Contribution to Supply Chain Management and Incentive Modeling with Application from the Upstream Oil and Gas Industry

by
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Thesis submitted in fulfillment of
the requirements for the degree of

PHILOSOPHIAE DOCTOR
(PhD)

University of Stavanger
Faculty of Science and Technology
2011

University of Stavanger

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IBSN: xxx-xx-xxxx-xxx-x
ISSN: xxxx-xxxx

PREFACE

This thesis is submitted in fulfillment of the requirements for the degree of *Philosophiae Doctor* (PhD) at the University of Stavanger, Faculty of Science and Technology, Norway. The research has been carried out at the University of Stavanger with one year at Stanford University. The compulsory courses attended as part of the degree requirements have been given at the University of Stavanger, Copenhagen Business School and Norwegian School of Economics and Business Administration. The fulfillment of these requirements has been confirmed by the doctoral education committee at the Faculty of Science and Technology.

I want to thank the Research Council of Norway for their financial support during my stay at Stanford University (grant no. 179-539).

I wish to thank my supervisor Jan Frick for his contribution, and I am grateful for his effort. His support and our inspiring conversations have been a great pleasure and a motivator for me during my PhD. Further, I want to thank Louis Durlofsky and Khalid Aziz for inviting me to Stanford University and their hospitality during my stay. I also want to thank Mike Herbert at ConocoPhillips for interesting talks during the years and for letting me perform my case study at his department. I also want to thank my department at the University of Stavanger for their support during my PhD project. Further, I want to thank colleagues for pleasant conversations and enjoyable moments.

I also want to thank my friends and family. Especially, I want to thank my father, sister and brother for their motivation during this project. A special thank goes to my mother who always supported me so much in my upbringing. Her kind words and encouragement was deeply appreciated and will always be treasured.

Finally, I want to thank my fiancée Nora Marie and our two precious daughters Tyra Margaretha and Ella Sophie for their moral support, patience and love during my PhD.

Stavanger, April 2011

Knut Arne Sund

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SUMMARY

The general subject of this thesis is incentive modeling related to inter-organizational relationships and supply chain management in the oil and gas industry. More specifically, it includes an embedded multiple case study and outlines five of the single most important challenges to overcome in inter-organizational relationships in the integrated operations environment. Further, it analyzes and optimizes the value of incentive-based contracts with risks and rewards.

The thesis addresses the issues and challenges related to inter-organizational relationships, supply chain management and incentive modeling. The main objectives for this thesis are to study the inter-organizational relationships and supply chain management in the oil and gas industry and develop an incentive-based model for better collaboration through the dynamical gain and release of resources between the involved parties.

In addition, the aims of the thesis are to:

- Study the relationships between the involved parties in the inter-organizational relationship context and present the five most important findings.

- Analyze the differences between a fixed price contract and an incentive-based contract with risk (a punishment for lower performance than agreed) and reward (benefit for better performance than agreed). This will occur by:
    - Performing a joint welfare analysis between the operator (principal) and service provider (agent); and
    - Conducting an individual profit maximization analysis between the operator and service provider

- Optimize the gain and release of resources in an inter-organizational relationship setting between the operator and service providers, and between the service providers through balancing payment and contribution between the parties given the following conditions: a social choice function, incentive compatibility, participation constraints and implementing a revelation principle.

The thesis consists of two parts. Part I outlines and provides the used theories and summarizes part II. Further part I discusses the relationship between the literature and the main research questions and objectives and relates the theory to the findings in part II. Part II includes papers that address several topics related to the research questions and objectives in the thesis. Part II is seen as the main scientific contribution to the thesis. Its main contributions are as follows:

Paper 1, Sund, K. A. and Bratvold, R. B. (2008) *Integrated operations: How effective is the current relationship between operating companies and suppliers?* Proceedings of SPE Intelligent Energy Conference and Exhibition, Amsterdam, The Netherlands. Here, we focus on improving collaboration between operators and suppliers. This offers perhaps the greatest challenge and, we believe, the greatest potential for achieving the much anticipated value creation from integrated operations. We contribute to this by identifying the key disconnects

between operating companies and suppliers. We found the key disconnects with the development and use of an embedded multiple case study, focusing the inter-organizational relationships among one large operator, three large service providers and several small service providers on the Norwegian Continental Shelf.

Paper 2, Sund, K. A. (2008) *Developing New Resources: How to Gain Dynamic Capabilities and Competitive Advantages from Integrated Operations in the Upstream Oil & Gas Industry.* Proceedings of The Third Annual Meeting of Smart Fields Consortium, Stanford University, California, USA. I found that selected companies in the oil and gas industry could use incentive-based contracts with risks and rewards to bring about competitive advantages and dynamic capability. This is gained through better project planning and execution, better information sharing, the avoidance of goal incongruence, the avoidance of inappropriate key performance indicators and the avoidance of suboptimal resource allocation. The findings were obtained using an embedded multiple case study.

Paper 3, Sund, K. A. and Hausken, K. (2010) *Fixed Price Contract Versus Incentive-Based Contract in the Oil and Gas Industry. S*ubmitted for possible publication in the International Journal of Global Energy Issues (IJGEI). We outline how the incentive-based contract and the fixed price contract affect the profits and time usage differently. Both actors prefer incentive-based contracts when the project is completed in less than the estimated time and the service provider's variable income is low, or the project is completed in more than the estimated time and the punishment is intermediate. The operator prefers fixed price contracts and the service provider prefers incentive-based contracts when the project is completed in less than the estimated time and the service provider's variable income is high, or the project is completed in more than the estimated time and the punishment is lenient. The operator prefers incentive-based contracts and the service provider prefers fixed price contracts when the project is completed in more than the estimated time and the punishment is harsh. Both actors never jointly prefer fixed price contracts. The two actors collectively always prefer incentive-based contracts. These results were obtained with an individual maximization and a joint welfare analysis. We find the results remarkable given the current prevalence of fixed price contracts. The result follows since costs associated with moral hazard, adverse selection, monitoring and coordination decrease with the use of incentive-based contracts.

