthquake. The captors measure the vibration and describe the propagation of the wave, the intensity, the quickness, and so on. Analysis of those data enables determination of oil napes’ location.

Sercel wanted to replace its technologies to keep its advances comparable to its American competitor (Input-Output) and was looking for a research laboratory to study technological options for its products. As a profit-making public institution, CEA-LETI (Nuclear Research Agency – Laboratory for Electronic and Instrument Technologies) evaluated possible contributions of micro technologies on the products. CEA-LETI is an applied research centre for MEMS, information and healthcare technologies, and provides a unique interface between industry and academic research by transferring innovative technologies and by managing 1,500 families of patents.

“Sercel was in search of new solutions for their current product. CEA was the one which was able to listen and address the need.... The decision to work with CEA and not with CNRS [National Institute for Scientific Research] can be explained by the fact that CNRS absolutely wanted to publish research in scientific journals to disseminate knowledge as something available for anyone. However,... customers want to buy and consequently protect their technological hedge, which cannot work with the purpose of public research.”

An R&D agreement, a technology transfer, and an exclusive license in geophysics between Sercel and CEA-LETI marked the beginning of a long-term partnership. They shared basic knowledge on the captor industry and on the MEMS. The partnership required complementarity between knowledge bits from intra- and extra-regional sources of knowledge, with Sercel located in Nantes providing the idea and CEA-LETI located in Grenoble providing the technology.

“The research contract between LETI and Sercel was an exclusive licensing agreement in the domain of geophysics.”

During this early stage, CEA-LETI faced physics laws making the realisation of such a specific captor impossible. Alternatives were to create a vacuum around the ship, directly on the ship, or within a packaging. Cross-sectorial and cross-technical approaches were required to address those options. CEA-LETI had to consider expectations of geologists and computer scientists, who wanted to shift from analogue to numeric signals to upgrade performances and increase the detection area. In 1994, those technological barriers pushed CEA-LETI to create 80% of knowledge bits through face-to-face collaboration and to use only 20% of the previous knowledge bricks.
4.2 Combination of knowledge bits as a cumulative process (1995–2004)

In 1995, this early feasibility study had been completed and three technologies were considered to be in the centre of the NPD: MEMS, ceramic packaging, and the chemical vacuum pump. To meet this need for expertise, Sercel and CEA-LETI were looking for suppliers and more especially a MEMS manufacturer that could provide adapted solutions.

“Sercel told us what oil prospection is about. They basically shared enough to make our MEMS captor well integrated.”

In 1997, CEA-LETI encouraged a top researcher to create a spin-off specialised in MEMS development and manufacturing: MEMS&Co, which was initially funded by venture capital sources, including Sercel.

“At first, Sercel was not too much involved, they were more like: Let’s wait and see. Then, Sercel was putting commitment in our company. The money was appreciated but that was beyond that....

CEA-LETI provided an exhaustive list of MEMS founders, including MEMS&Co, to let Sercel choose among them. After an impartial market study, Sercel signed a manufacturing agreement with MEMS&Co. As a sign of strong involvement, Sercel also took 10% of MEMS&Co’s shares.

Sercel had also signed formal supply agreements and manufacturing of sub-systems agreements with NTK (a Japanese firm designing ceramic packaging), Williams (an American firm specialising in packaging) and SAES Getters (an Italian firm having a monopoly on vacuum pumps), which constituted the first round of suppliers. In touch with Sercel since 1985, Williams strongly influenced knowledge dynamics and the technical specification of customer requests. To acquire particular manufacturing tools, Sercel also invested in Williams.

“After the pre-production, MEMS&Co financially participated to the equity stake of Williams by purchasing specific tooling which contributed to the production of 10,000 pieces in the US. Similarly, an equity stake purchase needs to be mentioned: Sercel is selling captors and trucks to CGG-Véritas, which is the owner of 100% of Sercel’s equity.”

