Removing Bottlenecks in Business Ecosystems

The Strategic Role of Outbound Open Innovation

Masucci, Monica; Brusoni, Stefano ; Cennamo, Carmelo

Document Version
Accepted author manuscript

Published in:
Research Policy

DOI:
10.1016/j.respol.2019.103823

Publication date:
2020

Removing Bottlenecks in Business Ecosystems: The Strategic Role of Outbound Open Innovation

Monica Masucci, Stefano Brusoni, and Carmelo Cennamo

Journal article (Accepted manuscript*)

Please cite this article as:
Masucci, M., Brusoni, S., & Cennamo, C. (2020). Removing Bottlenecks in Business Ecosystems: The Strategic Role of Outbound Open Innovation. Research Policy, 49(1), [103823]. https://doi.org/10.1016/j.respol.2019.103823

DOI: 10.1016/j.respol.2019.103823

REMOVING BOTTLENECKS IN BUSINESS ECOSYSTEMS: THE STRATEGIC ROLE OF OUTBOUND OPEN INNOVATION

Monica Masucci[a1], Stefano Brusoni[b], Carmelo Cennamo[c]

[a] University of Sussex Business School, Department of Strategy and Marketing, Jubilee Building, Falmer, BN1 9SL, Brighton, UK. Email: m.masucci@sussex.ac.uk

[b] ETH Zurich, Department of Management, Technology and Economics, Weingberstrasse 56/58, 8092, Zurich, Switzerland. Email: sbrusoni@ethz.ch

[c] Copenhagen Business School, Department of Strategy and Innovation, Kilevej, 14A DK-2000, Frederiksberg, Denmark. Email: cce.si@cbs.dk

Abstract

This paper investigates how firms can orchestrate outbound open innovation strategically to accelerate technological progress among the firms they collaborate with, thus removing technological bottlenecks in their business ecosystem. We examine how a major oil and gas producer fostered, through its internal corporate venture unit, the development of new technologies aimed at enhancing the effectiveness of the oilfield services offered by its key providers. The comparative analysis of five innovative projects suggests that two factors were critical for the successful deployment of the proposed technologies: their potential to broaden service providers' portfolios and the possibility to retain control over the relevant intellectual property. The concurrent presence of these two factors incentivized service providers to deploy the new technologies, aligning their interests with those of the oil major company. By revealing unexplored aspects of the interplay of inter-firm collaborations and open innovation processes, this paper extends our understanding of how firms can align the incentives and activities of other actors in their business ecosystems by strategizing their open innovation initiatives.

Keywords: business ecosystem, open innovation, technology bottleneck, corporate venturing

Accepted manuscript.

Formal publication: Masucci, M., Brusoni, S., and Cennamo C. (2019). Removing bottlenecks ecosystems: The strategic role of outbound open innovation. Research Policy 48 (2019). https://doi.org/10.1016/j.respol.2019.103823

[1] Corresponding author.

1. Introduction

Several industries have seen dramatic changes in their vertical structures in recent decades, shifting from integration to disintegration and, in some cases, reintegration of value-chain activities (Dietl et al., 2009; Jacobides, 2005; Kapoor, 2013). Changes in sectors' vertical scope redefine the structure of interdependencies between industry participants, and thus affect capability development, value creation and appropriation patterns within sectors (Baldwin, 2015; Cacciatori and Jacobides, 2005; Jacobides and Winter, 2005). A key implication is that the firm controlling the core asset(s) upon which other firms build to offer their complementary products and services can become the leading player, or "hub firm", of the emerging business ecosystem (Jacobides et al., 2018) and capture above-average rents in the sector (Baldwin, 2015; Jacobides et al., 2006).

However, value must be created in the first place. Recent research suggests that cooperation with other firms whose activities are interdependent is essential to enable technology advancements in highly interconnected business ecosystems[2] (Adner and Kapoor, 2010; Iansiti and Levien, 2004; Pisano and Teece, 2007). Yet, specialized firms may have little incentive to invest in developing novel technological solutions that primarily benefit the hub firm. This undermines the hub firm's capacity to create value (Adner and Kapoor, 2016; Cennamo, 2016) because specialized firms' activities become a critical technological bottleneck. While the ecosystem literature highlights the critical role of bottlenecks as constraints to value creation, it offers limited insights into how the hub firm can remove them (Jacobides et al., 2018). Thus, we ask: *how can the hub firm remove technological bottlenecks in the business ecosystem?*

Some studies point to vertical integration as a possible solution to dispel bottlenecks and manage ecosystem interdependencies (Adner and Kapoor, 2010; Hannah and Eisenhardt, 2016). However, vertical integration may not always be a viable or attractive option for firms. Therefore, identifying alternative strategies to address bottlenecks and to align the activities of other ecosystem actors is crucial. We propose that a hub firm may leverage outbound open innovation (OOI) – the practice of commercially exploiting assets and internal inventions outside firms' boundaries (Chesbrough, 2006b) – to induce firms that provide complementary services/products to accelerate technological progress, and thereby to resolve technological bottlenecks. Prior research suggests that firms can use OOI to generate additional revenue

[2] A business ecosystem defines the structure of interdependence of a set of firms that need to interact for a focal value proposition to materialize, or for inter-firms' specific complementarities to be achieved (see Adner, 2017; Jacobides et al., 2018).

streams (Alexy et al., 2009; Bidault, 2004; Chesbrough, 2007), to obtain access to complementary knowledge, to establish new industry standards and to expand the market for their products and services (Grindley and Teece, 1997; West, 2003). Where coordination costs are high, OOI can become a strategic mechanism to coalesce other firms around the hub firm's innovation and foster collaboration in an ecosystem, fomenting complementary innovation that can lead to the co-creation of new products and markets (Chesbrough and Garman, 2009; Leten et al., 2013). We extend this and the ecosystem literature by uncovering the mechanisms underlying this strategic orchestration process; that is, how the hub firm can use strategically OOI to influence other actors in its business ecosystems.

Focusing on the upstream oil and gas industry, we compare and contrast the deployment fortunes of diverse OOI projects carried out by a major oil and gas producer through its internal corporate venture unit. These projects were initiated in areas that the producer typically outsourced, in the hope of enhancing the effectiveness of providers' complementary services through the deployment of novel technologies. While each project led to the discovery of a superior and viable technical solution, only those projects that also had the potential to broaden the service providers' portfolios were deployed. Retaining control over the intellectual property (IP) of the novel technology was also critical for the oil major to incentivize service providers to adopt it, enabling them to unlock value from it. More generally, our study documents how OOI can be used strategically to align innovation activities within the ecosystem and induce firms performing complementary activities to adopt novel solutions, thus removing technological bottlenecks and enhancing value creation.

These findings advance our understanding of OOI and its strategic role for a firm whose core activities are highly interdependent with those of providers of complementary services. We extend the literature by suggesting that a hub firm can reinforce its core business activity by aligning other firms' incentives in the ecosystem and promoting technological progress in complementary activities through the strategic orchestration of OOI. As recently highlighted by Vanhaverbeke and Cloodt (2014), the important link between a firm's strategy and its OI activities warrants further investigation, particularly as concerns the possible strategic uses of OOI. Our study contributes to this line of research by shedding light on key factors enabling the hub firm to use OOI strategically to resolve its external technological bottlenecks.

The remainder of the paper is organized as follows. After reviewing relevant literature, we illustrate our data and methods, providing a detailed description of the empirical context in which our study is grounded. Next, we present our findings and discuss how they inform extant research on OI and business ecosystems. We conclude by acknowledging the key limitations of our study and suggesting avenues for future research.

2. Background

The way in which the different activities in an industry's value chain are coordinated and divided up among firms has important implications not just for value capture (e.g. Jacobides et al., 2006; Porter, 1980), but also for value creation, because it influences firms' ability to develop and market their innovations (Adner and Kapoor, 2010; Hannah and Eisenhardt, 2016; Jacobides and Tae, 2015). Patterns of division of labour shape industry knowledge bases and the related trajectories of capability development (Brusoni et al., 2001; Brusoni and Prencipe, 2006), influencing firm-level innovative dynamics (Jacobides and Winter, 2005). As co-specialization emerges and consolidates, firms' unilateral attempts to change their sectors' vertical structures may meet strong resistance from other industry participants (Ferraro and Gurses, 2009; Jacobides, 2008; Scott et al., 2000) – even if this results in gradual technological obsolescence, unmet customer needs and a lack of capability development.

In managing the interdependencies arising from joint value creation, hub firms must deal with the challenges of coordinating the complementary activities of other firms in their ecosystems on whom they depend to unlock value from their core business activities (Adner and Kapoor, 2010). Apple, for instance, has to steer the development and marketing activities of an array of app developers to expedite the creation of complementary products that can enhance the value of its iPhone for final users (Kapoor, 2018). To align their incentives and coordinate their activities, Apple uses technology standards and platform interfaces, and sets market participation rules (Jacobides et al., 2018).

There is increasing evidence from the emerging literature on business ecosystems of how incentive misalignment or technical challenges experienced by "complementors" – firms specializing in products and services that are complementary to a hub firm's core technology/business – can constrain the production and supply of the required complements (Adner and Kapoor, 2010; Adner and Kapoor, 2016; Hannah and Eisenhardt, 2016). This creates bottlenecks (Baldwin, 2015) in the complements concerned, undermining the value-creation capacity of the hub firm. Thus, a strategic problem for the hub firm is how to dispel these bottlenecks and align the complementary activities of other actors. It is a complex issue since, unlike typical buyer-supplier relationships, specialized firms in business ecosystems are autonomous in terms of what they do, and how (Gulati et al., 2012; Jacobides et al., 2018).

While prior research has documented the existence of bottlenecks in different ecosystems (Baldwin, 2015), it provides limited evidence of how a hub firm can address them. Some studies discuss vertical integration into the complementary activities underlying the bottleneck components as a possible solution but highlight that this may trigger value-capture tensions that can ultimately impair joint value creation (Zhu and Liu, 2018). In his study on the US videogame industry, Cennamo (2016) shows that providers of videogame consoles, in order to address the bottlenecks in complements (i.e. videogames) that were holding them back from the launch of next-generation consoles, initially produced videogames in-house. However, in doing so, they entered into competition with external game developers with whom they needed to partner in order to create value for gamers, with detrimental effects on performance.

Besides the drawback highlighted above, vertical integration into the activities underlying bottleneck components may not always be viable, since firms may lack the required resources and capabilities. Therefore, alternative strategies to address bottlenecks need to be identified. Recent studies have pointed to OI as a potential mechanism to elicit collaboration around a core innovation (Chesbrough et al., 2014). In this view, by opening part of its innovation activity to other players, the hub firm can build collaborative relationships with multiple actors and direct complementors' activity (Alexy et al., 2013; Chesbrough et al., 2014; Leten et al., 2013).

2.1 OOI and its strategic use

OI models (Chesbrough, 2006a; Gassmann, 2006) can help explain how firms strategically manage their boundaries to accelerate new technology development and adoption (Jacobides and Billinger, 2006). Particularly relevant in the context of the present study is OOI, which has steadily increased over the last decade (Arora and Ceccagnoli, 2006; Gambardella et al., 2007; Grönlund et al., 2010; Tranekjer and Knudsen, 2012; Chesbrough and Brunswicker, 2014).

Firms pursue external knowledge exploitation for both monetary and strategic reasons (Fosfuri, 2006; Rivette and Kline, 2000). By selling or licensing-out their technologies, they may fully capitalize on their internal knowledge, generating additional revenue streams (Alexy et al., 2009; Bidault, 2004; Chesbrough, 2007). In this regard, OOI has often been associated with the use of strong appropriation mechanisms (Dahlander and Gann, 2010; West, 2006). Yet, besides monetary considerations, there are a number of strategic objectives that may drive them to engage in outbound open innovation, as summarized in Table 1. They include establishing new industry standards, gaining access to complementary knowledge through cross-licensing agreements and growing the market for their products and services (Grindley and Teece, 1997; Lichtenthaler, 2010; West, 2003).