Paper 4, Sund K. A. (2010) *Dynamic Resource Allocation with Self-Interested Agents in the Upstream Oil & Gas Industry.* Accepted for publication in the Journal of Operations and Supply Chain Management (JOSCM), *3*(2), 78-97. This paper analyzes resource allocation between principal–agent and agent–agent in the upstream oil and gas industry. I incorporate the parties' preferences in a principal–agent model. Further, I optimize the resource allocation between the parties because they are self-interested with the use of incentive-based contracts with risks and rewards. My optimization determines that to realize the highest profit, the principal and the involved agents should avoid any agents becoming dominant. Hence, the volume of sourced items from the agents should not vary too much. I further outline the on-boarding process of new agents in the network. In the end, I outline how the network needs to compensate for the potential loss of income for some of the agents if the network should fulfill the incentive-compatibility condition and participation constraint and ensure that the network evolves positively.

Part I

1. INTRODUCTION

1.1 Background

Integrated operations is "the use of information technology to change work processes to reach better decisions, remote-control of equipment and processes, and to move functions and personnel from offshore to onshore" (OLF, 2006 p. 6). Integrated operations are expected to provide benefits of NOK 300 billion (NPV) from oil production on the Norwegian Continental Shelf (NCS)[1]. Furthermore, the cost will be reduced by NOK 24 billion, providing an increased value of 9.6% (NPV). Even further, production will increase by 8.4% (OLF, 2007). To reach this goal, the industry is facing large challenges, including all forms of inter-organizational relationships between the operator and the service providers, and employers (Eriksen, Auseth, Tømte, Freeman, & Jahren, 2006). Because the integrated operations concept has been adopted by Norwegian petroleum organizations, different personnel and groups in on-land organizations, offshore organizations and many of the service providers are collaborating on new ways of working (Andersen et al., 2006).

However, as this was the main description for integrated operations a few years ago, the oil and gas industry has since evolved differently. The oil and gas industry on the NCS has recently experienced a huge increase in costs and thereby reduced productivity. It has been argued that costs related to rig hire and oil service are two of the largest cost drivers in drilling projects forcing a reduction in drilling productivity (Osmundsen, Sørnes, & Toft, 2008). There are several challenges related to inter-organizational relationships and integrated operations on the NCS (to describe the relationship between the operator and its service providers, we use both the term inter-organizational relationship and supply chain relationship). The absence of optimal contracts that tie actual performance to incentives has recently gained a lot of attention in the industry, but sadly little effort has been made in the field of incentive development. In this thesis, I argue that the lack of incentive-based contracts with risks and rewards are a major obstacle to overcome and can be a major contributor to realizing the value argued by the OLF. The majority of the service providers working with operators on the NCS have a contract with no incentives related to operations at all (a fixed price contract is typical). One type of contract, not used at large on the NCS, is incentive-based contracts including risks and rewards. This kind of contract compensates actual performance according to performance versus target, budget, schedule and/or quality. An incentive is a mechanism that motivates the involved parties to take a particular action.

The purpose of this thesis is to contribute to the development of incentive models for increased inter-organizational relationships between operators and service providers in the oil and gas industry. There seems to be little overall consensus on how to develop incentive-based contracts in the oil and gas industry, something I found disturbing given the importance of these kinds of contracts. The very few projects that have aimed to develop incentive-based contracts with risks and rewards have not succeeded. I argue that their objective to avoid different opportunistic behaviors (such as moral hazard and adverse selection) has not materialized because the design of the contract has included processes that have been

[1] The NCS is the continental shelf over which Norway exercises sovereign rights. Stretching 200 nautical miles from the Norwegian coast, its major parts are the shelves of the North Sea, Norwegian Sea and Barents Sea (The United Nations Convention on the Law of the Sea, 1982).

incongruent with the overall mission, for example, designing phases in the contract (this is better explained in Figure 3 in paper 1). Another problem with these few contracts is that the incentives have been to weak. This has led to frustration in the industry even though it strongly believes in incentive-based contracts.

1.2 Thesis research questions

The focus of this thesis is to examine contract development in inter-organizational relationships and supply chain relationships in the oil and gas industry. The purpose is to provide new insights into the interaction of an operator and its service providers within drilling processes and incentive modeling.

In the case study design and implementation phase, I outline the specific research questions related to our case study. In this section, I outline the research questions related to the thesis' overall objectives. This thesis tries to answer three main questions with use of the following methodologies.

In papers 1 and 2, I qualitatively find the most important issues restricting the evolvement of inter-organizational relationships related to integrated operations. In paper 3, I model and analyze an optimal incentive scheme and benchmark a fixed priced contract with an incentive-based contract with risks and rewards in a given situation. In paper 4, I optimize the resource allocation in principal–agent and agent–agent relationships, where there is a Pareto optimal social welfare function and incentive compatibility. Further, I describe how the mechanism can affect information revelation in the mechanism if the abovementioned factors are implemented. Below I outline this thesis' three main research questions.

Table 1 – Research questions

Papers 1 and 2
What are the most important issues relating to inter-organizational relationships in the oil and gas industry?

