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Evaluation of Innovation Strategies to Achieve Process Innovation in the Oil Industry

BY

Amir Bahman Radnejad

A THESIS

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ABSTRACT

This dissertation includes three essays exploring the development of technical process innovations in the oil industry. Currently, the industry is facing a fast-changing technological environment, calling for innovations addressing its environmental, social and financial challenges. This context is interesting because the study of both the oil industry, as a process- and resource-oriented industry, and of technical process innovations has been lacking in the business literatures. The first essay studied a new entrant to the Canadian oil industry that aimed to develop a disruptive process innovation. By studying this case, I identified some of the challenges that the firm faced through developing the innovation, including a) a lack of resources, b) a vertical leadership style, c) tension between the investors` expectation to gain quick profit and the lengthy process of technology development, and d) internal collaboration. The study suggests that to address these barriers, new entrant firms may: 1) utilize inter-firm collaboration, 2) develop intra-firm collaboration, 3) develop non-vertical leadership skills, and 4) secure long-term investments. The second essay, a multiple case study of innovation intermediaries in the Canadian oil industry, followed the finding of the first essay on collaboration. In this essay, I extended the open innovation model both theoretically and practically by identifying the boundary conditions that motivate firms and the approaches that have been implemented in practice in applying this model. The second essay suggests that institutional forces (e.g., normative and coercive forces) are the primary motivators for adopting open innovation in response to the social and environmental concerns faced by the oil industry. In addition, by building on meta-organizations' taxonomy, the study demonstrates that establishing not-for-profit innovation intermediaries was necessary to govern adoption of open innovation in this industry. The

third essay explored one of the most successful models of such innovation intermediary and discusses its successes and failures. The conceptual model that was derived from the findings combines strategic bridging organisational concepts with open innovation model ideas to help us understand how an innovative technologies network at the industry level is built.

PREFACE

Essay Three, which is presented in chapter 4, has been published in *International Journal of Innovation Management and Entrepreneurship, Vol 19(1-2): p. 77-98* (Radnejad, A., and Vredenburg, 2015). I am the lead author, responsible for the major areas for concept formation, data collection and analysis, and manuscript composition of this paper. Dr. Harrie Vredenburg is the supervisory author on this paper and is involved in the early stage of determining the topic and contributed to the manuscript edits. Inderscience retains copyright of this article.

All three Essays, which are presented in Chapter 2, 3, and 4, involved interviews with experts and managers in the Canadian oil and gas industry. The research was approved by the Conjoint Faculties Research Ethics Board at the University of Calgary (Ethics file No 7336).

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If you want to go fast, go alone. If you want to go far, go together. –African Proverb

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Table of Contents

ABSTRACT II

PREFACE IV

ACKNOWLEDGEMENT V

LIST OF TABLES XI

LIST OF FIGURE XII

CHAPTER ONE: INTRODUCTION 1

1.1 INNOVATION IN THE OIL INDUSTRY 1

1.2 INTERNAL RELATIONSHIPS AMONG EACH DISSERTATION ESSAY 4

REFERENCES 9

CHAPTER TWO 12

DISRUPTIVE TECHNOLOGICAL PROCESS INNOVATION CAPABILITY IN A PROCESS-ORIENTED INDUSTRY: LESSONS FROM A CASE STUDY 12

ABSTRACT 12

2.1 INTRODUCTION 13

2.2 LITERATURE REVIEW 17

2.2.1 Disruptive innovation 17

2.2.2. Technological Process Innovation 20

2. 3 RESEARCH METHODOLOGY 22

2.4 CASE STUDY 26

2.4.1 HOP as a new entrant in the oil industry 26

2.4.2 The history of GET 28

2.4.3 Challenges to develop GET 34

2.5 DISCUSSION 44

2.6. CONCLUSION, APPLICATIONS AND LIMITATIONS 49

REFERENCES 51

CHAPTER THREE 62

THE EVOLUTION OF THE RESEARCH AND DEVELOPMENT OPEN INNOVATION MODEL TO ADDRESS ENVIRONMENTAL CHALLENGES IN THE PETROLEUM INDUSTRY 62

ABSTRACT: 62

3.1. INTRODUCTION 63

3.2. LITERATURE REVIEW 64
3.2.1. The open innovation model, innovation intermediaries and meta-organizations 64
3.2.2 Neo-Institutional theory 68
3.3. RESEARCH METHODOLOGY 69
3.3.1 Research Context and Design 69
3.3.2 Data collection 72
3.3.3 Data Analysis 73
3.4. FINDINGS 76
3.4.1 The open innovation model as a tool to develop environmental technical innovations 76
3.4.2 Innovation intermediaries as a tool to apply open innovation 81
3.5. DISCUSSION 95
3.6. CONCLUSIONS, LIMITATIONS AND FUTURE RESEARCH 101
REFERENCES 102
APPENDICES 110
Appendix 1 110
Appendix 2 111
CHAPTER FOUR: COLLABORATIVE COMPETITORS IN A FAST-CHANGING TECHNOLOGY ENVIRONMENT: OPEN INNOVATION IN ENVIRONMENTAL TECHNOLOGY DEVELOPMENT IN THE OIL AND GAS INDUSTRY 112
ABSTRACT 112
4.1 INTRODUCTION 113
4.2 LITERATURE REVIEW 117
4.2.1 Open innovation 117
4.2.2 Absorptive capacity 121
4.3 METHODOLOGY 123
4.3.1 Data collection 125
4.4 CASE STUDY 126
4.4.1 Creation of PTAC 126
4.4.2 The PTAC model 137
4.4.3 Pitfalls of the PTAC model 139
4.5 ANALYSIS AND DISCUSSION 141

4.6 CONCLUSIONS 146
REFERENCES 146
CHAPTER FIVE: CONCLUSIONS 153
5.1 SUMMARY OF FINDINGS 153
5.2 THEORETICAL CONTRIBUTIONS AND MANAGERIAL IMPLICATIONS ... 157
5.3 LIMITATIONS AND FUTURE DIRECTIONS 159
REFERENCES 161
APPENDIX -- COPY-RIGHT PERMISSION 164

LIST OF TABLES

Table 2. 1. Barriers facing Incumbents to Develop Disruptive Innovation Capability (re-created from Assink`s (2006)) 19

Table 2. 2 GET technology as a disruptive technological process innovation 30

Table 2. 3 Sample quotations 41

Table 3. 1. Meta-organization taxonomy regenerated from (Gulati et al., 2012) 67

Table 3. 2 The four cases 71

Table 3. 3 Quotation examples for R&D Collaboration on environmental and social issues 79

Table 3. 4 Weaknesses and strengths of four industry founded innovation intermediaries extracted from the interviews 94

LIST OF FIGURE

Figure 2. 1 Selective codes and their distribution 26

Figure 2. 2 Challenges theme and their distribution with the "Barriers and Challenges" code 35

Figure 3. 1. Selective codes and their distribution 75

Figure 3. 2. Nodes cluster based on word similarity 75

Figure 3. 3. Innovation Intermediaries time line creation and Oil price (adjusted prices) 84

Figure 3. 4. Innovation Intermediaries` Organizational Design based on Meta-Organization Taxonomy..... 97

Figure 4. 1. Number of joint R&D agreements from 1996 to 2011 (environmental projects vs. non-environmental projects), Source: Extracted from PTAC's Annual reports (PTAC, 1996–2011)..... 136

Figure 4. 2 Share of environmentally-focused projects from the total investment in joint R&D 137

Figure 4. 3 PTAC collaborative model (see online version for colours), Source: PTAC (2012) 138

Figure 4. 4 Collaborative open innovation model (see online version for colours) 143

CHAPTER ONE: INTRODUCTION

1.1 INNOVATION IN THE OIL INDUSTRY

During the past three decades the oil industry has experienced significant technological shifts that have redefined industry practices. By the late 1990s, the volume of oil discovered worldwide declined significantly from its peak in 1960s (Omer, 2008). At the same time, the energy forecast produced by the International Energy Agency (IEA) and the Energy Information Administration (EIA) predicted a substantial increase in energy consumption, specifically, fossil fuel consumption by 2100 (Omer, 2008). In response to these factors, the oil industry has developed revolutionary technologies (e.g., horizontal drilling, hydraulic fracturing, and Steam Assisted Gravity Drainage (SAGD)), which have enabled the industry to increase the rate of recovery of conventional oil reservoirs and to extract unconventional reservoirs (e.g., shale oil and gas and oil sands) economically.

The application of these technologies has increased the oil supply; however, it has created new challenges for the oil industry. In particular, the extraction of unconventional reservoirs has spurred international public debate about its environmental impact. As a result, the industry faces strict environmental regulations and procedures. The impact of both the new technologies and the harsher regulations has increased the cost of extraction for oil firms. Therefore, there is pressure on the industry for technical innovations that can reduce both costs and environmental impacts. Therefore, the challenges that the industry is faced with are how to develop the required innovations (either sustaining and/or disruptive) and what the most suitable innovation strategies are. During the past four years, I have focused my research extensively on investigating these questions.

I argue finding answers to these questions is relevant, not just to the oil industry, but to any industry facing similar challenges (i.e., extracting resources while facing environmental and financial challenges). In addition, studying innovation strategies in these type of industries, which are named either resource-based industries and/or process-oriented industries (Stadler, 2011), seems interesting for business academics since it can contribute to the business literature from different ends, as discussed below.

First, firms within the oil industry cannot gain a competitive advantage through product differentiation or product innovation, but only through effective process innovations (technological or organizational), such as those for cost reduction, increased production of resource-in-place, and/or expedited regulatory approvals. Thus, by studying innovation in the oil industry, we can gain a better understanding of the challenges faced by firms developing process innovations (either sustaining or disruptive). Studying process innovation is important since it has been neglected in scholarly innovation research relative to product innovation (Crossan & Apaydin, 2010; Frishammar, Kurkkio, Abrahamsson, & Lichtenthaler, 2012; Laursen & Salter, 2006; Stadler, 2011; Un & Asakawa, 2015). It is important to note that innovation mechanisms are different for product and process innovation on dimensions such as goals, valuation, imitability, rareness, substitutability and competitive impact (Un & Asakawa, 2015). As such, knowledge that is derived from product innovation studies may not transfer directly into process innovation (Damanpour, 2010; Pisano & Shih, 2012; Stadler, 2011; Un & Asakawa, 2015). Thus, there is a need to understand whether the barriers, challenges and capabilities to develop a process innovation are the same as product innovation.

Second, within such industries, competition between firms does not concern technology development but acquiring, accessing and producing prospective reservoirs. Therefore, there is less competition between oil producers to patent technologies they develop. This is apparent when we consider that most of the newly developed technologies, including radical technological innovations such as multi-stage hydraulic fracturing, or fracking, horizontal drilling, and SAGD are not patented by any oil and gas company. This circumstance differentiates oil industry from other traditionally studied industries in the innovation literature such as IT, pharmaceuticals, and industries involved in fast-moving consumer goods (FMCG). In all these industries, patenting and securing intellectual property (IP) plays an important role in competition among firms. Therefore, studying the oil industry will contribute to a greater understanding of innovation strategies that suit industries with competitive environments similar to the oil industry.

Third, innovation in the oil industry does not follow the traditional linear path of "laboratory to market place"(Pretorius & Magee, 2005). While some innovations emerge from research and development (R&D) laboratories in the oil industry, the majority of innovation occurs through the development and deployment of different technologies in the field during day-to-day operations, and without being reported as formal R&D (i.e., hidden innovation) (NESTA, 2007). This process challenges our current understanding of innovation development; therefore, further exploration of innovation and innovation strategies in the oil industry is required.

Fourth, traditionally, the oil industry has applied the closed innovation model; however, through the past three decades, many firms have shifted to the open innovation model. The open innovation model is defined as "… the use of purposive inflows and outflows

of knowledge to accelerate internal innovation, and expand the markets for the external use of innovation, respectively (Chesbrough, 2003, p 2)". The open innovation model has challenged the closed innovation model practices in ways such as developing ownership of intellectual property over the entire cycle of innovation to enjoy its full rent (Teece, 1984). Although Chesbrough (2003) argued that the 21st century is the era of open innovation, the model has been criticized by some scholars regarding its originality, its vagueness, the challenges associated with protecting the internal capabilities of the firm, and the circumstances under which a firm should apply the model (Christensen, Olesen, & Kjær, 2005; Dittrich & Duysters, 2007; Trott & Hartmann, 2009; Van de Vrande, De Jong, Vanhaverbeke, & De Rochemont, 2009; West & Gallagher, 2006; Wikhamn & Wikhamn, 2013). Therefore, studying why the oil firms have shifted towards the open innovation model and how the model has helped them to achieve their innovation goals, can extend our understanding of the open innovation model, which enables us to respond some of the critiques. This PhD thesis also aims to extend and modify the open innovation model.

1.2 INTERNAL RELATIONSHIPS AMONG EACH DISSERTATION ESSAY

This doctoral dissertation consists of three essays that aim to address the above mentioned research questions in the context of the Canadian oil industry. There are five reasons why the studies were conducted in the specific geographical setting of Canada. First, Canada has the one of the largest proven unconventional reservoirs and is currently the largest producer of this resource. The extraction of these resources is heavily challenged by environmental groups. Thus, the Canadian oil industry is trying to address these challenges by developing innovations. Second, the Canadian oil industry is one of

the most technologically advanced. Firms in the region have either been the first to introduce the technological advancement or the first to apply technical innovations that were developed elsewhere. For this reason, studying innovation in the Canadian oil industry is relevant. Third, these firms operate under very strict environmental regulations, which has propelled the industry to become more innovative. Fourth, the major companies' head offices are concentrated in a very limited number of locations, resulting in lower cultural diversity and a lower range of external influences (e.g., a single governmental policy) than other, more dispersed industries. Studying oil firms with similar business, cultural and regulatory environments assists us in controlling for as many external influences as possible (Eisenhardt, 1989). Fifth, I had extensive access to the headquarters of all major firms and organizations active in the Canadian oil industry. This access allowed me to meet with industry leaders and gain a unique and comprehensive perspective on the industry`s challenges with innovation.

In addition, all essays followed the same qualitative method and research design. The essays followed the case study approach (essay 1 and 3 are 'single case' and essay 2 is 'multiple-case'). In total, I interviewed approximately fifty experts in the field. Each interview lasted between 30 to 90 minutes. Detailed notes were taken through the interviews, and when permitted, they were recorded and transcribed. In total, I gathered approximately 500 pages of transcribed materials. In addition, more than 1,000 pages of public materials, including web pages, annual reports and media reports were studied and added to the data base of the research.

The first essay is "Disruptive Technological Process Innovation Capability in a Process-oriented Industry: Lessons Learned from a Single Case Study". In this essay, I studied a

firm within the Canadian oil industry that aimed to disrupt the industry by introducing a disruptive technical process innovation. The firm strictly followed the traditional closed innovation model and failed to commercialize its process innovation, which was also environmentally friendly. Studying this firm was an exceptional research opportunity, as I was able to interview almost all the former senior managers and senior staff of a company, which occurs rarely. As a result, I was able to build a very comprehensive and rich data set. Thus, I can confidently claim that data saturation was reached. It was also a unique opportunity to study a firm that aimed to disrupt the industry but failed to do so. As Bill Gates once noted "It is fine to celebrate success, but it is more important to heed the lessons of failure." From a theory-building perspective, there is a need to study new entrant firms who aim to disrupt their industries, in order to identify the challenges that they face. By studying this case, I identified some of the challenges that the firm faced while developing the innovation. This study's findings strongly suggest applying collaborative approaches such as the open innovation model while developing process innovation within the oil industry.

The second essay, "The evolution of the research and development open innovation model to address environmental challenges in the petroleum industry", aimed to explain the most effective way to apply the open innovation model within the industry. The study utilized a multiple-case study approach that included four main innovation intermediaries. An innovation intermediary is "an organization or body that acts as an agent or broker in [some] aspect of the innovation process between two or more parties" (Howells, 2006, p 720).

The four selected innovation intermediaries were established to directly foster innovation collaboration within the industry. These four organizations are the only innovation intermediaries founded within the past two decades by the industry. They include all the stakeholders in the industry as founders, members, and affiliated members. In addition, they are not-for-profit organizations, and the sole goal of their establishment, as stated in their mission, vision, and mandates, is to facilitate open innovation.

This particular study allowed me to explore why the industry has adopted the open innovation model by examining the factors that led to this strategy. To better understand this shift to the application of the open innovation model, I have applied institutional theory as the theoretical framework of the paper. The study suggests that normative and coercive forces are the primary motivators to adopting open innovation in order to respond to the social and environmental concerns faced by the industry. In addition, by building on meta-organizations` taxonomy, this study demonstrates that to enjoy the benefits of the open innovation model over time, the industry has applied and evolved innovation intermediaries' organizational structure.

The third paper, "Collaborative competitors in a fast-changing technology environment: open innovation in environmental technology development in the oil and gas industry", aims to provide a comprehensive model of the most effective innovation intermediary founded by the oil industry. The last essay studied the Petroleum Technology Alliance of Canada (PTAC) which was founded to advance the open innovation model within the industry. PTAC is, by far, one of the most successful innovation intermediaries in the oil industry. It has been active for nearly two decades. To my knowledge, PTAC is the longest lasting organization of its kind within the oil industry. I am thankful for the

extensive access I had to this organization. The director of PTAC, Dr. Asgarpour, granted me access to all its members and non-public documents. Therefore, I can confidently claim that the data gathering process reached the most reliable level of data saturation.

Studying PTAC, a not-for-profit and industry-founded innovation intermediary, provided unique insights into the operations of such an innovation intermediary. It demonstrated how firms participating in collaborative projects are able to fund a project and share the generated intellectual property through a collaboration-competition model. This paper provides a model that can be utilized to create similar organizations in other industries facing the same challenges. This essay has been published in the International Journal of Entrepreneurship and Innovation Management in 2015.

In summary, these three studies provide a greater understanding of the challenges faced by the oil industry to develop innovation (either sustaining or disruptive). In addition, the essays describes how these challenges can be overcome by utilizing the open innovation model through establishing innovation intermediaries. This knowledge can be applied in other industries facing similar challenges. In addition, these studies could provide further insight on the Chesbrough`s (2003) open innovation model. The studies also suggest that institutional forces help propel the application of the open innovation model within the industry. In addition, they indicate that the open innovation model can be applied as an innovation strategy for new entrants aiming to disrupt the industry. Finally, a theoretical model was suggested to found and structure innovation intermediaries.

The following sections of the dissertation contain the three essays, followed by an overall conclusion that suggests potential future research areas that have logically developed from the analysis presented in these essays.

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CHAPTER TWO

DISRUPTIVE TECHNOLOGICAL PROCESS INNOVATION CAPABILITY IN A PROCESS-ORIENTED INDUSTRY: LESSONS FROM A CASE STUDY

ABSTRACT

While established firms dedicate a significant amount of their resources to maintain 'business as usual' and aim to improve current technologies by sustaining innovations, new entrants are more motivated and able to develop disruptive innovations to gain a bigger share of the market. However, the barriers and challenges new entrants face and the capabilities required to develop disruptive innovations have been less studied. In this single case study, we identify and describe the challenges that a new entrant in the oil industry faced when developing a potentially disruptive technical process innovation. The identified challenges are: a) a lack of resources (i.e., capital, technical and human), b) a vertical leadership style, c) the tension between the investors` expectation to gain quick profit and the lengthy process of technology development, and d) lack of internal collaboration. The study suggests that when faced with these barriers, new entrant firms should consider: 1) enhancing inter-firm collaboration, 2) developing intra-firm collaboration, 3) developing non-vertical leadership skills, and 4) securing long term investments. We argue that the lessons learned from the case study extend the scholarly and practical understanding of disruptive process innovation. We suggest that new entrant firms within process-oriented industries should consider when facing the challenges of developing such innovations.

Keywords: Disruptive Innovation, Process Innovation, Innovation Capabilities, Process-Oriented Industries, Oil Industry

2.1 INTRODUCTION

"It is fine to celebrate success, but it is more important to heed the lessons of failure." - Bill Gates

While innovation has been identified as a main source of growth for firms (Penrose, 1959; Schumpeter, 1934), a competitive economy demands changing managerial approaches from developing sustaining (or evolutionary) innovations towards developing disruptive (or revolutionary) product, process and business model innovations (Christensen, 1997; Hamel, 2002; Tidd, Bessant, & Pavitt, 2009). However, as Christensen (1997) argues, established firms have been less successful in their ability to identify, develop and commercialize disruptive innovations. He observes that established and larger firms dedicate a significant amount of their resources to maintain 'business as usual' and aim to improve current technologies by sustaining innovations while new entrants have less financial restrictions and are more motivated and able to develop disruptive innovations (Christensen, 1997).

Scholars have confirmed Christensen`s argument by empirically studying the factors inhibiting established corporations from creating radical innovations and particularly disruptive innovations (see table 1) (Assink, 2006; Dougherty, 1992; Henderson, 1993; Paap & Katz, 2004; Sharma, 1999). However, what has been studied less are the barriers new entrants face in order to develop disruptive innovations and the capabilities required to address those. Considering ex-ante ability of disruptive innovation theory, this paper aims to identify the barriers and the required capabilities by studying a new entrant, in a single case study. The studied firm aimed to develop and introduce a potential disruptive technological process innovation in a process-oriented industry, although unsuccessfully.

The case company, a new entrant to the oil industry, planned to develop a technology that would disrupt the unconventional oil industry around the world. This single case study is unique and worth exploring for several reasons. First, the case helps us to gain a greater understanding of the challenges faced by firms aiming to develop disruptive process innovations, in particular disruptive Technological Process Innovations (TPIs). Studying process innovation is important since it has been ignored in scholarly innovation research relative to product innovation (Asakawa, Nakamura, & Sawada, 2010; Crossan & Apaydin, 2010; Frishammar, Kurkkio, Abrahamsson, & Lichtenthaler, 2012; Laursen & Salter, 2006; Un & Asakawa, 2015). It is important to note that innovation mechanisms are different for product and process innovation on dimensions such as goals, valuation, imitability, rareness, substitutability and competitive impact (Un & Asakawa, 2015). As such, knowledge that is derived from product innovation studies may not transfer directly to process innovation (Damanpour, 2010; Pisano & Shih, 2012; Stadler, 2011; Un & Asakawa, 2015). Thus, there is a need to understand whether the barriers, challenges and capabilities to develop a potential disruptive process technology are the same as for a potential disruptive product innovation.

Second, the firm was operating in a process-oriented industry (i.e., the oil industry). Process-oriented industries have been less explored in academic literature compared to product-oriented industries (Stadler, 2011). Process-oriented industries, such as oil and gas, produce an undifferentiated product (a commodity). As such, firms cannot gain a competitive advantage through product differentiation or product innovation, but only through effective process innovation (technological or organizational) that lead to cost reduction, increased production of resource-in-place, and/or expedited regulatory

approvals (Radnejad & Vredenburg, 2015). In addition, the process-oriented industries are usually highly capital intensive. The studied firm spent about half a billion dollars (CND) to in an attempt to develop its innovative process technology. Exploring this specific case increases our understanding of the specific conditions required to develop potentially disruptive technological process innovation in such industries.

Third, the authors had extensive access to this firm. One of the researchers was a non-executive independent director of the firm for nine years and acted as the complete participant. "In 'complete participation', the ethnographer is or becomes a member of the group that is being studied"(DeWalt & DeWalt, 2010, p 259). Therefore, as a result of this unique opportunity, the authors were able to observe the challenges faced by the firm during the development of this technology.

The findings of the paper suggest that new entrant firms may face a number of challenges to develop a disruptive process innovation, including a) a lack of resources (i.e., capital, technical and human), b) the adoption of a vertical leadership style, c) balancing tension between the investors' expectation to gain quick profit and the scientists and engineers' expectation to have adequate technology development time, and d) internal collaboration problems. Developing disruptive process innovation capability can help new entrant firms to address these barriers. This study has identified four antecedents to develop this needed capability. First, firms may consider expanding their external collaboration through different means, such as applying the open innovation model (Chesbrough, 2003) or making strategic technology alliances (James, 1985). Developing a disruptive technical process innovation in a process-oriented industry is complex and expensive, which makes it extremely difficult for a single firm to tackle. Second, internal collaboration

competency is another important factor for a new entrant firm to achieve disruptive process innovation capability. Developing process innovation requires collaboration with different sectors of the firm (e.g., lab engineers, field engineers, scientists and external stakeholders); however, it also creates potential tensions due to differences in expertise and knowledge backgrounds. The firm needs to manage these tensions during lengthy and complex development of a disruptive process innovation. Third, new entrant leaders who are looking to disrupt the industry may have strong ideas, visions and biases about the innovation, which may motivate the leaders to adopt a vertical leadership style – i.e., formal and hierarchical top-down leadership (Carson, Tesluk, & Marrone, 2007; Ensley, Hmieleski, & Pearce, 2006). This study shows that the adopted vertical leadership style inhibited the firm`s ability to fully expand its innovative capability to develop its disruptive process innovation. Thus, it can be argued that it is potentially beneficial if leaders of new entrants adopt a more participatory management style, which is defined as providing opportunities for non-management employees (e.g., scientists and engineers) to influence the decisions (Collins, 1997). Fourth, regardless of how promising the innovation looks, the goal of a quick win for a disruptive technical process innovation in such industries may not be achievable. Thus, the investors (i.e., either through public market and/or private investment) and leaders of the firm need to consider this possibility and prepare a long-term plan.

The next section reviews the relevant literatures on disruptive innovation and technological process innovation to provide an adequate understanding of each concept. Following the literature reviews, the single case study methodology is explained. Next, the case study section provides knowledge about the firm, the technology and challenges

the firm faced through the development of the technology. Finally, the discussion section discusses the competencies that a firm may require in order to facilitate the process of developing a disruptive technical process innovation.

2.2 LITERATURE REVIEW

2.2.1 Disruptive innovation

Schumpeter`s creative destruction theory (Schumpeter, 1942) provided the initial base for the concept of disruptive innovation introduced by Christensen (Bower & Christensen, 1995; Christensen, 1997). A disruptive innovation is "a successfully exploited product, service or concept that significantly transforms the demand and needs of an existing market or industry, disrupts its former key players and creates whole new business practices and markets with significant societal impact" (Assink, 2006,p 218). Christensen`s theory of disruptive innovation initially suggested five characteristics for a disruptive innovation: 1) having inferior performance on one or two aspects of traditional attributes; 2) offering new value propositions; 3) a lower price compared to the existing product/service; 4) appeals to lower-end and price-sensitive segment of the industry; and 5) improves product`s performance through time and penetrates the market from niche to main stream (Christensen, 1997; Christensen, 2006; Christensen & Raynor, 2013; Gilbert, 2003). For example, the personal computer industry, while initially provided slower and less capable computers than mainframe computers, was able to disrupt the mainframe computer industry by offering new values, such as more affordability and portability that could attract the attention of a niche market. The greater affordability of personal computers opened a new market for those with an average income to buy computers rather than limiting it to wealthier organizations, such as corporations and

universities. Moreover, as the technology progressed, the industry was able to improve the performance of personal computers and further penetrate the mainstream market.