More recently, scholars have suggested that firms can use IP-sharing and free revealing strategies to elicit collaboration from other actors in their business ecosystems and to shape the direction of their innovation activities (Alexy et al., 2013; Jeppesen and Lakhani, 2010; Leten et al., 2013). Others have also highlighted that firms can leverage open collaboration platforms to share knowledge and ideas with other members of their ecosystems, and accelerate the development and commercialization of complementary innovations (Chesbrough and Garman, 2009). While these studies have enriched our understanding of the strategic objectives underlying firms' use of OOI, shedding light on its potential to foster collaboration in ecosystems, they offer limited insights on how to achieve that. In particular, the mechanisms through which firms may entice other ecosystem actors to exploit the knowledge that they internally developed and intentionally shared remain poorly understood.

Prior research on desorptive capacity and outward technology transfers highlights that many firms fail to achieve the benefits sought from their OOI initiatives due to their limited ability to identify opportunities for external knowledge exploitation (Lichtenthaler and Lichtenthaler, 2010). It also highlights that the reasons driving a focal firm to externally exploit its knowledge influence its decisions in terms of IP management and organizational structure (Ziegler et al., 2013). To tackle the challenges arising from the external exploitation of their knowledge assets, many firms establish dedicated organizational units (Bianchi, et al., 2011; Chesbrough and Winter, 2014). These organizational vehicles expedite the external exploitation of internal ideas and technologies by leveraging specific resources and skills, and orchestrate commercial deployment for projects lacking internal applications (Vanhaverbeke et al., 2008).

(Table 1 about here)

Although recent studies have contributed to shed light on the organizational implications of OOI processes and on the challenges they pose (Chiaroni et al., 2011; Mortara and Minshall, 2011), questions about their underpinning mechanisms remain. Extant research has primarily focused on the firm-level determinants of outbound initiatives, neglecting their critical interdependencies with the activity of other firms in the ecosystem and with their project-related decisions (Vanhaverbeke et al., 2014). The need to complement firm-level analyses of OI with research at other levels has been repeatedly highlighted (West et al., 2006; Chesbrough and Bogers, 2014), but with little progress as yet. Heeding the call for multi-level research on OI

(West et al., 2014), our exploratory study captures how firms embed OOI projects in their ecosystem strategies, uncovering the mechanisms they use to accelerate technological progress in their complementary activities, thus removing external technological bottlenecks.

3. Data and methods

We address our research question by studying how a hub firm leveraged outbound open innovation to prompt the deployment of new technologies by other actors in its ecosystem, which, in turn, enabled the hub firm to remove external technological bottlenecks. We followed a qualitative research approach (Miles and Huberman, 1994). We chose a method based on the comparative study of five OOI projects supported by the internal corporate venture unit of a focal oil and gas company to explore the mechanisms and factors that enabled the projects' successful deployment, and ultimately influenced their uptake by external actors (Eisenhardt, 1989; Yin, 2014). We selected innovative projects dealing with upstream activities that had been outsourced to oilfield service providers and compared them across several dimensions to uncover the elements that led to their different outcomes in terms of deployment. Below we describe our research setting and empirical strategy, illustrating our data collection and analysis.

3.1 Research setting

The oil and gas industry has traditionally been characterized by high levels of vertical integration (Inkpen and Moffett, 2011). For over a century, oil majors such as BP, ExxonMobil, Shell and their predecessors have been managing activities ranging from oil and gas exploration to retailing gasoline and other refined products. However, starting from the early 1980s, their vertically integrated structures were partially dismantled, changing the scope of their activities (Yergin, 2008). In addition to divesting non-core assets, oil majors outsourced activities that yielded low margins – such as oilfield services, marine transportation and IT – to external contractors (Cibin and Grant, 1996). The emergence of specialized firms along the value chain progressively eroded the advantages of vertical integration, increasingly inducing oil majors to rely on intermediate markets for technology-intensive activities too (Bozon et al., 2005; Gooch, 1997). This applied particularly to the upstream area of the industry (see Figure 1), where oilfield service providers (both large diversified firms and specialized niche ones) began to pioneer advanced technological solutions in activities such as seismic testing and reservoir characterization, well completion and drilling.

(Figure 1 about here)

Over time, oil majors' increasing reliance on their oilfield service providers for new technology development has profoundly altered the balance of power (Bagheri and Di Minin, 2015; The Economist, 2012). Today, the industry's technology leaders are large diversified service companies such as Halliburton, Schlumberger and Baker Hughes, which provide complete solutions across a wide spectrum of technology fields. In contrast, most oil majors orchestrate work performed by service companies. Their expertise in several upstream areas has, thus, progressively faded away, leaving them critically dependent on the technologies developed by oilfield service providers (Acha and Cusmano, 2005; Pellegrini et al., 2012).

With the depletion of most easy-to-access oilfields, and the consequent need for oil majors to use advanced technologies to unlock new reserves in remote and hostile environments, the daunting consequences for value creation of this dependency became apparent. On one hand, the demand for specialized equipment and novel solutions from service companies has grown dramatically over the past decade, often exceeding supply (The Economist, 2012). On the other hand, oilfield service providers have generally focused on incremental technologies, leaving oil majors' quest for more radical developments unattended. Given the high risks and cost of failure associated with the development of breakthrough technologies, they had little incentive to pursue them, which explains the slow pace of technological progress in the industry (Lloyd's Register Energy, 2014; Perrons, 2014).

The company we investigated, Elektra (a pseudonym), is a key player in the upstream oil and gas industry and is widely regarded as an innovative leader. In the mid-90s, to promote long-term and step-changing innovations, Elektra created an internal corporate venture unit called BV (a pseudonym) which offers creative people an outlet to initiate innovative ideas.[3] To be eligible for funding, ideas must potentially provide a huge profitability gain or open new growth opportunities. Following an approach typical of venture capitalists, ideas are reviewed and nurtured until they reach a technical proof of concept, a stage known internally as "graduation". Possible deployment options for "graduate projects" include internal deployment, licensing, partnering or commercialization through new ventures.

Our focus is on five BV projects in drilling, logging and completion – upstream activities that Elektra outsources to service companies. The sample selection proceeded as follows. First,

[3] BV acts as an orchestrator within Elektra, assembling teams of experts and industry players to assess the potential of new technologies and identify possible deployment routes.

in order to enhance comparability and minimize extraneous variation (Eisenhardt, 1989), we included only projects that had been reviewed and funded by BV, excluding those developed elsewhere in the company. We then restricted our focus to technological projects dealing with outsourced activities in which Elektra no longer had in-house expertise and, hence, required cooperation with third parties. Within this sample, we selected projects that differed in terms of deployment outcomes (achieved vs not achieved) and manner of deployment, with the aim of maximizing variation. Our emphasis on deployment was motivated by the fact that deployment challenges are a major barrier to technological progress in the upstream oil and gas industry (Lloyd's Register Energy, 2014), where risk-related issues deter most firms from acting as first implementers of novel solutions. To account for risk elements, we ensured that the risk profile of the selected projects also varied.

Based on the criteria highlighted above, BV team members helped us to identify the projects most suitable for our investigation from among those for which richer information could be obtained either by interviewing the people involved or through archival data, or both. Our final sample consisted of five projects that we will call "Alpha", "Beta", "Gamma", "Delta" and "Omega" (see Table 2 for a summary of their characteristics).

(Table 2 about here)

3.2 Data collection and analysis

Given the nature of our study, spanning both micro-level (project) and meso-level (industry) dimensions, our data collection strategy encompassed multiple and differentiated sources of information. Both primary and secondary data at the industry, organizational and project levels were gathered and integrated (see Appendix A for a full overview of our data sources).

We reviewed industry reports, books, newspaper articles and journal publications, and interviewed multiple representatives from relevant players (e.g. oil majors, service companies, professional bodies) to gain a thorough understanding of the oil and gas industry, and of the roles played by different actors. Overall, we conducted 12 open-ended interviews in two separate rounds (2008, 2010). We also participated in six professional workshops, where we gathered information on technology development strategies, challenges and trends in the industry before triangulating it with interview and archival data.

In parallel, we collected data from Elektra. We carried out 38 interviews in three separate rounds between 2008 and 2010, gaining a comprehensive overview of the new technology projects that the firm had invested in over the previous 15 years and the strategic rationale behind them. We conducted a first round of open-ended interviews with BV managers, the director of Elektra's internal venture capital fund and other senior executives involved in critical decisions on the development of new technology ventures. They helped us capture relevant aspects of the BV review and funding process and identify target respondents for the two subsequent rounds of interviews, which were more focused on project-level dynamics. Whenever possible, we approached proponents and sponsors of the five BV projects selected for investigation, as well as members of the panel committees that reviewed them. We followed a semi-structured interview protocol[4], with questions typically addressing the genesis of the project and its main characteristics, the resources and capabilities required to move it forward, the key factors that influenced its progress, and its outcomes and potential deployment routes. Full access to project files stored in a central database owned by BV was provided, and internal documentation (including technology portfolio reviews, project plans, budgets and minutes of meetings) was reviewed to obtain information about each project. We also participated in some panel meetings, which allowed us to capture how the BV review and funding process worked. We aimed to ensure data triangulation and control for retrospective biases by relying on multiple data sources and informants (Eisenhardt and Graebner, 2007).

Data analysis followed the logic of comparative case study research, combining within-case analysis with cross-case comparison (Eisenhardt, 1989; Yin, 2014). We began by assembling all interview transcripts and archival documents for each of our five cases. After that, we started coding data on a within-case basis, using a thematic approach[5] (Flick, 2006; Yin, 2010). First, we engaged in a thorough and "active" reading of the data, noting down ideas for possible patterns (Braun and Clarke, 2006). Then, guided by our analytic interest, we searched for statements that contained references to the nature of the novel technologies and to how they could create value, to the key implementation hurdles and to the actors involved in the process. Each of the identified statements was assigned a descriptive label that reflected the concept represented in that specific segment of text. This yielded us a list of first-order codes that were then consolidated across the five cases. Next, by continuously iterating between data and literature, we grouped first-order codes that shared common characteristics into more general

[4] Interviews typically lasted between 30 minutes and one hour, were tape-recorded, transcribed and, subsequently, submitted to interviewees for verification. Any follow-up questions needed were posed by phone or email.

[5] Thematic coding derives from Strauss's original work (1987) and is appropriate specifically when comparing groups or entities that differ along specific lines of interpretation of a certain phenomenon (Strauss, 1987) or certain structural or processual characteristics (Flick, 2006). The procedure was adapted by Flick (2006) to enable comparative analysis across groups or categories; we applied it here to compare projects along a few critical dimensions.

second-order themes. Some of these themes were consistent with existing open innovation literature (e.g. control over IP) while others emerged from our case evidence (e.g. potential impact on complementors' portfolios). In total, we identified six themes that were present in all five cases. Finally, by further abstraction, we grouped second-order themes into three main aggregate themes, which seemed to reflect the key elements of the overall story our data told about the deployment of novel technologies. Throughout the coding process the first and second authors, although working independently, interacted systematically to validate and refine codes and themes. The final data structure is presented in Tables B1 and B2 in Appendix B.

The thematic structure developed through the coding process served as a basis for our cross-case comparison (Flick, 2006), which aimed at identifying factors that could account for the different deployment outcomes of the five investigated projects. These factors, reported in Table 3, emerged from the systematic search for analogies and differences across the five cases, which was conducted separately by the first and second authors. The comparison was not aimed at revealing processual issues (as we did not code process data), but at identifying connections and patterns across core variables (e.g. IP rights and broadening effect) that might explain different deployment outcomes. Once key patterns were established, we asked relevant informants in the BV unit to validate their plausibility (Eisenhardt, 1989).