Supporting the entire process, a second round of suppliers was involved, such as a supplier for CEA-LETI (cards development) and SET (development of materials for the manufacturing process). Additionally, knowledge dynamics were developed with GRENOBLE INP, UJF and CNRS, reinforcing the anchoring of its cluster. In France, Sermat (research centre) and the University of Besançon were involved. Globally, PFL (Polytechnics Federal School of Lausanne) in Switzerland, Fraunhofer (research centre in applied sciences) in Germany and Kyocera (firms specialised in ceramic packaging) in Japan were also involved.

“We had to innovate by using new materials to decrease the cost by replacement materials. Consequently, we have experienced a series of changes: aluminum-gold (expensive), silicon (abrasive), and then silver.”
In addition, the NPD had to address the divergence of interests, deadlines, and other operational stakes in an efficient technology and supply network where many activities (80% according to CEA-LETI) were dedicated to creation. Indeed, the research field was very new and required important fieldwork to overcome the lack of knowledge on MEMS under vacuum and realise prototypes between 2002 and 2004.

4.3 Industrialisation of a composite-based product (2004–2011)

Once prototypes had been developed, the knowledge biography studied the industrialisation and manufacturing of a seismic captor dedicated to oil prospecting, which was composed of MEMS, ceramic packaging, and a chemical vacuum pump. Intensive collaboration resolved engineering issues of reliability and process reproducibility.

“There is a need for complementary knowledge across diverse fields where we try to assemble micro-technology bricks.... To develop prototypes, we combine three bricks of knowledge on micro electro mechanical systems, ceramic packaging and chemical pump.”

The first round of suppliers was identical: NTK, Williams, and SAES Getter. As a unique French firm able to handle technical assembly of MEMS, packaging, and a chemical vacuum pump, HCM was in charge of the assembly. New knowledge dynamics were developed between CEA-LETI, MEMS&Co and other research centres such as Sermat and Novatec for the industrialisation.

“The product specification of Sercel was very simple and precise: Measure 0.1 G with an error of 1/1.000.000 (Captor 120 DB). To give you a comparison, the precision of a car air-bag is 1/1.000.”

In addition to selling 180,000 seismic captors in 2008, Sercel was selling special trucks able to create important vibrations on the earth with heavy tooling to CGG-Véritas (General Geophysics Company), which owns 100% of Sercel. All those products are high-tech and long-lasting. Afterwards, to sell maps of the ground, CGG-Véritas conducted an ultrasound scan of the sea depths. Those maps are sold to states that control oil concessions and access for oil exploitations.

4.4 Valorisation of vacuum technologies for new captor applications (2004–2011)

An overlap occurs between industrialisation and valorisation. Valorisation extends beyond a single application for oil prospecting. Indeed, the same kind of vacuum
technologies for MEMS might have various applications and a higher return on investments, which is strongly linked to the notion of fungibility.

“The MEMS seismic captor is part of the accelerometer family. We had to be specialised on one segment first among three: Geophone (great precision), airbag captor (medium precision), the Wii (low precision).”

Because technical specifications of the oil prospection sensor were very high (captor 120 DB at 0.1G with a precision of 1/1,000,000), the aim was to maximise the use of knowledge and to limit new knowledge creation by reusing knowledge without increasing costs. This BM would be based on a trans-sectorial new product, new market, revolutionary applications and disruptive innovation.

“This technology, as it is now, can be transferred to Ulis, Sofradir, PACA, to produce new types of bolometers (measurement by night, night vision, and infra-red).”

Today MEMS&Co is developing new applications for sensors, micro fluidics and bioMEMS, RF MEMS foundry and optical MEMS.

Additionally, the NPD team identified five major potential applications in different sectors: sciences, the military industry, the automotive industry, healthcare, and the game industry.

“We try to multiply the possibility to sell our product across industries: automotive, oil prospection, etc.... We have numerous application opportunities such as in the aeronautics, infra-red or automotive.”

Related to healthcare, biotechnologies applications such as medical captors are also possible, and related to the game industry, the Wii captor is also part of the accelerometer family which does not require high precision and vacuum. Such applications would be very new and driven by mass production at a very different scale and pricing. Such trajectories would definitely diversify activities and the portfolio of the BM.