Paper 3
What is the optimal choice of contract and how does it affect the realization of value for the involved parties in an inter-organizational setting under given parameters value?

Paper 4
What is the optimal mechanism to regulate resource allocation between the principal and involved agents (and between agents) in an inter-organizational setting given some additional constraints to regulate the relationship?

1.3 Case study design and implementation

In papers 1 and 2, I outline a case study used in our thesis. The case study obtains data from multiple data sources. I involved an operator owning a petroleum license and seen as a principal, three of its closest service providers/contractors seen as agents, and some small service providers/contractors. As I gathered data at different levels in the organization and its partners, I decided to use an embedded multiple case study research design. This research design is appropriate because it is considered to yield a wider, more comprehensive and more trustworthy model than a single case design. The study design is recommended because it gives the possibility to conduct parallel replications of an experiment (Yin, 2003), and it is the preferred methodology when the aim is to study relationships between companies in an inter-organizational setting. This is due to the research designs ability to highlight the importance and the knowledge of varying views that may occur between different parties (Hedstrom & Swedberg, 1998). When the relationship between the research context and the research interest is unclear, the embedded case study has one of its strengths as the methodology is considered to be effective when focusing on environments

The interview guides involved both open-ended and possible follow-up questions. For the semi-structured interview, I used two interview guides. One for the principal and one for the agents. The interview guide also contained an introduction, a case study proposal, focus, background and case study objectives. Based on increased knowledge during the course of the first interviews I decided to rewrite some of the questions. For practical reasons, I used a digital voice recorder for the interviews and they were subsequently forwarded to the respondents within 24 hours after each interview. I received voluntarily written feedback on the forwarded material from some of the respondents. The average length of the interviews was 90 minutes, but some lasted up to 3.5 hours.

1.3.1 Information gathering and the case study research questions

A total of 27 interviews with 23 questions outlined in a semi-structured interview guide were conducted. In addition to the semi-structured interviews, I obtained data from direct observations, archival records, and participant observations. Prior to this, approximately six months of work were spent to gather relevant information on the organizations. This was very helpful when structuring the interviews, because this phase provided inputs from the employees in terms of research focus. I also spent a number of days in the operator's work environment, as I wanted to elicit informal information (e.g. information not obtained in formal interviews, printed presentations etc.), through conversation with employees, and also to observe employees in their daily work and in their group meetings. In addition, I was invited to participate in a one-day training session for the onshore drilling center employees, as well as innovation seminars related to integrated operations. Lunches, coffee breaks and other informal gatherings with employees were also situations where I obtained information relevant for the study. As a consequence, I obtained information that would not typically be shared in formal gatherings. I regard this information to be highly valuable for my case study. The multiple data collection methodology was appropriate for me as I collected information from a vast number of sources. This strengthens the analyses (Eisenhardt, 1989c; Yin, 2003).

I will not outline the research questions in detail because these were shown in paper I. However, in short the study involves several questions related to incentives, conflicts, information flow, geographical distance, integrity, health, safety and environmental (HSE) level, trust, organizational development, skills, development and goal measurement. More broadly, the case study focuses on the inter-organizational relationships and dynamics between involved parties. It also focuses how incentives between companies positively or negatively influence critical success factors when implementing integrated operations. The importance of moral hazard and adverse selection between the involved companies is also included.

1.3.2 Data analysis

Given the embedded multiple case study design, the analysis was conducted at different levels in the organization, with its collaborating partners and the industry at large. The study design gave me the possibility to conduct analysis on different levels in the organizations. This was beneficial for my research having interviewed both personnel in leading positions and employees with no supervisory responsibility. As the scope in my study concerns employees behavior in an inter-organizational setting at different levels in the organizations, I found this methodology to be suitable. When analyzing information from case studies, one of the greatest challenges is to define the strategy and techniques for the methodology based on the fact that it is not well defined in the literature. The case studies should have a general analytical strategy and try as hard as possible to prioritize what to analyze and why (Yin, 2003). All information from interviews, historical documents, and formal and informal meetings where coded and categorized through the computer software QSR NVivo7[2]. The value of using such software is realized through analysis of the usage of particular words and how frequently the words are repeated. As a consequence, the meanings and insights relevant for the study could be derived.

1.4 Scientific characteristics of the thesis

The Research Council of Norway (2000) defined scientific quality as:

1) Solidity – the purpose of the work needs to:
    - Be well known and described;
    - Comply with all rules, assumptions, limitations or constrains introduced;
    - Be clear and rational;
    - Be rooted in the literature of the different disciplines it relates to; and
    - Have methodological principles and models that can be subjected to order and systems to ensure that critiques can be raised and that it is comprehensible.
2) Originality – the work needs to:
    - Address new perspectives and ideas to problems;
    - Challenge today's common practices;
    - Illustrate and/or prepare the content of applying new principles or ideas;
    - Identify and propose solutions to new ideas; and
    - Address new problems.
3) Relevance and usefulness – the work needs to:
    - Contribute to the development of its disciplines;
    - Have a view on solving problems of its concerns; and
    - Further develop and solve the problems of interest.

All papers in the thesis will be published, have been published or have already been submitted for publication in international journals or conference proceedings. When the thesis has been submitted, I argue that the criteria above have been met through input from the academic environment and industry as well as supervision arrangements and the publication process.

1.5 Thesis objectives

This thesis addresses issues and challenges related to inter-organizational relationships and incentive modeling in the oil and gas industry. Its main objective is to develop an incentive-based model for better inter-organizational collaboration in the supply chain through a dynamical gain and release of resources between the involved parties.