4. Case evidence: oiling the wheels of complementary technology development

Many of the voices we heard in upstream oil and gas lament that the current competence distribution has gradually slowed the development of step-changing innovations. At a time when technology is crucial to access new oil and gas reserves and maximize recovery from existing ones, most large oilfield service providers prefer to engage in incremental improvements, claiming that "*oil majors should be only happy with what they (service providers) have been supplying for the last few years*", as one of our interviewees recalled.

Given the reluctance of service companies to invest in highly innovative technologies, recent years have seen oil majors start to develop them independently. "*There are cases in which companies like Elektra need to step up to the challenge and develop new technologies in-house, since otherwise nobody else in the industry would do it. It is like disturbing a commodity market, where service companies have no interest in upgrading their technologies*" (AM, innovation manager at Elektra).

As several of Elektra's technology officers pointed out, the objective of oil majors' renewed efforts towards technology development is not to enter areas of expertise traditionally managed by the service industry, but to increase innovation at the level of majors' complementary assets, setting new standards and spreading new capabilities that can enhance their productivity and yield additional returns. Once developed and tested, most of these complementary technologies are either directly licensed to service companies or marketed through new ventures.

To extend the search for innovative ideas beyond the scope of internal R&D activities, Elektra, like its peers, has embraced OI, and set up BV to nurture promising but unproven concepts and speed up the development and deployment of new technologies also in non-core business areas. The five new technology development projects we analysed in this study were all executed between 1996 and 2007, but only two, Alpha and Beta, were successfully deployed, while Gamma, Delta and Omega were discontinued before reaching the field. Their in-depth investigation allowed us to uncover critical factors that influenced their deployment outcomes.

The following case narratives, which are based on the accounts of the actors involved in the projects and on related archival data, illustrate salient aspects that ultimately shaped their fates.

4.1 Project Alpha

Alpha was initiated in 2003 with the objective of developing an entirely new perforation technique for the Exploration & Production (EP) business, enabling access to difficult hydrocarbons (tight reservoirs with low permeability) and substantial productivity improvements in impaired wells.

Perforating is one of the final steps in completing a new well, opening a path for fluids to enter the well from the hydrocarbon reservoir. It typically entails lowering high-energy explosive devices into the well and firing them to create holes through its steel casing and cement liner. "*It's a very mature industry. There is stuff that has been around since the First World War. We had some brainstorming sessions to figure out how we could make it better, where better wasn't just meaning incremental improvement but game-changing better*" (AMK, lead proponent of Project Alpha).

The proposed novel perforating technique was based on the highly innovative combination of jet ballistics technology, largely applied in the arms industry, with Elektra's geotechnical and well-engineering expertise. This project, funded by BV, was carried out in cooperation with a leading international defence company and a provider of perforating solutions, who had Elektra's internal venture capital fund (EVC) as one of its strategic investors. "*We linked up with an external company that was developing tanks and munitions systems, and we directed their attention to the EP business by tapping their knowledge base. We brainstormed together* *and came up with a couple of ideas that were novel not only to us and to the oil industry, but also to the arms business"* (AMK).

As a result of its broad range of applications (see Table 2), the new technology had the potential to open up a big market for "ultra-deep hole perforators" that had not been occupied either by competitors or service companies, and consequently was not available to Elektra's operations. Elektra does not carry out perforation, which is outsourced to service companies, so its main expected benefit from investing in this project was to get access to difficult hydrocarbons with lower costs and increased productivity rates. "*Elektra's interest is to get the technology to the field as soon as possible and be a well-recognized co-developer and favoured customer"* (GB, sponsor of Project Alpha).

Members of Elektra knew that this area of expertise was fading away, and that they were left in the hands of their main service providers, which had no incentive to switch to new perforating technologies potentially cannibalizing their existing ones. Nevertheless, Alpha was questioned during BV review meetings. "*The biggest criticism was: why should we do this in-house? Why don't we just leave it to the service industry? It's their area of expertise*" (MB panel expert). However, BV's managers were strongly committed to moving this technology forward. They supported and funded project Alpha until a successful technical proof-of-concept was achieved. Reaching that stage was a prerequisite for the pursuit of any subsequent deployment plans. "*At that point, you have to decide whether you are going to drive the invention all the way to the end, or take it to the service industry and ask them to run it*" (AMK).

In principle, completion technology is left to large service companies such as Schlumberger, Halliburton and Baker Hughes, which manufacture perforating gun systems and charges for the whole industry. Although their involvement in Alpha's deployment seemed natural from a commercial standpoint, BV's early attempts to attract their interest repeatedly failed. The innovative perforation technology, which could allow oil producers to achieve substantial productivity gains, was seen as competing with service providers' existing products. "*Elements of the service industry started feeling pretty nervous about this invention, since we put pressure on them to upgrade their technologies and come up with new products*" (AMK).

The project's lead proponent and the BV sponsor had been very active in raising interest about the new technology, involving experts and potential deployment partners in the early stages of its development process. Members of other Elektra teams had provided feedback on how to get to a field test quickly and suggested companies that could be suitable "homes" for the technology. However, arranging field trials posed huge problems: Elektra's operating units were focused on optimizing day-to-day operations, so spending time and money on unproven technologies was seen as a waste of resources. Moreover, since major service companies tightly cover perforating services, contractual issues made it tough to organize field trials of technologies that were not their own.

Finding a first implementer was a real challenge. Eventually, a few operating units made themselves available to run and test the technology. In 2007, Elektra decided to invest, through EVC, its internal venture capital fund, in a small firm manufacturing the new perforating solutions, together with the defence company that had the IP rights on the technology. Through this joint-venture Elektra could secure an exclusive licence for a few years, and the manufacturing firm currently sells perforating tools to over 50 service providers. "*That's the weird part of it. We developed something for which we are the customers in the end. We invented something that service companies sell back to us for big money through our operations, but what Elektra gets out of it is a well that produces more than before*" (AMK).

4.2 Project Beta

Beta started in 1996 with the aim of developing a new method that could combine logging and casing operations, thus saving rig time and reducing operational risks. The problem of getting logging tools stuck in highly deviated or horizontal wells had become increasingly common, and drillers needed an alternative to traditional wire-line and logging-while-drilling techniques.

The proposed novel well-logging technology, quickly patented by its inventor, incorporated a drill bit with a centre that could be disengaged and re-engaged while the bit was downhole. This allowed drilling operations to be suspended and logging tools to be run in the hole through the drill pipe, recording data in memory modes. Given the expected cost savings – estimated at around 50% – this new method could potentially transform the way Elektra acquired log data and eventually become the new industry standard. It was opening up a new technology play, generically termed "wireless logging", that allowed a number of high-impact applications (see Table 2) in a global market then worth about $500 million.

The project progressed relatively quickly through the BV review and funding process and, thanks to the project proponent's network and to the early involvement of potential deployment partners, field trials and a prototype were in place as early as 1999. That required the development team to cooperate closely with a small UK well-service company manufacturing the required logging tools. "*Elektra doesn't drill, doesn't make the equipment, and doesn't do the measurement. We have no in-house expertise in that. So, when we came up with the idea for this new technology, we needed help and support from those companies to move it forward*"

(CM, sponsor of project Beta). However, despite Beta's advantages, the main oilfield service providers seemed uninterested in supporting its development. They had made huge investments in traditional logging technologies, for which they could charge oil majors higher costs, and wanted to stick with them. Switching to technologies more efficient than their established ones would have meant lower revenues for them. "*In the end, the companies that are willing to help are those who see Elektra as a potential partner and not as a competitor, which means just the small ones. They need to grow their business, so they're happy to work with us*" (CM).

The initial field trial, run by one of Elektra's operating unit, was successful, and the project was soon taken over by EVC, which wanted to fast-track the commercialization of the new technology. Commercialization to third parties was the planned deployment route, although none of the major services companies had been willing to act as first implementer. "*Since there is always some intrinsic failure risk, everybody was suggesting that we try with someone else first, and come back when the technology was clearly working. We had come up with a good idea but we had to face market rules!*" (JR, lead proponent of Project Beta).

In 2005, EVC founded a new company, FB, to take the novel logging technology to market. With 14 registered patents, FB soon started commercializing different technological solutions, setting a new standard for the industry. The company worked closely with a manufacturer of logging tools to deploy several related applications. Gradually, Schlumberger and other service companies started adopting the new technology, and it grew quickly. In 2011, FB was acquired by Schlumberger, which added wireless logging solutions to its technology portfolio.

"*It is difficult to say whether the whole potential of the technology has been exploited. We had to be practical at a certain point and focus on our main objective, which was getting an alternative and cheaper logging technique. Since our service companies didn't want to innovate on that, Elektra had to take the initiative*" (CM). This implied also taking the technology to the market, bypassing the initial resistance of major service providers to deploy it.

4.3 Project Gamma

Project Gamma was initiated in 2002 with the objective of developing an alternative completion technique to improve sand control and minimize lost hydrocarbon production. Completions are the conduit between hydrocarbon reservoirs and surface facilities and are a critical part of any hydrocarbon field development project. They have to be designed to safely maximize hydrocarbon recovery from the well and may have to last for several years under ever-changing conditions. "*When you have a well and put it into production, besides oil and gas, you also get* *water – and, if the formation is weak, quite a lot of sand. Sand can be very damaging since it can easily erode pipelines. So, it is a major issue for us. This problem of sand control and its impact on oil production is a day-to-day problem that service companies try to solve by using filters that are quite expensive and hamper productivity, so it is not a good solution overall*" (TA, lead proponent of Project Gamma).

The proposed novel completion technique aimed to use mechanical cohesion to defer or prevent sand production in reservoirs. It relied on the "stress shielding" ability of slots cut into the wellbore. Since it was basically an alternative application of an existing water-jet technology, the new downhole solution only required optimization work, and could be implemented easily and quickly. Elektra had the opportunity to be the leading implementer, although the targeted final customers were major service companies, which actually run well-completion operations for most oil majors – a market worth about $200 million p.a., according to the proponent's estimates. Service companies, however, couldn't really see a market for this completion technique, which, although more efficient, offered a limited range of applications.

With only some computer modelling and experimentation needed, development progressed rapidly, and the project soon entered its execution phase. However, "*we didn't get our operating units or potential deployment partners involved at this stage. We decided to approach them at the end of the process, when a clear deployment strategy had been defined*" (TA). Despite successful laboratory tests, arranging field trials posed huge problems. Elektra had decided not to pursue commercialization to third parties immediately, but to try publishing a few articles first to raise awareness of the new technique – thus gaining legitimization as first implementer. "*There was some discussion on the deployment, and it was thought that since Company X had the patent on the water-jet that we were using to cut slots in the wellbore, it was better to keep the new technique as Elektra's knowledge*" (GB, sponsor of Project Gamma). Since the novel completion solution used an extant technology, it was difficult to protect it with a patent. Publishing articles on it was a clear strategy to initially circumvent this risk. Moreover, since a big service company owned the technology, it was difficult to appropriate value. "*Eventually we decided to keep it for ourselves and try to pursue internal deployment first*" (GB). However, getting availability from Elektra's operating units to run field trials was challenging, as none of them wanted to act as first implementer. Though technically successful, Project Gamma ended up being unsuccessful from a deployment standpoint and was officially discontinued in 2005.

4.4 Project Delta

Project Delta started in 2001 with the aim of developing a novel downhole welding technique, enabling tight connections in high pressure and high temperature (HPHT) wells. The availability of tools and equipment that could operate in such extreme environments has become vital to oil and gas companies, which must drill ever deeper in increasingly hostile conditions due to declining reserves. Welding two elements downhole requires reducing wellbore fluid pressure to a specific level, which is a challenge. The proposed method entailed the formation of a sealing weld, joining an upper and a lower wellbore casing element by means of a mechanical locking mandrel.