“It would be interesting to have a biotech application. Located in Meylan, ELA develops solutions for the human body. However, we have to consider that there is a clear wish from this particular market that MEMS should be the most basic.”

Figure 2 presents the entire knowledge biography of MEMS&Co by focusing on BM, OI, and KM. The BM, which is central to our work, is characterised by a value chain in Figure 2. In the original IBD the BM was highly complex, with multiple stakeholders. This complexity presented a challenge in offering a fair sharing of revenues across stakeholders and in balancing costs, revenues, and investments. In the FBD, five additional value chains were created (science, military, automotive, healthcare, game applications), offering the possibility of increasing the return on R&D expenditures/return on investment and of having a balanced portfolio of activities across various industries.

OI is characterised in Figure 2 by small arrows starting from the value chain to external stakeholders. In the IBD, CEA-LETI research that would result in the birth of MEMS&Co was very active in involving external stakeholders through the outside-in process. Research centres, universities, and firms were mobilised locally in Grenoble, nationally, and internationally. In the IBD, MEMS&Co still benefited from inflow of knowledge from existing stakeholders. What was new was the use of an inside-out
process. Indeed, the inside-out process requires taking existing internal knowledge to new industries, which allows horizontal diversification and potential economies of scale across industries.

The KM perspective appears in the timeline at the bottom of Figure 2. In the IBD, MEMS&Co aimed to guarantee complementarity between knowledge bits from different stakeholders. OI and KM are strongly embedded. MEMS&Co developed an outside-in process by capturing technological bricks, which were themselves cumulative. In the FBD, MEMS&Co developed fungible applications by developing inside-out OI.

**Figure 2** Knowledge map from a BM, OI, and KM perspectives

5 Discussion

Our discussion distinguishes the IBD from FBD from the perspectives of BM, OI, and KM and offers several propositions.

5.1 Initial business development

In the IBD, the design of the BM is very important to the spin-off’s survival. In defining its initial BM, MEMS&Co anticipated the maturing and decline of the industry producing classic electromagnetic captors and offered a radical innovation using MEMS in precise captors, and was able to successfully deliver its products to Sercel. The replacement of an analog signal by a numeric signal was justified by its significant increase in the detection area. The first commercialisation of innovation was vital for MEMS&Co to support its IBD.

MEMS&Co was able to design a viable BM by balancing R&D costs and limited streams of income. The IBD of MEMS&Co not only had revenue streams from clients but also investment streams, an aspect not explored in the field of BM. Having 10% of MEMS&Co’s equity, Sercel is both a client and a shareholder, providing a blended revenue-investment stream that is oil industry-specific. As all stakeholders of the value chain own shares upstream and downstream in the value chain, BM stability and sharing of the related revenues are guaranteed. Those insights from this industry add to the existing literature on value capture (Casadesus-Masanell and Ricart, 2010) and on BM viability (Chesbrough and Rosenbloom, 2002; Zott and Amit, 2010; Teece, 2010).
Initial and further business development

Proposition 1 In IBD, the design of a spin-off’s BM needs to
a) consider evolution of the industry to forecast new value propositions to potential customers
b) balance R&D costs and revenue/investment streams from clients to ensure BM viability
c) encourage cross-equity in the entire value chain to guarantee BM stability and revenue sharing across stakeholders.