The aims of this thesis are:

- Outline the five most important findings and study the relationships between the involved parties in the inter-organizational relationship context.

[2] http://www.qsrinternational.com/products_nvivo.aspx.

- Outline and analyze the differences between an incentive-based contract and a fixed price contract. Hence, the following analysis are outlined for the operator and the service provider:
    - A joint welfare analysis; and
    - An individual profit maximization analysis.

- Further, optimize the gain and release of resources between the operator and service provider, and between the service providers. This is done by balancing payment and contribution between the parties given the following conditions for the inter-organizational relationship: a social choice function, incentive compatibility, participation constraints and implementing a revelation principle.

1.6 Structure of the thesis

The thesis consists of two parts. Part I is an introduction and a summary of part II that consists of four papers and is the main part of the thesis. Part I starts with a general introduction to the thesis. Then, in section 2, the literature review is outlined. In section 2.1, the literature review consisting of the theoretical perspectives used in the paper that are directly relevant for our research questions and objective is outlined. Then, in section 2.2, I compare and summarize those theories and their scope and relationship to the thesis. Next, in section 2.3 I describe the theoretical perspectives relevant for our research questions and objectives that were excluded from the papers. In section 2.4, I compare and summarize those theories, scopes and relationships. In section 2.5, I outline a model and describe the relationship between the theories described in sections 2.1–2.4 and the papers in part II. In section 2.6, I outline the importance of market dynamics in inter-organizational relationships, and argue for its importance for the thesis. In section 2.7, I outline the supply chain management theory and the relationship to the thesis. In section 3.1, I summarize the papers in part II and its key-contributions. In section 3.2 I outline the value of a mixed methods research-the balanced approach to research, and in 3.3, I outline the value of the results, and synergies. In section 3.4, I outline the papers contribution to the dissertation. At the end of part I, I provide a recommendation for future research.

2. LITERATURE REVIEW

In this section, I highlight some of the relevant literature for the thesis. Section 2.1 provides an overview of the theoretical perspectives related to our research questions and objectives. Section 2.2 compares the theories used in section 2.1 and assesses their scope and relationship to the thesis. Section 2.3 introduces the theoretical perspectives relevant for our research questions and objectives that were excluded from the papers. Section 2.4 compares the theories in section 2.3 with regards to their scope and relationship to the thesis. In section 2.5 I outline a model and describe the relationship between the theories described in sections 2.1–2.4 and the papers in part II. In section 2.6, I outline the importance of market dynamics in inter-organizational relationships. Then, in section 2.7, I outline the importance of supply chain management theory and the relationship to our articles.

2.1 Theoretical perspectives

2.1.1 Resource-based view of the firm

The resource based view of the firm theory (RBV) is defined to be within the economic research discipline and the aim is to quantify an organization's strategic resources (Barney, 1991; Peteraf, 1993; Teece, Pisano, & Shuen, 1997; Wernerfelt, 1984). One of the theory's main objectives is to highlight an organization's competitive advantages that can be related to their resources. The RBV theory highlights the importance of strategic resources, as it argue for the importance of company competitive advantages. Further, it is argued that if a resource situation should be preferred over its competitors, those resources has to be heterogeneous and not perfectly mobile and as a consequence resources become strategic (Barney, 1991; Peteraf, 1993; Teece et al., 1997; Wernerfelt, 1984). An organizations resources may be classified as all their controlled assets, capabilities, processes, attributes, information, and knowledge that has its aim to contribute to realizing strategies to increase an organizations efficiency and productivity (Wernerfelt, 1984).

In the literature, the RBV theory has been decomposed into descriptive and normative components (Rugman and Verbeke, 2002). At both company and industry levels, the descriptive component highlights specific characteristics of the resource profile for each organization as they can bundle their resources, and thereby allow the involved parties to realize new resource combinations. Four characteristics, often called VRIN resources, characterize the normative component (Amit & Schoemaker, 1993; Barney, 1991; Peteraf, 1993; Rugman & Verbeke, 2002):

- Valuable—the resources must create value;
- Rare—they are difficult for others to adopt;
- Imperfectly imitable—they are difficult to duplicate; and
- Non-substitutable—they are difficult to substitute.

Organizations can obtain sustainable competitive advantages if they develop VRIN resources used to implement new value-creating strategies that cannot be easily duplicated by other organizations (Wernerfelt, 1984; Barney, 1991; Peteraf, 1993). Amit & Schoemaker (1990) have argued that resources are tradable and non-specific to the firm, whereas capabilities are firm-specific and used to utilize those resources available within the firm. Competitive advantages can be realized by using resources in specific combinations that lower the costs or increase productivity. To obtain knowledge about an organizations competitive advantage one needs to analyze and understand their various competences related to strategic core activities (Amit & Schoemaker, 1990; Amit & Schoemaker, 1993). Yet another way of classifying resources is (Amit & Schoemaker, 1993; Barney, 1991; Peteraf, 1993; Rugman & Verbeke, 2002):

- Physical—E.g., specialized equipment, geographical location, production facilities;
- Human— E.g., expertise, knowledge, skills; and
- Organizational—E.g., work process, planning, systems for better coordination.

To be considered strategic, a resource must be able to contribute to an organization's increased efficiency (Wernerfelt, 1984). Organizations can't enhance their advantages and efficiency from resources alone, as they demand coordination between groups of resources. The capacity of a group of resources aiming to accomplish specific activities is recognized as the resources capability. It may also be an organizations competence or skills as these enables to coordinate and exploit its own resources (Barney, 2002; Grant, 1991). Capability is realized through coordination between people and other resources, and is not to acquire resources at a fixed price. An organizations capability has to be built gradually to increase competitive advantage and it is not easily bought (Teece et al., 1997).