Reflecting on this definition, three points need to be considered to avoid misunderstandings of disruptive innovation. First, disruption should be considered a relative phenomenon; meaning that an innovation can be considered a sustaining innovation for a focal firm while it is considered disruptive for other players in the market (Yu & Hang, 2010). Second, the incumbent businesses will not necessarily be replaced by the entrants. They may continue their business in a niche market (Schmidt & Druehl, 2008; Yu & Hang, 2010). Third, some scholars argue that disruptive innovation is a *post-hoc* theory and thus is unable to provide *Ex ante* predictions (Danneels, 2004; Tellis, 2006). However, other scholars have argued that the theory can provides predictive information (Christensen, 2006; Govindarajan & Kopalle, 2006; Schmidt & Druehl, 2008). For example, Govindarajan and Kopalle (2006) argue that we can identify firms that are likely to develop a disruptive innovation. In another example, Schmidt (2004) argues that firms can predict whether a market is ready to be disrupted. In general, as Christensen (2006) argues, disruption is not necessarily defined by the outcomes of the technology.

To develop disruptive innovations, firms face significant uncertainty regarding technological feasibility, commercial viability, organizational capability and social acceptability (Hall & Martin, 2005). Thus, building on the dynamic capability literature (Teece, Pisano, & Shuen, 1997), firms need to develop a disruptive innovation capability. This is defined as an internal drive and energy to generate, develop and experiment with radical new ideas aiming to change the pattern of the existing market (Assink, 2006).

However, incumbents are unlikely to develop such a capability since they benefit from sustaining and capitalizing on their current capabilities and avoid any path which ultimately makes their existing capabilities obsolete (Ahuja & Morris Lampert, 2001; Christensen, 1997; Henderson, 1993; Unsworth, 2001). Assink`s (2006) review of the empirical literature revealed a comprehensive list of barriers that prevent most incumbents from developing disruptive innovation capability. The summary of his findings is provided in Table 2.1.

Table 2. 1. Barriers facing Incumbents to Develop Disruptive Innovation Capability (re-created from Assink`s (2006))

Barriers facing Incumbents to Develop Disruptive Innovation Capability
1) The Adoption Barriers A. **Existing Successful Products/Services** B. **Successful Business Model** C. **Lacking Organizational Dualism** D. **Excessive Bureaucracy** E. **Status-quo Stifling** F. **Path Dependency and Dominant Design**
2) The Mindset Barriers A. **Inability to Unlearn** B. **Lacking Distinctive Competencies** C. **Obsolete Mental Models** D. **Theory-in-Use**
3) The Risk Barriers A. **High Risk and Uncertainty** B. **Lacking Realistic Revenue & ROI expectation** C. **Risk Averse Climate** D. **Unwilling to Cannibalise Own Investment**
4) The Nascent Barriers A. **Lacking Creativity** B. **Lacking Market Sensing & Foresight** C. **Senior Management Turnover**

D. **Learning Gap**

5) The infrastructural Barriers

A. Lacking Mandatory Infrastructure and Follow-through

Compared to the incumbents, entrants have a higher chance of developing a disruptive innovation capability since they are not facing the majority of the above mentioned barriers (e.g., such as having a successful product, risk-averse climate, keeping status quo, etc.) (Anderson & Tushman, 1990; Bower & Christensen, 1995; Christensen, 1997; D'Este, Iammarino, Savona, & von Tunzelmann, 2012; Henderson, 1993; Henderson & Clark, 1990). However, new entrants do face some barriers when introducing a disruptive innovation that has yet to be identified as such. In addition, there is a need to identify the competencies that firms need to develop to face those barriers. This paper aims to identify these barriers and competencies.

2.2.2. Technological Process Innovation

Process innovation is defined as "changes in the ways in which a product/service is created and delivered" (Tidd et al., 2009, p 21). It may enhance a firm`s competitive position by increasing efficiency, reducing costs, increasing production volume, reducing production time, and improving quality and reliability (Frishammar et al., 2012; Gopalakrishnan, Bierly, & Kessler, 1999; Kurkkio, Frishammar, & Lichtenthaler, 2011; Lim, Garnsey, & Gregory, 2006; Pisano, 1994). As a result of its variety of effects, process innovation has been categorized into two main types: Organizational and Technological Process Innovation (TPI) (Edquist, Hommen, & McKelvey, 2001).

Organizational process innovation focuses on improvements in organizational practices, strategy, administrative processes, organizational structure, management processes and so on (Armbruster, Bikfalvi, Kinkel, & Lay, 2008; Edquist et al., 2001). Technological process innovations are new components and technologies within an organization's production system or service operation (i.e., faster delivery time, greater operational flexibility, and less production costs) that enhances the production/delivery of a product/service to the user (Abernathy & Utterback, 1978; Boer & During, 2001; Damanpour & Gopalakrishnan, 2001; Knight, 1963). TPI can be created and developed internally, or adopted from elsewhere (Gopalakrishnan & Damanpour, 1994; Meyers, Sivakumar, & Nakata, 1999).

Building on the dynamic capability literature (Teece et al., 1997); to develop process innovation, firms need to enhance their process innovation capability, which is defined as "a firm`s ability to acquire, assimilate, transform, and exploit technically related resources, procedures, and knowledge for process innovation purposes such as engineering know how" (Frishammar et al., 2012, p 519). Frishammar et al (2012) have identified three antecedents for process innovation capability: 1) Strategy, 2) Collaboration and 3) Culture.

A firm-level strategy which supports process innovation is one of the main factors which can shape a successful process innovation (Reichstein & Salter, 2006; Utterback & Abernathy, 1975). In addition, prior research has emphasized the effectiveness of external and internal collaboration on the process innovation capability of a firm (Asakawa et al., 2010; Gopalakrishnan et al., 1999; Pearce & Ensley, 2004; Sawy, Eriksson, Raven, & Carlsson, 2001). Regarding internal collaboration, a firm needs to

provide opportunities for its people from different disciplines to create and develop ideas together and to facilitate the flow of knowledge and ideas within the firm`s boundary (Frishammar et al., 2012; Stadler, 2011). In addition, inter-organizational collaboration through shaping strategic technology alliances (Hagedoorn, 1993) and/or open innovation model provides the opportunity to share risks and costs associated with process innovation (Chesbrough, 2003; Chesbrough, 2006; Chesbrough, Vanhaverbeke, & West, 2006). Among different types of inter-organizational collaboration, Research and Development (R&D) collaboration with suppliers have the highest impact on process innovation (Asakawa et al., 2010). Finally, the presence of an innovation culture can empower employees, encourage experiments, and create an effective relationship between top managers and the operating staff. It also supports risk takers and can lead to an increase in the process innovation capability of a firm (Akgün, Keskin, & Byrne, 2009; Ekvall, 1996; Pearce & Ensley, 2004; Repenning & Sterman, 2002). However, the question remains as to whether the mentioned antecedents for process innovation capability are enough to develop a *disruptive* process innovation capability.

2. 3 RESEARCH METHODOLOGY

An in-depth single case study method (Yin, 2009) was selected as the research method. Thus, a relatively new entrant and small oil company which was active in upstream oil industry was selected as the single case study. We have selected the upstream side[1] of the oil industry, as an exemplary case of a process-oriented industry (Stadler, 2011), as we acknowledge that the oil industry is heavily dependent on process innovation, both technological and organizational.

[1] "Upstream" refers to the extraction and production of oil.

To keep the case confidential – a condition of participation for some of the interviewees - the firm is disguised with a fictional name. In addition, we have changed some specifications of the case, such as the foundation year, termination year, and the name of technology to preserve the anonymity of the case. These changes do not result in any material difference in the context, process, or the result of the research.

To provide construct validity and to triangulate our data, we used multiple sources of evidence, including semi-structured interviews with executive managers, senior engineers and senior scientists involved with the development of the technology, the annual reports of the firm, press releases and other available public documents that cover relevant information about the case (Eisenhardt, 1989; Eisenhardt & Graebner, 2007; Yin, 2009).

In addition, one of the authors acted as a complete participant. "In 'complete participation', the ethnographer is or becomes a member of the group that is being studied" (DeWalt & DeWalt, 2010, p 259). In this case, he was an independent non-executive board member for nine years. Through his term, the researcher attended and observed board meetings and engaged in the process of technology development. To decrease the effect of the potential observer bias in the study (Schwartz & Schwartz, 1955), almost all the interviews (except one of them which was completed in 2009) were conducted by the non-participant researcher. Therefore, the role of the observer was to cross-reference and triangulate the data gathered through the interviews.

The interviews started with key people on the board of directors and senior managers. After those, individuals were identified through the "snowball" technique to get access to additional experts who were aware of the organizations' models and the industry (Yin, 2010). These interviews focused on influential and well-informed individuals within the

firm, the industry and university-based engineering scientists who had knowledge about the technology, the firm and the industry. Almost all of these interviews (except one interview that occurred in 2009) were conducted in 2015-2016, after the company failed to commercialize the technology and merged with another junior company.

In total of 14 semi-structured interviews were conducted. The position titles of the interviewees` included: CEO, CFO, Vice President, Operations Manager, Board Member, Senior Engineers, Senior Scientist, Professor and Director of Government's Regulator body. Each interview lasted between 30 to 90 minutes. Detailed notes were taken through the interviews and, where appropriate, were recorded with permission and transcribed (210 pages of transcriptions).

To keep the identity of participants confidential, we addressed them as senior manager number X (for those who held managerial positions, 6 people in total), senior technical staff number X (for those who held non-managerial positions, 6 people in total) and external expert number X (2 people in total). The number given to each participant in each group was random.

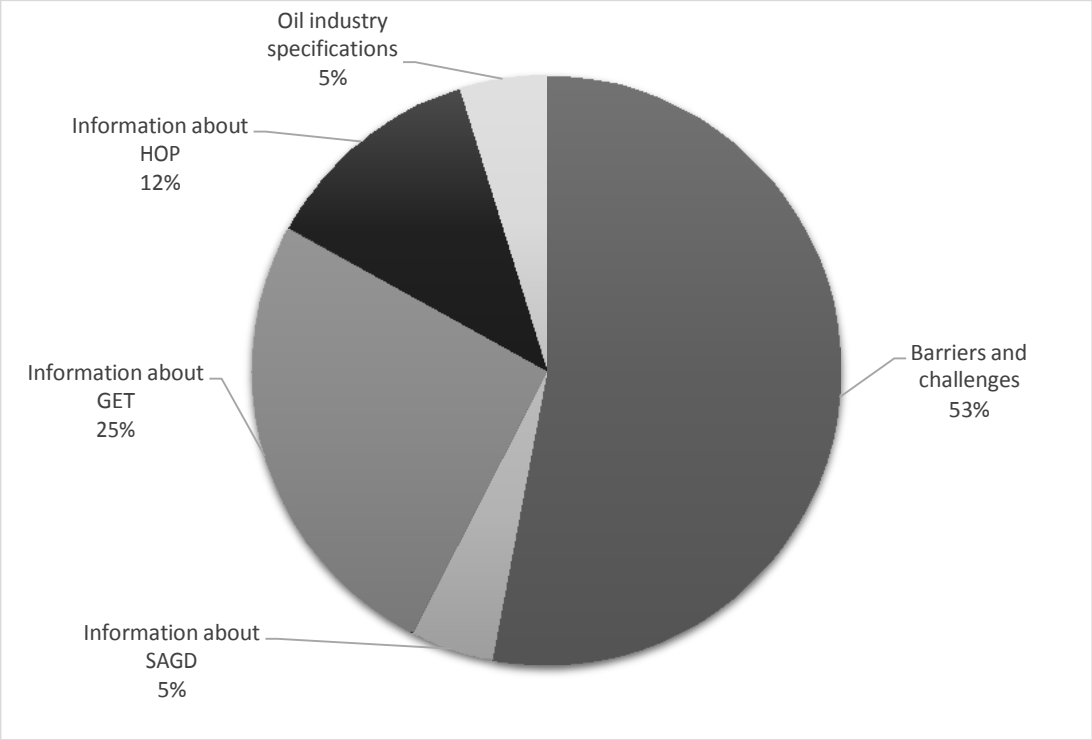
In addition to conducting interviews and gathering active participation data, more than 200 pages and webpages, including the annual public reports of the firm, investment bankers` reports, third party reports on development of the technology and the related articles published in the media, were gathered and analyzed through the data gathering process. The transcriptions, notes and documentary data were analysed using the Nvivo 10 software.

As suggested by Strauss et al. (1994), the data were coded in three stages: with open codes, axial codes, and selective codes. The first level of coding was with "open codes," which are the initial categories developed from the data gathered. We selected one or two key words of each section of data and coded that section with those words. In total 250 codes (including near 495 reference points) were created in this level of coding.

The second level was with "axial codes," which are based on assembling the data in new ways after open coding. At this level, we categorized the key words and grouped those codes according to similar themes. There were 23 codes created at this level. The last level of coding was with "selective codes," which are developed from the axial codes. For this third stage of coding, we re-assessed all codes in the second stage and re-arranged them into higher level themes that are more comprehensive. In this stage, we were specifically looking for the codes that were addressing the barriers and reasons the firm could not commercialize its potential disruptive process technology. Thus, all the codes addressing the barriers were grouped under the title "Barriers and lessons learned". In addition to this major code, we identified four others codes that help us to gain a greater understanding of the case, the industry and the technology. The four codes are: "Information about SAGD[2]", "Information about GET", "Oil industry specification" and "Information about HOP". Figure 2.1 shows the 5 selective codes and their distribution throughout all the codes.

[2] Steam Assisted Gravity Drainage; we explain about this technology later in details

Figure 2. 1 Selective codes and their distribution



2.4 CASE STUDY

2.4.1 HOP as a new entrant in the oil industry

In 1984, High-tech Oil Producer (HOP) was incorporated in Alberta, Canada and later in 1994, it became a public company. In 2015 the firm merged with another junior oil company. HOP was considered a junior and new entrant in the oil industry compared to other players in the market with respect to the age of the company and the volume of oil production:

- **Age factor:** The senior and major oil companies active in the industry are generally around 100 years old (e.g., BP formed in 1909, Suncor in 1917, Husky in 1938, Royal Dutch Shell in 1907, and Imperial Oil in 1880).
- **Production factor:** Major oil companies produce more than 100,000 barrels per day just in Canada (e.g., Suncor at 562,000 barrels/day, CNRL at 478,000

barrels/day, Imperial at 261,000 barrels/day, and Husky at 226,500 barrels/day), while HOP`s light oil production was less than 40,000 barrels/day in Canada (Alberta Oil Magazine, 2014).

In addition, in 2001, a significant stake of HOP was acquired by a private investment company. As a result, the investment company obtained a number of seats on the company's board of directors and appointed a new CEO, who was also one of the new major shareholders. By having a new entrepreneurial CEO, HOP restructured and started a brand-new approach. Before 2001, HOP`s business model was simple and similar to other oil production firms, maximizing conventional and light oil production in Canada. However, by gaining an entrepreneurial and adventurous leader to head the firm, the direction of the company changed significantly. The new management considered the light oil production a cash-cow for the two main new business strategies of the firm. Based on the first business strategy, the firm started an operation in challenging reservoirs in Colombia and Peru in 2003. The goal was to eventually spin off these subsidiaries once they matured and could stand on their own.

The second strategy of the firm was to start two pilot projects to test their newly acquired disruptive process technology, Green Extraction Technology (GET) process, in unconventional reservoirs (e.g., oil sands and heavy oil). The goal behind developing the technology was to profit from it within three business models: First, using the technology on the firm’s assets and to earn a positive rate of return; Second, to license the technology to third parties, mainly internationally, to earn royalty incomes and also develop the technology further (i.e., testing in different reservoirs to increase the know-how and increase competitiveness of the technology); and third, partnering or farming-in with other firms owning assets that could benefit from the technology, thereby monetizing the

value of the technology. Therefore, HOP was restructured in 2001 and considered as a new company which aimed to make a revolution within the unconventional oil industry by developing a new extraction technology.

2.4.2 The history of GET[3]

By the late 1990s, the volume of oil discovered worldwide declined significantly from 270 billion barrels in 1960 to 40 billion barrels in 2000 (Omer, 2008). At the same time, the energy forecast produced by the International Energy Agency (IEA) and the Energy Information Administration (EIA) predicted a substantial increase in energy consumption and, specifically, fossil fuel consumption by 2100 (Omer, 2008). As a consequence, the upstream oil industry found itself with a need to: 1) increase the rate of recovery of conventional oil reservoirs, and 2) develop unconventional reservoirs more economically and later with the increasing environmental pressure, in a more environmental friendly manner (Radnejad & Vredenburg, 2015). These two initiatives led the industry to develop several revolutionary technologies, such as horizontal drilling, hydraulic fracturing, and Steam Assisted Gravity Drainage (SAGD).

SAGD was developed through a consortium named Alberta Oil Sands Technology and Research Authority (AOSTRA) which was led and initiated by the government of Alberta, with participation by the University of Calgary and 15 major oil companies. AOSTRA started to develop SAGD in 1978 and introduced it as a commercially viable technology to the oil industry in 1998 (Deutsch & McLennan, 2005). AOSTRA and the industry invested $620 million through the development of this technology (Wiggins, 2009). SAGD revolutionized the industry by providing the opportunity to economically

[3] All the information in this section with regards to GET and HOP were extracted from the interviews and internal documents

extract unconventional oil (i.e., oil sands) that was not economically feasible to develop by using established other technologies, such as mining at that time.

However, although SAGD changed the face of the heavy oil industry, it has its own challenges. For example, it is an expensive extraction method (with the current oil price which is less than $50 per barrel, new SAGD projects are not commercially feasible). More importantly, the SAGD process faces several environmental issues, including water usage, gas consumption, carbon emission, and land usage. Therefore, it has been criticized by environmental activists and regulators. However, since the North American oil price was around $40 per barrel (adjusted price) in 2000 and was predicted to increase further, the major oil companies aimed to develop incremental innovations making the process more environmentally friendly and cost effective instead of changing the entire process.

In the meantime, the new HOP CEO realized the disadvantages of the SAGD process and aimed to radically change the entire process. In 2001, he became familiar with GET process technology which was laboratory-developed by a Canadian university, a Canadian government research agency and a British university, and was later patented and owned by a governmental research organization in Canada. The new CEO recruited university engineering scientists who were world experts in the technology, external consultants, including investment bankers, and also industrial technical experts to evaluate the technology. Their reports indicated that the technology had the possibility of revolutionizing the unconventional oil industry, and ultimately, had the potential to disrupt SAGD. Table 2.2 matches GET with Christensen`s characteristics of disruptive innovation, mentioned in the literature review section.

Table 2. 2 GET as a disruptive technological process innovation

Characteristic of Disruptive Innovation	GET proposed Specifications
Inferior performance on one or two aspects of traditional attributes	1) Lower peak oil rate 2) Higher well spacing (100 vs 75 meters)
Offering new value propositions	1) Higher recovery Factor 2) Upgrading of the oil subsurface 3) Effective in shallow reservoirs 4) Significant (50%) reduction in GHG emission and significantly smaller surface/land footprint
Lower price compared to the existing product/service	Lower capital cost (60% less than SAGD) and operating costs (50% to 70% less than SAGD) due primarily to lower facility requirements and little or no natural gas consumption
Appeals to lower-end and price sensitive segment of the industry	1) Because of all cost and environmental advantages of the technology, smaller companies with less productive reservoirs would become more active and profitable within the industry 2) Small companies can tolerate oil price fluctuation more easily
Improvement through time and penetrate the market from niche to main stream	The company planned to licence the technology to firms in China, Russia, India and South America to develop the technology further and farm-in on projects based on the technology. Ultimately, the technology would be able to disrupt the dominant SAGD market in the USA and Canada

However, the technology had yet to be tested in the commercial environment, and further development in a pilot field was necessary. Thus, the CEO convinced the board of directors to buy the patent of the technology in 2004. He then recruited an experienced individual as a Vice-President (VP) and assigned him the task of developing and fully commercializing the technology.

To develop the technology, the firm used the classic closed innovation model. The advantages of the closed innovation model include leveraging first mover advantages and protecting a company's knowledge-based resources, or intellectual property (IP), by keeping them internal (Pretorius & Magee, 2005). In addition to these advantages, there were three internal factors that strengthened the logic of selecting the closed innovation

model as the innovation strategy of HOP. First, there was a strong belief supported by several external and internal reports that the technology was nearing commercialization and appeared as a relatively quick win. Thus, there was no need to look for external help and the firm would be able to develop it on its own, which ultimately, would lead the firm to enjoy the full benefit of it, as mentioned below by the respondents.

"Management had a great confidence they did not want to share it with anyone". The senior technical #3

"Collaboration was not the position we took at the time. And I think for valid reasons because it looked like it was going to work and we would be at least ahead of the game." The senior manager #3

Second, the firm had adequate access to capital to commercialize the technology. The Canadian light oil division of the firm, coupled with its South American operations, financed the development stage. In addition, HOP was a public company and the board was confident that they could raise more money through the stock market. Third, majority of the board members had limited openness to collaborating with outsiders, as mentioned by one of the respondents:

"*Partners are a challenge. We are not really a great partner, partnering on a financing basis is challenging, it is challenging on an operating basis and it is even more challenging on an R&D basis. So how do you control who owns it. We made a decision to go 100 percent on this … So we see partnering as a very inefficient way to do business." The Senior Manager #2*

In 2004, after developing a computer model for the technology process, simulations were run based on the lab results, and passing the proof of concept stage was complete. HOP started its first pilot project in an oil sands reservoir. The initial investment for the first pilot project cost nearly $50 million. The first pilot project successfully produced upgraded oil; however, it could not reach a commercialized rate of production (i.e., 500

barrels per day based on the spot oil price in 2004-5). To manage some of the technical challenges (e.g., sand production and equipment erosion) and to obtain a steady-state commercialized production level, the firm planned to expand its pilot project and test it in another reservoir. However, due to the lengthy process of getting governmental approval in the operating province, the firm started the second pilot in a heavy oil reservoir in another province that had a faster regulatory process.

Initial results of the second pilot project in 2007-8 were positive. Thus, the firm`s executive board, technical staff, shareholders, investment bankers, media and independent experts started to believe that it was going to be a quick and tremendous win for HOP. As a result of these predictions, the share price gradually increased from less than $5 per share in 2006 to nearly $35 per share in 2008.

After approximately eight years of development, the firm was confident that commercialization was near. In addition to this belief, the constant pressure of investment bankers to follow the industry trend, to divest its subsidiaries and to refocus on the focal business, pushed the firm to gradually (in a period of two years) sell its other subsidiaries (i.e., the light oil and the South American operations) that were acting as a cash-generator for the development of the GET project. By doing so, the firm became a pure player in the oil sand/heavy oil technology development sector. Becoming a pure player (which was highly recommended by the firms` investment bankers at that time) was considered a superior option for the investors in the stock market since the shareholders would gain 100% benefit if the technology was a win and also those who were not interested in the technology development would be able to make a decision whether to keep the shares, as mentioned by one of the interviewees:

"The Colombian assets and the Canadian Conventional Assets (Light Oil) were opportunistic purchases. They were purchased to help fund the development of this technology, though they were also growing independently as well to create business units and businesses that can operate on their own. I think, what we saw was that not necessarily pressure to develop this technology but from a corporate perspective more of an interest from shareholders to own specific businesses, rather than a conglomerate. So, that was the main reason behind ultimately spinning out the Colombian assets and spinning out the Light Oil assets and becoming a pure Heavy Oil sands play that focused on the GET." The Senior Manager #1

Although becoming a pure player was recommended by financial advisors and supported by number of the board members, it did not gain the support of all board members. Some members opposed the strategy, creating a slower than expected "spinning out" process. However, after two years, the spin-out process was complete and HOP became a pure player.

By spinning out the other two divisions, the firm was left with a budget of nearly $100 million to commercialize the technology; a sum that was considered adequate capital to commercialize at that time. However, the last two years proved challenging to commercialize the technology. Although, the second pilot achieved many positive results and advanced the technology in many ways, it could not reach an acceptable production rate, as stated by two of the respondents.