Of the three OI basic processes (Gassmann and Enkel, 2004), the outside-in process dominates the IBD stage. To manage technological convergence and increasing product complexity, in the IBD stage MEMS&Co mobilised diverse external organisations, including research centres, universities, and suppliers. First, MEMS&Co benefited from outside-in processes from CEA-LETI and CNRS, Sermat, Novatec, and Fraunhofer. Employing an efficient inside-out process, CEA-LETI created the spin-off MEMS&Co and generated revenues from IPR’s royalties. Second, MEMS&Co benefited from university outside-in processes from GRENOBLE INP, UJF, the University of Besançon, and the Polytechnics Federal School of Lausanne. Third, MEMS&Co benefited from suppliers’ knowledge, especially the first round of suppliers: NTK, Williams, and SAES Getters. Such an outside-in process relies on trust stemming from the conventional client–supplier relationship, where suppliers influence knowledge dynamics and technical specifications. The second round of suppliers offered outside-in insights but with a greater cognitive distance. Prior research has advanced the need to use external knowledge in combination with internal knowledge (Von Hippel, 1988; Pisano, 1990; Lane and Lubatkin, 1998). In the case of a spin-off like MEMS&Co, the sources of external knowledge are suppliers and university outside-in processes, while the source of internal knowledge is, in the end, also external from research centres. In line with the literature on OI, we argue that spin-offs are a unique structure able to rely on external knowledge exclusively during the IBD stage.

Proposition 2 In IBD, spin-off offers a unique structure which exclusively benefits from the outside-in process mobilising
a) external knowledge from a great diversity of regional, national, and international organisations (universities and suppliers)
b) internal (externally developed) knowledge from research centres’ inside-out process.

In the IBD stage, KM is particularly important. Our study investigated the need for complementarity between knowledge bits from intra- and extra-regional sources of knowledge and between different stakeholders (firms, research centres, and universities). In the development of the oil captor, cross-sectorial and cross-technical knowledge was needed to bring together the three main technologies (MEMS, ceramic packaging, and the chemical vacuum pump). MEMS&Co was able to create an innovative and complex captor thanks to composite knowledge from Sercel, CEA-LETI, NTK, Williams, and SAES Getters. However, once those relationships had been developed, cumulative knowledge became increasingly significant in developing technological bricks such as the vacuum, the deep engraving, parametric, and so on. Continuous improvement in the technological bricks was necessary to ensure quality. Compositeness positively affected
modular innovation (Clark, 1985; Henderson and Clark, 1990) and allowed MEMS&Co to develop captors at a faster pace.

Proposition 3 In IBD, spin-offs need to
   a. guarantee cross-sectorial and cross-technical complementarity between knowledge bits from different stakeholders
   b. enable the firm to bring together different technologies into a modular and complex innovation
   c. benefit from knowledge compositeness capturing cumulative technologic bricks.

5.2 Further business development

From a successful IBD, MEMS&Co developed a successful FBD BM including sciences and the military, automotive, healthcare, and game industries. Instead of adapting the BM and changing its position with respect to barriers to change (Chesbrough, 2010), MEMS&Co created multiple new BMs. MEMS&Co’s flexible structure allowed reuse of income from the existing BM to finance new BMs, which aimed at shifting from the commercialisation of oil prospecting to the valorisation of it. Value creation comes from the reuse of vacuum technologies in novel applications and allowed MEMS&Co to develop trans-sectorial new products, new markets, revolutionary applications, and a disruptive innovation. The value capture of the new BMs was designed to increase return on investments from the IBD.

Proposition 4 In FBD, a spin-off needs to multiply the number of new BMs to
   a. reuse incomes from the existing activities to finance new activities
   b. reuse technologies in novel applications’ value propositions through valorisation
   c. exploit business opportunities in multiple industries
   d. capture value that increases return on investments from the IBD
   e. support organisational growth.

In the FBD stage, MEMS&Co did not necessarily use the inside-out process to generate new streams of revenue from IPR licensing and technology transfers to external partners. Instead of externally exploiting ideas in different markets, MEMS&Co internally exploited ideas in different markets. The ability to develop an ‘inside-in process’ offered the possibility of linking diversification horizontally and benefiting from risk sharing across industries and economies of scale and scope linked to the strong strategic fit across products’ value chain.

During the FBD, MEMS&Co did not externalise its knowledge and innovation, and internal corporate venturing did not prevent MEMS&Co from meeting the time to market. Collaboration with external stakeholders allowed MEMS&Co to achieve timely FBD. More specifically, MEMS&Co developed local multi-stakeholder governance to
develop further military application with Ulis (Veurey), Thales (Valence), and Sofradir (Grenoble) or healthcare applications with ELA (Meylan).