By potentially enabling downhole welding for spider wells and low casing flow wells in HPHT environments, this novel solution could lead to a 15% reduction in well costs and enhance oil recovery by 5%, as well as significantly lowering operational risks. Although no fundamental new technology was required, developing the downhole robotics for this project was expected to be challenging. Given the lack of in-house expertise, external contractors had to be involved in the design and development of welding and ancillary equipment.

Funded by BV, Project Delta was run in cooperation with three companies specialized in downhole welding systems, welding power supplies and cable design. As they worked on proving technical feasibility, the project team actively explored possible deployment opportunities with major service companies (such as Halliburton). However, finding a commercialization partner that wanted to play a leading role in developing and bringing this technology to the market under a licensing agreement with Elektra, which owned the IP, proved to be a major challenge. The main oilfield service providers preferred to stick to alternative existing technologies, since they generally deemed that the novel welding solution would not have enabled them to broaden the range of services they could offer, and, hence, increase their revenues. Despite being technically sound, Project Delta failed to find a first implementer and, therefore, was closed with no uptake by the business.

4.5 Project Omega

Project Omega was initiated in 2000 with the aim of developing a novel method to measure drilling fluid parameters with a downhole chemical sensor. Drilling fluids are used to aid the drilling process and maximize recovery by transporting cuttings to the surface, controlling pressure, cooling and lubricating drilling bits and preventing formation damage. Their performance is critical for borehole stability, and the timely detection of deficiencies in their chemical composition may help prevent significant well- and safety-related problems.

In recent years, the development of microfluidics techniques has allowed chemical assays traditionally conducted in labs to be performed on small chips on site, allowing much faster responses to detected problems. The technique proposed by Project Omega would measure fluid composition using an integrated microchip sensor, enabling downhole real-time analyses. This highly innovative solution was expected to represent a step-change in preventing borehole instability and taking remedial action, thus becoming the new industry standard. It could potentially allow Elektra to achieve a $10million/year reduction in well costs from decreased rig downtime and generate significant revenues for deployers through many applications.

Funded by BV, Project Omega was run in partnership with an external contractor specialized in lab-on-a-chip solutions that owned the IP rights to the novel sensor. Securing a strong IP position was key for Elektra, which aimed to patent the method for applying this tool to hydrocarbons. While trying to reach a proper IP contract with the microfluidic technology provider, the project team and its BV sponsor engaged with several major oilfield service providers to explore their interest in deploying the novel tool under a licensing agreement. However, despite its many potential applications and a successful proof-of-concept, Project Omega failed to obtain service companies' buy-in. Although a couple of them had initially showed some interest in acting as first implementers, bearing the cost of trying the technology in the field, negotiations did not progress, and commercialization plans eventually fell through.

4.6 Cross-case comparison

Our case evidence reveals that, within the same context, we can observe quite heterogeneous deployment outcomes. While the technologies from Alpha and Beta were successfully brought to market and gradually adopted, Gamma, Delta and Omega failed to be implemented. Why? In this section, we explore alternative explanations for such heterogeneity and identify factors that, within our sample, appear to drive it. As Table 3 summarizes, we compared our focal projects according to six dimensions that coincide with the second-order themes identified through our coding: degree of novelty, expected implementation benefits (for Elektra), control over IP, potential impact on complementors' portfolios, engagement with deployment partners and availability of a first implementer. These dimensions were grouped into three broader categories: technology attributes, deployment incentives and enabling factors for deployment.

(Table 3 about here)

Technology attributes. Technological and economic characteristics of a technology influence firms' decisions to invest in novel solutions and shape their development and deployment paths. Through our coding process, we identified two technology attributes that were relevant across all cases: *degree of novelty* and *expected implementation benefits*. First, we considered whether the degree of novelty of the solutions proposed could explain differences in their deployment. Interestingly, radical projects (Alpha and Beta) seemed to be more successful in terms of deployment than incremental ones (Gamma and Delta). This seemed to suggest that, despite being riskier, radical projects might appear more attractive in terms of deployment, as being potentially more impactful. However, the evidence of Omega does not support this claim: although it promised a radical change in fluid measurement techniques, its deployment failed. Next, we compared the key benefits expected by Elektra from the implementation of the novel technologies. Irrespective of whether they were deployed or not, all projects seemed to have the potential to deliver productivity improvement and cost reduction benefits. This attribute, therefore, seems more a prerequisite for investing in the novel technologies, rather than a factor discriminating between those that were or were not deployed.

Deployment incentives. Many novel technologies fail to reach the market due to the lack of incentives from potential deployers. Identifying factors that may incentivize their adoption becomes, then, crucial to foster their implementation. Through our coding, we identified two factors that seem to play an incentivizing role for deployment: *control over IP* and *the potential impact on complementors' (the targeted deployers) portfolios.* We explored whether variations in the IP profiles of the novel technologies and in the associated possibilities to extract value from commercialization could explain our results. However, our evidence does not present a consistent pattern. Both Gamma and Delta were unsuccessful from a deployment standpoint, but while for Gamma no IP rights on the technology could be enforced, Delta could rely on strong IP protection. We then considered whether the potential broadening or deepening impact that the novel solutions could have on the portfolios of technologies owned by the complementors (the target deployers), and their respective financial implications, could be a discriminating factor between successful and unsuccessful projects. Projects having a potential broadening impact (Alpha and Beta), and, hence, a potential to yield service providers additional revenue streams, seemed generally more successful in terms of deployment than those having a deepening impact (Gamma and Delta), which could instead yield lower extra returns for them. However, Project Omega provides conflicting evidence: although it could potentially broaden the range of services that adopters could offer, its deployment failed.

At this point we noted a pattern emerging from our data. Neither strong IP control nor a potential broadening impact per se appeared to be sufficient to incentivize service companies to deploy the novel technologies, as suggested by project Delta and Omega respectively. Our intuition was that successful deployment was determined by the combination of a strong IP control and a potential broadening (not deepening) impact on the portfolio of services that deployers would be able to offer as a result of the technology adoption.

Evidence from Alpha and Beta, in which this combined effect can be observed, supports this logic. Both projects aimed at introducing highly innovative technologies, potentially enabling a broad range of applications in oilfield operations. Given its quite diverse applicability, Alpha "*could solve a number of difficult hydrocarbons issues*" (GB, sponsor of Project Alpha), with significant productivity gains for oil producers. IP rights could be enforced through an exclusive licence agreement, which was highly desirable since it could secure an initial competitive edge. Despite competing with service companies' existing products somewhat, and "*disturbing a commodity market*" (GB), this novel technology could enable service providers to broaden the range of solutions offered to their customers, and potentially open up a new market for ultra-deep perforators. Similarly, the novel well-logging technology proposed by Project Beta offered a number of high-impact applications that could significantly broaden service providers' portfolios, opening up an entirely new technology play with huge commercial prospects. Although "*service companies wanted to keep using their established technologies, for which they could charge more to oil producers*" (CM, sponsor of Project Beta), the potential of adding new revenue streams to their business was a lure difficult to resist. With 14 patents covering the broad Beta technological umbrella, the new logging solutions were rapidly brought to market by a new company set up by EVC, Elektra's internal venture capital fund. Interestingly, the technologies from both Alpha and Beta were deployed by investing in new ventures that pursued their initial commercialization, as indicated in Table 2. This deployment approach, which Elektra contemplates only when full control on IP is attainable and new technologies are real breakthrough with a potential to broaden considerably the range of solutions available in the market, set the ground for the subsequent adoption by the main service providers.

Enabling factors for deployment. Finding a "home" for a novel technology is often a challenge, especially when external deployment is pursued. Firms resort to different strategies to lower the risk of having orphan projects and to help them get implemented. Through our coding, we identified two factors that seem to play an enabling role for deployment: *the* *engagement with potential deployment partners* and *the availability of a first implementer*. We first considered whether the stage at which potential deployment partners were involved could explain differences in the deployment outcomes of the projects. For both Alpha and Beta, the engagement with operating units and other potential deployers was sought at an early phase of the development process by the respective project teams. "*Whenever I met people in the operating units who were knowledgeable in this area of expertise, I was getting them involved. I was showing this technology and saying that it would be ready in a couple of years*" (AMK, proponent of Project Alpha). "*It's very difficult to pursue this type of project completely internally, since you need the hardware from the outside; you don't have the equipment. But you also need support from operating units, since they are the ones actually allowing you to do the trials*" (JR, proponent of Project Beta). Although it eased the deployment of Alpha and Beta, especially in the arrangement of their field trials, the early involvement of potential deployment partners did not appear sufficient to enable the adoption of Delta and Omega, whose deployment failed. The availability of a first implementer, an entity ready to run and test a novel technology as soon as it is fully developed appears instead more critical to successful deployment. Typically, firms are reluctant to act as first implementers and prefer to wait until novel solutions have been fully tested elsewhere and it is clearly demonstrated that upsides exist. However, the possibility of having preferential access to new technologies allowing them to solve relevant operational problems and/or significantly improve their performance, may offset their reservations. Importantly, by trying them out in the field, first implementers reduce the risks associated with the implementation of novel solutions, enhancing their chances of being subsequently deployed, as the evidence of Alpha and Beta suggests.

In sum, our findings suggest that Elektra succeeded in introducing innovative technologies in its ecosystem when they had the potential to broaden the range of services that service companies could offer – but only when this was coupled with control over the IP. When these two factors were both present, service companies, despite initial reluctance, were incentivized to adopt and deploy the novel technologies, since they could gain a potential competitive edge over their rivals and increase their returns. Ultimately, this also affected the likelihood of finding a first implementer willing to bear the costs of trying the technologies in the field.

5. Discussion and conclusions

In this paper we studied how an ecosystem's hub firm can strategically leverage OOI to align the complementary innovation activities of other ecosystem actors, thus removing external technological bottlenecks that constrain its value creation capacity in the core business.

We focused on the upstream oil and gas industry to elucidate how the hub firm (an oil major in our context) strived to induce its providers of complementary services to adopt new technologies. Following the externalization of R&D in several upstream activities, oil majors' competitiveness in oilfield exploration and production has become highly dependent on the pace of innovation of service providers. By favouring investments in incremental technologies, these companies have represented a main source of bottlenecks in the ecosystem, keeping oil majors from advanced technical solutions that could potentially yield productivity gains.

The slowdown in the development of radical innovations in the upstream oil and gas industry reflects some more general dynamics of firm innovation in ecosystems: vertical specialization along the value chain and the interdependencies arising from it, which create room for critical bottlenecks that may hamper technology advancements (Adner and Kapoor, 2010; Cacciatori and Jacobides, 2005; Jacobides and Winter, 2005). While prior work on business ecosystems has highlighted the critical role of interdependence among actors and how it may lead to the emergence of bottlenecks (Adner and Kapoor, 2010), it has provided limited insights on how firms can align the activities of other ecosystem actors to solve this issue.

We provide evidence supporting the idea that, by investing strategically in new technologies that can offer value creation possibilities also to its complementors (service providers in our context), the hub firm can align their incentives and entice them to adopt the new technologies. Figure 2 offers an illustration of how, in our context, the hub firm orchestrated its relationships with different actors within the ecosystem to remove technological bottlenecks through the external deployment of novel technologies.

(Figure 2 about here)

Drawing on our cross-cases evidence, Figure 2 synthesizes an emerging process in which the hub firm's orchestrating unit contributes to aligning incentives across the ecosystem to foster the deployment of novel technological solutions. First, it actively engages with external specialized actors who possess the skills needed to develop the focal technologies (step 1 in Figure 2). Coordinating the development of novel technologies is the first step of the orchestration process represented in Figure 2. The alignment of the incentives of the firms ultimately deploying these technologies in the field, the oilfield service providers in our research context, is a critical part of the orchestration process (step 2 in Figure 2). It determines the subsequent deployment and adoption of these technologies by providers of complementary services (step 3 in Figure 2). In its orchestrating role, our focal organizational unit is tasked with selecting technologies that would allow the alignment of the service companies' interests with the hub firm's objectives. Critical here is securing control over the technology's IP and identifying technologies that have the potential to broaden service companies' offerings, thus enhancing their revenue prospects. Bottlenecks are removed when the providers of complementary services, upon the adoption of the novel technologies developed by the hub firm, can provide the latter with services based on these novel and more effective technology solutions (step 4 in Figure 2).[6] Thus, the success of this outbound open innovation process orchestrated by the hub firm is grounded critically in the alignment of the incentives for the deployment of these technologies.