"We never really had any kind of safety issue, never really control issue, never really had any kind of thing that was like a total fatal flaw other than we couldn't get the production rates to commercial level…we produced a very high quality oil so when you list the things at the beginning, can you design a project to handle the process? Can you manage and control the process? Yes, yes, can you deal with the produced gas? Yes. You know we had the sand control issues, I think we progressed a lot in that too. Did we produce oil that could sell and had value and was accepted in the oil stream? Yes, which is huge but could we control the process to the point we knew what levers to pull to optimize the process to get commercial production rates…that was the big issue." The Senior Manager #5

"…We beat SAGD in any other matters: less surface occupation, upgraded oil, far lower energy consumption, lower CO2 consumption, working in shallow reservoirs and lower cost…But…we needed to increase the production rate which we could not." The Senior Technical Staff #3

In 2014 and 2015, the firm had spent nearly half of its predicted operational commercialization budget without any certainty of success. As well, the price of oil was dropping precipitously after late 2014. During the last several months, the project was only reaching the operational cost breakeven point. At this time, the management and board of directors, who were under significant pressure from the firm`s shareholders, the public market and media, made a decision to reduce their spending on the development of this technology and sought other opportunities to diversify the company`s portfolio. Finally, after more than 10 years in the development process and spending nearly $500 million, the firm was merged with another junior company to protect the interests of the shareholders. The new entity operated the second pilot project for one more year and then shut down the entire project due to the significant drop in the price of oil. Although the GET project concluded in 2015, many believe that either the technology could have been commercialized under HOP`s management, or it will be commercialized in the future by some other company, as one of the respondents suggested:

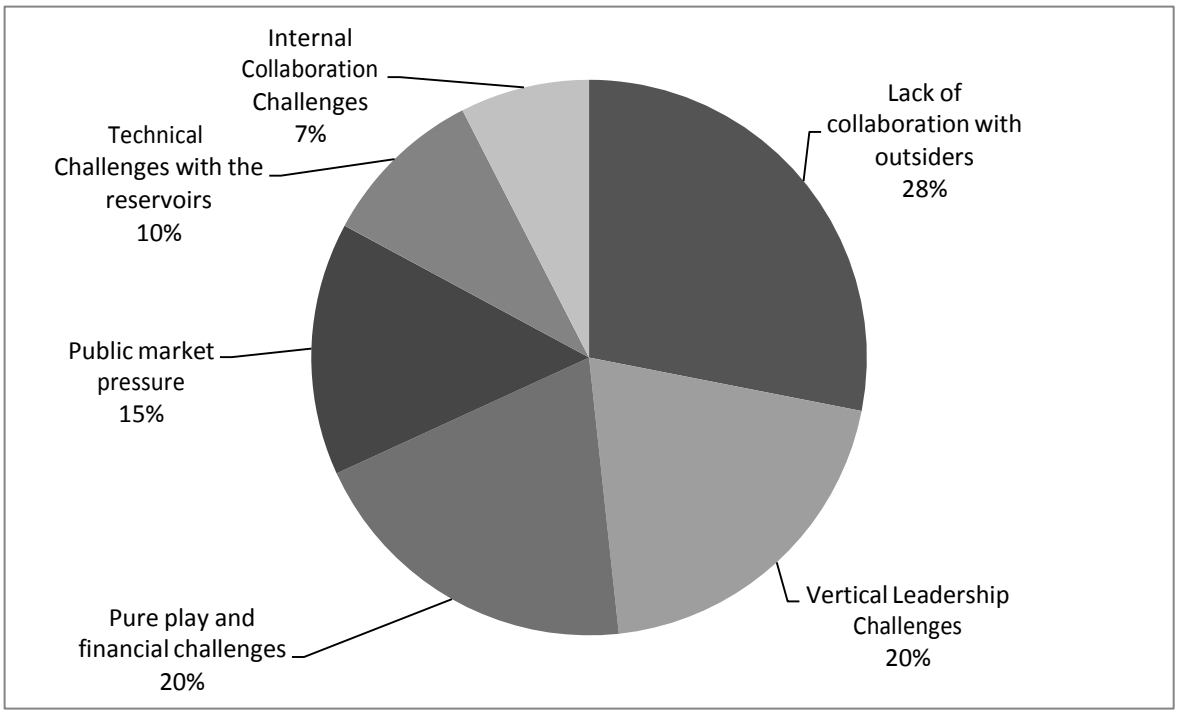
"I don't think it is dead, let's say it's dormant, I wouldn't say it's dead because there's too many things that were successful and again the overarching thing is that it produced an upgraded oil. So, I think that there might be new technologies that come along and could enable the process to be commercial." The Senior Manager #5

2.4.3 Challenges to develop GET

There are a number of technical and non-technical challenges that HOP faced to develop the technology. Through our interviews we have identified six major challenges that were

coded under the main code of “Barriers and challenges”. Figure 2.2 shows the list of barriers and their distribution within the codes.

Figure 2. 2 Challenges theme and their distribution with the “Barriers and Challenges” code



2.4.3.1 Lack of collaboration with outsiders

As mentioned earlier, HOP employed the closed-innovation model as its R&D strategy. It bought the patent rights and hoped to license the technology after its success demonstration. Thus, through the development process collaboration with other companies (including producers and service), universities and research organizations was not a viable option for the management team. On a couple of occasions, some major players, nationally and internationally, showed interest to collaborate with the firm. In these cases, neither side (i.e., HOP and incumbent firms) could come to an agreement on

the terms of collaboration. The only time that the firm sought external help was through short-term consulting contracts with individual experts outside of the firm.

Setting aside the ongoing debate regarding the potential success of patenting or licensing of a process innovation in the oil industry (i.e., patenting a process technology has not been a common practice in the oil industry), the closed-innovation strategy led to minimal access to external resources, and consequently, caused many challenges in the development of the technology. It can be argued that external help such as technical experts, additional technologies and extra funds could have saved the technology. All respondents, either directly or indirectly, mentioned frequently in the interviews that collaboration would have assisted the technology development process significantly. Below are some examples:

"When you are having problems with sand formation and you want to change your slot sizes, if you were part of an alliance with Shell, for instance, you could access some world level people who understand exactly what screens do and how they function … you would be able to get some very good advice on solving that very specific technical problem" Senior Technical Staff #5

"We didn't expand our knowledge into the world to try and find that out, as much as we probably could have… looking back, should we have tried to engage the world earlier? Probably yes". Senior Manger #3

"To successfully develop GET, we needed to have a consortium of companies like COSIA[4]" Senior Technical Staff #3

2.4.3.2. Vertical Leadership Challenges

Although the CEO and VP were the main champions of the innovation, there were challenges in their adopted leadership style which left little opportunity for other team

[4] Canadian Oil Sands Innovation Alliance (COSIA) is an alliance of 13 oil sands producers focused on accelerating the pace of improvement in environmental performance in Canada's oil sands through collaborative action and innovation.

members to voice their ideas. Both the CEO, a petroleum engineer (with advanced education in finance), and VP & COO, a geologist, had comprehensive technical backgrounds within the oil industry. In addition, they were visionaries who recognized the opportunity within the technology and aimed to change the face of the industry. As a result, they were very passionate, dedicated and interested in making the technology work. This led them to create a top-down decision making process (i.e. vertical leadership style), in which they controlled the technology development process. In this hierarchical top-down structure, the leadership (i.e., CEO and COO/VP) made the ultimate decisions. Those decisions were made based on their own personal knowledge and experience about the technology, sometimes in consultation with the staff.

Their decisions included both the general direction of the firm and also technical decisions in the field. Therefore, the leadership became extensively involved in minor technical decisions and the staff had limited decision making power in their areas of expertise. In some occasions, the technical staff had to follow management orders reluctantly, as respondents mentioned:

"I think really it was the people at the top that you know at the end of the day they made all the decisions technically or nearly all of them. So, it was almost irrelevant how smart of people they hired…CEO, would make nearly every technical decision." Senior Technical staff # 1

"The president can make you; it is his company, so if he wants to add more air or if he wants to do things he can … because they can force you." Senior Technical staff # 2

"They (i.e. leaders) always had a chance to convince us to do crazy things... Don't be afraid to say crazy things because they were crazy things." Senior Technical staff # 4

This compromised innovative thinking and collaboration within the firm. At times, staff were instructed to follow the directions given by the top management. As a result, the

team members could not effectively share their experiences and knowledge of the process, or try alternative solutions to existing challenges which bounded the development process, as mentioned by our respondents:

"I would say we stifled innovative thinking just by being very one dimensional … So I think we could have been more successful if we had more free flowing thought through that group.. I think that the leader has to be one that encourages and supports and tries to make the team be very innovative, not technicians and I think we had too much of a push to be technicians as opposed to being innovative." Senior Manger # 4

"You (a leader) need the ego; you need the drive to push through a new process. You can't do it without that. The trick is to harness it, the trick is to have an agreed upon way of doing things so that you can harness those egos but direct that energy, right, and you know that was kind of lacking so that was all over the place." Senior Technical Staff #5

2.4.3.3 Pure Play and Financial Challenges

In the first 10 years of development, the firm had access to a significant amount of cash from the other two cash-generating subsidiaries of HOP. Therefore, the firm was able to spend money on wells, well equipment and completion techniques. However, after spinning out the two cash-generating subsidiaries and becoming a pure player in the oil sands technology development sector, the firm remained with a budget of $100 million to develop the technology.

As a result, the firm lost its distinctiveness as a mainly internally-funded innovator and became a classic cash-burn tech startup. This point was highlighted and discussed by some of senior managers. However, equity market pressures to spin out prevailed and overruled the misgivings of several directors and senior executives. The below quotation is the response from a director who was in favor of spinning out to justify the pure-play strategy:

"We are not running a university lab with endless money. We are running a business and we need to make money now. We cannot wait any longer for this to work." The senior director #7

Later, as predicted by some, the lack of cash-making businesses to fuel the technology development process left the firm in a financially challenging environment. The burn rate was much higher than expected and the $100 million budget would not be sufficient, as stated by our respondents:

"But basically we were running out of money, but I think we were closer to success than we may have thought we were." The senior manager #4

"We started off with about one hundred million dollars after all was said and done. And we start eating into it because we aren't making money so you know in a year, year and half and we are down to $50 million. And you can see that if we keep going down this path, all that is going to happen is that we are going to run out of money." Senior Technical Staff #2

As a result, the board of directors which had to protect the shareholders` interests made two main strategic decisions: first, slow down the amount of spending on the technology development project and second, look for other opportunities to diversify the firm`s portfolio again (i.e., exiting the pure play strategy). As a result of the second strategy, the firm ultimately merged with another junior firm who had cash-generating operations in other countries. The new entity was not able to continue funding the project due to the significant drop in oil price (more than 60% in 2015), which created financial difficulties for the firm. Thus, they shut down the project after one more year of development.

2.4.3.4 Public market pressure (push for commercialization)

As a result of media coverage, technical assessments reports, and growing share price, a high level of faith and confidence were created around the technology. This led to the creation of high expectations among the board and among other shareholders in the

public market. These growing expectations did not match the reality of developing a disruptive technical process innovation. The experiences from similar developments (e.g., SAGD development took more than 20 years and cost $620 million) illustrated that developing a radical technological process innovation in the oil industry would be expensive and lengthy. Therefore, the leadership faced many challenges in responding to these growing expectations.

In addition to these growing expectations HOP, as a public company active on Toronto Stock Exchange, was required to provide quarterly financial reports and press releases. To support the share price, the firm needed to assure the market and investors that the development process was going smoothly. This was an additional pressure on the team to come up with positive results for the next quarterly report.

Meanwhile, the leaders struggled to manage these tensions and to find a balance between the market pressure and the technology development process. They sought fast results to satisfy their investors` expectations. Ultimately, the public market pressure combined with a lack of ability to control the shareholder's expectations placed immense pressure on the technical team to rapidly commercialize the technology. These pressures did not allow for more thoughtful approaches such as "how does this work". Instead, approaches such as, "how can we get to a specific rate of production" were utilized, which ultimately compromised the quality of the technology development process. Table 2.3 provides quotations and examples from the respondents on this topic.

Table 2. 3 Sample quotations

Quotation samples regarding the push to commercialization
1. *"They pushed it ahead too fast. … they needed to see results very fast… so, the speed of which results were needed sometimes dictated the way you operated the project… I think that was part of the problem … the whole push was always to get there. So there was a whole bunch of things how do you get more and how do you get there instead of actually doing the science of what was happening, we were trying to get there. Because if the answer is how I do get here than people will try things that maybe aren't necessarily scientific right... all this management had a huge push to get to this number, so they would put a lot of pressure on the team to add more air or do this or do that and these guys who were putting the pressure on were not the scientists, they were management" Senior Technical Staff #2*
2. *"The push from the management made technical people to make some mistakes." Senior Technical Staff #3*
3. *"Some decisions were made not totally on the technical side…they want the process to be faster and they do something not scientifically." The Senior Technical Staff #6*
4. *"I would say from a management perspective they went to commercialization way too fast." Senior Technical Staff #1*
5. *"The time lapse between having a pilot project and also the thinking about it being a commercialized project was really tight." The Senior Manager #4*
6. *"If I could go back, I would not go public to develop the technology. Being public company added lots of pressure on us" Senior Manager #2*
7. *"Well, if you're an operating oil and gas company, shareholders buy stocks based on production and debts and all the other costs. But they want to see production, having a company that is calling itself commercially viable but were only a few hundred barrels a day or less is not obviously a commercial company …and thus the shareholders and the board of directors are putting pressure on the team… " Senior Technical Staff #1*
8. *"For example when we wanted use a new method, the reservoir needed 6 months to be warmed up. Markets could not tolerate that and efforts were made to warm up the reservoir more quickly with negative results: senior Manager #6*

2.4.3.5 Technical Challenges with the reservoirs

GET was tested as a pilot project in two different reservoirs (i.e., oil sands and heavy oil), which created some difficulties within the technology development process. The first difficulty was the difference between the types of reservoirs. The knowledge and experience gained from the pilot test on the first reservoir (oil sands) could not be fully transferred to the second reservoir (heavy oil), creating new learning challenges. The

second difficulty was that the second reservoir was not a virgin reservoir, meaning, that it was partially extracted and depleted by other technologies before GET was applied. This created a number of challenges and hindered the application of GET technology. For example, one of GET`s advantages in its design was that pumps were not required to be installed. However, the conditions in the second reservoir required the installation of pumps and they became one of the most challenging parts of the technology, taking up to three to four years of development time and a significant amount of additional capital. The quotation below from one of respondents summarizes the above argument.

"One of the problems might be with GET, we tried it in a reservoir that was oil sands, then when we try it in a reservoir at which was heavy oil, which is different and there was bottom water and there was some different things. I mean there was a lot of other things: the oil sand ones were virgin, no one had drilled or depleted it, well then in the heavy oil one was a depleted reservoir because it had been primary produced and there was already wells and there was some water, there was a lot of different things that could have affected it. So, one of the things that happened is, they were not all the same, reservoirs are not all the same. So maybe if we went to a different reservoir and test GET, it would be easy." The Senior Technical Staff #2

It was significantly challenging to apply the technology to these reservoirs, and this knowledge was not unknown to the management team. These reservoirs were purchased deliberately with the intent that if the technology was to become successful, it should stand up in the toughest situations. While the reasoning behind this strategy appeared valid and acceptable, the results showed it to be unsuccessful. The contrasting strategy would be to test the technology on simpler reservoirs to work out the fundamental concepts and gain experience with the technology prior to attempting more complex testing. This strategy could have attracted other investors and companies and allowed HOP to continue their technology development.

"I think if you want to prove a technology that builds confidence in the investors, I would go for the best reservoirs." External expert number #1

2.4.3.6 Internal Collaboration Challenges

Although the team was dedicated to advancing the project, the team members had some difficulties working collaboratively. The internal collaborative issue was observed across all sections of the firm, including operation managers, lab scientists and field engineers. The first challenge of collaboration was the difficulties of communicating across disciplines and corporate functions in a high-paced environment. The firm's staff were experienced and very competent. They took a risk in working for a small and innovative firm with relatively lower salary, in the hopes of being compensated later, when the technology would become the next revolution within the industry. While the team members were experts in their respective fields, they faced challenges to communicate their expertise to other team members. Having such members work as a team was a challenge for the management, as one of the respondents mentioned:

"The problem with any professional is that they bring their own baggage to the table. They are smart and intelligent people but they are also very set in their ways sometimes. So, we have trouble..." The Senior Manager #2

The second challenge, as the study shows, is common in the oil industry: getting the field engineers to work effectively with the lab scientists/engineers. Engineers working directly in the field believe that because they have hands-on experience, they understand the challenges better than those who work on computer models in a lab setting. However, those who are working on models believe they have a better understanding of the technology and their models are more accurate than the engineers'. In the case of HOP, it was even more challenging, as one of the respondents pointed out:

"There is always a tension between what the folks in the field are doing and what they are seeing what they are feeling and what kind of the head office view is and that's common, that's not unusual. I think in this case it may have been a little bit more, there may have been more tension because a) it wasn't showing commercial results and b) it was difficult to define what the levers were for making the process work." The Senior Manager #5

The third challenge was that operational managers and leaders put less value on the modeling process. Thus, the development process was approached with less scientific rigor because they believed it to be a time-consuming process. The firm was seeking to gain an acceptable level of production quickly, as one of the respondents noted below. By alienating one group (lab engineers) and favoring the other group (field engineers), the tension grew between the two groups and disabled members from working together effectively:

"It was different incentives. Scientists want to figure out why it works and how it works …but these guys (management) want to get to the production" The technical staff #2

2.5 DISCUSSION

The findings of the paper suggest that new entrant firms may face a number of challenges in developing a disruptive process innovation. The challenges can be categorized as a) lack of resources (i.e., capital, technical and human), b) adopting a vertical leadership style, c) balancing the tension between shareholders' and public market expectations to gain quick profits and the lengthy process of technology development (especially in the case of public firms), and d) internal collaboration challenges.

Building on these findings, we suggest combining two concepts: disruptive innovation capability (Assink, 2006) and process innovation capability (Frishammar et al., 2012) to create a 'disruptive technical process innovation capability', which is defined here as *a*

firm`s ability to attain, modify, and/or capitalize on a technology that can disrupt an existing process. Defining this specific capability can help us to identify the antecedents required to build such a capability in new entrant firms that are active in a process-oriented industry. The current study suggests four antecedents that can help to tackle the above challenges, as discussed below.

First, firms should consider utilizing external resources through collaboration with other firms, while protecting the core competency of the firm. As the study demonstrated, it is possible for individual inventors, private research labs and universities (as we saw in the case of both SAGD and GET) to create and show proof of the principles (POP) of a disruptive technological process innovation in a process oriented industry such as the oil industry. However, to show the proof of the concepts (POC) of the technological process innovation and successfully deploy it in commercial fields, extensive pilot projects are required. These pilot projects are expensive, technically complicated, time-intensive and risky (e.g., environmental risk hazards). Thus, it seems that for new entrants, the level of human, technical and capital resources necessary creates a challenge to develop a disruptive process innovation to revolutionize a process-oriented industry (e.g., oil industry) on their own.

Therefore, the study suggests that external collaboration with incumbents and governments through making strategic technology alliances (Hagedoorn & Schakenraad, 1994) or applying the principles of the open innovation model (Chesbrough, 2003) may be a necessity to develop such a disruptive technological process innovation. The study demonstrated this necessity by showing how SAGD became a viable option for the oil industry through a consortium of companies, universities and governments (i.e.,

AOSTRA) and how GET failed to be a more environmentally friendly extraction option for the industry due to its development in isolation. Therefore, we argue that to develop the disruptive innovation process capability, firms need to be able to utilize external resources through collaborating with outsiders. However, the leadership challenge of disruptors is to balance the tension between utilizing the external resources through collaboration and safe guarding an acceptable level of financial reward for the firm. This finding is aligned with Frishammar et al (2012) and Stadler (2011) studies that argued in favor of external collaboration to develop process innovation.

Second, in addition to developing the competency to utilize external financial, technical and human resources through collaboration, new entrants may need to improve their internal collaboration competency. Changing an entire extraction process requires the collaboration of individuals within a firm with a variety of technical knowledge and experience to work effectively together. As this study showed, the internal collaboration was challenging during the development of the innovation in a process-oriented industry such as the oil industry. Scientists who work in laboratories on models must work effectively with field-engineers to develop a disruptive process innovation. However, this intra-collaboration is difficult as it is an uncommon practice within the industry. Most of the incremental process innovations happen in the field when problems arise and does not follow the traditional linear path of 'laboratory to marketplace' (Pretorius & Magee, 2005; Radnejad & Vredenburg, 2015).

Third, the study shows that vertical leadership may inhibit the ability of team members to effectively share their experiences and knowledge, which ultimately decreases the innovative capability of the firm. As the study shows, the leadership of HOP, specifically

the CEO, was highly motivated to develop a disruptive technological process innovation. The CEO found the technology and championed it to the board. He also created a highly talented team to develop the technology. Throughout the interviews no one denied the passion and support of the CEO and the VP to develop the technology.

However, the leaders became intensively involved with the process of innovation development and created a vertical management structure. They supported employees to take risks and experiment, however, only in the direction that they thought was the best for the technology. While their drive towards the success of the technology was unquestioned, at times they were unable to fully utilize the human capital available to them, and thus contributed to challenges in commercializing the technology.

Therefore, we suggest that a more collaborative management style such as a participatory management style (Collins, 1997), in which the leaders enable the team members to share their view points with the leadership, and allow the team members to be more influential in the decision making process, which may have aided in problem solving the technical difficulties. Teams directly involved in technology development require a substantive amount of authority. Particularly those working towards a disruptive technical process innovation due to its complexity and the variety of knowledge and expertise required to become successfully commercialized. In addition, for new entrants, this challenge is more challenging and relevant because of their relatively smaller size, the significant role of their visionary leaders, lack of established organizational structure and lack of innovation development experiences within the firm.

Fourth, while selling shares addresses the need for capital to develop a disruptive process innovation, it can create severe unintended consequences (e.g., the quarterly reports) for

innovative firms. Thus, it would be more advisable for new entrants to first exhaust other sources of funding that have a high long-term investment tolerance in the forms of private investment market and/or governments` funding.

The process of developing a disruptive process innovation in industries such as the oil industry requires long-term planning due to the high level of technical complexity (e.g., SAGD took more than 10 years to develop). This study shows that if new entrant firms gain capital from sources that expect short-term development process and rapid commercialization, they will face major challenges. In the case of HOP, their attempts to balance the investors' expectation to gain quick profit and the scientists and engineers' expectation of adequate technology development time placed significant pressure on leaders of the firm. This led to several problematic decisions such as 1) choosing a different test reservoir (heavy oil) in another province with faster regulatory approval process to speed up the process of technology development, and 2) ignoring the scientific approach to develop the technology and pushing technical staff to be result-oriented. In addition, becoming a pure player and selling cash-rich subsidiaries led to losing a significant advantage in financing the technology development. This decision was partly due to the pressure of the public market on the board to distinguish between the technology development sector and oil production sector of the firm.

Therefore, new entrants may consider obtaining financial capital from diversified resources that support the lengthy process of technology development. This is more important for new entrants than incumbents because they have less resources to sustain the long-term development process and they are more dependent on external investment.

As such, the source of their capital becomes an important factor in the success of the innovation.

2.6. CONCLUSION, APPLICATIONS AND LIMITATIONS

After comprehensively studying the case of HOP, the findings suggest that new entrants need to develop a Disruptive Technical Process Innovation Capability (DTPIC) to successfully disrupt the existing process. To do so, firms need to overcome barriers such as lack of resources (i.e., capital, technical, and human), leadership challenges, team work challenges and the expectations of investors. Our findings indicate that to address these barriers, new entrant firms may 1) utilize inter-firm collaboration; 2) develop intra-firm collaboration; 3) develop non-vertical leadership skills; and 4) secure long term investments.

These findings extend disruptive innovation theory by specifying some of the antecedents that new entrant firms need to develop a capability to successfully introduce a disruptive process innovation. Previous studies in the field of disruptive innovation have mainly focused on how incumbents are unable to identify, invest and develop disruptive innovation while the barriers faced by new entrants have remained largely unknown. This study has identified some of those barriers and also suggests competencies that these firms may need to develop to counter those barriers. In addition, for the first time, this study examined the disruptive innovation as an ex-ante phenomena and identified a technology's potential ability to disrupt the industry based on Christensen's criteria of disruptive innovation. We believe that by considering disruptive innovation as a theory that has both ex-ante and post-hoc capabilities, we can increase our understanding of the innovation phenomena.

In addition, we believe that our case study and findings will assist senior managers and investors in process-oriented industries to make better decisions in the process of developing disruptive innovation. The increasing environmental pressure on resource-based industries such as mining, steel, agriculture, and energy, demands these industries to develop radical innovations. In order to make a revolution in these industries, new entrants may need to enhance their collaboration, leadership and long-term planning as the three key competencies to the development process of disruptive innovation.

The main limitation of the research is the outcome of the technology. Although many believed that the technology could have been commercialized or will be commercialized in the future (some version of this technology is currently working in India), one participant believed that the technology itself was a failure, not because of the barriers mentioned but because the physics underlying the technology failed. While this perspective was not shared by any other participant (either those within or outside of the frim), there is a possibility that the failure was due to the nature of technology.

While the case study method provides a means to examine the disruptive innovation process with some depth, it may be limited in its ability to generalize the findings to all cases. The nature of a single case study is to extend the existing theories, build new theories and provide a more comprehensive perspective (Yin, 2003). In this study we aimed to describe in detail the process of developing a potentially disruptive innovation and to identify some of the pitfalls that occurred during the process. We believe that the context of this study is not so unique that some degree of generalizability is inappropriate. The findings here reflect what we believe to be a result of working with an innovation that has a high potential to change the market in a significant way and the decisions of

that process. However, as the findings are based on a single case study, we are eager for further studies that examine this phenomenon in other contexts (e.g., other process-oriented industries).

Moreover, future research is needed to determine what model of collaboration is best suited in process-oriented industries. As mentioned, to develop a potentially disruptive innovation requires a significant amount of capital (e.g., the numerous pilot tests required) that is unlikely to be available to new entrants or small companies. Thus, we need to identify a collaboration model that protects the rights of small companies while making it worthwhile for incumbents to participate and invest. Finally, we hope that future research can shed light on how what we have learned from a process oriented industry can be transferred to product-oriented industries.

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CHAPTER THREE

THE EVOLUTION OF THE RESEARCH AND DEVELOPMENT OPEN INNOVATION MODEL TO ADDRESS ENVIRONMENTAL CHALLENGES IN THE PETROLEUM INDUSTRY

ABSTRACT:

Scholars have yet to address *why* and *how* open innovation model can be applied effectively within industries while diminishing its potential cost and challenges. In this paper, we extend open innovation model both theoretically and practically by identifying a) the boundary conditions that motivate firms within resource-based industries to apply the model and b) the approaches that have been implemented in practice in applying the model. In this multiple-case study, we explore *why* and *how* firms within the upstream Canadian oil industry have evolved to apply open innovation model over time to deal with the industry's challenges. First, our findings show that institutional forces, normative and coercive forces, were the primary motivators for adopting open innovation to respond to the social and environmental concerns faced by the industry. Second, by building on the taxonomy of meta-organizations, we demonstrate that an industry-founded and not-for-profit innovation intermediary, as a meta-organization, is a necessary tool to address problems of adopting open innovation in this industry. We argue that the experiments of the upstream oil to develop a suitable organizational design for such innovation intermediaries suggest that a moderate level of stratification accompanying either close or open membership is the most suitable design. The findings from this study can be helpful to other industries, particularly other resource- based industries, which seek to effectively employ open innovation model and innovation intermediaries.

Keywords:

Open Innovation Model, Innovation Intermediaries, Meta-organization, Sustainable Development, Institutional Theory, Resource-Based Industry, Oil Industry

3.1. INTRODUCTION

Since Chesbrough (2003) introduced the "open innovation" model, the idea has attracted significant attention from both practitioners across a variety of industries and business scholars (Chesbrough & Crowther, 2006; Christensen, Olesen, & Kjær, 2005; Dittrich & Duysters, 2007; Gassmann & Enkel, 2004; Harison & Koski, 2010; Parida, Westerberg, & Frishammar, 2012). The open innovation model has challenged some of the traditional protective practices in innovation management, such as ownership of intellectual property over the entire the cycle of innovation to enjoy its full rent (Teece, 1984) (also known as the closed innovation model), and has encouraged collaboration models (Chesbrough, 2003). Although there are benefits and costs to both innovation strategies (closed and open), research has yet to determine which is preferable, given the context of the industry.