Proposition 5 In FBD, a spin-off needs to benefit from an inside/outside-in process we define as a blending of an ‘inside-in process’ pursuing internal corporate venturing and an ‘outside-in process’ benefitting from external sources of knowledge instead of implementing the coupled process. An inside/outside-in process enables the spin-off to benefit from
a horizontally linked diversification
b risk sharing across industries
c economies of scale and scope linked to its strong strategic fit across products’ value chain
d local multi-stakeholder governance within its surrounding cluster of innovation.

In FBD, KM focuses on aspects different from those in IBD. Since the original captor was of the highest precision and technological development is highly transferable, MEMS&Co reused its technologies without much additional effort. MEMS&Co is currently developing new applications for sensors, micro fluidics and bioMEMS, RF MEMS foundry, and optical MEMS. The reuse of the initial oil captors is viable for developing earthquake captors, night measurement captors, air bag captors, medical captors, Wii captors, and so on. MEMS&Co identified FBD and developed new applications by recombining and reusing existing knowledge (Kogut and Zander, 1992). As a ‘innovation multiplier’ (Gassmann et al., 2011), MEMS&Co benefited from strong knowledge fungibility by reusing knowledge in different products, fields, and industries. KM positively affects financial results since the IBD costs are divided by the number of FBD. Fungible knowledge brings higher rent from a general technology reused in different contexts (Antonelli, 2003; Gambardella and McGahan, 2010).

Proposition 6 In FBD, a spin-off needs to easily recombine and reuse existing knowledge and technologies to
a develop new applications in different contexts
b benefit from knowledge fungibility
c have better returns from the initial knowledge development
d generate higher rent from general technology reuse
e become an ‘innovation multiplier’.

Overall, we distinguish IBD, characterised by a single BM, an outside-in OI, and composite KM, from FBD, characterised by multiple BMs, an inside/outside-in OI, and fungible KM (Figure 3). We argue that the single BM of the IBD finances the multiple BMs of FBD. We also argue that the outside-in OI of the IBD is diversified with the addition of the inside-in OI, together becoming the inside/outside-in OI in the FBD. Finally, we argue that the composite KM of the IBD is reused as fungible KM of the FBD.
6 Conclusions

Our article offers definitional, theoretical, and empirical contributions. First, we provide a definitional distinction between IBD and FBD for growth. We specifically focused on IBD and FBD of start-ups with limited resources, funding, and market power. Second, we offer a BD theoretical framework that integrates three complementary streams of literature: BM, OI, and KM. Third, we explore the similarities and differences between IBD and FBD from the perspectives of BM, OI, and KM, leading to a definition of those two distinctive BD stages. Fourth, we empirically study the evolution of BM, OI, and KM from IBD through FBD. We argue that in a successful spin-off, a shift occurs from single to multiple BMs, from outside-in OI to inside/outside-in OI, and from composite KM to fungible KM.
Our study is subject to a few limitations. A common limitation of a single longitudinal case is uniqueness and the non-generalisability of findings. We studied one spin-off from a research centre and thus cannot compare our results to other types of spin-offs. In addition, retrospective biases may exist in the exploration of events that occurred before we began collecting data.

Our study suggests a number of questions for further research. From a BM perspective, how can a spin-off identify future industry life-cycle evolution to best define its value proposition to potential customers? Do revenue/investment streams from clients and cross-equity foster BM stability and viability in other industries? From an OI perspective, what are the main differences between technological spin-offs and regular start-ups in terms of OI processes? What are other alternatives to the outside-in, inside-out, and coupled processes? From a KM perspective, how does the firm combine knowledge complementarity, cumulability, compositeness, and fungibility for knowledge, technologic bricks, and products/services? How can the firm use fungible knowledge to develop ad-hoc commercialisation to meet industry specifications? These questions demonstrate that both initial and future BD offer a very challenging research agenda.

References


Initial and further business development