2.1.2 The dynamic capability approach

The focus on how competitive advantages are achieved by organizations has lately been intense. Productive companies can often respond quickly to the market and conduct rapid and flexible product innovations, combined with management's capability to efficiently coordinate and redeploy internal and external competences. Other companies have followed a resource-based strategy to accumulate valuable assets. Teece et al. (1997) argue it is unclear whether this strategy can bring about a significant competitive advantage.

Prahaland & Hamel (1990) argued that competitiveness derives from the ability to build core competences faster than one's competitors. Further, they argue that the success factor is how the organization can adapt fast to volatility in the environment. This is realized by the management's ability to consolidate technologies and production skills into competencies.

The dynamic capability approach tries to explain how and why some firms gain competitive advantages. In the dynamic capability theory, the word "Dynamic" refers to the capacity to develop the competence to align the firm's competitive advantages with the changing business environment. This is because compressed time-to-market and the rapid development of new technology make the future competition and market difficult to determine. The word "Capability" refers to strategic management when adapting, integrating and reconfiguring skills, resources and functional competences internally and externally to match the requirements of a changing environment (Teece et al., 1997). Often organizations develop organization-specific capabilities and thereafter further develop competences to respond to shifting markets (Penrose, 1959; Sine, Mitusuhashi, & Kirsch, 2006; Wernerfelt, 1984). "Dynamic capability" can be viewed as the different organizations' business processes, expansion paths and market positions. Both conceptual and empirical knowledge is relevant in the dynamic capability framework (Barney, 1991; Penrose, 1959; Williamson, 1975, 1985).

Eisenhardt & Martin (2000) argues that it is possible to identify dynamic capabilities in an organization. First, it may be identified in situations where e.g. managers use their skills to establish product development routines aiming to create products and services to raise performance. And secondly, it may be identified through strategic decision-making where managers combine their personal knowledge to make better decisions for the company (Clark & Fujimoto, 1991; Eisenhardt, 1989b). Other examples on dynamic capability comes from industries trying to bring about the gain and release of resources. Organizations may renew and align their competitive advantages with changing business environments (Eisenhardt & Martin, 2000). Dynamic capability can also be alliances and acquisition routines aiming to bring new resources into the organization from other organizations (Haragadon & Sutton, 1997).

2.1.3 The principal–agency theory

The principal–agency theory tries to "understand the causes and consequences of goal congruence and principal–agent problems" (Barney & Hesterly, 1996 p.124). Others has described the principal-agency theory as a theory for organizational structure of the firm (Alchiean & Demsetz, 1972; Jensen & Meckling, 1976; Fama 1980). Further, Eisenhardt (1989a) and Jensen (1983) have related the principal–agency theory with contracts, and have argued that the surviving contracts are those that minimize agency costs. Further, the authors have stated that the principal–agency theory tries to describe an organization as a nexus of contracts with its aim to regulate the principal and agents relationship. Barney & Hesterly (1996) argues that the principal–agency theory concerns the challenges that occurs when one tries to motivate and control cooperative action. The challenge they argue for is that the agent prioritize its own goals instead of the principal goals (Barney & Hesterly, 1996):

- Agent: The agent is an individual or group of individuals that execute tasks or activities to meet the principal's goals or objectives; and

- Principal: The principal is an individual or group of individuals who delegate authority to agents to achieve predefined goals.

A core problem in the principal–agency theory is to motivate the agent to behave according to the principals goals' in a situation where the agent has information that do not accrue to the principal. This problem combined with a situation where there are divergent goals or interests between the parties may lead to challenges in the principal-agency relationship. This is largely because it is difficult for the principal to directly monitor the agent's behavior. The principal can only measure performance of the agent's action based on his own results (Barney & Hesterly, 1996). As exogenous factors outside the principal's control affect the outcome, this also challenge the monitoring process of the agents' actions that impacts on operations (Grossman & Hart, 1983).

Asymmetric information often gives the agent an advantage over the principal (i.e., different information between two collaborating parties). Information asymmetry can lead to strategic misrepresentation, and to prevent this evolving, both parties must avoid behaving opportunistic. It is important that the involved parties in the transaction gain a minimum amount of surplus (informational rent/the individual's return as it shares private information) for their contribution in order to secure their willingness to still participate (Milgrom & Roberts, 1992). If not compensated properly, they may leave the network and join another. The network is often regulated by a contract and it has been argued that low powered contracts (e.g., fixed price contracts) prevent employees from acting as they ideally should do (Milgrom & Roberts, 1992). This may create costly and inefficient solutions for the involved parties (Holmstrøm & Milgrom, 1994). If there is not enough rent, this can affect the transaction because there is not enough surplus for the transaction to evolve, even if some parties sees it as feasible (Milgrom & Roberts, 1992). To ensure that the agents' behavior and actions are executed in the principal's interests, the principals could design incentive systems that favor all collaborating parties (Eisenhardt, 1989a). Regarding asymmetric information and uncertainty, the principal–agency theory inhibits two problems (Eisenhardt, 1989a; Milgrom & Roberts, 1992):

- Adverse selection: The principal cannot be confident that the agent is performing the work for which it is being paid, but rather work for its own interest; and

- Moral hazard: The agent can pursue its own interest. Hence, moral hazard is post-contractual opportunism, or those conditions under which the principal cannot be sure that the agent has put forth maximal effort because the efforts are difficult to observe.