To address the tension between the costs (e.g., adopting external innovations, controlling intellectual property (IP) and finding appropriate partner(s)) and the benefits (e.g., sharing resources, cost, and risk) of the open innovation model, two questions need to be addressed. First, *why* do firms within an industry collectively apply the open innovation model? Second, *how* can firms within an industry collectively apply the model to enjoy its benefits while minimizing its costs and challenges? By using multiple case studies to investigate the upstream Canadian oil industry, a resource-based and a process-oriented industry (Stadler, 2011)[5], we first explore *why* the upstream oil industry would adopt the open innovation model. Using institutional theory as a guiding framework, we argue that normative and coercive forces are the primary motivators for adopting open innovation model to respond to the social and environmental concerns faced by the industry. Second, we investigate *how* the upstream oil

[5] It is worth mentioning that Forestry industry, as an example of another resource-based industry, has started the shift towards the open innovation in 80s and 90s. This shifts has studied by several scholars from different views.

industry has evolved its practices to benefit from open innovation while, at the same time, dealing with its challenges. By studying all the major iterations of the Canadian oil industry`s innovation intermediaries in the past two decades, we show that the industry has converged on the idea that an industry-founded and not-for-profit innovation intermediary, with a moderate level of stratification while having either closed or open membership (i.e., extended enterprise and managed ecosystem designs (Gulati, Puranam, & Tushman, 2012)), facilitates the application of the model. Innovation intermediaries, as a form of meta-organizations, facilitate the process of identifying, accessing, and transferring solutions to problems (Howells, 2006; Sieg, Wallin, & Von Krogh, 2010; Spithoven, Clarysse, & Knockaert, 2011).

This paper contributes to the innovation literature by tackling two key issues. First, we examined *why* and *how* the majority of firms within an industry choose to adopt open innovation, given the cost and risks associated with this strategy. Second, we introduce institutional theory as a theoretical framework to identify the boundary conditions of when industries might apply open innovation. Finally, we respond to Gulati`s (2012) call to map meta-organizations onto a particular context and explain what conditions support the various designs of meta-organizations. In addition, we argue that the lessons learned from the experiments of the oil industry can be helpful to other resource-based industries (such as the mining, forestry and fishing industries) that seek to effectively employ the open innovation model and innovation intermediaries to boost their innovations to address social and environmental challenges.

3.2. LITERATURE REVIEW

3.2.1. The open innovation model, innovation intermediaries and meta-organizations

The open innovation model is defined as "… the use of purposive inflows and outflows of knowledge to accelerate internal innovation, and expand the markets for the external use of

innovation, respectively (Chesbrough, 2003, P 2)". In other words, the literature on open innovation argues that the boundaries of the focal firm should become more porous to allow innovative ideas to move between its inside and outside (Chesbrough, 2006). Chesbrough (2003, 2006) argues that the 21st century is "the era of open innovation" for three main reasons. First, there is high mobility and availability of knowledge workers or skilled workers. Second, the capability of external suppliers to provide technologies and capital has increased dramatically. Last, private venture capital for starting a business based on innovative ideas is more accessible than before. In addition to these factors, utilizing the open innovation model creates some advantages, including minimizing risk, reducing R&D costs, and accessing technical and non-technical resources not held by the focal firm (Holmes & Smart, 2009; West & Bogers, 2013). Given these factors and advantages, firms are opening up their boundaries and collaborating with suppliers, competitors, and customers in the process of innovation to stay competitive and survive in the market (Gulati et al., 2012).

Besides the various advantages of collaboration through open innovation, there are significant challenges in actively managing the process, including identifying the external valuable resources and adopting external innovations into the focal firm (Chesbrough & Crowther, 2006; Dodgson, Gann, & Salter, 2006; Jeppesen & Lakhani, 2010; Katz & Allen, 1982; Laursen & Salter, 2006; Piller & Walcher, 2006; Van de Vrande, De Jong, Vanhaverbeke, & De Rochemont, 2009). This is colloquially referred to in the industry as the "Not Invented Here" syndrome. The degree of these challenges depends on the degree of the absorptive capacity (AC) of a firm (Cohen & Levinthal, 1990; Zahra & George, 2002). AC is defined as the capacity "of acquiring external knowledge and assimilating this knowledge by means of incorporating it into the firm's knowledge base" (Lichtenthaler & Lichtenthaler, 2009)

One possible reason for insufficient AC is the low level of affinity for collaboration between firms, which stems from a lack of collaboration experience and a lack of an efficient network within the industry (Barney, 2001). Brown (1991) and Westley and Vredenburg (1991) introduced the concept of the strategic bridging organization to address low levels of absorptive capacity caused by a lack of networking ability. Strategic bridging organizations bring together all the players, including private firms, multinational corporations, NGOs, and government agencies, to collaborate on a project. A strategic bridging organization acts as a third-party stakeholder and "enters collaborative negotiations to further their own ends as well as serve as links among domain stakeholders" (Westley & Vredenburg, 1991,p 68). Strategic bridging organizations are able to crystalize the problem domain and to facilitate the process of collaboration where in the past there existed mistrust, social, cultural and political problems (Sharma, Vredenburg, & Westley, 1994).

The strategic bridging concept was subsequently adopted to explicitly facilitate open innovation. Howells (2006), Gassman and Chesbrough (2010), Sieg et al. (2010), and Spithoven et al. (2011) use the term "innovation intermediary" to describe a strategic bridging organization in the open innovation context. An innovation intermediary is "an organization or body that acts as an agent or broker in [some] aspect of the innovation process between two or more parties" (Howells, 2006,p 720). Innovation intermediaries such as Nine Sigma and InnoCentive, open innovation service providers, investigate multiple markets and technology domains to connect innovation seekers and providers. As a result of their network building, knowledge can flow from where it exists to where it does not (Garcia & Vredenburg, 2003). Although innovation intermediaries facilitate the process of open innovation, there are significant challenges to how their organizational structure should be designed to create an effective network among agents and

effectively provide innovative solutions to existing problems (Sieg et al., 2010; Westley & Vredenburg, 1997). Meta-organizational design may help to address these challenges.

Innovation intermediaries are a form of meta-organization (Gulati et al., 2012). Meta-organizations "comprise networks of firms or individuals not bound by authority based on employment relationships, but characterized by a system level goal" (Gulati et al., 2012, p 573), or a 'domain level goal' (Westley & Vredenburg, 1997). These organizations are defined by two dimensions: permeability of boundaries and degree of stratification (Gulati et al., 2012). The first dimension, permeability of boundaries/membership, addresses the structure around the membership of these organizations, including how an agent can become a member; how long an agent can stay on-board as a member and the exclusivity of the membership. The second dimension, stratification, concerns the extent to which the decision making process follows a formal hierarchical and traditional organizational design.

According to these two dimensions, Gulati et al. (2012) categorized meta-organizations into four types; a) *Closed community* organizations that have closed boundaries and low stratification (i.e., less hierarchical decision making), such as technical standards committees of industries, b) *Open community* organizations that have open boundaries and low stratification, such as Wikipedia, c) *Extended enterprise* organizations that have closed boundaries and high stratification (i.e., high hierarchical decision making) such as franchising networks, and d) *Managed ecosystem* organization that have open boundaries and high-stratification, such as the Android operating system. Table 3.1 shows Gulati`s taxonomy meta organizations.

Table 3. 1. Meta-organization taxonomy regenerated from (Gulati et al., 2012)

	Low Stratification	**High Stratification**
Closed boundaries	*Closed community*	*Extended enterprise*

	(e.g. International committees)	*(e.g., Franchising network)*
Open boundaries	*Open community* *(e.g., Wikipedia)*	*Managed ecosystem* *(e.g., Android)*

3.2.2 Neo-Institutional theory

Institutional theory highlights the role of social concerns, legitimacy, and the cultural environment of organizations in their adoption of certain practices, as opposed to profit maximization (Selznick, 1994, 1996). In other words, institutional theory aims to explain *how* and *why* firms adopt similar strategies under certain institutional pressures (DiMaggio & Powell, 1983). Neo-institutional theory introduces three types of institutional isomorphism: coercive, mimetic, and normative (DiMaggio & Powell, 1983). Coercive isomorphism occurs when firms face formal and informal pressures from organizations on which they are dependent, such as regulations passed by governments, and/or cultural expectations from society within which firms perform (DiMaggio & Powell, 1983). Mimetic isomorphism is based on uncertainty. To confront uncertainty and ambiguity caused by technical and environmental change, firms follow and model other successful firms and organizations (DiMaggio & Powell, 1983; March & Olsen, 1976). The third source of institutional isomorphism is normative and it results from the professionalization of a line of work, occupation, or vocation. This force is not caused by any external sources (e.g., society or government) but through the effect of the individual members of the firm. When members of a firm share the same education and training, say an engineering or MBA degree or the same professional network, their shared values, beliefs, and characteristics shape the firm's practices (DiMaggio & Powell, 1983).

Institutional theory has been widely utilized as a theoretical framework in studies addressing the adoption of sustainable development by different firms and organizations (Bansal, 2002, 2005; Bebbington, Higgins, & Frame, 2009; Escobar & Vredenburg, 2011; Westley et al., 2011).

Particularly, Escobar and Vredenburg (2011) and Bansal (2005) have studied the adoption of sustainable development by oil and gas companies from an institutional theory perspective. Escobar and Vredenburg (2011, p 60) argued that "in the oil and gas industry, the institutionalization of sustainable development is more likely to take place at the national level rather than the international level" (p. 60). Isomorphism forces are more likely to occur here because the national level is: (1) coercive (i.e., has clear regulation and enforcement mechanisms), (2) normative (i.e., shares certain values and beliefs), and (3) mimetic (i.e., has a proven strategy to reduce uncertainty). In addition, Bansal (2005) noted that institutional and resource-based factors influence the adoption of sustainable development by firms. However, neither of these papers addressed the effect of institutionalization of sustainable development on innovation strategies of the oil and gas firms at the national level.

In this paper, we investigate how these institutional forces for sustainable development influence the innovation strategies of firms within the oil industry to shift towards the open innovation model. In addition, by building on the taxonomy of meta-organizations, we investigate how these forces ultimately led to the creation of various organizational forms of innovation intermediaries, as types of meta-organizations.

3.3. RESEARCH METHODOLOGY

3.3.1 Research Context and Design

Eisenhardt (1989a) proposed that to control for as many external influences as possible, and to define the limits for generalizing the findings to build and extend a theory, a single industry should be studied. To address the research questions, therefore, we have selected the upstream side (i.e., the extraction and production) of the Canadian oil industry as the context for our study for four reasons. First, as a result of conventional resource scarcity, the oil industry has

experienced rapid technological change. The industry required new technologies to allow firms to extract from new hydrocarbon reservoirs, namely unconventional reservoirs (e.g., shale oil and gas and oil sands). Oil producer firms have applied open innovation principles in their innovation strategies and thus make that industry an ideal context for this study.

Second, Canada has one of the largest proven unconventional reservoirs and is currently the largest producer of this resource. In addition, these firms are under the toughest environmental regulations that have pushed the industry to become more innovative. Therefore, the Canadian industry is one of the most technologically advanced because the firms have been either the first to introduce the technological advances or the first to apply technical innovations that were developed somewhere else. This high technological turbulence and innovation in the industry makes it even more appropriate to our study of innovation.

Third, the industry produces an undifferentiated commodity. Therefore firms cannot gain a competitive advantage through product differentiation or product innovation, but only through cost reduction, increased production of resource-in-place or expedited regulatory approvals, all of which are derived from effective process innovation. It is important to note that process innovation has been ignored in scholarly innovation research relative to product innovation (Crossan & Apaydin, 2010; Frishammar, Kurkkio, Abrahamsson, & Lichtenthaler, 2012; Laursen & Salter, 2006; Stadler, 2011; Un & Asakawa, 2015). Thus, studying innovation in the oil industry can add to our understanding of the application of the open innovation model in a process innovation-oriented setting. Fourth, the major companies' head offices are centralized in a limited number of locations, resulting in lower cultural diversity and lower range of external influences (e.g., a single governmental policy) than other more dispersed industries (Sharma, Vredenburg, & Pablo, 1999).

The multiple case study method (Yin, 2009) has been selected as the research strategy. We selected four organizations that were established to directly foster innovation collaboration within the industry. These four organizations are the only innovation intermediaries that were founded within the past two decades in the Canadian oil industry. They include all the stakeholders in this industry as founders, members, and affiliated members. In addition, they are not-for-profit organizations, and the sole goal of their establishment, as stated in their mission, vision, and mandates, is to facilitate open innovation.

To keep the cases confidential – a condition of study participation of some of the interviewees - the four organizations have been disguised with fictional names. In addition, we have changed some specifications of the cases, such as the foundation year, termination year, and the number of funders and members to preserve the anonymity of the cases. These changes do not result in any material difference in the context, process, or the results of research. The detailed information about the cases is given in Table 3.2.

Table 3. 2 The four cases

ORGANIZATION	**NETWORK FOR OIL SANDS RESEARCH OF CANADA (NOSRCAN)**	**CANADIAN HYDROCARBON RESEARCH AND DEVELOPMENT ASSOCIATION (CHRDA)**	**CANADIAN OIL SANDS STRATEGY INITIATIVE (COSSI)**	**OIL SANDS TECHNOLOGY GROUP (OSTG)**
FOUNDATION YEAR	1993 (Re-structured 2009)	1995	2009	2011
TERMINATION YEAR	2011	N/A	2011	N/A
MAIN FOUNDERS	- 6 major oil sand producers - 2 Universities - 4 Government agencies	- 25 major oil producers	- 6 major oil sands producers	- 10 major oil producers
MEMBERS	- 7 Producers - 19 Service, Supply, and	- 27 Producers - 4 Governments - 9 Individuals	N/A	N/A

	Technology Companies - 6 Research Organizations & Learning institutions - 3 Government Agencies	- 14 Learning institutions & Research Providers - 3 Midstream - 131 Service and suppliers		
MANDATES	- Meet the environmental and economic challenges of **Unconventional** sector - Focused on pre-competitive needs of industry, principally mining-based operations - An industry-led network that facilitates collaborative research	- Primarily focus on **Conventional** resources, secondary focus on unconventional resources - Facilitate the collaboration and eliminate redundancy - A focus on user problems and specific research projects to solve those problems	- A focus on accelerating environmental, social, and economic performance of **Unconventional** sector	- Collaborate to accelerate improvement in environmental performance in the priority areas related to **Unconventional** sector - Accelerate the pace and scope of environmental innovation, working with a broad range of participants within and outside of Canada.

3.3.2 Data collection

To provide construct validity, we used multiple sources of evidence, including semi-structured interviews, the annual reports of each organization and other available public documents that cover relevant information about the cases. Moreover, to increase the internal validity of the research, we triangulated our data sources by interviewing different experts within and outside of the organizations to offer alternative explanations of the findings (Eisenhardt, 1989b; Eisenhardt & Graebner, 2007; Yin, 2009).

The interviews started with key people on the boards of directors of each organization. After those individuals were identified, the "snowball" technique was used to get access to additional experts who were well-informed regarding the organizations' models and the industry (Yin, 2010). These interviews focused on well-informed stakeholders, including government officials

working with the industry, senior managers and engineers active in R&D division of the industry and university professors working closely with the industry

Thirty-four semi-structured interviews were conducted between the summer of 2012 and spring of 2015. The interviewees represented producers, suppliers, service companies, university professors and the government. Interviewees have either held senior positions within the four organizations or have championed initiatives led by them. Their position titles included: president, vice president, chief technology officer, technology development director, innovation manager, sustainable development director, executive manager, lead engineer, senior engineer, university professor and executive board member. Each interview lasted between 30 to 60 minutes. Detailed notes were taken through the interviews and, where appropriate, were recorded with permission and transcribed (for a total of 14 interviews).

In addition to conducting interviews, more than 400 pages of documents, including the annual public reports of each organization and related articles published in the media were gathered and analyzed. Moreover, the authors attended two public talks organized by CHRDA and OSTG at a university. The talks added further value to the study since they were held at a major university to introduce these organizations to academic researchers on campus so as to facilitate the collaboration between them and the organizations. Detailed notes were taken through the talks and question and answer sessions and one of the talks was recorded (with permission) and transcribed.

3.3.3 Data Analysis

As suggested by Strauss et al. (1994), the data were coded in three stages: open codes, axial codes, and selective codes. The first level of coding was “open codes,” which are the initial categories developed from the data gathered. We selected one or two key words of each section

of data and coded that section with one or two words. In total, 400 codes were created. The second level was “axial codes,” which are based on assembling the data in new ways after open coding. At this level, we categorized the key words and grouped those codes according to similar themes. 75 codes were created at this level.

The last level of coding was “selective codes,” which are developed from the axial codes. For this third stage of coding, we re-assessed all codes in the second stage and re-arranged them into higher level themes that are more comprehensive. For example, the “collaboration challenges” code was created by merging 11 axial codes. These 11 codes and an example of each code are provided in Appendix 1. The re-assessment process resulted in the creation of 13 selective codes. Figure 3.1 shows the 13 selective codes and their distribution throughout all the codes.

These 13 codes can be categorized into two sets. The first set discusses issues surrounding innovation intermediaries (i.e., creation, mandates, structure, termination, IP, comparison, and pitfalls and advantages of innovation intermediaries). The second set of codes covers the issues surrounding the industry and collaboration (i.e., industry specification, motivation to collaborate, collaboration challenges, and external factors in collaboration and transferring the model). This classification is supported by cluster analysis based on word similarity using NVivo software (Version 10). This method involves clustering together codes that share greater similarity as defined by the frequency of words. Codes that are displayed further apart share less commonality. Figure 3.2 shows the relationship between the codes by clustering them based on word similarities.

Figure 3. 1. Selective codes and their distribution

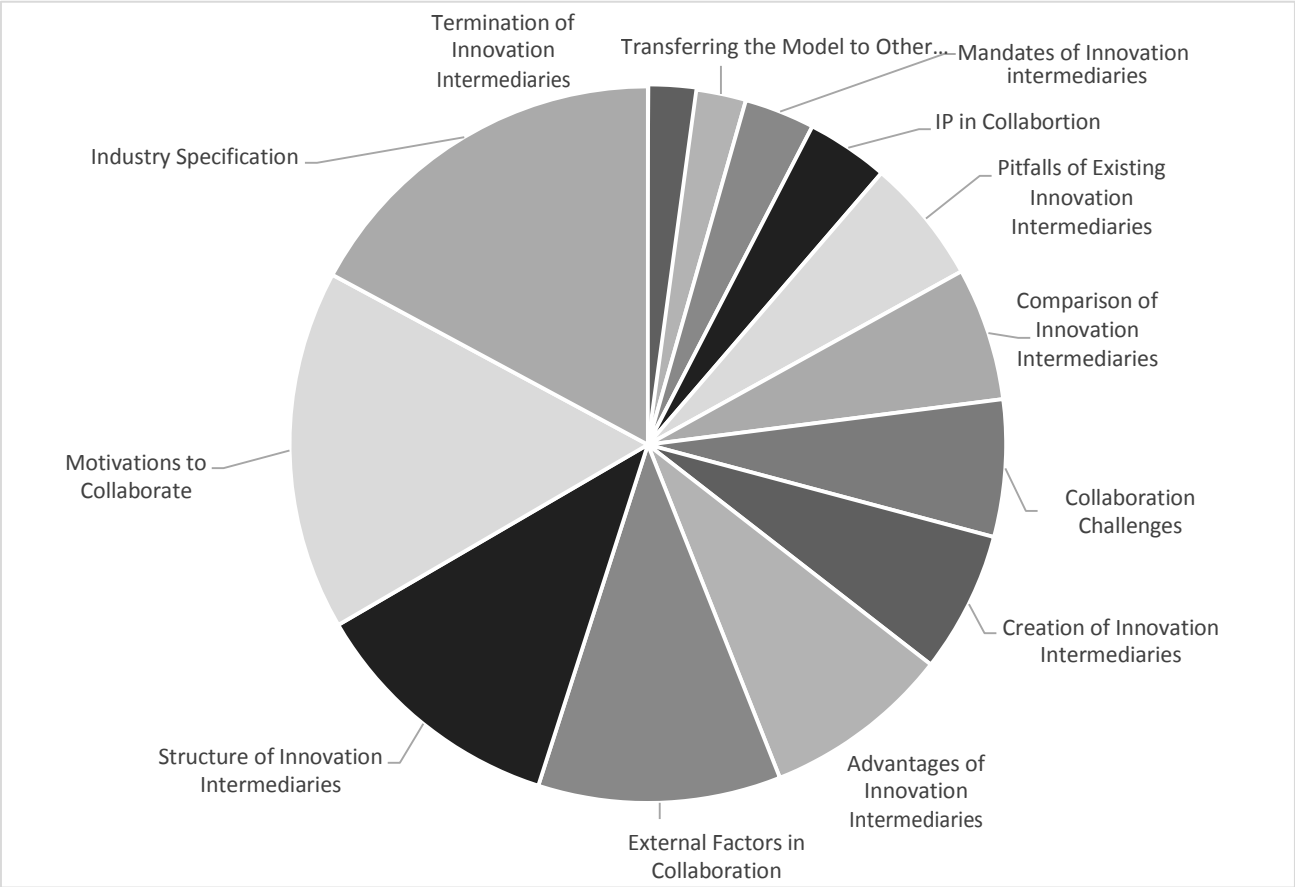
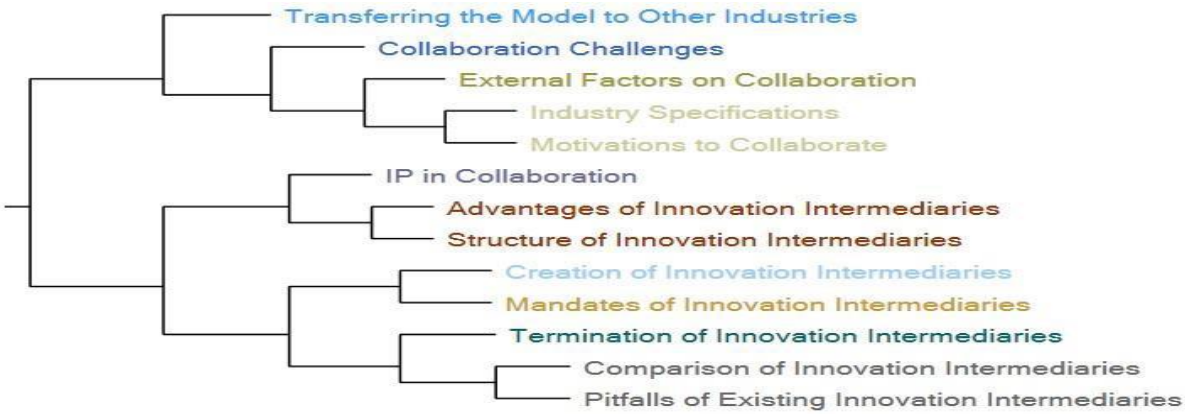


Figure 3. 2. Nodes cluster based on word similarity



3.4. FINDINGS

3.4.1 The open innovation model as a tool to develop environmental technical innovations

By the late 1990s, the volume of oil discovered worldwide declined significantly from 270 billion barrels in 1960 to 40 billion barrels in 2000 (Omer, 2008). This phenomenon led to an almost static volume of proven oil reserves between the late 1980s and 1990s (around 1,100 billion barrels) (British Petroleum, 2015). At the same time, the energy forecast produced by the International Energy Agency (IEA) and the Energy Information Administration (EIA) predicted a substantial increase in energy consumption and, specifically, fossil fuel consumption by 2100 (Omer, 2008). As a consequence, the upstream oil industry found itself in a business environment that called for greater rapid technological change. The condition also required the industry to increase the rate of recovery of conventional oil reservoirs and to develop unconventional reservoirs economically, such as shale oil and gas and oil sands (i.e., bitumen) (Radnejad & Vredenburg, 2015).

These two initiatives -- the increase in the recovery of conventional resources and the extraction from unconventional reservoirs -- led the industry to develop several revolutionary technologies such as horizontal drilling, hydraulic fracturing, and Steam Assisted Gravity Drainage (SAGD) that provided access to challenging reservoirs involving oil under deep water and oil mixed in sand. The development of these new technologies marked a new era of technology development. This new era has two main characteristics: first, a high level of technical complexity, and second, a low technical maturity, which creates a fast changing technical environment. Appendix 2 provides some of the experts' ideas about current technology status of the industry.

New demands for technical innovation is even more relevant in the case of the development of unconventional reservoirs since their exploitation faces stricter environmental public expectations and regulation (i.e., institutional forces), which requires more advanced technology

to make the development feasible. Thus, companies extracting bitumen face the question of how to increase their innovative capabilities to enable them to develop new resources in a more environmentally acceptable way and with less cost.

In the 1990s, in response to low oil prices and low profit margins, the major oil producers (e.g., BP, Chevron, Shell and Exxon and its Canadian subsidiary Imperial Oil) downsized their internal R&D and relied more on service companies (e.g., Halliburton, Schlumberger, Weatherford, etc.) and research institutions (e.g., universities) as sources of R&D and innovation. The service firms and research organizations, however, were unsuccessful in replacing the internal R&D because they needed the producers' oil fields to test new technologies. Pilot projects are key to commercialization but they involve high risk, significant cost, and the chance of losing existing production. Consequently, outsourcing of innovation still required producers to provide a facility to test the new technology. As some interviewees mentioned:

> *"In the oil and gas industry the amount of money that is spent in the field is substantially higher than any other industry…Not only does the producer have to spend huge amounts of money, but there is a chance of losing existing production by trying some of these new projects. So, as one can see, the main challenge arises out of the cost, business risk, and the complexity which is involved in the commercialization stage." (President of CHRDA)*

> *"One of the challenges with innovation is if somebody has a widget, how we actually get time from a company to plug it in and test it." (President of OSTG)*

Thus, to provide access to an appropriate oil field while sharing cost, risk, and resources such as people, human knowledge and technologies, a firm needs to collaborate and apply open innovation as an innovation strategy to respond to the specific needs of technical innovation. According to a respondent:

> *"What happened in the early 1990s, first in oil sands and later in conventional oil and gas, the companies decided that they couldn't afford to do the research on a sole proprietary basis and therefore they should get together and jointly do research or jointly fund research on those problems that were mutual across more than one company.*

Although companies continued to do research in their own best interest, they increasingly sought out other companies to share the cost, particularly where the problems were industry wide or the opportunities were industry wide." (Senior Manager in a producer company)

As stated in the above quote, firms are willing to collaborate in R&D, thus following an open innovation process in some cases while acting independently in others, following a closed innovation process. Here, the delineator between collaboration and independence is competition. On one hand, there are projects that may develop a competitive advantage for one firm and, in that case, companies are not willing to collaborate. For example, R&D projects that mainly address downhole challenges, such as a new method for extracting reservoirs or reducing the costs of production, create a competitive advantage for a firm even for a short period of time because the cost savings are directly related to production and thus create direct value for shareholders. On the other hand, there are R&D projects that are in what is known as a pre-competitive stage. These are projects in proof of concept and/or proof of principle stages that are considered as non-competitive. In these cases, companies are willing to collaborate.