Figure 2 elucidates how a hub firm can use outbound OI strategically to orchestrate ecosystem members' activity and influence the pace of new technology development and adoption within the ecosystem. By shedding light on the mechanisms enabling this process, our study enhances our understanding of the interplay between the structure of technological interdependence in the ecosystem and firms' open innovation activities, contributing to research on ecosystems and OI in several ways. We discuss this in the next section.

5.1 Contribution and theoretical implications

Ecosystem research has highlighted the importance of a hub firm's orchestration activities for managing interdependencies and unlocking value creation (e.g. Dhanaraj and Parkhe, 2006; Nambisan and Sawhney; 2011; Teece, 2007). Yet, the mechanisms that a hub firm can use to align ecosystem members' activities remain poorly understood. Some studies have pointed to vertical integration as a strategy to manage ecosystem interdependencies and address potential bottlenecks to value creation (Adner and Kapoor, 2010; Cennamo, 2016). However, given the

[6] The strategic use of OOI elucidated here shifts the focus from a firm's own new product development (typical for inbound OI) towards developing technologies that can affect the strategic drivers in the industry so as to benefit the hub firm's core business. This shift is echoed in Vanhaverbeke and Chesbrough (2014), using an example that, incidentally, focuses on the relationship between oil companies and service providers.

complexity and costs associated with this governance structure, vertical integration may not always be a viable or attractive option for firms (Jacobides et al., 2018).

While acknowledging bottlenecks as important constraints to value creation in innovation ecosystems and discussing issues of coordination and alignment as critical to prevent their emergence, prior work offers limited insights into how bottlenecks can be resolved. Our study contributes to filling this gap by suggesting that a hub firm can use OOI strategically to manage ecosystem interdependencies and address technological bottlenecks in its complementary activities. Whereas prior research has focused on the design choice of the structural elements of the ecosystem – i.e. the "alignment structure" (Adner, 2017) – influencing members' incentives (e.g. rules for participation and transaction within the ecosystem), our study points to the hub firm's orchestration of OOI investments as a dynamic emerging process of alignment of ecosystem members' incentives. By developing and externally exploiting technologies that also offer value-creating opportunities to other actors in the ecosystem, the hub firm can steer those actors' complementary activities so as to benefit its core business. The investments in new technologies orchestrated by the hub firm become, then, a strategic mechanism for aligning the incentives and shaping the technology investments of other ecosystem actors.

The strategic use of OOI unearthed by our study contributes to enriching our understanding of the reasons that may drive firms operating in business ecosystems to externally exploit their knowledge and ideas. While prior work has highlighted various strategic objectives that may lead firms to practice outbound open innovation (Grindley and Teece, 1997; Lichtenthaler, 2010; West, 2003), it provides limited insights into how those objectives may be shaped by firms' interdependencies with the activity of other ecosystem actors. Our findings suggest that firms embedded in ecosystems of interdependent innovations may resort to OOI to address external innovation challenges, such as technological bottlenecks in their complementary activities, that hinder their value creation capacity in the core business. By shedding light on the mechanism underpinning this strategic use of OOI, which revolves around the investment in new technologies that may align the incentives of the ecosystem actors involved, our study informs the literature in several ways.

First, by suggesting that the success of the outbound open innovation process orchestrated by the hub firm depends on its ability to identify technologies able to incentivize adoption by external deployers, we add to the literature on desorptive capacity. While prior work has highlighted that a firm's ability to identify valuable opportunities for external knowledge exploitation is key to the success of its OOI initiatives (Lichtenthaler and Lichtenthaler, 2010; Ziegler et al., 2013), it provides limited insights into how the perspective of the potential knowledge recipient is integrated into this identification process. Our findings suggest that, by considering the perspective of potential deployers, firms may be able to identify technologies offering them appropriate incentives for adoption, thus improving their desorptive capacity.

Second, by focusing on project-level dynamics, as solicited by recent OI studies that have highlighted the dearth of OI research at the project level (e.g. West et al., 2014), we uncovered that, by investing in technologies with a broadening potential for its deployers and for which a strong control over the relevant IP could be exerted, the hub firm could align their incentives and get the novel technologies deployed. The potential deployers evinced no interest in adopting technologies that merely offered efficiency gains within the same technological trajectory or for which there was insufficient control over IP. By suggesting that the successful orchestration of OOI projects revolves around the identification of technologies that can offer both value creation and value appropriation opportunities to the potential adopters, our findings underscore the importance of taking the business model of other firms in the ecosystem into account when pursuing OOI in ecosystem settings.

Third, by suggesting that a strong control over the technology IP is crucial to align the incentives of potential deployers and entice them to adopt the technologies developed by the hub firm, we contribute to the current debate on the role of appropriability in OOI activities. The practice of OOI has been traditionally associated with the presence of formal IP protection mechanisms, enabling firms to appropriate value from the external exploitation of their knowledge (Dahlander and Gann, 2010; West, 2006). However, recent studies on free revealing have highlighted that firms practicing OOI may decide to voluntarily waive some of their IPRs to achieve more strategic objectives, such as growing the market or attracting third-party contributions (Henkel et al., 2014; West, 2003). Our findings suggest that the possibility of exerting strong control over the IP of novel technologies expedites the hub firm's pursuit of their external exploitation by enabling deployers to extract value from them. By pointing to control over IP as a mechanism to align the activities and incentives of different ecosystem actors, our study contributes to shed further light on the link between appropriability and OI in ecosystem settings, answering recent calls for more research in the area (Chesbrough and Bogers, 2014; West et al., 2014).

5.2 Managerial implications

Our study also yields important implications for practitioners. It suggests that firms may effectively use OOI as a strategy to remove bottlenecks in the business ecosystem and to accelerate progress outside their boundaries. The effectiveness of this strategy, however, depends on firms' ability to select technological projects able to incentivize adoption by external deployers. Therefore, when deciding about investments in technologies for which external deployment is sought, managers should weigh the potential impact on the product and service portfolios of the prospective adopting firms, which may affect their actual implementation. Another important implication concerns the allocation of resources for technology development. The assessment of the potential of different technologies to be deployed may inform related resource allocation decisions. Projects deemed unlikely to be adopted can be opportunely discontinued, avoiding escalation of commitment. Our findings also suggest that, by engaging key potential deployment partners early in the process, managers may increase the chances of finding a "home" for the novel technologies.

5.3. Limitations and future research

Like every study, ours has its limitations, which also represent promising avenues for future research. First, the study draws on a small sample of projects within a single company and industry setting. While this enhances comparability across cases and helps us identify the key discriminant factors, it raises concerns about generalizability. In particular, the industry in which our study is set – the upstream oil and gas industry – presents some idiosyncratic characteristics (e.g. oligopolistic industry, strongly integrated value chains) which may limit the generalizability of our findings. Nevertheless, we believe that the ecosystem dynamics and OI strategies we have explored characterize a growing number of industries and organizations. We also identified clear boundary conditions for the successful deployment of OOI projects that can help determine whether or not our insights apply to other contexts. However, their interplay could still be influenced by other factors specific to the alternative setting. Future research could investigate OOI dynamics in other contexts and enlarge upon our boundary conditions.

Second, at this stage, our study offers limited evidence of the diffusion at industry level of the new technologies examined. A longer time horizon would be required to actually observe their commercialization and adoption patterns across the industry.

Third, although we interviewed multiple actors, including service companies, to understand the different roles they played in the ecosystem's innovation dynamics and their respective objectives, this paper provides no direct account of how service providers viewed the specific projects we investigated. We indirectly captured their perspectives and gained an understanding of their incentives to deploy the focal technologies through the project files made available by the hub firm, which included minutes of the meetings held to discuss projects' deployment prospects. However, this might have limited the set of elements we were able to identify that might have influenced service providers' deployment decisions. Future research should delve deeper into the incentives of different ecosystem members in order to capture possible influences on the key actors and their relationships.

Fourth, our study is limited in prescriptions about the OOI projects that were not deployed. Although OOI seems not to work in the case of deepening technologies and insufficient control over IP, the hub firm could still be interested in seeing these technologies implemented. What should the hub firm do then if the alignment of incentives with service providers in the ecosystem cannot be established through OOI for such technologies? In the case of deepening technologies, irrespective of the control over IP, one option could be deploying the technology directly by investing in the complementary activities. In the case of broadening technologies but limited control over the related IP, one option for the hub firm could be to gain IP control by acquiring the specialized contractors owning the IP and then seek external deployment. Given that this would entail significant resources, it might be an attractive option inasmuch as it offers the hub firm the opportunity to acquire broader skills/technologies applicable to other areas. Future research should investigate deployment strategies in the cases outlined above.

Finally, our study focuses on the alignment of incentives for providers of complementary activities and services in the focal firm's business ecosystem at the upstream level. While we believe that our framework can be applied also to complements produced downstream (i.e. services that complement and extend the value of the product system for the end customer), the mechanisms might be different and context specific. For instance, Adner and Kapoor's (2010) study on the semiconductor lithography equipment industry suggests that when the technological bottlenecks are located downstream, the focal firm may invest directly in the production of those complements to remove the bottlenecks. Similarly, in looking at the console videogame industry, Cennamo (2016) finds that console platform owners invest more intensively in the direct production of complements (i.e. games) when transitioning to next-generation platforms to overcome the initial shortage of supply of complements due to the limited incentives of complementors to commit to the novel technology at early stages. While in Adner and Kapoor (2010) the focal firm may invest to safeguard from potential value appropriation concerns, in Cennamo (2016) the platform owner invests mainly to create an initial market for the novel technology, thus generating some initial value for complementors in terms of addressable demand. Both studies are concerned with incentive alignment, a central aspect in the ecosystem literature (Adner, 2017). In Adner and Kapoor (2010) the market already exists; the mechanism of incentives alignment is more about disciplining complementors' cooperative behaviour. In Cennamo (2016) it is more about broadening complementors' market opportunities. Future research should explore alternative mechanisms to align incentives among ecosystem actors and their effectiveness in different contexts.

Despite these limitations, we believe our exploratory study and its findings point to interesting directions for future research on OOI and shed light on critical and underexplored aspects of relevant strategic dynamics in business ecosystems.

Acknowledgements

We would like to thank Gabriella Cacciotti, Roberto Camerani, Simon Parker and Mariachiara Restuccia, as well as participants at the First World Open Innovation Conference and Academy of Management Conference 2015, for their helpful feedback on earlier versions of this paper. We gratefully acknowledge the support received by the managers and employees of "Elektra", who provided tremendous help in the data collection and analysis process. Finally, we would like to thank the editor and the three anonymous reviewers for their excellent guidance and comments.

References

Acha, V., Cusmano, L., 2005. Governance and co-ordination of distributed innovation processes: patterns of R&D co-operation in the upstream petroleum industry. Economics of Innovation and New Technology 14, 1-21.

Adner, R., 2017. Ecosystem as structure: An actionable construct for strategy. Journal of Management 43, 39-58.

Adner, R., Kapoor, R., 2010. Value creation in innovation ecosystems: how the structure of technology interdependence affects firm performance in new technology generations. Strategic Management Journal 32, 306-333.

Adner, R., Kapoor, R., 2016. Innovation ecosystems and the pace of substitution: re-examining technology s-curves. Strategic Management Journal 37, 625-648.

Alexy, O., Criscuolo, P., Salter, A., 2009. Does IP strategy have to cripple open innovation? MIT Sloan Management Review 51, 71-77.