Fixed price contracts has been argued not to be optimal to regulate relationships given the possibility of moral hazard and adverse selection (Holmstrøm & Milgrom, 1994). As a consequence, such contracts may not be the best way of organizing relationships between principals and agents (Jensen & Meckling, 1976). The agent may not perform optimally given that his compensation will be the same regardless of his quality and effort when the relationship is regulated with a fixed price contract (Eisenhardt, 1985). Some authors have argued that it is more efficient to replace a fixed price contract with a residual claimant-based contract related to the firm's profit (Alchian & Demsetz, 1972). This reduces the incentive for adverse selection and moral hazard as the agents are being compensated based on their performance (Jensen, 1983). This kind of contract (outcome-based contract) can be used to align goals between the principal and agent (Eisenhardt, 1989a).

2.1.4 Incentive theory

Incentive theory can be dated back to Ronald Coase's "The Nature of the Firm" in which he outlined contracting theory and its relationship with the environment (Coase, 1938).
Within neoclassical economic theory, the organization is considered to make all off its own decisions to maximize utility. Neoclassical theory considers human beings to be rational, with no intention to predict individual and organizational behavior. Incentive theory suggests that human beings are not perfectly rational and can behave opportunistically, recognized as bounded rational, moral hazard and adverse selection (Coase, 1938; Simon, 1947). Different opportunistic behavior is also seen as problematic in transaction cost theory and the principal–agency theory. Williamson (1975) argued that the organization should choose the contract that minimizes production and transaction costs. The transaction cost literature differentiates between three different kinds of contracts: market-based contracts, relational contracts and hierarchical contracts (Macneil, 1980). In market-based contracts, the transactions are outlined in detail and price is the main mechanism. When the deliverables or the transaction cannot be specified, one often use relational contracts. This contract type takes into consideration the uncertainty related to a contract's complexity and the fact that it cannot take into consideration all this complexity up front. A relational contract is commonly used when

there is a network relationship and the possibility for long-term collaboration. To use a relational contract, the parties must trust each other. Hierarchical contracts are commonly used within an organization and in situations where the main mechanism is authority (Macneil, 1980). As observed, trust, price and authority dominate the three contracts, but each can be a part of different contract formats (Bradach & Eccles, 1989). Macneil (1980) argued that market-based contracts focus on results and hierarchical and relationship-based contracts focus on results *and* behavior. Further, Bradach & Eccles (1989) argued that in market-oriented contracts there is little authority. Together with price, this contract can be a valuable mechanism. In hierarchical and relational contracts, trust, authority and price can be involved as a mechanism.

In the thesis, I use the terms fixed price contract and incentive-based contracts (or incentive-based contracts with risks and rewards). Fixed price contracts, I argue, can be considered closest to hierarchical contracts. I could have used the term cost price contract, which is also often used on the NCS. The service providers on the NCS are mostly regulated through fixed price contracts with no or few incentives related to operations. To some degree, a contract with some kind of incentive (i.e., a cost-plus contract) can be used to create low powered or weak incentives that are costly and ineffective (Holmstrøm & Milgrom, 1994). This contract often involves a renegotiation that occurs later and that can weaken the incentives. This is because it affects the form of the original contract and creates difficulties for later renegotiations. The actors might even take the later renegotiation process into consideration when negotiating the original contract (Hart & Moore, 1988; Tirole, 1999). As an agent is compensated for its performance, a fixed price contract may lead to underachievement as the compensation is the same regardless of the results (Eisenhardt, 1985). Then it can be more efficient to replace a fixed price contract with an incentive-based contract affecting the agent's profit. The incentive-based contract makes compensation dependent on performance, and a motivator for the agent not to behave opportunistic (Alchian & Demsetz, 1972; Jensen & Meckling, 1976).

Incentive-based contracts are uncommon and almost never used on the NCS. This contract format is considered to function as a relationship contract, affecting the involved parties' behavior and results. The incentive-based contract involves reward (bonus) and risk (punishment), and involves compensation for real performance measured up against target, budget, schedule, quality etc. The incentive could be a material reward (for example a financial reward). If the agent does not meet the level of contribution agreed up front, the reward decreases and in some situation it may even become negative. Then we have a punishment. As the agent gets punished if not performing as agreed upon, an incentive-based contract involves some kind of risk for the agent (for further explanation of the incentive-based contract, se paper 3).

The key success factor for an organization is the organizations adaptability, and the fixed price contract is argued to be unsupportive in terms of adaptability (Laffont and Tirole, 1999; Williamson, 1985). The fixed price contract does not take the industry's volatility sufficiently into consideration, and this is seen as a problem as the transaction will be affected negatively. Some actors exploit the situation for their own benefit, as the involved parties may disagree on how the new resources should be adopted. The literature outlines possible solutions to avoid opportunistic behavior with use of incentive mechanisms (Holmstrøm & Milgrom, 1994). This mechanism is often developed as a relational contract format. The incentive-based contract has to increase the value for all parties. To realize goal congruence and avoid opportunistic behavior, Grossman and Hart (1986) argues that the adaption of incentive-based contracts can achieve this as one increases the value for all parties when the final outcome is shared by all involved parties.

2.1.5 Mechanism design theory

The mechanism design theory affects the principal–agent problem and is often proposed to be its "modeling" side. It has received a lot of attention over recent decades and has proved to be an important application in microeconomic theory development. It's main objective is to model a decentralized optimization problem with self-interested agents that possesses private information over their own outcomes and preferences (Salanié, 1998). For example, the purpose of mechanism design is to reveal true information (preferences) in an environment with asymmetric information. Further, this information-revealing problem constitutes a constraint in social decisions as the involved agents' preferences are unknown (Mas-Colell et al., 1995; Whinston & Green, 1995).