Non-competitive R&D activities include projects that aim to address the common challenges of the industry, such as environmental and social concerns. With the increasing power of environmental groups and, consequently governments, the pressure on the industry to employ environmentally-friendly technologies in oil extraction has intensified significantly within the past decades. Governments have passed a variety of increasingly stringent regulations regarding emissions, water treatment, soil reclamation, and conservation of wild animal and plant species in operating areas. These regulations and institutional forces are also coupled with significant pressure from local and aboriginal people in the areas of operation such as the western provinces in Canada and northern states in the USA. Because these pressures threaten the existence of the

industry (as in some states and municipalities in the US, fracking has been banned as a result of the environmental concerns), especially the unconventional side, efforts made by any one single firm are not sufficient. Therefore, R&D activities that address these concerns are considered non-competitive. Table 3.3 provides respondents' viewpoints about R&D collaboration on environmental issues.

Table 3. 3 Quotation examples for R&D Collaboration on environmental and social issues

Quotation examples
"The environmental technical innovations are not being driven by a fundamental need to innovate our core business. They are being driven by, primarily, environmental externalities that are being imposed on the industry. The industry is not comfortable managing that on a company-by-company basis, so they see more of a collective response." (Senior manager in a producer company)
"If we only implement an environmental technology, the odds of it can change. President Obama's decision on building more pipelines is zero. If the industry implements that technology, there's at least a 5%, maybe 10% chance it can affect people who have that decision-making ability, the premiers, the presidents and the prime ministers. You're trading off a zero chance to something that's small, but material." (Senior manager in a producer company)
"We cannot have just certain companies that reduce their GHG emissions and other companies say we will pay penalties because all these oil will be blended together and it would be shipped to consumers and then the market would make the problem. So if we want to solve the problem, we should do it together. So we need collaboration to solve that problem." (President of CHRDA)
"It's only on environmental matters that collaboration is easier because there are no IP issues." (Senior government official related to oil industry)
"The main reason is all companies recognize that environmental is an industry issue and is part of the license to operate and it's not a competitive advantage but it's a necessity to have public support for operations. And therefore even if a company doesn't cooperate and collaborate on production, they'll cooperate and collaborate in environmental issues that they know they have and other companies have, then why should they fund 100% of the cost through solving the problem when everyone else has the same problem." (Operations manager of a producer firm)
"Unlike producing hydrocarbons, there is no real competitive advantage when it comes to environmental technologies... The competitive advantage is diluted when it comes to emission control technology or other green initiatives." (Senior manager/ engineer in a producer firm)

"It would be very helpful in the oil industry to collaborate since there are lots of environmental problems that should get solved by all companies. And there is no IP issue here. Additionally, if companies do not collaborate to solve the environmental problems there is possibility that the industry will lose its license to operate." (R&D manager in a producer company)

"If corporations like these do not pay attention to these risks they can be threatened by NGOs that are active globally. So these NGOs who have global bases can do strong lobbies, they can arrange rallies or strikes, they can do lots of other stuff. And these are going to be headlines in the news so it is again reputational risk. The question is that whether I want take this risk or not. So the motivation is for all oil and gas to be more active and collaborative in environmental fields." (Vice president of energy distribution firm)

Thus, there were two main forces that have been the primary push to apply the open innovation model in non-competitive and pre-competitive areas in the oil industry: (1) low oil prices and low profit margins that motivated firms to share R&D cost, risk, and resources such as people, knowledge, technology, and fields to test; (2) tough environmental regulation imposed by the governments and high pressure from society (i.e., social licence to operate) that resulted in the creation of common non-competitive technical areas. Although the low oil price was one of the necessary motivations to start the move towards an open innovation model, it was not a sufficient one. In the first decade and a half of the 21st century, the industry experienced a significant rise in the oil price (Figure 1). However, the industry did not stop nor decrease its efforts to apply open innovation. The only difference observed was that the industry became more profitable as a result of a higher commodity price. The industry, therefore, was strengthened financially and became more confident to invest in R&D without getting direct help from other stakeholders, such as government agencies and public funds.

Given this history, although the low oil price was among the major motivations to start applying the open innovation model, it alone was not sufficient to make the industry in the past three decades to open up its R&D. Public demand for sustainable development and extra attention to environmental concerns were the requisite additional condition pushing the oil industry to apply the open innovation model.

Excluding the first driver of open innovation (i.e., financial motivation resulted from low profit margin) the second driver is mainly derived from institutional forces. For example, common environmental technical challenges have become a concern when the industry experiences pressure from government (i.e., coercive force) and from society (i.e., normative force) to pay more attention to environmental concerns. Before the environmental pressure on the industry that started at the end of the 1980s and the beginning of the 1990s, there was no significant effort from the industry to resolve its environmental problems. Environmental technical challenges were not a concern. However, due to the push from governments (i.e., coercive force) and from society (i.e., normative force) in the industrialized countries, oil firms have started to consider environmental and sustainability issues as a common challenge, which has led them to apply the open innovation model. Institutional forces were therefore indirectly the main drivers of application of open innovation in the oil industry.

3.4.2 Innovation intermediaries as a tool to apply open innovation

While utilizing open innovation as the preferred innovation strategy to develop environmental and pre-competitive technologies, the oil industry has faced several challenges, including issues surrounding IP, culture, change in leadership, funding, time and differences in companies' size. The first and most important challenge is the intellectual property (IP) issue. Although the industry aimed to collaborate in mainly non-competitive and/or pre-competitive areas, securing and protecting the internal technical know-how is still a priority for any active firm. Designing a platform where companies are able to share their resources without losing control over them and to secure their share from the outcomes of collaboration has been a significant challenge for the industry.

The second challenge for R&D collaboration is the corporate culture and values of the firms involved in the collaboration. For example, some firms are innovative with a high capacity to take risk. Whereas the cultures of other firms do not appreciate innovation -- they have a short-term profit orientation -- and so they are less willing to take any risk. In addition, some firms have a high collaboration culture and thus sharing noncritical resources is considered a reasonable level of risk. However, other firms lack such a culture and suffer from the "Not Invented Here" (NIH) syndrome, being unwilling to try new ideas from outside. These kinds of cultural differences hinder the process of collaboration.

The third challenge is change in leadership: when leaders who initiated the collaboration agreement between firms leave their organizations, the success of those agreements is compromised. The fourth challenge concerns the funding of the collaborative research and development activities. When it comes to the financial side of collaboration, reaching an appropriate model between the participants is a major challenge.

The fifth challenge is concern for time, as the collaboration process is often slow and time-consuming because of the various activities that need to be coordinated. Since the response time and project management can be accomplished faster within a firm, as there are fewer factors and fewer participants to consider than when coordinating among firms, open innovation through collaboration is less appealing.

The difference in size of companies attempting to collaborate is another challenge. Small junior companies do not have enough resources to share, so they prefer to not participate in collaborations and leave the R&D for large firms. In the case of unconventional resources in North America, as a result of the technical revolution and the free competitive market, there are many junior and small firms that are active in the industry. In addition, regulations such as the

anti-competitive legislation in the USA and Canada, prohibit some forms of collaboration. Finally, a lack of absorptive capacity, lack of collaborative experience and lack of trust are other challenges of the open innovation model. Appendix 1 provides the list of challenges with representative quotations' from respondents.

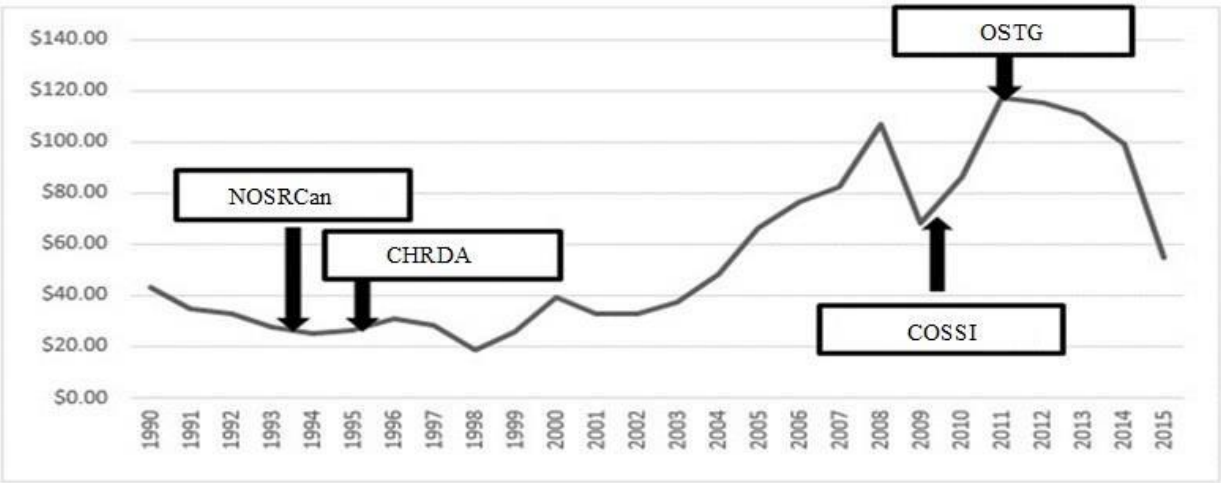
To respond to these challenges, the main players in the industry have together attempted to systematically apply open innovation by founding several innovation intermediaries. The role of these organizations is not just to act as agents to match an innovator to a firm but to create standards for R&D collaboration by introducing specific IP platforms and a funding structure that will lead to increased trust between participants and accelerate the pace of collaboration. The innovation intermediaries are also tasked with finding problems and possible solutions from inside and outside the industry. Following these efforts, these organizations make and manage consortia to develop ideas and share the results with different stakeholders to transfer the knowledge to their in-house R&D for adoption in their field operations. As stated by a respondent:

> *"Imagine there was no bridging organization, you have an inventor who wants to commercialize an innovative technology. He has to knock the door of each company to see who is interested in his technology. So you need the organization to create the consortia. And it cannot be just one company because each company has its own projects and it does not go around the industry to see who is doing what. Companies do not have time, energy and network to create the consortium that includes some other companies. So the inventors` ideas would die before they start."(President of CHRDA)*

The next section expands on the foundation and operation of innovation intermediaries in the unconventional oil industry. The unconventional oil industry was a pioneer in the utilization of innovation intermediaries in the oil industry. During the past three decades, the unconventional oil producers in Canada have founded three organizations of this kind NOSRCan, COSSI, and OSTG. This section is followed by a description of the efforts of the conventional oil industry in

utilizing innovation intermediaries. After the success of the unconventional oil industry in employing innovation intermediaries, the conventional oil industry founded one innovation intermediary, the Canadian Hydrocarbon Research and Development Association (CHRDA). Figure 3.3 shows the innovation intermediaries' time line creation.

Figure 3. 3. Innovation intermediaries time line creation and oil price (adjusted prices)



3.4.2.1 The evolution of innovation intermediaries in the unconventional oil industry

In the beginning of the 1990s, following the lead of two main oil sands producers, the major stakeholders (including oil sands producers, government research agencies and universities) came together to establish one of the first innovation intermediaries, the Network for Oil Sands Research of Canada, "NOSRCan," in 1993. NOSRCan, as a non-profit company, aimed to act as an industry-led network that facilitated collaborative research mainly to address issues in the area of environmental technologies and pre-competitive RD&D needs (see Table 1).

NOSRCan was structured to coordinate a network of members and founders. Based on NORSCan`s model, any organisation active in the oil sands industry could become a member by paying a fixed annual membership fee (ie. open membership design). However, it did not have

a central research facility and could not provide direct funding to research projects. It operated as an informal entity that boosted collaboration between members, as stated by a respondent:

> *"In that time, in the oil sands industry, I think companies didn't really want to create a formal entity, they wanted to have an organization that would be informal but at the same time have/create a climate for them to talk to each other and to do agreements on the side." (Founding committee member of NOSRCan)*

NOSRCan included a number of research groups, forums, and consortia that were formed based on voluntary representatives from interested member firms. In each of these groups members discussed the potential projects and some of the projects received funding by the members. These projects were conducted in laboratories or on sites defined by the project sponsors. In addition, when a group identified a problem that was beyond its capacity to solve, the organization would call for proposals for interested members to work together with those who responded to the call.

NOSRCan followed an IP-sharing policy that allowed its members to learn, contribute and use the results of collaborative research. Based on this sharing system, those who founded and conducted the research owned the IP, although all of the other members who paid a royalty were able to use the technology. This IP sharing policy was an ideal model to start, but as the organization proceeded the IP sharing was negotiated case by case.

Unfortunately, NOSRCan became "the victim of its own success" as stated by its last and only director's report to the World Heavy Oil Congress in 2012. As a result of successful projects and significant growth in the oil sands industry, the number of members of NOSRCan grew exponentially. The existing volunteer-run system could not provide the necessary communication between members and NOSRCan became unable to meet the growing expectations. In addition, as a consequence of the increasing number of members, the conflicts of

interest between members grew and the consent on the initial agreement about IP sharing vanished. Furthermore, over a decade after the foundation of NOSRCan, a significant number of founding leaders left their executive positions in the founding firms/organizations and the new leaders were not fully engaged with NOSRCan. Thus the founder companies started to be less involved in the organization, and an operational gap formed and continued to grow between them and NOSRCan. Finally, while other methods of operation, such as so-called *in situ* methods of extracting oil from sands deep underground, were becoming more popular within the industry, the organization was unable to change its focus since it was heavily dominated by surface mining firms.

As a result, the industry leaders realized that NOSRCan faced the same challenges that initiated its creation (refer to section 4.3), and two remedies were selected to solve the issue. First, the founders hired a full-time executive director and additional staff to ensure that NOSRCan could respond to the new needs of the industry and be able to manage the numerous member firms. Second, the CEOs of seven major oil sands producers established and incorporated a new exclusive innovation intermediary, the Canadian Oil Sands Strategy Initiative (COSSI) in 2009 (it started as a pilot organization in 2007). COSSI had three main specifications. First, it mainly focused on environmental technical issues in *in situ* extraction. As one of the respondents commented:

> *"Its focus was mostly on in situ and also, it started to focus very solidly on environment and looking at the transformative areas that the industry hadn't thought about it" (Founding committee member of NOSRCan)*

Second, the structure was closed membership design -- just the founding members were part of the organization. Research institutions (including public and private), service companies, and government agencies therefore did not play a role in the creation and everyday operation of

COSSI. By implementing this change, the oil sands producers believed that they could control and manage its challenges such as communication, conflicts of interest and IP sharing. The decision to found a closed membership organization was strengthened by the higher commodity price and resultant higher profit margins and so the industry was strengthened financially, which shored up more confidence to invest in R&D activities without help from other stakeholders such as government agencies and public funds. As a result, they were able to found COSSI (and later OSTG) based on sharing their own capital and resources. Third, since its incorporation, COSSI had a full-time executive director who was responsible for overseeing and leading the organization`s activities.

COSSI facilitated collaborations between founding members and other outside firms. It included four working groups: water management, land stewardship, technology breakthrough, and sustainable communities. Similar to NOSRCan, it facilitated the communication and collaboration between members and enhanced the utilization of ideas and technologies outside of the group by using open source techniques such as the innovation prize through Nine Sigma. COSSI achieved a number of accomplishments and successfully developed technologies to address environmental concerns. However, a lack of capital, resources and the commitment of founders hindered its activities. In addition, although there was significant effort to delineate between the activities of NOSRCan and COSSI, their activities overlapped in some cases. Accumulation of these factors, plus the failure of NOSRCan to adapt to the growing industry, made the leaders of the industry rethink its strategies. Based on the gained experiences, the industry players realized that the time to unify its collaborative activities to answer increasing concerns about environmental and economic performance was due. Thus, in 2011, NOSRCan

and COSSI were terminated by mutual agreement between the founding firms and members and their projects were transferred to the newly founded Oil Sands Technology Group (OSTG).

OSTG was created exclusively by ten major oil sands producers that produce 95% of the oil sands production in North America. OSTG acts similarly to its predecessor organizations (NOSRCan and COSSI): it supports and facilitates collaboration within the founder firms and among the founder firms and non-founder firms, institutions, and agents. OSTG does not fund collaborative projects; they are directly funded by the participants. However, this does not imply that OSTG is simply a forum like NOSRCan. It has a $10 million budget collected from founder firms per year to conduct and manage studies that are deemed feasible by the research committee consisting of founder firm representatives and a full-time director. The mandate of OSTG, according to its director is:

> "*What OSTG is all about is to enable responsible sustainable growth in the North American oil sands while delivering accelerated improvement in environmental performance through collaborative action in innovation."(The Director of OSTG)*

OSTG enjoys the advantage of exclusivity held by COSSI. Besides, by having major producers on the board, it does not suffer from a lack of resources and capital. In addition, to resolve the commitment issue, the organization was created directly by the CEOs of the 10 companies and the Director of OSTG is assigned to report directly to the CEOs every month. In addition, the CEOs are committed to holding a meeting every six weeks to share their latest views regarding collaboration and the direction of OSTG. Furthermore, the CEOs have set clear environmental performance goals in each of four main research areas (tailings, water, land, and greenhouse gases), and they have asked OSTG to publicly report its progress towards those goals. By following this defined pathway, the evaluation of OSTG by both the founders and the public has become more transparent. The lack of tools to measure success was one of the main

disadvantages of the previous organizations which now have been addressed in the structure of OSTG.

Furthermore, founders of OSTG have tried to address potential IP issues, such as preventing any free-rider effect by any one firm. They signed a joint venture agreement that allows the founders to share their technologies, innovations, research results, and patent use rights with each other without paying any royalty, as long as the usage of those assets is for environmental purposes in the oil sands industry. According to this agreement, each firm has the option to use the other members' patents without paying for them as long as it also shares some of its own IP. The free patent use is a unique feature of OSTG. As the director of OSTG stated:

> *"We don't know any other alliance in the world where companies are literally signing away their patent use rights and giving it away free of charge. Deep collaboration, by the free flow of IP we have got to understand that it is unique." (Director of OSTG)*

The advantages of OSTG have brought it a significant reputation. However, the expectations of firms active in the industry, governments, and society also have increased considerably. Although its start created a wave within the industry with all the parties speaking about its potential to develop game-changing technologies through collaboration, the pitfalls with the model have become apparent to industry players over time.

The main pitfall that hinders its success concerns the role of lawyers and firms' corporate counsel within OSTG. To overcome the IP problem, the founders heavily engaged lawyers in the collaboration process between the founders of OSTG and the external stakeholders (such as service companies, public and private research institutes and universities). This led to a greater emphasis on the role of lawyers in the collaboration. By establishing lawyers among of the main players, the collaboration process has become far slower than it used to be in the other innovation intermediaries. In addition, some research partners, such as academic researchers,

started to face a variety of boundaries created by lawyers that did not fit with their professional agendas. Thus, it has created hesitation toward collaboration under the OSTG umbrella.

Another challenge is overcoming the differences between the founders of OSTG. While some of these founders do not produce oil sands in North America or their production is very limited, the rest are among the largest and oldest North American producers of unconventional oil. Thus, the founders have a different agenda and understanding of the industry which has resulted in further challenges. In addition, while some of the founders were also founding members of NOSRCan and COSSI, others did not have any experience with this sort of collaboration but brought with them the needed resources and capital. Therefore, while OSTG has not encountered problems regarding resources and capital required for projects (unlike COSSI), because of the differences in experience and goals of the founding members, the organization has faced a problem in aligning its members.

As a result, some of the industry experts and leaders believe that OSTG should make two major changes to its structure. First, it needs to reduce the number of members to something similar to what COSSI had, and second, it should reduce the formality of the operation (getting closer to NOSRCan). Despite these challenges, industry experts believe that OSTG will be successful, as a respondent mentioned:

> *"We are cautiously hopeful and optimistic with OSTG as a whole…in time; OSTG is going to be successful" (Senior Manager in a producer company).*

3.4.2.2 Innovation intermediaries in the conventional oil industry

Similar to the unconventional sector, in the 1990s, 25 conventional oil producers gathered and studied the innovation intermediaries` models within and outside of the oil industry to find the most suitable model to follow. Considering the success of NOSRCan at that time, the conventional oil producers founded the Canadian Hydrocarbon Research and Development

Association (CHRDA) based on the model of NOSRCan in 1995 (see Table 1). CHRDA aimed to facilitate collaborative research and eliminate R&D redundancy within the industry. It has an open boundaries design, which means that any organisation active in the oil industry can become a member by paying a fixed annual membership. As a result, a significant number of active firms, agencies, and institutions involved in the oil industry became members of CHRDA (see Table 1).

In the beginning, CHRDA focused on promoting collaboration on research and development rather than commercialization. Later, CHRDA increasingly moved from supporting earlier stage research and technology development towards the demonstration and deployment phases. CHRDA started highlighting technical projects that addressed the basic needs of the industry (non-competitive areas) and responded to the increased pressure on environmental and social issues by increasing its advocating of research projects that address these issues.

CHRDA has several advantages over NOSRCan. First, although it does not have an in-house research laboratory similar to NOSRCan, it plays a role that is more than just a forum for members to discuss potential collaborative projects. CHRDA manages the details of the collaborative projects from dealing with IP issues to allocating funds. Second, from the beginning of its establishment CHRDA has had a fixed operational budget and full-time staff. These advantages have helped it achieve a higher level of presence in the industry. In addition, whereas NOSRCan was designed for a specific section of the unconventional oil industry, namely oil sands, CHRDA has a wider spectrum of projects that cover the entire conventional oil industry. This scope has led more participants in collaborative R&D. In addition, CHRDA has initiated research projects that were aimed to help guidelines, policies, and regulations to have

better scientific bases for them than simply assumptions. As a result of these kinds of projects, some regulations and guidelines have changed in favor of the industry.

As well, CHRDA has a unique IP sharing model where IP ownership is negotiated between funders and research providers. Although CHRDA does not take any IP ownership, it extensively covers IP ownership in both funders' and service providers' agreements. It may provide up to 15% seed money, but it does not take any IP ownership or expect any future financial compensation from commercialization of the technologies. This enables CHRDA to act as a neutral broker to effectively facilitate negotiations between funders and technology providers. Although CHRDA's goal is for research providers to retain their IP ownership, ownership of the IP is negotiated between funders and technology providers on a case-by-case basis.

These advantages make CHRDA one of the most successful innovation intermediaries founded by the industry. Based on third party report on evaluating the success of CHRDA, after nearly two decades of operation, CHRDA has managed nearly 450 projects which have created between $90 million to $350 million of value for the industry through more effective environmental policies, reducing costs and improving environmental performance. Also, it was able to leverage $99 million from other sources, such as governmental funds, for its collaborative projects. Comparing the industry investment of $19.2 million with the return created by CHRDA, this rate of return clearly demonstrates the success of CHRDA.

Of course CHRDA is not without challenges that threaten its continued success. CHRDA has started to fund some of its projects and operations through a volunteer payment method by members. A significant number of CHRDA's members that are small companies either cannot afford to make the payment or are not concerned with solving environmental issues. Thus the

firms that make the payment feel that the small companies are getting a free ride. This has resulted in an increased gap between large and small members.

Another challenge that CHRDA faces is having a variety of opinions on each project. A lack of common understanding of issues makes the decision process longer than planned. In addition, some have criticized CHRDA for a lack of focus concerning balancing the need for in-depth research and research that provides practical knowledge for the industry. To respond this challenge, they suggest that if CHRDA decreases the number of collaborative projects which it facilitates and manages, it can then give greater attention and resources towards defining suitable projects for the industry. As well, CHRDA has a variety of members, including government agencies and some service companies that were considered as outsiders by producer firms. This can lead to the creation of a gap between the producers and the organization, which ultimately decreases the contribution of producer members.

CHRDA and OSTG are currently the only major innovation intermediaries in the Canadian oil industry that aim to facilitate the open innovation model. Although they are active in two different sectors of the industry (conventional and unconventional oil), they are often compared by industry experts and leaders. The main difference between these organizations is their level of hierarchical structure, closed membership vs. open membership, and their IP strategies. In comparison to OSTG, CHRDA has an open boundaries design so other stakeholders and shareholders can become a member. In addition, when it comes to IP, CHRDA has less formal procedures than OSTG. This difference creates a friendlier environment at CHRDA for collaboration without paralyzing them with a heavy legal structure as in the case of OSTG. As stated by a respondent:

"I find CHRDA to be more open and transparent than OSTG. OSTG is much more controlled. You have to sign legal documents and also only those companies that participate get to develop and it's very closed off from rest of industry." (Senior manager in a producer company)

OSTG, based on only major producer firms and directly involved with some of the projects, is more closed than CHRDA, which is based on different types of stakeholders and shareholders and has an administrative role. Some believe that OSTG can be more successful, as a respondent mentioned:

"OSTG is getting bigger than CHRDA. It might be more successful than CHRDA since one, it has a focus on oil sands; two, the environmental issues in oil sands have a sense of urgency so there would be more effort to solve it faster than what CHRDA is doing; three, OSTG has been shaped by CEOs and they are going to have a greater control over what OSTG is doing so they can facilitate the collaboration process; four, OSTG would focus on technology rather than just focus on basic and applied research." (Senior manager in a producer company)

Since OSTG is fairly new, we could not conduct a full comparison between these two models. Also, we should mention that because of the dropping oil price, OSTG is facing some difficulties to fund its collaborative projects, while CHRDA is not affected due to its diverse sources of funding. To conclude this section, Table 3.4 provides a summary of strengths and weaknesses of each of the four organizations as extracted from the interviews.