Alexy, O., George, G., Salter, A., 2013. Cui bono? The selective revealing of knowledge and its implications for innovative activity. Academy of Management Review 38, 270-291.

Arora, A., Ceccagnoli, M., 2006. Patent protection, complementary assets, and firms' incentives for technology licensing. Management Science 52, 293-308.

Arora, A., Fosfuri, A., Gambardella, A., 2001. Markets for Technology: The Economics of Innovation and Corporate Strategy. MIT Press, Cambridge.

Bagheri, S.K., Di Minin, A., 2015. The changing competitive landscape of the global upstream petroleum industry. Journal of World Energy Law and Business 8, 1-19.

Baldwin, C.Y., 2015. Bottlenecks, modules, and dynamic architectural capabilities. Harvard Business School Working Paper, 15-028.

Bianchi, M., Chiaroni, D., Chiesa, V., Frattini, F., 2011. Organizing for external technology commercialization: evidence from a multiple case study in the pharmaceutical industry. R&D Management 41, 120–137.

Bidault, F., 2004. Global licensing strategies and technology pricing. International Journal of Technology Management 27, 295-305.

Bozon, I., Hall, S., Oygard, S., 2005. What's next for big oil? McKinsey Quarterly, 95-105.

Braun, V., Clarke, V. 2006. Using thematic analysis in psychology. Qualitative Research in Psychology 3, 77-101.

Brusoni, S., Prencipe, A., 2006. Making design rule: a multi-domain perspective. Organization Science 17, 179-189.

Brusoni, S., Prencipe, A., Pavitt, K., 2001. Knowledge specialization, organizational coupling and the boundaries of the firm: why do firms know more than they make? Administrative Science Quarterly 46, 597-621.

Cacciatori, E., Jacobides, M.G., 2005. The dynamic limits of specialization: vertical integration reconsidered. Organization Studies 26, 1851-1883.

Cennamo, C., 2016. Building the value of next-generation platforms. Journal of Management, doi:10.1177/0149206316658350.

Chesbrough, H., 2003. Open Innovation: the New Imperative for Creating and Profiting from Technology. Harvard Business School Press, Boston.

Chesbrough, H., 2006a. Open Business Models: How to Thrive in the New Innovation Landscape. Harvard Business School Press, Boston.

Chesbrough, H., 2006b. Open innovation: a new paradigm for understanding industrial innovation, in: Chesbrough, H., Vanhaverbeke, W., West, J. (Eds), Open Innovation: Researching a New Paradigm. Oxford University Press, Oxford, pp. 1-12.

Chesbrough, H., 2007. The market for innovation: implications for corporate strategy. California Management Review 49, 45-66.

Chesbrough, H., Bogers, M., 2014. Explicating open innovation: clarifying an emerging paradigm for understanding innovation. In: Chesbrough, H., Vanhaverbeke, W., West, J. (Eds), New Frontiers in Open Innovation. Oxford University Press, Oxford.

Chesbrough, H., Brunswicker, S., 2014. A fad or a phenomenon? The adoption of open innovation practices in large firms. Research-Technology Management 57, 16-25.

Chesbrough, H., Garman, A., 2009. How open innovation can help you cope in lean times. Harvard Business Review 87, 68-76.

Chesbrough, H., Vanhaverbeke, W., West, J., 2014. New Frontiers in Open Innovation. Oxford University Press, Oxford.

Chesbrough, H., Winter, C., 2014. Managing inside-out open innovation: the case of complex ventures, in: Chesbrough, H., Vanhaverbeke, W., West, J. (Eds), New Frontiers in Open Innovation. Oxford University Press, Oxford, pp. 208-222.

Chiaroni, D., Chiesa, V., Frattini, F., 2011. The open innovation journey: How firms dynamically implement the emerging innovation management paradigm. Technovation 31, 34-43.

Cibin, R., Grant, R.M., 1996. Restructuring among the world's leading oil companies, 1980–92. British Journal of Management 7, 283-307.

Dahlander, L., Gann, D.M., 2010. How open is innovation? Research Policy 39, 699-709.

Dhanaraj, C., Parkhe, A., 2006. Orchestrating innovation networks. Academy of Management Review 31, 659-669.

Dietl, H., Royer, S., Stratmann, W., 2009. Value creation architectures and competitive advantage. California Management Review 51, 24-48.

Eisenhardt, K.M., 1989. Building theories from case study research. Academy of Management Review 14, 532-550.

Eisenhardt, K.M., Graebner, M.E., 2007. Theory building from cases: opportunities and challenges. Academy of Management Journal 50, 25-32.

Ethiraj, S.K., 2007. Allocation of inventive effort in complex product systems. Strategic Management Journal 28, 563-584.

Ferraro, F., Gurses, K., 2009. Building architectural advantage in the US motion picture industry: Lew Wasserman and the music corporation of America. European Management Review 6, 233-249.

Flick, U., 2006. An Introduction to Qualitative Research. Sage, London.

Fosfuri, A., 2006. The licensing dilemma: understanding the determinants of the rate of technology licensing. Strategic Management Journal 27, 1141-1158.

Gambardella, A., Giuri, P., Luzzi, A., 2007. The market for patents in Europe. Research Policy 36, 1163-1183.

Garud, R., Jain, S., Kumaraswamy, A., 2002. Institutional entrepreneurship in the sponsorship of common technological standards: the case of Sum Microsystems and Java. Academy of Management Journal 42, 196-214.

Gassmann, O., 2006. Opening up the innovation process: towards an agenda. R&D Management 36, 223-228.

Gooch, S.G., 1997. Drilling contracts and alliances: the pendulum swings. Journal of Petroleum Technology 49, 576-583.

Grindley, P.C., Teece, D.J., 1997. Managing intellectual capital: licensing and cross-licensing in semiconductors and electronics. California Management Review 39, 8-41.

Grönlund, J., Rönnberg Sjödin, D., Frishammar, J., 2010. Open innovation and the stage-gate process: a revised model for new product development. California Management Review 52, 106-131.

Gulati, R., Puranam, P., Tushman, M., 2012. Meta-organization design: rethinking design in interorganizational and community contexts. Strategic Management Journal 33, 571-586.

Hannah, D.P., Eisenhardt, K.M., 2016. How firms navigate cooperation and competition in nascent ecosystems. Strategic Management Journal 39, 3163-3192.

Henkel, J., Schöberl, S., Alexy, O., 2014. The emergence of openness: How and why firms adopt selective revealing in open innovation. Research Policy, 43 879-890.

Iansiti, M., Levien, R., 2004. The Keystone Advantage: What the New Dynamics of Business Ecosystems Mean for Strategy, Innovation, and Sustainability. Harvard Business School Press, Boston.

Inkpen, A., Moffett, M.H., 2011. The Global Oil & Gas Industry: Management, Strategy and Finance, PennWell Corporation.

Jacobides, M.G., 2005. Industry change through vertical disintegration: how and why markets emerged in mortgage banking. Academy of Management Journal 48, 465-498.

Jacobides, M.G., 2008. How capability differences, transaction costs, and learning curves interact to shape vertical scope. Organization Science 19, 306-326.

Jacobides, M.G., Billinger, S., 2006. Designing the boundaries of the firm: from "make, buy or ally" to the dynamic benefits of vertical architecture. Organization Science 17, 249-261.

Jacobides, M.G., Cennamo, C., Gawer, A., 2018. Towards a theory of ecosystems. Strategic Management Journal 39, 2255-2276.

Jacobides, M.G., Knudsen, T., Augier, M., 2006. Benefiting from innovation: value creation, value appropriation and the role of industry architectures. Research Policy 35, 1200-1221.

Jacobides, M.G., Tae, C.J., 2015. Kingpins, bottlenecks, and value dynamics along a sector. Organization Science 26, 889-907.

Jacobides, M.G., Winter, S.G., 2005. The co-evolution of capabilities and transaction-costs: explaining the institutional structure of production. Strategic Management Journal 26, 395-413.

Jeppesen, L.B., Lakhani, K.R., 2010. Marginality and problem-solving effectiveness in broadcast search. Organization Science 21, 1016-1033.

Kapoor, R., 2013. Persistence of integration in the face of specialization: how firms navigated the winds of disintegration and shaped the architecture of the semi-conductor industry. Organization Science 24, 1195-2013.

Kapoor, R., 2018. Ecosystems: broadening the locus of value creation. Journal of Organization Design 7, 1-16.

Kline, D., 2003. Sharing the corporate crown jewels. MIT Sloan Management Review 44, 89-93.

Leten, B., Vanhaverbeke, W., Roijakkers, N., Clerix, A., Van Helleputte, J., 2013. IP models to orchestrate innovation ecosystems. California Management Review 55, 51-64.

Lichtenthaler, U., 2010. Technology exploitation in the context of open innovation: finding the right “job” for your technology. Technovation 30, 429-435.

Lichtenthaler, U., Lichtenthaler, E., 2010. Technology transfer across organizational boundaries: absorptive capacity and desorptive capacity. California Management Review 53, 154-170.

Lloyd’s Register Energy, 2014. The Lloyd’s Register Energy Oil And Gas Technology Radar. An assessment of the sector’s innovation trends and drivers. Lloyd’s Register.

Miles, M.B., Huberman, A.M., 1994. Qualitative Data Analysis an Expanded Sourcebook. Sage Publications, Thousand Oaks.

Mortara, L., Minshall, T., 2011. How do large multinational corporations implement Open Innovation? Technovation 31, 586-597.

Nambisan, S., Sawhney, M., 2011. Orchestration processes in network-centric innovation: Evidence from the field. Academy of management perspectives 25, 40-57.

Pellegrini, L., Lazzarotti, V., Pizzurno, E., 2012. From outsourcing to open innovation: a case study in the oil industry. International Journal of Technology Intelligence and Planning 8, 182-196.

Perrons, R.K., 2014. How innovation and R&D happen in the upstream oil & gas industry: insights from a global survey. Journal of Petroleum Science and Engineering 124, 301-312.

Pisano, G.P., Teece, D.J., 2007. How to capture value from innovation: shaping intellectual property and industry architecture. California Management Review 50, 278-296.

Porter, M.E., 1980. Competitive Strategy: Techniques for Analyzing Industries and Competitors. Free Press, New York.

Rivette, K.G., Kline, D., 2000. Rembrandts in the Attic: Unlocking the Hidden Value of Patents. Harvard Business School Press, Boston.

Scott, R.W., Ruef, M., Mendel, P.J., Caronna, C.A., 2000. Institutional Change and Healthcare Organizations - From Professional Dominance to Managed Care. University of Chicago Press, Chicago.

Strauss, A.L., 1987. Qualitative analysis for social scientists. Cambridge University Press, Cambridge.

Teece, D.J., 2007. Explicating dynamic capabilities: the nature and microfoundations of (sustainable) enterprise performance. Strategic Management Journal 28, 1319-1350.

The Economist, 2012. The unsung masters of the oil industry, July 21.

Tranekjer, T.L., Knudsen, M.P., 2012. The (Unknown) providers to other firms' new product development: what's in it for them? Journal of Product Innovation Management 29, 986-999.

Vanhaverbeke, W., Chesbrough, H., 2014. A classification of open innovation and open business models, in: Chesbrough, H., Vanhaverbeke, W., West, J (Eds.), New Frontiers in Open Innovation. Oxford University Press, Oxford.

Vanhaverbeke, W., Cloodt, M., 2014. Theories of the firm and Open Innovation, in: Chesbrough, H. Vanhaverbeke, W., West, J. (Eds.), New Frontiers in Open Innovation. Oxford University Press, Oxford.

Vanhaverbeke, W., van de Vrande, V., Chesbrough, H., 2008. Understanding the advantages of open innovationp in corporate venturing in terms of real options. Creativity and Innovation Management 17, 251-258.