An important feature is that collective decisions are made without the involved agents' personal preferences because this information may not be shared publicly. The agents should ideally reveal their private information as the environment is recognized to have incomplete information (Salanié, 1998). Further, Salanié (1998) argue that private information is elicit through the implementation of an optimal system-wide solution. The principal must offer incentives for the agents to reveal information. Hence, a system-wide solution has to implement a social welfare function with incentive compatibility to ensure that the involved parties reveal their true information.

Mechanism design theory constitues a general approach in terms of the involvement of organizations. The focal organization uses an input (e.g., some kind of a message or signal from an agent), and then responds to it. The goal is to construct a mechanism in order to optimize the outcome with respect to the involved agents' private information in a situation where the agents are self-interested and try to optimize their own portfolios (Arrow, 1963; Dasgupta, Hammond, & Maskin, 1979; Mas-Colell, Whinston, & Green, 1995; Myerson, 1981). Further, mechanism design theory tries to optimize the outcome for both the principal and agents (Samuelson, 1984). In Table 2, I compare the theoretical perspectives used in the thesis and relate them to the main arguments and scope of this thesis.

2.2 Comparison of the underlying theories

There are many similarities between the theories used in this thesis. Most of the theories regulate the relationship between the focal company (principal/operator) and its involved agents (service providers). RBV theory argues for the need for new resources and the importance of inter-organizational relationships. As a consequence, this will lead the involved parties to build competences faster than their competitors, which is also argued by the dynamic capability approach. The principal–agency theory is a practical tool to address important issues of inter-organizational relationships. Incentive theory and mechanism design theory are practical for setting up a mechanism to regulate these relationships. Below I outline a table of these theories, their main arguments and scopes.

Table 2 – Theoretical perspectives used in the paper and directly related to my research questions and objectives

	Main arguments	Scope	Relationship with the thesis
Resource based view (RBV) theory	• Resources enhance the organization's competitive advantages and efficiency • This is realized by an coordination between groups of resources	• The organization's resources in a competitive advantage setting • Mostly examined at the organizational level	• Provides theories to identify a firm's resources that maximizes competitive advantage
Dynamic capability approach	• Competitiveness is the ability to build core competences fast • The success factor is the ability to consolidate technologies and production skills into competencies to respond to volatility in the industry and become adaptable	• How and why only some firms gain competitive advantages • How some industries realize dynamic capabilities through the gain and release of resources	• How to develop competences to stay competitive • Builds core competences fast and efficiently
Principal–agency theory	• Tries to solve the problem of minimizing agency costs • Further, the theory tries to understand the causes and consequences of goal congruence	• The study of the problems of motivating and controlling cooperative action	• Avoids opportunistic behavior by providing the involved parties at least a minimum amount of surplus for their contribution • Describes an organization as a nexus of contracts
Incentive theory	• This theory argues that the organization should choose the contract that maximizes productivity and minimizes transaction costs	• Fixed price contracts and incentive-based contracts • Regulates the transactions between principals and agents	• Fixed price and incentive-based contracts are mechanisms affecting behavior as well as operational and financial performance indicators • The contracts serve as mechanisms regulating resource allocation
Mechanism design theory	• Deals with the decentralized optimization problem with self-interested agents • The purpose is to design an mechanism to reveal true information (preferences) in an environment with asymmetric information	• How this information-revealing problem constrains inter-organizational relationships • The mechanism involves incentive compatibility, social welfare function and revelation principle	• Outlines a mechanism and optimizes the relationships between principals and agents with private information and self-interested behavior

2.3 Theoretical perspectives relevant for my research questions and objectives but excluded from the papers

The following section outlines the generic theoretical perspectives relevant but excluded from the papers. The reason I want to outline the theoretical perspectives here is that they are related to the thesis' research questions and objectives as well as to the theoretical section outlined in section 2.1. I will also relate the theories to my findings in part II, as they are not used in my papers. Because I want to keep the theoretical foundations of the thesis as simple and manageable as possible, I chose to focus on the few theories outlined below. The reason for including the theories in sections 2.3.1–2.3.3 in the thesis and not in the paper is that they are relevant for the scope in all the papers. Therefore, they are outlined in the thesis to avoid repeating the theories in the papers.

2.3.1 Inter-organizational relationship

The literature tries to apply inter-organizational relationship studies where several organizations are involved. The focus is among the involved organizations instead of within one organization (Håkansson, 1982). Inter-organizational relationships emerge, evolve, grow and dissolve over time as a consequence of individual activities (Ring & Van de ven, 1994). Below, I outline an interaction model that aims to analyze the industrial market at large. The model includes four main groups (Håkansson, 1982; Håkansson, 1987):