Table 3. 4 Weaknesses and strengths of four industry founded innovation intermediaries extracted from the interviews

	Strengths	**Weaknesses**
NOSRCan	- Sharing IP - Creating forums - Includes most industry stakeholders	- Volunteer run system (lack of full-time staff) - Conflict of interest between members - Change in leadership of founder members - Overly controlled by mining based firms
COSSI	- United board members - Focus on newer challenges of the	- Lack of resources and capital

	industry - Full time staff	
OSTG	- Fixed budget for research controlled by the organization - High level of CEOs involvement - Full-time staff - Clear and measurable goals - Not only sharing IP generated out of collaborative research but also sharing some existing patents and technologies	- Tough legal system and given overly high level of importance to lawyers - Lack of unity among board members in some cases
CHRDA	- Managing collaborative projects - Full-time staff - Sharing IP - Includes most industry stakeholders - Accepting of "hand shake deals" than fully secure contract made by lawyers - Access to variety funding sources	- Voluntary payment system - Broad focus

3.5. DISCUSSION

We can divide the motivations for applying the open innovation model in the upstream oil industry into two main categories: (1) financial motivations: sharing cost, risk, and resources; and (2) motivations to deal with sustainable development issues: environmental and social challenges. We argue that the latter category was created by coercive and normative institutional forces and was the primary driver for adopting open innovation model in the oil industry.

Our findings are supported by other scholarly research in this area. Escobar & Vredenburg (2011) and Bansal (2005) have suggested that institutional forces on oil firms at the national level resulted in the movement towards institutionalization of sustainable development. Based on the findings from this study, we build upon the previous studies and argue that institutional forces for sustainable development have influenced Canadian oil firms to apply the open innovation model. In other words, Canadian oil firms have applied the open innovation model in response to environmental regulations (i.e., coercive force) and social pressures (i.e., normative force). In addition, due to the success of the open innovation model in unconventional oil, the conventional sector started to adopt the strategy to gain legitimacy (i.e., mimetic force).

Therefore, this study extends the current understanding of the drivers of open innovation model. Adding to the argument of Chesbrough (2006) regarding the motivations of applying open innovation model in the 21st century, we argue that the institutional forces push to apply a sustainable development agenda in resource-based industries, such as the petroleum industry and forestry, creates new type of motivations to apply the open innovation model. In addition, we suggest that this finding might be extended to other industries, such as mining, that consider environmental and social issues as a common threat to the entire industry.

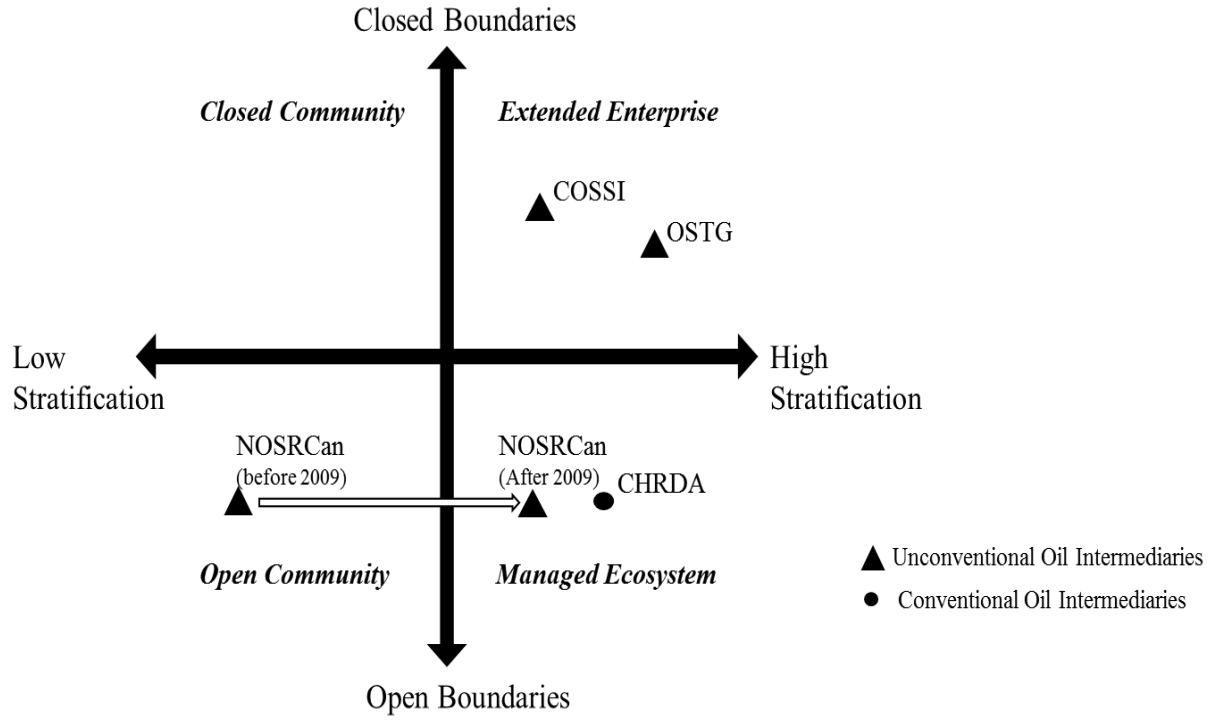
In addition, the study describes *how* the oil industry has applied the open innovation model by creating not-for-profit innovation intermediaries. The study suggests four main advantages of industry-founded innovation intermediaries. First, they strengthen collaboration by directly involving CEOs and executives of partnering firms which reduces misunderstandings between the partners. In addition, significant media publicity which boosts the momentum for the intermediaries makes CEOs of partner firms give more attention and safeguard to these organizations and their collaborative activities. As we showed here, even when the collaboration process faced difficulties they chose to restructure the organizations rather than disassembling them.

Second, government agencies and environmental groups were invited to work directly with these neutral organizations and share their viewpoints, expertise, and resources. This opportunity channelled these outside resources into productive environmental outcomes rather than antagonistic anti-business actions. In addition, some of the existing regulations that may have been ineffective were adapted to help the sustainable growth of the industry, as we saw in case of CHRDA. Third, these organizations have actively created various forums and workshops that help stakeholders come together to discuss and find a solution to an industry problem. Fourth,

these organizations have provided a kind of IP sharing policy as a framework for collaboration, which has facilitated the negotiation process between the participants of the collaborative project.

Moreover, this study `s description of four innovation intermediaries founded by the oil industry allows us to fit them in the meta-organizations taxonomy introduced by Gulati et al. (2012), as shown in Figure 3.4. It is worth noting that the finding of our study suggests that meta-organizations exist on a continuous spectrum rather than distinct categories as suggested by Gulati et al.(2012).

Figure 3. 4. Innovation Intermediaries` Organizational Design based on Meta-Organization Taxonomy



Before 2009, NOSRCan`s organizational design can be categorized as an *open community* (open boundary, low stratification) organization. It had an informal management configuration defined by a flat, non-hierarchical, structure. The organization mainly acted as a shell for the industry to

pursue its collaborative activities. In addition, it aimed to have all stakeholders of the industry as members which gave it an open boundary structure. Our study suggests that until 2009 this model was successful under specific conditions; first, the unconventional sector was relatively small in the 1990s compared to the 2000s and 2010s. Second, the environmental concerns were significant but the pressure from the government and society were less earlier on than those of the more recent decades after several pipeline spills and other environmental incidents (e.g., duck deaths in Syncrude tailings ponds) that caused greater coercive forces. Third, earlier extraction was limited to surface mining methods while, more recently, other techniques became popular and added to the technological innovation turbulence of the industry. Altogether with the increasing industry size, increasing environmental pressure and increasing variety of extraction methods (that led to increase in institutional forces), the industry realized that the open community design was no longer suitable. Thus, they shifted NOSRCan`s organizational design towards a more formal and hierarchal structure with additional management layers (e.g., adding a president/director and staff) while keeping its open boundary/membership. This resulted in a *managed ecosystem* (open boundary, high stratification) design for NOSRCan.

With increasing the level of technical and environmental complexity of the unconventional sector, conflicts, tensions and misunderstandings between the stakeholders of NOSRCan such as governmental agencies, environmental groups (i.e. institutional forces), producers, and service companies also increased substantially. To address these kinds of challenges and institutional forces the industry leaders on the production side were motivated to create another organization with closed boundary membership design. The decision was facilitated by the high oil price in 2000s and early 2010s that yielded more profit and consequently extra R&D money for unconventional producers. As a result, COSSI was created, as an *extended enterprise* (closed

boundary, high stratification), based on a limited number of oil sands producers - 6 major producers. This level of exclusivity, however, caused a lack of resources and capital to carry out the collaborative R&D projects that were needed. Therefore, OSTG was created to have more players on its membership board (10 companies).

OSTG had a more permeable boundary but was highly hierarchal, structured and formalized (i.e., *extended enterprise*). The industry followed this shift to avoid potential opportunistic behaviours since the founders not only shared their current and future research activities on environmental concerns but also shared their previous technologies and patents. The greater safeguarding, unfortunately, added more formality and weakened the collaborative spirit among its members. As a result of the strict structure, OSTG faced challenges to attract additional participation from outside stakeholders and retaining the collaboration among its members. For example, public research organizations such as universities were less willing to collaborate with OSTG. They did not want to get involved due to the legal barriers since their philosophy is based on sharing their knowledge within the academic and non-academic community.

CHRDA, which was created by the conventional sector, was founded on improvements from NOSRCan and followed the *managed ecosystem* design. The organization still remains active today and, based on its annual reports, it has been the most successful organizational intermediary founded by the industry. Although the intensity of environmental, regulatory, and social forces (i.e., institutional forces) in the conventional sector is less than the unconventional sector, because of the nature of unconventional reservoirs and their extraction methods, CHRDA was able to successfully reach a fine balance between protecting the collaboration from opportunistic behaviours and providing a collaborative environment, one that is relaxed, friendly, and trustworthy. Its long standing achievements are proof of this claim. In considering that the

main goal of R&D collaboration in the industry is to address the industry's environmental challenges, the creation of a friendly environment and the avoidance of adding legalistic formality to the process of collaboration is as crucial as safeguarding the collaboration against opportunistic behaviours.

The above findings regarding the design of innovation intermediaries contribute to the innovation and organizational change literature from different ends. First, meta-organizations exist on a continuous spectrum (as shown in Figure 2.) rather than distinct categories as suggested by Gulati et al.(2012). Second, by studying innovation intermediaries as a form of meta-organizations in the context of the oil industry, we responded to Gulati et al.`s (2012) call to map meta-organizations onto a particular context and explain what conditions support the various designs of meta-organizations. Our study showed that the suitable design of a meta-organization depends on different factors, including the amount of institutional forces that exist within the industry. We show that both a *managed ecosystem* (e.g. NOSRCan and CHRDA) and *extended enterprise*` designs (e.g. COSSI and OSTG) are capable of facilitating the process of open innovation. However, a *managed ecosystem* design is more appropriate if the industry needs other stakeholders (such as governments) to sponsor its R&D activities. As well, in a fast paced technical environment with a variety of stakeholders, the situation demands an innovation intermediary with some level stratification to manage the complexity. With increasing the institutional forces, the need for higher stratification increases, as we saw the shift from open community design to extended enterprise design within an unconventional industry because of the substantial increase in institutional forces over time. However, our study also showed that high levels of stratification may hinder the effectiveness of an innovation intermediary. As such, a moderate level of stratification (e.g., CHRDA and COSSI) can provide a balance between

cooperative needs and complexity demands. Finally, we argue that the lessons learned from these experiments can help managers in a variety of other industries, particularly those that are resource-based, to establish innovation intermediaries that can successfully facilitate the application of the open innovation model.

3.6. CONCLUSIONS, LIMITATIONS AND FUTURE RESEARCH

Managers face the question of *why* and *how* to collaborate without their firms losing their competitive advantage. Our study identified pre-competitive and non-competitive areas that can benefit from using the open innovation model with fewer challenges. In the case of the oil industry, sustainability concerns (i.e., environmental and social pressures) create institutional forces that lead to the creation of non-competitive or precompetitive areas at the industry level. We suggest that a number of other industries (e.g., forestry, fisheries, nuclear, mining, chemical, and pulp and paper) are facing the same external forces. Governments and societies are becoming more aware of environmental impacts (i.e., institutional forces) caused by these industries. As a consequence, stricter environmental regulations have been passed and resulted in greater cost of production. These industries, therefore, need to respond to these environmental and social concerns in a sustainable and cost-efficient way or face a substantial increase in their production costs, and, in the case of some industries, see their replacement by alternative industries. Based on our evidence from the Canadian oil industry, applying the open innovation model at the industry level in these non-competitive and competitive areas can help these industries move towards sustainability.

Our study has also illustrated the application of the open innovation model with the goal of addressing a common threat to an industry (such as, in the case of oil and gas, environmental and social pressures) through the formation of innovation intermediaries that can facilitate this

process. In the end, by building on the meta-organization concept, this study provides suggestions regarding the suitable organisational design for such innovation intermediaries. The most important limitation is a lack of data regarding the success and/or failure of OSTG. This organization is relatively recently founded and so there is limited data regarding its performance. To evaluate its success and compare it with another similar organization, there needs to be future research when there is more information about its performance.

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APPENDICES

Appendix 1. 11 Axial codes and their examples that created the selective code, "collaboration challenges"

Axial codes	Examples
1. **Regulation**	• *"The law has been a very specific barrier for collaboration because Competition Act prohibits a lot of collaboration because it seems anti-competitive. About a third, if not half, of the constraints are due to either the actual Competition act or the fear of being perceived as being anti-competitive."*
2. **Public Judgment**	• *"There are both perceived and real risks. When you talk about the media attention that our collaboration activities have gotten, there is the perceived risk that if we announce we fail in either initiatives or not, there will be a backlash on us. Then there's the real risk that if we actually do fail, as opposed to just fail individually, that the media coverage will simply be, 'This was the last ditch effort for the oil sands companies. They have nothing left. Why do we have them?'"*
3. **Size**	• *"Small companies want to be followers, so rather than coming and making alliances, they want to wait till technology develops and they can take advantage of it."*
4. **Leadership**	• *"These kinds of collaborations depend on the individuals who are running the companies. By changing managers, companies' attitudes can totally change towards these collaborations."*
5. **Lack of experience**	• *"Most of the lessons are still being learned because, ultimately, we haven't spent enough time doing this in our sector."*
6. **Funding**	• *"We really need to drive value out of the dollars that we have to pay. So the funding models need to be appropriate for the output that you are going to get. So, you are going to pay the dollars you'd hope to get something gainful out of it. They should be fair and equitable as well."*
7. **Absorptive Capacity**	• *"An important factor for the successful utilize of a technology coming out of the collaboration activities is the company has to have a technology receptor capacity."*
8. **Trust**	• *"Everybody was there to learn from somebody else but not to share. So it was a low trust environment, and so in my view it actually inhibited what we all wanted."*
9. **Speed**	• *"If you built it internally there is always the thought that you can do things faster because you have control."*
10. **Culture and organizational values**	• *"Well first of all what you have to recognize is every company has a different corporate culture. And some corporate cultures believe that more can be gained through collaboration, and other corporate cultures believe that they know best and they should do everything themselves and they are competing with some other oil company."*
11. **Competitiveness and IP**	• *"When you say major challenges I would say... There are several challenges that I would list them... The first one is IP.... How do we manage intellectual property? This has been a concern when we promote collaboration of developing technologies."*

Appendix 2. Oil industry as a high tech industry

Quotation sample recognizing the oil industry as a high tech industry
9. *"When where we are extracting some very, very difficult resources in the ground and it's a very complex process trying to extract these resources from the ground which requires a sophisticated technology, you need not just technical knowhow but technical investments with regards to equipment and understanding processes…I mean in terms of computing technology, visualization technology and a lot of computing innovations, there is no question that the industry became a high tech industry."(High level manager of producer company A)*
10. *"Almost everything we drill is horizontal, with hydraulic fracturing. Those technologies are several years old, at the most, and still being worked on and developed today." (High level manager of a producer firm)*
11. *"On the oil sand side, most of the potential resource is going to be accessed using in-situ technologies versus mining. In situ, again, relatively new technology, we and our peer companies are still trying to work it out. Things like solvent are being investigated. It demonstrates the newness of the technology when most companies in the industry are looking at solvents, and everyone has their own proprietary chemical concoction…thus it is not mature technology." (R&D manager of a producer firm)*
12. *"The oil and gas industry since the early 80s has been increasingly hi-tech and a utilizer of new technology. Such as remote sensing, well automation, 3D measurement while drilling, down whole logging and seismic, and so on. And so as oil and gas became more difficult to find and recover, the industry developed higher tech and higher technology approaches to get the more difficult to recover reserves."(Founder member of CHRDA)*
13. *"You got upstream oil and gas which exploration and production and the upstream portion is very very very high tech." (Vice president of a service company)*
14. *"I believe that the technology is extremely important to the oil and gas industries especially when we look at unconventional resources, it is the only way forward to increase production, lower costs, improve greenhouse gases and lower greenhouse gases." (CEO of a service company)*

CHAPTER FOUR: COLLABORATIVE COMPETITORS IN A FAST-CHANGING TECHNOLOGY ENVIRONMENT: OPEN INNOVATION IN ENVIRONMENTAL TECHNOLOGY DEVELOPMENT IN THE OIL AND GAS INDUSTRY

ABSTRACT

The open innovation model has been the topic of many studies, but studies of applications of the model in resource-based industries are scarce. In this research, we examine the deployment of the open innovation model in resource-based industries through the case of the Canadian oil and gas sector. Our findings show that the need for technical innovation is rapidly increasing as a result of the nature of the new complex fossil fuel reservoirs the industry is now developing. High research and development costs, long development cycles, resistance to change and high technical risk, we find, are obstacles hindering the development of new innovative technologies. In response to these challenges to innovation, the Canadian industry experimented with a unique model of open innovation by establishing an industry-level organisation. In this study, we explore this emerging model of open innovation and interpret its successes and failures through the use of the theoretical literature. The conceptual model that we derive combines strategic bridging organisational concepts with open innovation ideas to help us understand the building of an innovative technologies network at the industry level.

Keywords: open innovation; collaboration; strategic technology alliances; STA; innovation management; innovation intermediary; organisational bridging; resource-based industry; absorptive capacity; PTAC; sustainable development; energy; Canada; oil and gas industry.

4.1 INTRODUCTION

As the western Canadian sedimentary basin's conventional oil and gas resources went into serious decline, as did other global basins', over the past decade, the Canadian industry was faced with the need of developing new technologies to economically increase the rate of recovery of conventional oil and gas reservoirs and to economically extract unconventional resources, such as bitumen, or oil sands, and shale, or 'tight', oil and gas.

As a consequence of the production declines from conventional oil and gas resources there was a shift in focus in Canada and the USA to unconventional oil and gas resources to fulfil current and future demand. This shift in focus occurred in Canada and the USA rather than elsewhere in the global oil and gas industry because that was where the effects of production declines were first felt – due to the fact that the US Permian basin and western Canadian sedimentary basins were two of the earliest historically to see oil and gas development and thus the first to reach the point that reservoirs were in serious decline – and because Canada and the USA have the most open and freely competitive oil and gas industries, providing incentives for innovation.

This shift changed the attitude of the industry to technical innovation. The oil and gas industry in the early 21st century faced complex resource reservoirs in deep water, sand and shale that required sophisticated technologies to extract. Without new technologies, extracting these resources was not cost-effective, feasible or environmentally acceptable. Thus the need for technical innovation in the first decade of the 21st century in the oil and gas industry rapidly increased.

As the Canadian oil and gas industry had become more competitive over the closing decades of the 20th century, firms had closed or seriously downsized their research and development (R&D) departments due to the high cost of doing R&D, long development cycles, high technical risk and challenges of appropriating the benefits of technical innovation. Additionally, as the industry was coming out of a long period of low commodity prices and thin profit margins, there has been a degree of scepticism and an endemic resistance to change in the industry. Consequently, the Canadian industry was faced with the question of how the companies which were active in the extraction of unconventional oil and gas could increase their innovative capabilities to enable them to extract new resources in a more environmentally acceptable way and with less cost.

Before describing our Canadian case study, we examine what the innovation and strategic management scholarly literatures say on the question of increasing firms' innovative capabilities. Hagedoorn and Duysters (2002, p.168) define innovative capabilities as "the specific expertise and competence related to the development and introduction of new processes and products". According to Dodgson et al. (2008), Deschamps (2005), Tidd et al. (1997) and Chesbrough (2006), firms can develop their innovative capabilities either internally (closed innovation) or by getting help from external sources (open innovation).

Based on the closed innovation model companies engage in all business activities related to innovation, such as idea generation, development and financing, on their own. The closed innovation model requires large internal R&D investment. The alternative to the closed innovation model is the open innovation model which encourages engaging in extensive collaboration, mainly in R&D, with other parties. One of the approaches

proposed to help to structure inter-firm collaboration in the interest of open innovation is the non-equity strategic technology alliance (STA) between firms.

There is an ongoing discussion between scholars regarding the advantages of collaboration in the process of innovation, or open innovation, compared to those of closed innovation. For instance, Hagedoorn and Duysters (2002) argue that external linkages, such as strategic technology alliances, can be an option to reduce and share the cost and uncertainties in the process of innovation. Additionally, according to Sampson (2007), collaboration can provide access to others' information and technology which, under normal circumstances, is difficult to achieve.

Studies such as McNaughton (2001) and Pretorius and Magee (2005) investigated and discussed the open innovation model and inter-firm collaboration within the context of industries that were traditionally classified as 'high-tech' industries such as the pharmaceutical industry and the information technology industry. The oil and gas industry has been largely ignored by open innovation scholars possibly as a consequence of the industry's outdated public image as a 'low tech' industry that is not concerned with innovation.

We believe that, given the energy resource supply-side changes underway, there is a need to study innovation models in the context of the upstream oil and gas industry for several reasons. First, the industry is focused mainly on industrial process innovation while studies reported in the scholarly literature virtually exclusively focus on product innovation. The oil and gas industry produces a largely undifferentiated commodity so firms cannot glean competitive advantage through product differentiation; they can, however, glean competitive advantage from cost reduction, increased production of

resource-in-place or expedited regulatory approvals all derived from effective process innovation. Second, the industry is transitioning from a relatively 'low-tech' industry (i.e., mature status without significant need for advanced technology) to a relatively 'high tech' industry (i.e., immature status with significant demand for high technology and innovations), presenting an opportunity to study how the industry evolution might affect the innovation strategies of the firm. Thirdly, the oil and gas industry operates differently from other high technology industries in that much of its innovation occurs 'in the field' in day-to-day operations. In other 'high tech' industries, innovative technology and ideas mostly come out of the formal laboratory research and development process, some innovation comes out of the R&D lab in the oil and gas industry, the majority of innovation happens through the development and deployment of different technologies in the field (Pretorius and Magee, 2005).

Extant studies in the scholarly literature have tried to answer whether the open innovation model, constituting collaboration in R&D and forming STA, can facilitate the innovation process within the industry. Drawing on the collaboration and resource-based view of the firm theoretical literatures rather than the open innovation literature, Sharma and Vredenburg (1998) and Westley and Vredenburg (1991) have argued that collaboration through strategic bridging organisations can facilitate the application of an open innovation model in the oil and gas and grocery retailing industries respectively. We, thus, set out to explore the ideas put forth by Sharma and Vredenburg (1998) and Westley and Vredenburg (1991) in the current study; we investigate whether the application of the strategic bridging organisation concept is useful for enhancing innovation in the upstream oil and gas industry. Other questions addressed in this study are, what are the advantages

and disadvantages of open innovation in the industry? and How and why do oil and gas firms in the upstream industry collaborate with one another with the view to increasing their innovative capabilities?

The next section is a review of the relevant scholarly literature on open innovation, collaboration models such as STA, innovation intermediates and resource-based theory of the firm followed by describing the research methods used in this exploratory study. Then findings from a single comprehensive case study are discussed in the case study section. Finally, we discuss our contribution to open innovation theory and how open innovation might enable resource-based industries, particularly the oil and gas industry, to improve performance.

4.2 LITERATURE REVIEW

4.2.1 Open innovation

In this study we explore how oil and gas firms are able to achieve more effective innovation with external partners, or to put it in the phrase in the extant literature, through open innovation. We also discuss what the challenges of open innovation appear to be. The concepts of open innovation and closed innovation are defined in the innovation literature. Following the closed innovation model companies build internal R&D departments to carry out idea generation, idea development, finance and commercialisation on their own (Pretorius and Magee, 2005). The advantages of the closed innovation model include leveraging first mover advantages and protecting a company's knowledge-based resources, or intellectual property (IP), by keeping them internal (Pretorius and Magee, 2005).

The closed innovation model comes from an idea of the firm being defined as a single unit working in an aggressive and uncharted environment. However, this idea has been challenged variously both in theory and in practice by scholars proposing a more inter-organisationally collaborative model of the firm. For example, Child and Smith (1987), Kanter (1989) and Miles and Snow (1984) have argued that a firm can be more efficient and flexible by collaborating with other firms while Westley and Vredenburg (1991, 1997), Sharma et al. (1994) and Sharma and Vredenburg (1998) have examined collaborations with organisations that are not business firms and argue that these collaborations can lead to more creative, effective and innovative outcomes. The arguments of these authors advocating inter-organisational collaboration can be seen as the conceptual underpinning of the open innovation model, a model that promotes collaboration and utilisation of the external linkages in the innovation process.

Thus open innovation, which is defined as "a paradigm that assumes that firms can and should use external ideas as well as internal ideas, and internal and external paths to market, as the firms look to advance their technology" [Pretorius and Magee, (2005), p.xxiv], guides companies to not only employ internal resources but also to utilise external resources to facilitate innovation.

STA are one of the mechanisms available to shape R&D collaboration to achieve open innovation goals. Devlin and Bleackley (1988) argue that STA could constitute a competitiveness-enhancing strategy of a technology-oriented company. Such an inter-firm cooperation agreement attempts to achieve competitive advantage for partners by aggregating, sharing or exchanging valuable resources with participants (Das and Teng, 1999).

Organisational structures used in strategic technology agreements are either equity agreements (such as joint venture) or non-equity (sharing the resources and capabilities without making a separate legal identity for the alliance, such as joint R&D) (Hagedoorn, 1993; Narula and Hagedoorn, 1999; Sampson, 2007). The non-equity STA is the type of strategic technology agreement applicable to the idea of open innovation and is what we studied. One could argue that an equity or joint venture agreement that results in a new legal entity is effectively creating a new entity that contains or internalises the collaboration and is not open innovation at all. According to Narula and Hagedoorn (1999), between 1990 and 1994 the non-equity type of technology agreement was used in 77.8% of STA cases they studied.

The STA open innovation model has several advantages. First, R&D involves high capital cost and high risks, especially in the oil and gas industry (Devlin and Bleackley, 1988). Hagedoorn and Duysters (2002) argue that collaboration in the process of innovation (such as STA) is an option to reduce and share the cost and uncertainties in the process of innovation.