Vanhaverbeke, W., West, J., Chesbrough, H., 2014. Surfing the new wave of open innovation research, in: Chesbrough, H., Vanhaverbeke, W., West, J (Eds.), New Frontiers in Open Innovation. Oxford University Press, Oxford.

West, J., 2003. How open is open enough? Melding proprietary and open source platform strategies. Research Policy 32, 1259-1285.

West, J., 2006. Does appropriability enable or retard open innovation? in: Chesbrough, H., Vanhaverbeke, W., West, J. (eds.), Open Innovation: Researching a New Paradigm. Oxford University Press, Oxford.

West, J., Gallagher, S., 2006. Challenges of open innovation: the paradox of firm investment in open-source software. R&d Management 36, 319-331.

West, J., Salter, A., Vanhaverbeke, W., Chesbrough, H., 2014. Open innovation: the next decade. Research Policy 43, 805-811.

West, J., Vanhaverbeke, W., Chesbrough, H., 2006. Open innovation: a research agenda. In: Chesbrough, H., Vanhaverbeke, W., West, J. (Eds.), Open Innovation: Researching a New Paradigm. Oxford University Press, Oxford.

Yergin, D., 2008. The Prize: The Epic Quest for Oil, Money and Power. Free Press, New York.

Yin, R.K., 2010. Qualitative Research from Start to Finish. Guilford Press, New York.

Yin, R.K., 2014. Case Study Research, Design and Methods. Sage Publications, Thousand Oaks.

Zhu, F., Liu, Q., 2018. Competing with complementors: an empirical look at Amazon.com. Strategic Management Journal 39, 2618-2642.

Ziegler, N., Ruether, F., Bader, M.A., Gassmann, O., 2013. Creating value through external intellectual property commercialization: a desorptive capacity view. The Journal of Technology Transfer 38, 930-949.

Tables and figures

Table 1. Strategic use of outbound OI

Implementation vehicles	Strategic Objectives	Mechanisms	Exemplary References
IP sharing	• Develop technologies strategic for core business activity	• Ensure value capture for all innovators to stimulate interfirm cooperation	Leten et al. (2013)
Free/Selective revealing	• Elicit collaboration from other actors • Grow the overall market	• Reveal internally-developed knowledge to attract third-party contributors and users	Alexy et al. (2013) Jeppesen and Lakhani (2010); West (2003)
Technology out-licensing	• Access complementary assets	• Use cross-licensing agreements for knowledge exchange	Grindley and Teece (1997)
	• Set new industry standards	• Promote the large-scale adoption of new technologies	West (2003)
Open collaboration platforms	• Accelerate development and commercialization of complementary innovations	• Engage with external actors (users and firms) to spur ecosystem-related innovation	Chesbrough and Garman (2009)

Table 2. Project overview

Project	Technological Domain	Range of applications	Risk profile	Potential market size	Time to deployment (years)	Total budget allocated by BV	Involvement of external partners in technology development	Deployment outcomes	Type of deployment
ALPHA	○ Well completion: perforation technology ○ Typical area of expertise of service companies	Wide set of possible applications, e.g.: ○ Tight gas reservoirs ○ Fractured reservoirs ○ Heavy oil reservoirs	High-risk project: concept not yet proven even in military field	Large $ 1.5 billion p.a.	6–10	$ 875,000	Cooperation with a provider of military technology	Successful Technology available to the market and adopted by many service companies	Joint venture investment in a new company that commercializes the technology
BETA	○ Well logging technology ○ Typical area of expertise of service companies	Wide set of possible applications, e.g.: ○ Multi-well developments ○ Poor hole conditions ○ Impossible-to-log wells ○ Exploration dipstick wells	Technically simple project but highly complex and risky on the commercial side	Medium $ 500 million p.a.	6–10	$ 400,000	Cooperation with manufacturers of bits and logging tools	Successful Technology available to the market and part of a major service provider's portfolio	Creation of a new venture to commercialize the technology
GAMMA	○ Well completion: sand management technique ○ Typical area of expertise of service companies	Narrow set of applications, e.g.: ○ Open-hole completion ○ Cased hole well designs ○ Wells using expandable tubular technologies	Low technical risk but strong IP concerns	Medium $ 200 million p.a.	Less than 2	$ 470,000	No involvement of external partners given that no technology development work was required	Unsuccessful Novel solution not available to the market	Internal (within ELEKTRA's) application of the novel solution
DELTA	○ Well completion: downhole seal welding ○ Typical area of expertise of service companies	Wide set of possible applications, e.g.: ○ Spider wells in HPHT fields ○ Long casing flows in HPHT fields ○ Retrofitting of smart well equipment ○ Well repairs	High technical risk due to complex robotics work	Medium $ 350 million p.a.	4–6	$ 565,000	Cooperation with manufacturers of welding and ancillary equipment	Unsuccessful Novel solution not available to the market	Licensing of the novel solution to service companies
OMEGA	○ Well completion: downhole fluid chemical analyser ○ Typical area of expertise of service companies	Wide set of possible applications, e.g.: ○ Drilling fluids (ion content, shale inhibitors, biocides) ○ Completion fluids (compatibilities of acids and brines, pollutants) ○ Production fluids (scale prevention, geochemical analysis, incipient incompatibilities) ○ Enabler for deep-water drilling	Low technical risk but strong IP concerns	Medium $ 400 million p.a.	4–6	$ 675,000	Cooperation with an external contractor specialized in lab on chips solutions	Unsuccessful Novel solution not available to the market	Licensing of the novel solution to service companies

Table 3. Cross-case comparison

<table>
<tr><th rowspan="2">Deployment status</th><th rowspan="2">Project</th><th colspan="2">Technology attributes</th><th colspan="2">Deployment incentives</th><th colspan="2">Enabling factors for deployment</th></tr>
<tr><th>Degree of novelty</th><th>Expected implementation benefits</th><th>Potential impact on complementors' portfolios</th><th>Control over IP</th><th>Engagement with deployment partners</th><th>Availability of a first implementer</th></tr>
<tr><td rowspan="2">SUCCESSFUL PROJECTS</td><td>ALPHA</td><td><u>Radical</u>

Highly innovative technology with a potential to open up a new market for ultra-deep perforators</td><td>Productivity improvement

Cost reduction</td><td><u>Broadening effect</u>

The proposed technology outperforms those offered by oilfield service providers. Its adoption may broaden their portfolios but threatens to cannibalize some of their existing products.</td><td><u>Full control</u>

IP rights owned by another company, but ELEKTRA has an exclusive licence to use the technology for a few years</td><td><u>Early engagement</u>

Potential deployment partners approached in early stages of the technology development process</td><td><u>Yes</u>

ELEKTRA's operating units acting as first implementers</td></tr>
<tr><td>BETA</td><td><u>Radical</u>

Highly innovative technology with a potential to completely change the way ELEKTRA and the whole industry acquire log data</td><td>Productivity improvement

Cost reduction</td><td><u>Broadening effect</u>

Superior to conventional logging methods used by oilfield service providers, the proposed novel technology would enable them to broaden their service portfolios but would compete with some of their established solutions.</td><td><u>Full control</u>

IP rights with ELEKTRA through FB company</td><td><u>Early engagement</u>

Potential deployment partners approached in early stages of the technology development process</td><td><u>Yes</u>

ELEKTRA's operating units acting as first implementers</td></tr>
<tr><td rowspan="3">UNSUCCESSFUL PROJECTS</td><td>GAMMA</td><td><u>Incremental</u>

Novel completion technique based on the use of an already existing technology owned by one of the major service providers</td><td>Productivity improvement

Cost reduction</td><td><u>Deepening effect</u>

Based on an existing technology, the proposed completion technique threatens to cannibalize those used by oilfield service providers without enabling them to expand their portfolios, but just to deepen them.</td><td><u>No control</u>

No possibility to enforce IP rights since the patent on the employed technology was owned by Halliburton</td><td><u>Late engagement</u>

Potential deployment partners approached only in the final stage of the technology development process</td><td><u>No</u>

No first implementer available</td></tr>
<tr><td>DELTA</td><td><u>Incremental</u>

Novel completion technique based on the use of existing technologies but requiring complex robotics work</td><td>Productivity improvements

Cost reduction</td><td><u>Deepening effect</u>

The proposed welding solution outperforms those offered by oilfield service providers. Its adoption may help deepen their portfolios but threatens to cannibalize their alternative existing products.</td><td><u>Full control</u>

IP rights owned by ELEKTRA</td><td><u>Early engagement</u>

Potential deployment partners approached in early stages of the technology development process</td><td><u>No</u>

No first implementer available</td></tr>
<tr><td>OMEGA</td><td><u>Radical</u>

Highly innovative technology with a potential to completely change the way ELEKTRA and the whole industry measure drilling fluid parameters</td><td>Productivity improvement

Cost reduction</td><td><u>Broadening effect</u>

Superior to existing solutions used by oilfield service providers, the proposed novel technology would enable them to broaden their service portfolios but threatens to cannibalize their existing chemical analysing solutions.</td><td><u>Control by other company</u>

Patent on the microfluidic chips owned by a specialized external contractor</td><td><u>Early engagement</u>

Potential deployment partners approached in early stages of the technology development process</td><td><u>No</u>