Secondly, most companies do not have capabilities in every field of technology and scientific and engineering discipline to provide the necessary grounding to arrive at optimal innovation (Teece, 1988). According to the resource-based view of the firm (Barney, 1991), “firms’ resources are usually scarce, imperfectly imitable, and lacking in direct substitutes. Thus, the trading and accumulation of resources becomes a strategic necessity” [Das and Teng, (2000), p.36]. Open innovation through STA provides the opportunity to access resources that are needed to develop a technology with minimum superfluity (Das and Teng, 1999).

Thirdly, technology in many fields – and in related fields with substitutable products advances more rapidly now than historically, making it more challenging than ever to compete on technology. Consequently companies must compete in the creation and commercialisation of new knowledge and technology in a timely and cost effective manner (Devlin and Bleackley, 1988). Cooperation with outside organisations through STA can facilitate access to a new market, reap economies of scale in R&D thereby accessing more disciplinary specialties, improve appropriability of the innovation and co-opt and block competitors (Hagedoorn and Duysters, 2002; Hamel et al., 1989; Narula and Hagedoorn, 1999; Ohmae, 1989).

According to Sampson (2007), Das and Teng (2000), Teece (1988), Higginson and Vredenburg (2010) and Leonard-Barton (1992) collaboration can provide access to others' resources to develop a company's own resources that is difficult to achieve under normal circumstances. However, according to Hagedoorn and Duysters (2002) and Das and Teng (1999), the advantage of collaboration through mechanisms such as STA can become a disadvantage due to the danger of uncontrolable technnological transfer and loss of intellectual property between firms. This is more crucial if the techonology in question is the core competence of the firm. Das and Teng (1999) have called this risk relational risk and state that, "Relational risk is concerned with the probability that partner firms lack commitment to the alliance and their possible opportunistic behaviour could undermine the prospect of alliances. Such opportunistic behaviours include shirking, appropriating the partner's resources, distorting information, harbouring hidden agendas, and delivering unsatisfactory products and services." [Das and Teng, (1999), p.51]

According to Hamel (1998) and Mowery et al. (1996), these opportunistic behaviours are more severe when knowledge-based resources are involved since these resources are more vulnerable to uncontrolled transfers than physical-property-based resources. Therefore, the principal concern that would stop a firm from following the open innovation model and its R&D collaboration would be the danger of losing control over their knowledge-based resources or IP' (Das and Teng, 2000).

Additionally, sometimes companies neither act inapproprately nor attempt to misuse the collaboration but the alliance still may not be successful due to external challenges, such as changing governmental policies and/or market needs, low economic performance of society, such as recession, and other external factors, such as war (Das and Teng, 2000; Hagedoorn and Schakenraad, 1994; Kotabe and Scott Swan, 1995).

4.2.2 Absorptive capacity

A significant challenge in applying the open innovation model is having sufficient 'absorptive capacity' (AC) in the cooperating firms. AC is defined as "process stages of acquiring external knowledge and assimilating this knowledge by means of incorporating it into the firm's knowledge base" [Sharma et al., (1994), p.5]. Zahra and Goerge (2002) have divided AC into two parts, Potential AC, which is defined as acquiring and assimilating external knowledge, and Realized AC, which is defined as the transformation and exploitation of capabilities.

The level of AC in firms depends on a variety of factors such as:

1. Prior related knowledge, which helps employees to make sense of new knowledge
2. The capability of communication with the external environment and the structure of communication

3. The intensity of effort of the firm, which refers to the amount of effort that is dedicated to obtaining new external knowledge (Barney, 2001).

One of possible reasons for companies to have low levels of AC is a low level of affinity for collaboration between firms due to lack of collaboration experience and lack of an efficient network within the industry. Brown (1991) and Westley and Vredenburg (1991) introduced the concept of the strategic bridging organisation to address the problem of low levels of AC due to lack of experience with inter-organisational collaboration. According to Brown (1991, p.808): "Bridging organisations span the gaps among diverse constituencies to work on development problems". These strategic bridging organisations bring together all the players, including private firms, multinational corporations, NGOs and government agencies to collaborate on a project. A strategic bridge organisation acts as a third party stakeholder and "enters collaborative negotiations to further their own ends as well as serve as links among domain stakeholders" [Westley and Vredenburg, (1991), p.68]. Westley and Vredenburg (1991) argued that a firm can be motivated to act as a bridging organisation either based on egoistic factors (voluntary, self-serving and maintenance oriented) or altruistic factors (designed or mandated, problem focused and transformative).

The strategic bridging concept was subsequently adopted to explicitly facilitate the diffusion of the open innovation model. Howells (2006), Gassmann et al. (2010) and Sieg et al. (2010) use the term innovation intermediary to describe a strategic bridging organisation in the open innovation context. Innovation intermediaries have been defined as "an organisation or body that acts as an agent or broker in [some] aspect of the innovation process between two or more parties" [Garcia and Vredenburg, (2003),

p. 0]. Innovation intermediaries investigate multiple markets and technology domains to connect innovation seekers and providers. As a result of their network, knowledge flows from where it existed to where it does not exist (Garcia and Vredenburg, 2003).

Concepts such as open and closed innovation, STA and innovation intermediaries have been primarily discussed in the context of product innovation in 'high tech' information technology industries while innovation in the oil and gas industry is mainly about process innovation. According to Tidd and Bessant (1997), process innovation is changing the way a firm creates and delivers a product/service. Innovation in the oil and gas industry does not follow the traditional linear path of 'laboratory to marketplace' (Pretorius and Magee, 2005), and the industry is mainly dealing with what might be called hidden innovation. Hidden innovations have two main specifications:

1. They are not measured since they are not reported in formal R&D activities or patents awarded.
2. They contribute in real practice and performance (NESTA, 2007).

Therefore, this research attempts to understand how oil and gas companies behave with regards to innovation models and how they pursue open innovation. Do they create partnerships by making alliances with suppliers, universities and rival firms and take advantage of innovation intermediaries as discussed in the innovation literature or has the industry created its own path?

4.3 METHODOLOGY

This research tries to determine whether R&D collaboration as part of an open innovation model with suppliers, research institutions and even rival companies facilitates technical

innovation in the context of the upstream side of the oil and gas industry (i.e., exploration, development and production). Since the phenomenon we are interested in, R&D collaboration, cannot be separated from its industry context in this research, the case study is the appropriate empirical method for the current exploratory research.

The Canadian oil and gas industry is one of the largest producers of unconventional oil and gas in the world, and Canadian firms are pioneers in this fairly young segment of the industry. These companies are among the first companies that have either introduced the new technologies to the market or apply new technologies. Therefore, the Canadian oil and gas industry has been selected as the broader context for the study.

Within this broad context, we are focusing on an industry organisation called the Petroleum Technology Alliance of Canada (PTAC) for the case study. PTAC is a unique case not only in the Canadian oil and gas industry but also on a global scale. PTAC is the only non-profit organisation in the oil and gas industry that has members from different stakeholder groups, including governments, universities, research providers, inventors, service providers and suppliers, as well as oil and gas producers. PTAC has 28 producers, ten research providing institutions, five governments and 143 service and supply companies in its membership that provide rich data sources to understand how and why all of these different stakeholders in the oil and gas industry have chosen to collaborate with each other. PTAC might be seen as an indicator of changing attitudes in the industry with regards to innovation and collaboration.

Therefore, by studying the performance of PTAC and the projects that PTAC has facilitated, we identify unique aspects of PTAC's innovation model within the industry with which we try to contribute to the theories of open innovation.

4.3.1 Data collection

In order to conduct a single case study with construct validity we utilised multiple sources of data. Two extensive face-to-face interviews, each lasting about an hour, were conducted with the president of the organisation. These interviews were followed up with two more telephone interviews, each lasting about 30 minutes. The face-to-face interviews were audio-recorded and transcribed after each meeting. General observation notes were made at the end of each interview. Further follow-ups were made with the interviewee by e-mail to clarify relevant points. Additionally, one of the authors attended an industry conference that addressed issues regarding innovation in the oil and gas industry where the PTAC president gave an address. The speech and the questions and answers afterwards were audio-recorded with permission from the speaker and the conference organiser. This data collection took place over a three-month period in summer of 2012.

In addition to the interviews with the organisation's president, a content analysis of approximately 200 pages of documents, both PTAC internal documents, including the original proposal to establish PTAC and project reports and public documents, including annual reports (PTAC, 1996–2011), environmental reports, company newsletters and newspaper reports, was carried out to increase the reliability of the research through data source triangulation (Sharma and Vredenburg, 1998). To further triangulate the data sources and reach grounded theoretical saturation (Glaser and Strauss, 1967), semi-structured interviews were conducted with six members of PTAC who had been identified as participating in particular PTAC initiatives. Their organisations represented producers, suppliers, service companies and government, and their position titles included president, vice president, chief technology officer, technology development director,

innovation and continuous improvement manager and executive manager of operations. As well, we interviewed a founding director of PTAC who continues to serve as an independent director on the PTAC board and its executive committee. The interviews were audio-recorded and transcribed, and these transcriptions and documentary data were analysed using Nvivo9 software.

4.4 CASE STUDY

4.4.1 Creation of PTAC

Until the 1980s and 1990s major oil and gas companies such as Imperial Oil, Chevron, Shell and ExxonMobil who were active in the upstream side of the oil and gas industry in Canada and the USA maintained significant internal R&D budgets. They kept technology development in-house in order to secure a competitive advantage based on technology for their own firms. However after a significant drop in the price of oil in the 1980s and 1990s, the organisational structure of R&D changed significantly within the industry. As the profitability of the industry declined, firms cut their expenses with the R&D budget often being a favourite target for cuts. As stated by one interview respondent,

> *"It became more and more expensive to the oil and gas companies to do everything internal so when you look at the cost model, they had to look for ways to lower the cost." – Executive manager of service supplier A*

Moreover, the firms increasingly believed that although they invested heavily in R&D the outcome was generally disappointing. Some major companies, like Shell, investigated their R&D organisations and found them to be ineffective and inefficient in producing innovation. Firms with large R&D budgets, like Shell, discovered that they were actually

getting their innovations mainly from outside of their R&D units. As stated by a study respondent,

> *"Shell globally looked at where does their R&D come from, where does their innovation come from? They actually found out that only 5% came internally, 95% came (from outside)….so part of the reason that they decided not to do a lot of their own R&D is because they were finding that they were getting a lot from outside, you know, not internally.." – president of government organisation*

Consequently, large internal R&D budgets were no longer justifiable for the industry and some major producers2 such as BP, Shell and Exxon/Imperial Oil made the decision to decrease the size of their R&D budgets. Reductions in the producers' R&D budgets strengthened the role of oil and gas supply and service companies such as Halliburton, Schlumberger and Weatherford. Hence their share of providing new technologies for the industry has become more significant. As a respondent put it,

> *"The majors got out of doing the research on behalf of the entire industry because most of the research was transferred to service companies from the majors and the service companies then were left to do more of the research themselves and contracts with individual producers to test new concepts." – executive manager of producer B*

However, this shift in the industry from R&D done by producers to R&D done by service companies did not mean that service and supply companies were able to go through the entire process of innovation from basic and applied research to development and commercialisation alone. Service companies were dependent on producers that were able

to provide service companies a field to trial new technologies. This dependency of service and supplier firms on producers in the commercialisation and deployment stage required a considerable amount of investment and caused high risk for producers. For example, a producer can significantly drop its production rate in the field by testing thecommerciality of a new technology. A firm's daily production rate is the most important metric industry analysts monitor and markets respond to. Thus the cost of new oil and gas process technology includes the producer's risk of production declines resulting from failed technology innovations. As stated by one respondent,

> *"In the oil and gas industry the amount of money that is spent in the field is substantially higher than any other industry…Not only does the producer have to spend huge amounts of money, but there is a chance of losing existing production by trying some of these new projects. So, as one can see, the main challenge arises out of the cost, business risk, and the complexity which is involved in the commercialization stage." – President of PTAC*

On the other hand, a service supplier – a small company or a research institute – could have a technology that solves a problem but a producer may not be aware of the existence of that solution. Additionally, there was a high probability of duplicating projects. As stated by a respondent,

> *"A lot of other companies might have the same problem. So it doesn't make sense for the industry or for the Canadian economy to have that problem solved 8 or 10 times" – executive manager of major producer B*

Consequently, in order to overcome challenges, such as high risk and cost, lack of intellectual capital and equipment, and unnecessary duplication, the industry made a decision to experiment with the collaborative open innovation model at the industry level rather than one-to-one collaboration between a producer and a supplier. As stated by a respondent,

> *"I think that a lot of the companies realized that you cannot develop in a vacuum…there is a lot of great ideas that come from outside and there is a lot of smaller companies that can bring technology that can be used by the oil and gas companies to improve. … Not every company has key expertise in all areas of the business" – executive manager of service supplier A*

Some firms in the industry believe that solving the industry's largest challenges they will sustain a competitive advantage through patenting or IP' protection or at least a first mover advantage. These firms, thus, are not willing to collaborate as that will dissipate their potential advantage. Other firms in the industry reason that they as a firm cannot put together a team by themselves that will seriously address the major production challenges faced by the industry. These firms argue that the unconventional oil and gas part of the industry is so new, and complicated, and technologies are advancing so rapidly owning a specific technology will not help companies significantly.

> *"The problem and difficulty that you have today in the industry is that technical innovation happens too fast..." – chief technology officer of major energy company*

Since the new production technologies are usually being developed with help from suppliers, the technologies are usually soon disseminated by the suppliers to another producer company. Furthermore, the oil and gas industry, especially in the unconventional sector, is structured in a way that major companies can observe each other easily. The centre of the Canadian unconventional oil and gas industry is concentrated within a few dozen blocks in downtown Calgary, Alberta, a city of 1.2 million. There is high level of interaction between companies and their employees. The Calgary Petroleum Club and downtown restaurants and health clubs constitute a hub of professional socialising between industry executives and employees. Most geologists, geophysicists and engineers in Calgary's oil and gas industry are members of professional technical societies who publish the latest technology advancements extensively. In these circumstances keeping research and development confidential, many argue, may not be feasible. As reported by one respondent,

> *"In an industry like Calgary most innovations are pretty well out there in a year. Now they may be being developed on a proprietary basis but the awareness of them, the existence of them even how they performed quite often it's less than a year before it's a generally known or accepted fact and it's quite quickly emulated" – innovation and continuous improvement manager of producer*

The speed with which technical information travels today makes it difficult to retain and maintain IP' in-house. Sometimes companies might have a specific technology yet they are unable to make a connection between the technology and their own resources and business models and, thus, cannot take advantage of the technology in a timely fashion. Others subsequently solve the commercialisation challenge and appropriate the benefits

of early movers. For example, in the late 1990s Amoco was the first major company to experiment with hydraulic fracturing technology (fracking) to extract the type of natural gas resource that would later be called 'tight gas'. However, Amoco was unable to commercialise the technology. Today fracking, of course, has created a new business in the oil and gas industry that is worth billions of dollars in North America. Thus, owning the technology cannot necessarily lead to a sustainable competitive advantage if it cannot be commercially employed. The application of technology is the factor that distinguishes companies, not its ownership. As stated by a respondent,

> *"Three years ago we felt that all research had property value, improved our competitive position and should be developed in- house and kept secret. We now feel that, with the exception of some specialty areas, technical information moves so fast that we could not keep it secret if we wanted to. The real value lies in our ability to creatively apply new technology." – Executive of major producer*

The above observations by industry executives resulted in an inter-organisational industry innovation that fundamentally changed its innovation structure and outlook. An informal Calgary-based organisation of senior executives responsible for production operations called the 'Vice Presidents Breakfast Club', which included 25 Canadian-based oil companies representing a cross section of major, intermediate and junior companies, made the decision in 1995 to change the model of industry innovation to a collaborative open innovation model. The Vice Presidents Breakfast Club funded a not-for-profit organisation which was called the PTAC in 1996. PTAC was designed to include all stakeholders (by 2011, 28 producer companies, 143 service and supplier companies, five governments departments, two transport/pipeline/midstream companies, three educational

institutions, ten research providers and one venture capital firm were members of PTAC). PTAC was designed to facilitate the execution of problem solving research projects addressing industry needs. As described in PTAC's initial formation proposal,

> *"The purpose of PTAC is to provide a structure that will bring stakeholders together to identify industry problems and define research projects to deal with them. The objective is to leverage intellectual and financial resources, apply them to solving industry problems and improve industry performance."*

PTAC was designed to act as a neutral broker and not just be representative of producers. According to the PTAC's president, being a neutral facilitator helped PTAC get respect from all other stakeholders including individual inventors, not-for-profit organisations and small and medium enterprises. PTAC was structured such that it did not itself carry out research, in other words it was not a research institution. Instead, all the projects facilitated or managed by PTAC would be conducted by a third party. The PTAC model also was designed to give more attention to projects that addressed long-term needs and goals rather than addressing short-term needs. PTAC's focus, thus, was on strategic technologies.

The main challenge for PTAC has been identifying the technical fields in which companies, including suppliers and producers, are willing to collaborate. Clearly there are some areas of R&D in which companies are less motivated to collaborate. These areas include the types of new technologies that might produce competitive advantage, even for a short period of time as first mover advantage, by decreasing production cost or increasing production rates. The industry appears to not have any difficulty distinguishing between R&D projects that may provide competitive advantage, even as short-term first

mover advantage and projects that might help the entire industry become more sustainable. PTAC activities have, thus, largely focused on non-competitive areas.

One of these non-competitive research areas that have become a mainstay of PTAC activities is environmental technologies. Technical R&D projects with a focus on environmental concerns are categorised as non-competitive projects that firms are willing to collaborate on. Environmental problems faced by any one company are seen to become the problem of the entire industry as all their reputations are tarnished. 'Social license to operate' has become the challenge all agree in the industry must collaborate on maintaining. Although most believe that these environmental technology projects may not generate short-term profit, they can help the industry in the long-term to strive for sustainable development and maintain social license to operate. It is sometimes difficult, however, to make a distinction between where the environment begins and where the business ends. For example, technology that reduces CO2 emissions often does so by increasing energy input efficiency, which, of course, also favourably impacts production costs. Usually, participants in a collaborative project make the decision whether the project is competitive or not competitive with respect to environmental projects. As stated by a respondent,

> *"When it comes to developing environmental technologies, from my viewpoint, these technologies are non-competitive. Why? Because they may not necessarily reduce cost or increase recovery, but by helping our environment, I think it makes sense for the whole industry to participate in these initiatives. We need to develop our hydrocarbon resources in a sustainable way together, not just one company at a time..." – PTAC President*

"The agreement is that this will be a non-competitive, the environmental technology will be a non-competitive, technology space where there will be sharing of IP rights within defined limitations and boundaries." – Director of Technology Development of Producer A

There is also a regulatory element that stimulates cooperation on environmental issues in the industry. For instance, the Low Carbon Fuel Standard in California (California Air Resources Board, 2006) may affect the entire Canadian oil and gas industry. California, as a major importer of energy from Canada, has introduced legislation stipulating the maximum permissible CO2 emissions associated with fuel imported in to the state. This regulation and similar regulations can be a danger for the entire industry since oil is exported to USA by pipeline and there is no way to differentiate between low emission oil from one company and high emission oil produced by another, as oil is blended in the pipelines. In arriving at an emissions number for Canadian oil, California regulators would have to consider emissions produced by the entire industry, not just one single company. It, thus, behooves the industry to collaborate to share their technical and financial resources to solve the emissions and other environmental problems. As one respondent commented,

"The main reason is all companies recognize that environmental is an industry issue and is part of the license to operate and it's not a competitive advantage but it's a necessity to have public support for operations. And therefore even if a company doesn't cooperate and collaborate on production, they'll cooperate and collaborate in environmental issues that they know they have and other companies have, then why should they fund 100% of the cost through solving the

problem when everyone else has the same problem." – Operations Manager of Producer B

Reputational risk is another motivation for oil and gas companies to collaborate in the field of environmental concerns. Reputational risk can be categorised into two different components, internal risk and external risk. External risk refers to the reputation of a company in terms of the general public. If a firm cannot build a good reputation in the field of environment, not only might the company not get the legal license to operate but it may also lose its societal legitimacy with the public and environmental activists focusing on the industry. Reputational risk internal to the industry, on the other hand, also encourages firms to collaborate. Internal industry risk refers to the reputation of a firm in front of other players within the industry. Since environmental problems tend to become the industry's problem, when a firm experiences visible environmental problems and is not seen to be contributing actively to solving environmental problems that firm will get ostracised by the rest of the industry. Alternatively if a firm finds a solution to an environmental problem and does not share it the firm may be ostracised. Firms collaborate on environmental issues as they do not want to become ostracised by the industry. As stated by a respondent,

"If you could solve all the industries problems on water but you are not going to share it because it gives you an advantage, then you are like the devil squared, right? You know it's like, I will use an analogy, it's like some guy has got a cut and you have all the Band-Aids but you are not going to give him a Band-Aid because that's your advantage to have the Band-Aids for yourself. That doesn't sound right, people don't like that. So we extrapolate that to the environment, if

you have a fix for the environment and you don't share it they are really not going to like you because you can fix the problem and you are choosing not to." – Manager of Technology Development of Producer A

Since environmental projects may not result directly in firm profitability, most junior companies are not willing to invest in them. However, when they become a part of the consortium, which includes a variety of investors including major companies, government, universities and NGOs and they share their resources it places less pressure on their limited budgets.

The willingness of firms to collaborate on environmental concerns can be seen in the statistics that show that 54% of the projects, or more than 70% of financial investment value, have been dedicated to environmental projects (Figures 4.1 and4. 2).

Figure 4. 1. Number of joint R&D agreements from 1996 to 2011 (environmental projects vs. non-environmental projects), Source: Extracted from PTAC's Annual reports (PTAC, 1996–2011)

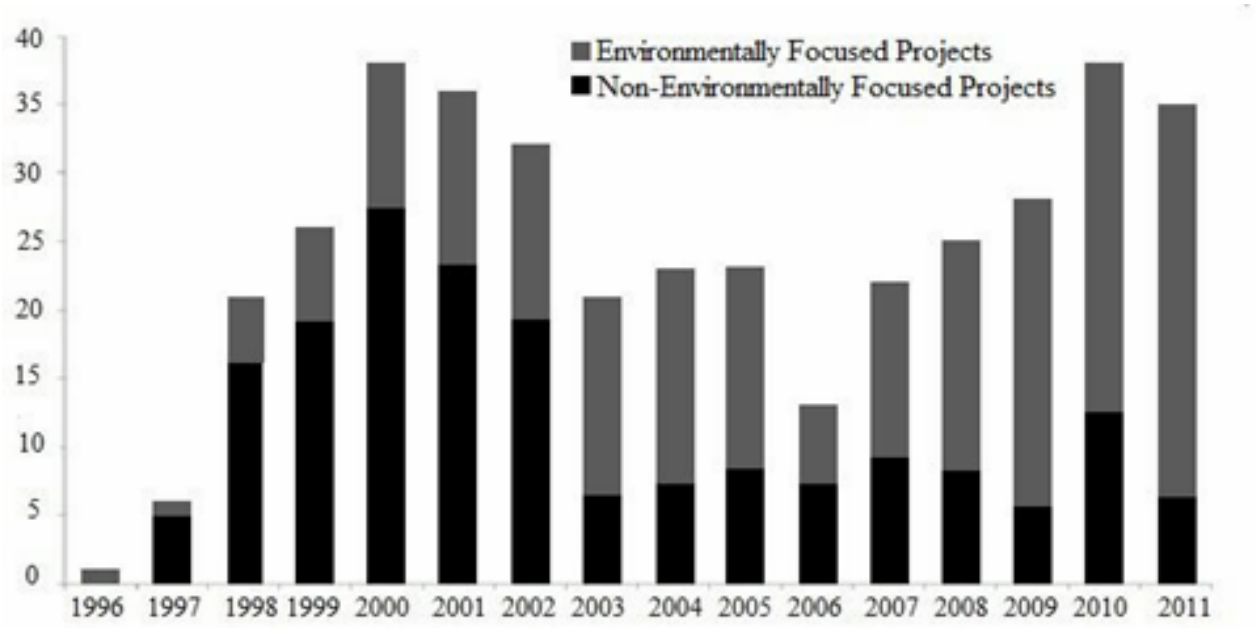
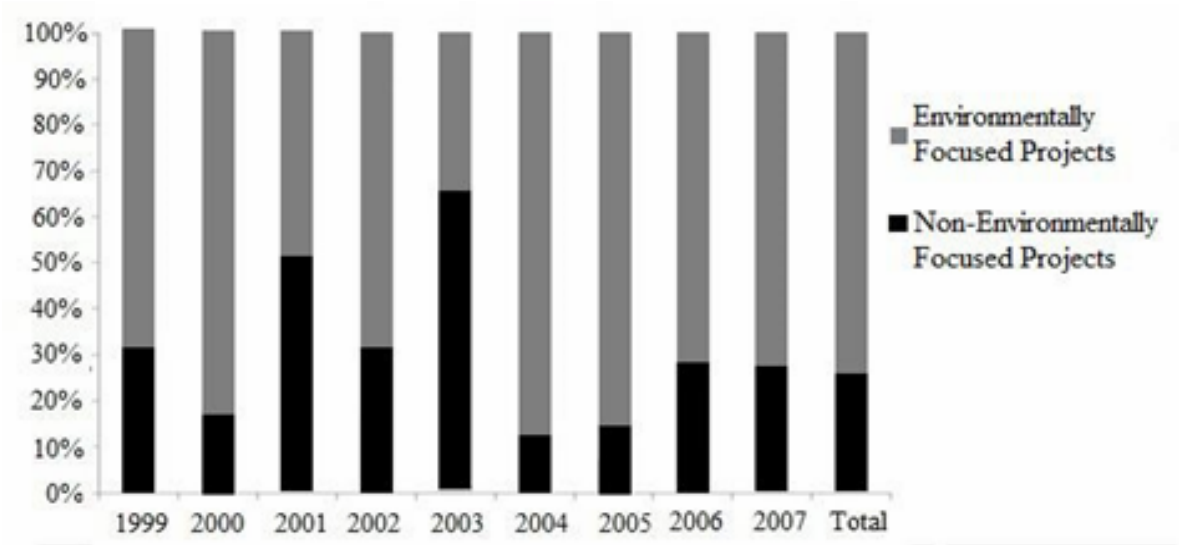


Figure 4. 2 Share of environmentally-focused projects from the total investment in joint R&D



4.4.2 The PTAC model

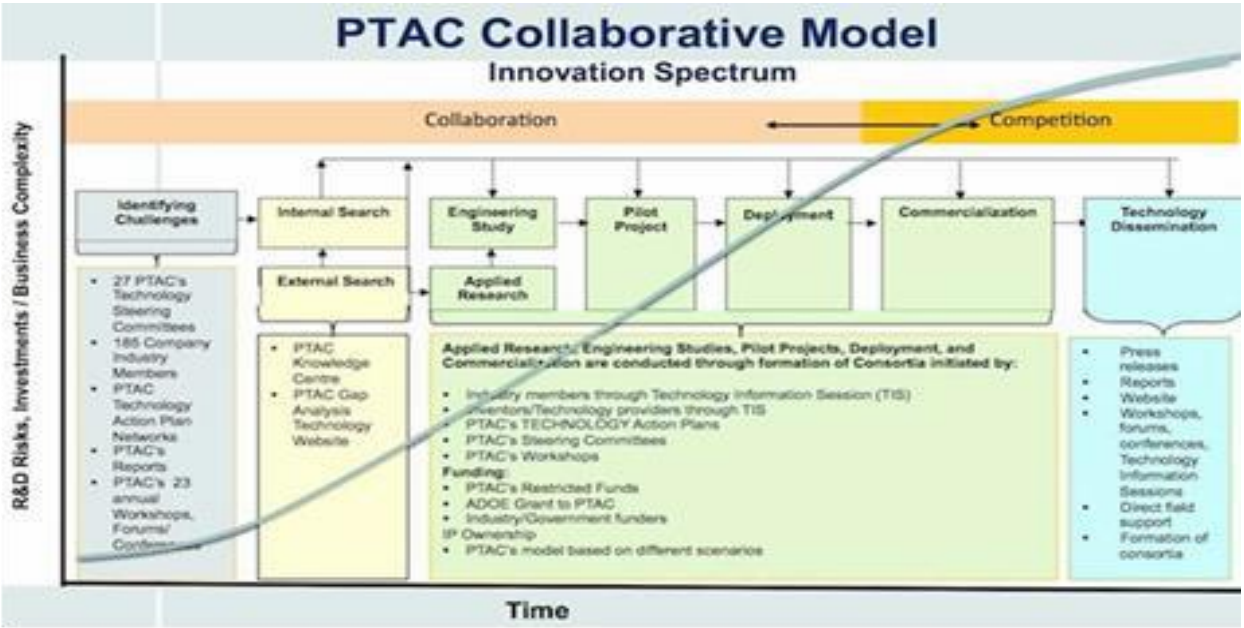
The collaborative open innovation model devised by the industry is comprised of three 'funnels' or screening/sorting mechanisms that PTAC facilitates. The first funnel is a network including all the stakeholders of the industry. By arranging workshops and meetings on different topics, PTAC learns what the challenges are. Then PTAC starts looking for solutions within the network including R&D providers, research institutions, small and medium enterprises and individual inventors. Again, PTAC is not an R&D supplier itself but rather a convener and facilitator of a network.

The second funnel commences once PTAC has identified a potential technological solution. Based on that potential solution, PTAC writes and distributes a request for proposals (RFP) to all stakeholders. In this funnel, organisations that might be interested in investing in the project would be identified. PTAC organises one or more consortia within the network to advance the project. These consortia include both financial backers or funders and project executers or suppliers. In these consortia, energy service companies usually are the suppliers and governments and producers are the financial

backers and funders. Then, within such a consortium, PTAC facilitates the development of technologies. In time the project moves from applied research to commercialisation/field implementation.

Usually the collaborative exercise stops at the end of the applied research stage or at the conclusion of the field trial/pilot project. Participants then transfer the findings, or possibly a new technology, to their own in-house R&D department according to the IP' agreement signed by all participants at the beginning of the collaboration. At this stage firms attempt to deploy the technology in their own production process. This step of routinized commercial field application is the last funnel of the PTAC model. Figure 4.3 illustrates the PTAC collaborative model. This model provides participants with technology and data at a significantly lower cost compared to doing the entire R&D for new technology development in-house.

Figure 4. 3 PTAC collaborative model (see online version for colours), Source: PTAC (2012)



One high-profile example of the application of the PTAC's collaborative model was a group of projects called VAPEX that included 26 funders and 14 R&D suppliers. The goal of the VAPEX projects was to invent a technology that decreased the production cost of bitumen and also eliminated GHG emissions. The VAPEX projects were started in 1998 and ended in 2001. Although the technology ultimately turned out to not be successful, VAPEX was an example of collaboration between a large number of companies in the oil and gas industry (California Air Resources Board, 2006). Another more recent example was the carbon capture and storage (CCS) project that was a collaboration between 17 funding companies including producers, transportation firms and provincial governments (Higginson and Vredenburg, 2010) that is currently at a protracted stage of commercial field implementation. PTAC has facilitated and managed 358 projects with a value of 164 million dollars since 1996 (PTAC, 1996–2011).

4.4.3 Pitfalls of the PTAC model

Whether a project is primarily environmentally-focused and deemed to be non-competitive or it is deemed to be competitive, there are challenges to make a collaboration work successfully. The management of the IP is probably foremost of the challenges. PTAC has devised its own approach to overcoming this problem. PTAC does not become involved in IP, meaning that there is no IP share for PTAC itself. PTAC acts solely as the convener and facilitator and does not have its own stake in any IP coming out of the process. According to the PTAC approach, research providers/technology developers retain ownership of the IP of the technology and funders obtain the technology and its IP royalty-free in return for funding the research. Therefore, in order to obtain maximum leverage from funding PTAC's collaborative R&D projects, producer firms must ensure that they develop/have the AC as a company to successfully adopt and

commercially use new technology developed from a project. They must, thus, become actively involved on the project advisory committee and have the technical receptor capacity to understand the new technology intimately, and be aware of the oil and gas reservoir characteristics, firm resources and facilities where the new technology is to be applied. Only when funding producer firms have the AC will they get the most out of the collaboration.

This is one of the characteristics of the oil and gas industry that makes it different from others. The technologies that are being used in one specific oil field or reservoir are heterogeneous to suit that particular resource asset, so new technologies need also to be adapted to that particular field (NESTA, 2007). Therefore, the last funnel of the PTAC model, adapting technology inside the firms by internal R&D, is the critical step that will allow for competitive advantage for participants in collaborative initiative.

Although IP management is far and away the most challenging aspect of collaborative technology development or open innovation, there are other challenges. Different corporate cultures of collaborative organisations pose another significant challenge to collaboration. In order to plan a successful collaboration, firms should be able to trust, communicate and share information with each other. If firms cannot trust or effectively communicate with each other the collaboration is likely to fail. Additionally, firms involved in collaboration should have a similar degree of risk aversion and a broadly similar innovation strategy. Most of these fundamental conditions necessary for successful collaboration are determined by an organisation's structure and a dominant culture. If the cultures of collaborating organisations are not aligned to some significant degree the technology development collaboration is likely to be in jeopardy. As observed by a respondent,

"Well first of all what you have to recognize is every company has a different corporate culture. Some corporate cultures believe that more can be gained through collaboration, and other corporate cultures believe that they know best and they should do everything themselves and they are competing on everything with other oil companies." – Executive Manager of Producer 2

4.5 ANALYSIS AND DISCUSSION

Our case describes an industry with many players that finds itself in a business environment calling for rapid production process technological change to develop unconventional resources under stringent environmental public expectations requiring large financial investment and extensive process customisation in order to be commercially useful. In order to respond to the demand for innovation the industry has developed a model which is able to facilitate the sharing of expertise, R&D sources, cost and risks between companies, reduce the level of duplication in R&D, and match the innovation strengths of small companies with the resources of large companies. The industry turned to a model used by the 'high tech' information technology industry of an open innovation model.

The open innovation model adopted from the information technology industry was adapted to the particular conditions of the oil and gas industry. Whereas the information technology industry is focused on product innovation the oil and gas industry's focus is industrial process innovation. An oil and gas company does not depend for its profitability on innovation directly, as is not being seen by the general public/market as an innovator, as does a product innovator in the information technology industry.

Innovation for an oil and gas firm is profitable if it reduces production costs, increases production rates or enhances access to energy resources through public acceptance or social license to operate. As a result, major producer firms are sometimes less sensitive about IP issues compared to firms in industries such as information technology and pharmaceuticals. At best, these firms believe, new technology will give them a bit of a head start on rivals in the form of a first mover advantage.

Some of the major challenges facing the oil and gas industry are environmental in nature and are considered to be environmental problems that are global to the industry. The entire industry must find solutions for these challenges. Therefore, they are considered to be non-competitive areas for firms and coming up with a solution by a firm will not provide it any sustained firm-level advantage. The industry has to work together, it is believed, to solve these problems. Finally, the new unconventional oil and gas sector of the industry has a significant corporate concentration in Calgary, facilitating communication and collaboration.

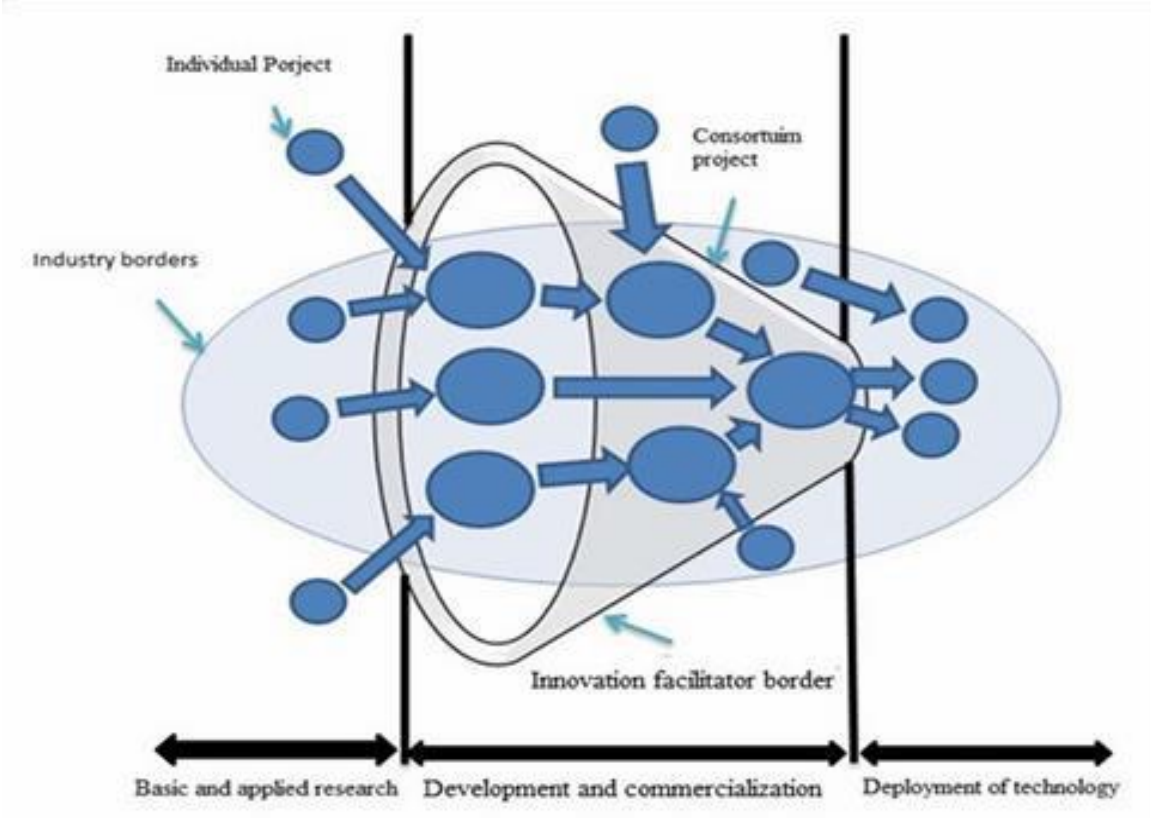
As a consequence of the above described confluence of factors the Canadian oil and gas industry turned to an open innovation model. The oil and gas industry version of the open innovation model, Figure 4, encourages the industry to decrease their in-house R&D intensity and increase the level of collaboration in the process of innovation through an industry-level convener and facilitator, PTAC.

In this oil and gas industry open innovation model, the role of the innovation strategic bridge or intermediary party has been redefined and become more significant. The innovation intermediary is defined in the literature as “an organisation or body that acts as an agent or broker in [some] aspect of the innovation process between two or more

parties" [Garcia and Vredenburg, (2003), p.720]. However, in the new model the innovation facilitator (innovation intermediary party) is not just an agent to match an innovator to a firm that needs that innovation. According to the new model, the innovation facilitator is created by the industry and is expected to focus on development and commercialisation in a broader sense. A significant proportion of active firms in the industry are members of this non-profit innovation intermediary organisation.

Innovations are being directed by the innovation facilitator. It is tasked with finding problems and possible solutions from inside and outside the industry. Then, it makes and manages consortia to develop ideas and in the end participants all share the results and deploy the technology in their fields (Figure 4.4). Funds that are paid by consortium participants are paid to a third party, which is usually a research institute, to conduct research and usually are managed by PTAC, the innovation facilitator, and an advisory committee consisting of stakeholder organisation members. Therefore, the opportunistic behaviours that are a threat to successful collaboration are to some degree controlled.

Figure 4. 4 Collaborative open innovation model (see online version for colours)



The existence of an innovation facilitator provides a number of advantages for collaborating firms. For example, it can facilitate the process of accessing the appropriate intellectual capital, property and R&D budget through its well-established network. The innovation facilitator also provides the opportunity for small R&D players and technology developers to introduce their new technologies to the entire industry through the innovation facilitator's technical sessions. Therefore, small companies and even individual inventors do not need to contact each major company to attract attention. Similarly major producer companies and service firms do not need to invest time, money and human resources to screen the industry to find new ideas. Another advantage of the innovation facilitator is its ability to decrease the level of R&D duplication within the industry.

Non-equity STAs appear to be the open innovation approach popular in the oil and gas industry. The projects targeted by the innovation facilitator address long term needs of the industry. Oil and gas producer firms are interested in the results of technological innovation, lower costs, higher production rates etc., rather than being seen by consumer markets as technical innovators as information technology firms might be. Hence STA is more suitable since the core advantage of alliances is to invest resources that are needed with minimum superfluity (Das and Teng, 2000; Eisenhardt and Schoonhoven, 1996).

In order for collaboration in innovation to succeed the AC of collaborating firms must be developed continually so that the collaborating firm will be in a position to effectively appropriate the results of the R&D collaboration. The innovation facilitator can play a role in helping firms to increase their potential AC but in order to increase their realised AC firms may need to restructure themselves and evolve their corporate culture to be more collaborative. R&D collaboration in the oil and gas industry is still relatively new and there are still cultural barriers to it reaching its full potential. Although companies are prepared to collaborate in areas that they do not consider competitive, collaboration breaks down when there is potentially valuable IP at stake that might give a firm a competitive advantage. Since the oil and gas industry engages continuously in negotiating complicated multi-company partnerships for developing large energy resource assets and regularly is engaged in complicated merger and acquisition negotiation, there may be opportunities for companies to expand the current open innovation model practiced in the industry to include negotiated IP shares of an innovation in areas considered competitive.

4.6 CONCLUSIONS

This article has introduced and described an open innovation model experimented with in the oil and gas industry that meets the needs in that industry. We relate this case to the extant literature on open innovation and discuss how and why this industry's experience may be different yet successful. We believe that our discussion extends our understanding of the open innovation phenomenon. The model we describe may be useful in other resource extraction industries that face similar strategic parameters to the energy industry with regards to expectations of new process technologies – lower costs, higher production rates, enhanced social license to operate.

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CHAPTER FIVE: CONCLUSIONS

5.1 SUMMARY OF FINDINGS

The three essays of my dissertation provide a comprehensive evaluation of innovation strategies to achieve process innovation (either sustaining or disruptive) in the oil industry, based on various theoretical perspectives. These include disruptive innovation theory, dynamic capabilities theory, institutional theory, and the resource-based view (RBV). Specifically, I have focused on the open innovation model (Chesbrough, 2003), its application challenges and its evolution within the oil industry throughout the three essays. These findings are summarized below.

The first essay examined the development of a disruptive technical process innovation by a new entrant to the oil industry. The findings of this essay highlight some of the challenges faced by new entrant firms to develop a disruptive process innovation. The challenges can be categorized as a) lack of resources (i.e., capital, technical and human), b) a vertical leadership style, c) balancing the tension between the shareholders' and public markets' expectation to gain a quick profit, and the lengthy process of technology development (especially in the case of public firms), and d) internal collaboration challenges.

Based on the findings, I suggest combining two concepts, disruptive innovation capability (Assink, 2006) and process innovation capability (Frishammar, Kurkkio, Abrahamsson, & Lichtenthaler, 2012) to create a disruptive technical process innovation capability, which is defined here as *a firm`s ability to attain, modify, and/or capitalize on a technology that can disrupt an existing process*. Creating this specific capability helps us identify the antecedents required to build such a capability in new entrant firms that

operate in similar industries. The first paper suggests four antecedents that can help address the challenges mentioned above.

The first, and most important, antecedent is utilizing external resources through collaboration with other firms. The study suggests that although applying the closed innovation model brings some advantages to the firms (e.g., securing the core competency and knowledge created, enjoying the full rent of innovation and the first mover advantage), it potentially creates major difficulties (e.g., lack of access to required human, capital and technological resources) for firms developing process innovations. Thus, the open innovation model might be a better option. Later, in the other two essays, I described in detail how firms can utilize external resources through the open innovation model. Second, creating an environment that facilitates internal collaboration among team members is essential to successfully develop a process innovation. Third, developing a leadership style that provides opportunities for team members to share their opinions with their leaders and that allows team members more influence in the decision making process, may assist in the development of a process innovation. Fourth, due to the long time it takes to develop a process innovation, new entrants should explore sources of funding that have a high long-term investment tolerance, such as private investment market and/or government funding.

The second essay elaborates on the findings of the first regarding the need to utilize external resources to develop process innovations through the open innovation model. The second essay examined the oil industry`s innovation strategy and four industry founded innovation intermediaries. These intermediaries provided insight into the fundamentals of the open innovation model in a technological process industry faced with

significant technical complexity. The findings of this essay can be divided in three sections. The first part of the study suggests that the motivation for a firm to apply the model can be divided into two main categories: (1) financial motivation, such as sharing cost, risk, and resources (Chesbrough, 2006) and (2) motivation that results from coercive and normative institutional forces, which are created by environmental and social challenges, loosely categorized as sustainable development issues. These findings have been supported by other research in this area (Escobar & Vredenburg (2011); Bansal (2005)).

The second part of the essay suggests that industry-founded innovation intermediaries may help industries (i.e., process-oriented industries and/or resource-based industries) to successfully apply the open innovation model. The study suggests four advantages of founding such innovation intermediaries within these industries. First, these organizations strengthen collaboration by having industry leaders such as CEOs and VPs on the executive board, discussing and sharing their expertise. Second, all stakeholders, including government agencies and environmental groups, have an opportunity to work directly with these neutral organizations and share their views, expertise, and resources. Third, these organizations actively create forums and workshops, which bring various stakeholders together for discussion and, ultimately, for finding solutions to an industry problem. Fourth, these organizations have provided a kind of IP sharing policy as a framework for collaboration, which has facilitated the negotiation process between the participants of the collaborative project.

Finally, the last section of the second essay examined four different governance models of an industry-founded innovation intermediary. By building on the meta-organization

concept, this study provides suggestions regarding the suitable organizational design for such innovation intermediaries. The study suggests that the managed ecosystem design is most relevant if the industry needs other stakeholders (such as governments) to sponsor its R&D activities. In addition, it suggests that it is more effective to establish organizations that have some moderate level of stratification. Lastly, the study suggests that having either a very low or a very high level of stratification hinders the process of open innovation. The study emphasizes the need to balance on hierarchal design with a collaborative spirit among participants.

While the second study looked at different governance models of innovation intermediaries, the third study focused on one very successful innovation intermediary and provided a detailed model of this organization. There are two general findings of interest from the third study. First, it shows how the industry worked towards applying the open innovation model and the decision process of creating an innovation intermediary. The reasons for applying the open innovation model were as follows: the fast changing technology environment, sharing of expertise, sharing R&D sources, sharing cost and risks between companies, reducing the level of duplication in R&D, and matching the innovation strengths of small companies with the resources of large companies. In addition, the essay suggests that non-competitive areas (i.e., environmental and social problems) are the best venues in which to collaborate and apply the open innovation model. Moreover, Non-equity strategic technology alliances appear to be popular with the open innovation approach in the oil and gas industry since it provides opportunity to invest resources that are needed with minimum superfluity (Das & Teng, 2000; Eisenhardt & Schoonhoven, 1996).

The second finding of interest was examining, in great detail, the structure and operation of an innovation intermediary. In this case, PTAC, a not-for-profit organization industry founded by industry, sought to find problems and possible solutions from inside and outside the industry. Then, it created and managed consortia to develop ideas, which led to all participants sharing the results and deploying the technology in their fields. Funds that are paid by consortium participants are paid to a third party, usually a research institute, to conduct research. The distribution of funds to the third party is managed by PTAC and its advisory committee consisting of member organizations. Therefore, opportunistic behaviors that threaten successful collaboration are minimized.

5.2 THEORETICAL CONTRIBUTIONS AND MANAGERIAL IMPLICATIONS

As mentioned in the introduction to this thesis, the open innovation model has been criticized by some scholars for its lack of originality, its vagueness, the challenges in protecting the internal capabilities of the firm and the circumstances in which a firm should apply the model (Christensen, Olesen, & Kjær, 2005; Dittrich & Duysters, 2007; Trott & Hartmann, 2009; Van de Vrande, De Jong, Vanhaverbeke, & De Rochemont, 2009; West & Gallagher, 2006; Wikhamn & Wikhamn, 2013). In my thesis essays I aimed to address some of these critiques and to expand on the open innovation model by introducing some important boundary conditions.

One of the critiques is the undefined circumstance under which the model should be applied as the innovation strategy of a firm. By utilizing Institutional Theory, the study shows that coercive and normative forces, which are created as result of social and environmental movements, create a situation more suited to applying the open innovation model. These sustainability concerns and institutional forces create non-competitive or

pre-competitive areas whereby R&D collaboration is less challenging for the firms since there is less concern about IP ownership and enjoying first-mover advantages. However, it is important to note that the industry context is an important boundary condition of applying the open innovation model.

Industries that extract natural resources and whose products are undifferentiated (such as commodities) can be suited to applying open innovation under the above circumstances. As mentioned earlier, these industries need to respond to environmental and social concerns in a sustainable and cost-efficient way or face substantial increase in their production costs and, in the case of some of these industries, see themselves replaced by alternative industries. Both scenarios place the entire industry in danger, not just a limited number of firms. Therefore, to respond to these challenges, a collective effort from the entire industry is needed. Thus, the open innovation model appears to be the best option.

In addition, for the firms within industries who did not build a high level of absorptive capacity (AC), the innovation intermediary studied here provides some suggestions on how to structure innovation intermediaries that can facilitate the application of the open innovation model. For the open innovation model to succeed, the AC of collaborating firms must be continually developed so that the collaborating firm will be in a position to effectively benefit from the advantages of the model. The innovation intermediaries can play a role in helping firms to increase their potential AC.

In addition to the theoretical contribution to expand and develop the open innovation model, I have addressed the process innovation gap in the literature. As mentioned earlier, process innovation has been neglected in scholarly innovation research relative to product innovation (Crossan & Apaydin, 2010; Frishammar et al., 2012; Laursen &

Salter, 2006; Stadler, 2011; Un & Asakawa, 2015). It is important to note that innovation mechanisms are different for product and process innovation on dimensions such as goals, valuation, imitability, rareness, substitutability and competitive impact (Un & Asakawa, 2015). As such, knowledge that is derived from product innovation studies may not transfer directly into process innovation (Damanpour, 2010; Pisano & Shih, 2012; Stadler, 2011; Un & Asakawa, 2015). By studying different cases of process innovation, I have aimed to highlight the challenges and barriers in developing process innovation. Moreover, as mentioned earlier, the challenges facing new entrants to develop disruptive process innovation have rarely been discussed. Studying a very interesting case of a potential disruptive innovation, allowed us explore some of the challenges of a new entrant firm. In addition, it suggested some ways to overcome these barriers and challenges.

I believe the findings of the three essays are very practical for managers within resource-based industries and/or process-oriented industries. The increasing environmental pressure on such industries (e.g., mining, steel, agricultural, and energy) demands that these industries develop innovation and particularly process innovations (either disruptive or sustaining). This dissertation provides practical insight and suggestions for managers within these industries to understand *when* and *how* to apply the open innovation model, and *how* they can overcome barriers facing process innovation, and particularly, disruptive process innovation.

5.3 LIMITATIONS AND FUTURE DIRECTIONS

Each essay in this dissertation has some limitations. For example, the first essay is based on a single case study. This may limit us in identifying challenges new entrants face.

Future studies can expand my findings by studying other cases. The second essay lacks data in the success and/or failure in the case of OSTG. The lack of data was not due to access to the organization, but rather, the OSTG being a very young innovation intermediary. It is not fair to judge whether it has been successful, especially in the oil industry where innovation takes a long time to develop and commercialize. Thus, further research is needed to study this organization in about five to ten years. Some might argue that applying a case study method is a common limitation of the essays of this thesis. As findings of the case study method are limited in its generalizability, we are eager to await further studies that examine our findings in other contexts (e.g., other process-oriented industries). More studies, possibly quantitative, are needed to confirm our findings.

In conclusion, today's oil industry does not only face environmental and social challenges but also profound financial challenges. As a result of the significant technological advancements achieved over the past three decades, the oil market faces a huge surplus. As a result, the oil price has crashed significantly through the past 18 months, having a large impact on the industry. Thus, oil firms are facing great financial challenges, especially those companies active in unconventional resources. In addition, the demand for oil could decrease even further in the near future, by the increasing popularity of electrical and hybrid cars (transportation consumes approximately 70% of produced oil). If this occurs, the possibility of higher oil prices would be less likely, further challenging the oil industry. Thus, it is clear that in the oil industry there is a high demand for new process innovations that reduce the extraction costs and the environmental impact. In addition, it should be noted that the oil industry is not the only industry facing these circumstances; other resource-based industries such as gas, coal, forest, aluminum,

copper and etc. are facing the same challenges to some degree. Thus, these industries need to find ways to develop new technologies more efficiently. My dissertation strongly argues for of collaboration strategies. However, questions still remain around how to implement these suggestions, or strategies, to create the best outcome for the industries. Future research will help us to explain this in more detail.

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