No first implementer available</td></tr>
</table>

Figure 1. Research setting

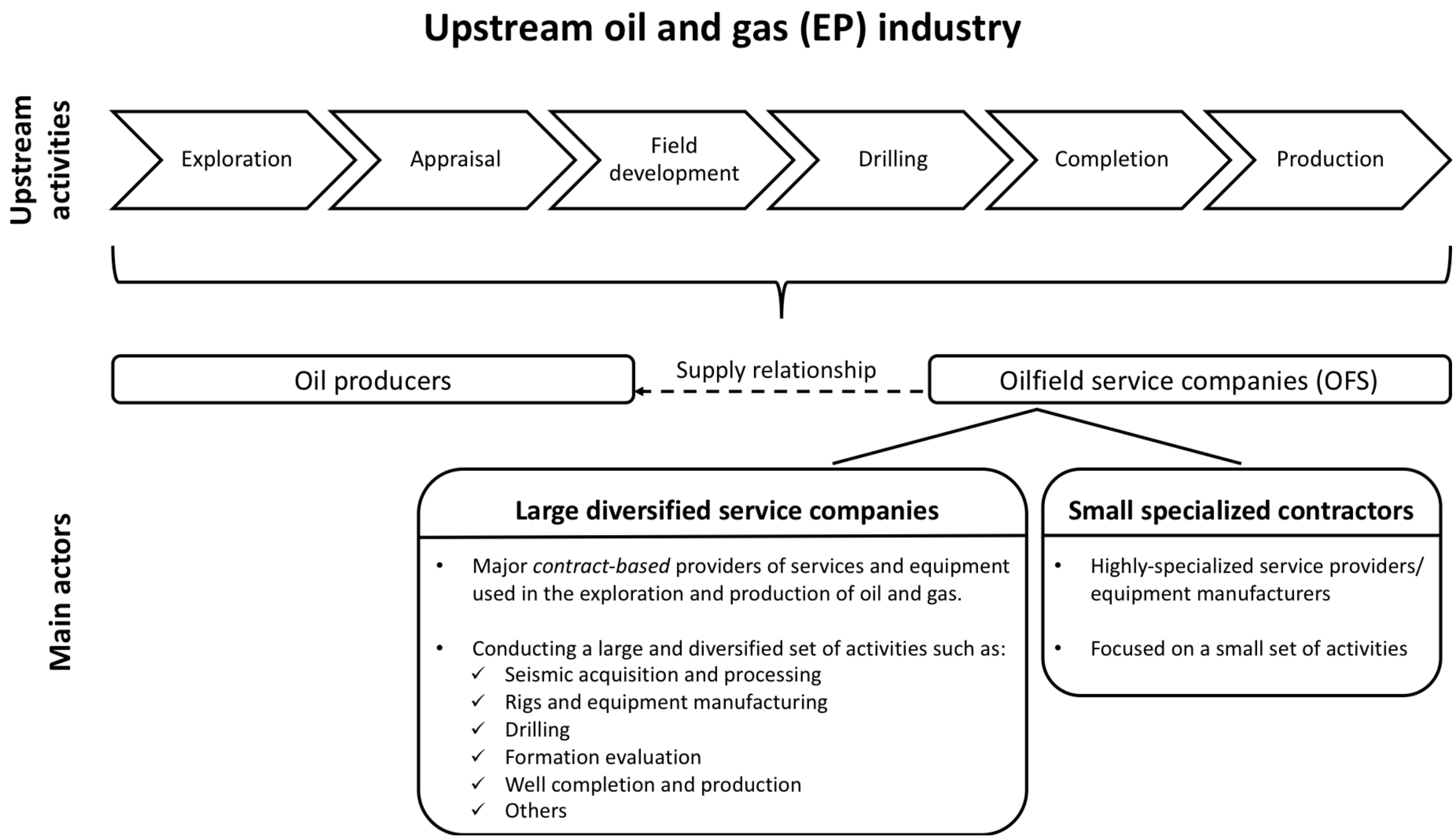
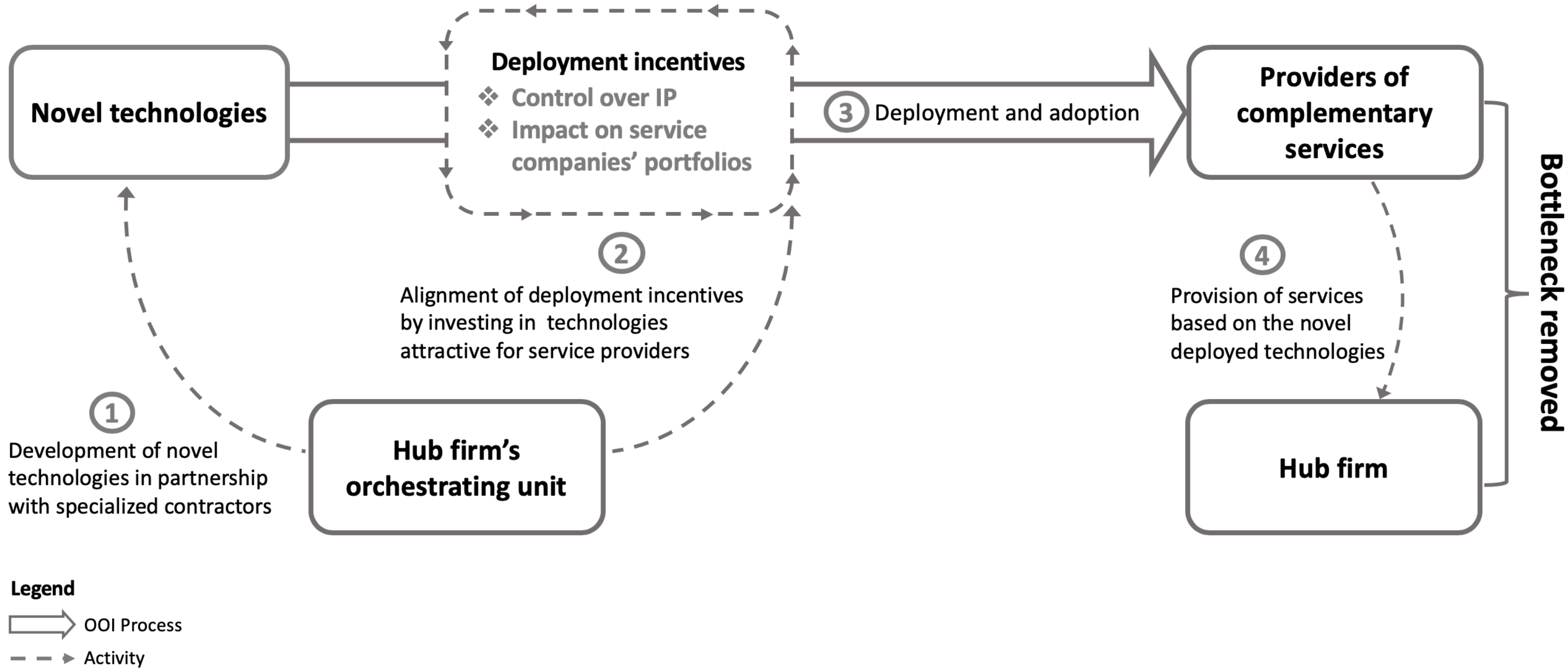


Figure 2. The hub firm's orchestration process



Appendix A. Sources of data

Table A1. Sources of data

Source of data	Type of data	Main focus and use in the analysis
Corporate Archives	**Books** published by Elektra between 1996 and 2010 1. *Emerging technological areas* 2. *Energy scenarios to 2050* 3. *BV activities and process* written by BV managing director and lead scientists 4. *BV success stories* written by BV managing director and scientists	Books written by Elektra's and BV's executives and senior scientists providing information on: key trends in the energy industry and innovation trajectories followed by most players; innovative activities run by the BV team and their role within BV projects successfully deployed.
	Internal presentations 1. BV review and funding process (3) 2. BV project evaluation criteria (4) 3. BV project domains and portfolio overview (2) 4. Innovation in the energy sector and strategic projects (2) 5. R&D portfolio reviews (3)	Presentations given by Elektra's and BV's executives illustrating respectively the strategic areas of innovation for Elektra and the functioning of the project review and funding process implemented by the BV unit. This material enriched our understanding of the domains of interest to the company and of the evaluation criteria guiding the selection and development of BV projects.
	Database containing semi-structured minutes related to the evaluation process of all 1,527 innovative ideas received and reviewed by the BV unit between 1996 and 2009. It includes presentations, project plans and budgets referred to each of the proposed ideas.	These project-level data enriched our understanding of the factors influencing the development and deployment of the innovative ideas vetted by the BV team, enhancing the validity of the insights gained from primary data.
Interviews on industry architecture	**Two rounds (2008; 2010)**, 12 interviews with 11 members: 1. **Elektra**: VP for EP R&D, managing director of Internal Venture Capital Fund, BV managing director and senior scientist 2. **Other oil major**: Head of Technology EP, VP for Breakthrough Innovation (2) Former VP for R&D and Technology Planning 3. **National oil company (NOC)**: Head of Technology Strategy 4. **Service company**: Technical Director 5. **Industry experts**: an academic professor and consultant that authored articles/books on oil majors and a senior industry lobbyist expert on technology development strategies in the industry	Broad questions on industry structure and competitive drivers; industry evolution since the first oil crisis; role of oil majors (including Elektra) and other industry players; innovative dynamics and oil majors' technology development and deployment strategies.
Interviews on BV unit and projects	**Three rounds (2008; 2009; 2010),** 38 interviews with 16 members 1. BV managing director and members of the BV team 2. Managing director of Elektra's Internal Venture Capital Fund 3. Proponents and sponsors of selected BV projects 4. Participants in BV panel review meetings	The <u>first round</u> of interviews focused on the genesis, structure, goals and practices of the BV unit. It helped us gain a good understanding of the role of the BV unit within Elektra, of how innovative ideas are evaluated and selected, and of their main deployment routes. The <u>second and third rounds</u> of interviews focused on project-level dynamics. Informants were asked questions on: the genesis of selected BV projects and their main characteristics; key events in their development process; resources/capabilities required to move them forward; main hurdles that hindered their progress; their overall outcomes and deployment routes.
Other archival sources	1. 9 reports on the oil and gas industry and the EP business (Datamonitor; Accenture, BCG, KPMG, Roland Berger: Society of Petroleum Engineers) 2. 14 academic and newspapers articles on the oil and gas industry 3. 3 scholarly publications on the BV unit	This material was used to gather information on the oil and gas industry, its main actors and dynamics, and evolution over time, and to triangulate related data gained from primary sources (interviews, workshop attendance). They enriched our understanding of the role of the BV unit within Elektra, of how they evaluate and select innovative ideas, and of their main deployment routes.
Professional workshop attendance	1. 21-02-08 **Enabling global innovation in E&P**, Society of Petroleum Engineers 2. 17-06-08 **The future of oil and gas**, Society of Petroleum Engineers (SPE) 3. 26-03-09 **Competitiveness: what future in the E&P industry?** SPE 4. 23-03-10 **SPE Intelligent Energy Conference**, Utrecht 5. 20-09-10 **SPE Annual Technical Conference and Exhibition**, Florence 6. 16-11-10 **R&D investment trends and the rise of NOCs**, SPE Workshop documentation (e.g. handouts) and personal research notes on presentations	Attended workshops mainly focused on innovation and competitive challenges and dynamics in the oil and gas industry. Information on the industry architecture and R&D investment trends were gathered and used to triangulate interview data and documental facts. They also helped gain a good understanding of the industry from the different perspectives of the actors involved.

Appendix B. Data structure

Table B1. Coding scheme

First order concepts	Second order themes	Aggregate themes
1. Radical innovation 2. Incremental innovation	**Degree of novelty**	**Technology attributes**
3. Productivity improvement 4. Cost reduction	**Expected implementation benefits**	
5. Exclusive license to use technology 6. Proprietary technology 7. IP owned by another company 8. No IP protection enforceable	**Control over IP**	**Deployment incentives**
9. Broadening effect on service portfolios 10. Deepening effect on service portfolios	**Potential impact on complementors' portfolios**	
11. Early engagement with potential deployers 12. Late engagement with potential deployers	**Engagement with deployment partners**	**Enabling factors for deployment**
13. No first implementer available 14. Operating Unit as first implementer 15. Service company as first implementer	**Availability of a first implementer**	

Table B2. Exemplifying evidence

Exemplifying quotations	Second order themes
1. Radical innovation *"The technology is totally new, based on completely different physics. It is totally new ground for the exploration and production industry"* **2. Incremental innovation** *"It is basically an alternative application of an existing technology"*	**Degree of novelty**
3. Productivity improvement *"We invented something that service companies will sell us for big money through our operations, but what Elektra gets back is a well that produces more than before"* **4. Cost reduction** *"This new welding method will enable potential cost savings of about 15%"*	**Expected implementation benefits**
5. Exclusive licence to use technology *"All IP is with company X, however we now have an exclusive licence. We discussed the option to try and buy the IP, but it didn't progress"* **6. Proprietary technology** *"We got 14 patents that covered a very wide range of applications"* **7. IP owned by another company** *"There was some discussion on the deployment. Since company X had the IP on the water-jet technology it was not clear how it was going to be finally packed"* **8. No IP protection enforceable** *"It is more like a technique. It is not something I could patent. It is very difficult to protect"*	**Control over IP**
9. Broadening effect on service portfolios *"It is a new technology play. It is a big area with several potential applications. The project has the potential to open up a big market for ultra-deep perforators that hasn't been occupied yet"* **10. Deepening effect on service portfolios** *"This problem of controlling sand is already addressed by service companies but with the use of filters, which are quite expensive and reduce production, so our solution was better overall"*	**Potential impact on complementors' portfolios**
11. Early engagement with potential deployers *"All these people were kept updated constantly on how this project was moving on. So, when it was finally tested and proven, they were ready to take it"* **12. Late engagement with potential deployers** *"If you have the end-customers of the project involved at an early stage, they might want to change it completely, and we don't like that. That's why we decided to involve them at the end of the project"*	**Engagement with deployment partners**
13. No first implementer available *"What I didn't have was a first implementer. Whenever you go for an invention, it is better to have a first implementer, somebody that as soon as it is ready is willing to run it"* **14. Operating Unit as first implementer** *"I got a feedback from the operating units that they had two wells available for us. But they were not driving the process, just sitting and waiting for us"* **15. Service company as first implementer** *"We explained the opportunity to potential partners, including company X, Y, Z. Company A expressed an interest in implementing the technology, and agreed to sponsor the field testing"*	**Availability of a first implementer**