1. The interaction process;

2. The participants in the interaction process;

3. The environment within which interaction takes place; and

4. The atmosphere affecting and affected by the interaction.

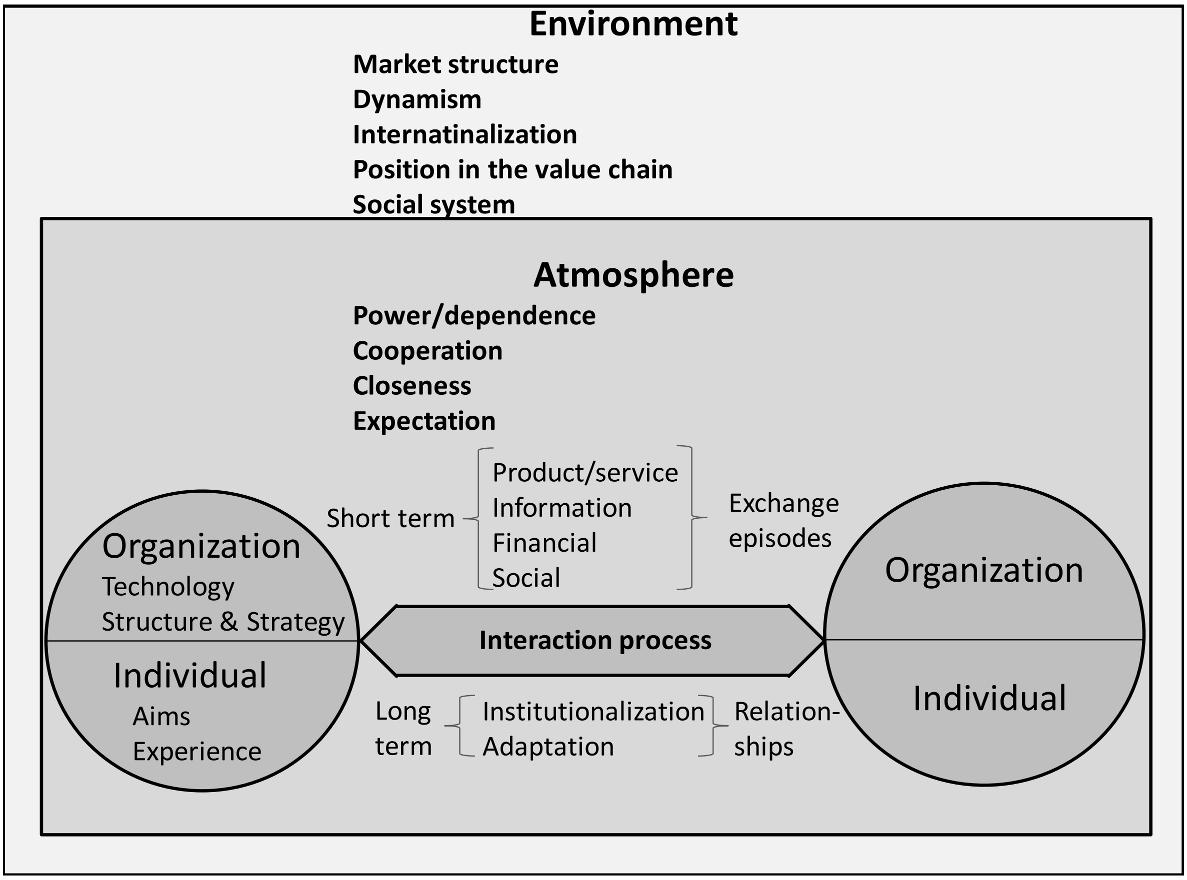

Figure 1 – An illustration of the interaction model regulating the relationship between organizations (Source: Håkansson, 1982; Håkansson, 1987)

More specifically, the model outlines the long- and short-term aspect of the interaction process between two companies (e.g., principal–agent). Håkansson (1982) argued that short-term is more "transactional" because it involves products and services, information and financial and social exchange, whereas the long-term is more "committable" because it involves long-sighted processes such as institutionalization and adaptation processes. Both the long- and short-term are influenced by the individuals and organizations involved. I argue in our articles that the incentives outlined should address incentives both at an organizational and individual level. This strengthens the arguments for the use of incentives in inter-organizational relationships because they regulate both levels.

The environment in which the interaction takes place also influences the process with factors such as market structure and social influences. Finally, the atmosphere will affect the interaction process. Together with the environment, the atmosphere is of huge importance for the scope of this thesis. The power between the involved parties will affect the process and can change as the relationship evolves. The parties have a clear view of the power relationship in the interaction process and the area where the power occurs. Conflicts can occur at the same level as cooperation, and one company can have cooperation in one relationship, whereas another relationship is characterized by conflict. Resource allocation between the parties is a typical area that leads to conflicts. In the interaction process, both parties' perceptions are related to power-dependency and cooperation–conflict (Håkansson, 1982). Further, Håkansson (1982) argued for the level of interaction as one can analyze the relationship between variables within a variable group and between variables within a subgroup.

The literature also differs between formal and informal inter-organizational relationships. Informal inter-organizational relationships are adaptable relationships where the involved parties' norms rather than contractual agreements regulate their contributions (Smith, Carroll, & Ashford, 1995). Their relationships are loosely coupled because the involved parties have no or little common agenda (Golden & Dollinger, 1993). Formal inter-organizational relationships are formal arrangements that bring together assets (tangible and intangible) because they involve two or more legally independent organizations aiming to produce a joint value added. Those arrangements feature in specific inter-firm collaborations because they are seen as “voluntary agreements between firms involving exchange, sharing or co-development of products, technologies or service” (Gulati, 1998). In this thesis, I define integrated operations and drilling activities in the oil and gas industry as a contractual agreement between different involved organizations because they cooperate to reach predefined goals. In the papers in section II, I argued that those goals are not jointly set for the best purpose for all involved parties.

Power and trust has a central place in the inter-organizational relationship framework. There are two distinctive parts of power and trust in inter-organizational relationships. First, power and/or trust are located at the interpersonal level and are informal, where either power or trust dominates the relationship between two actors. Secondly, power and/or trust originates within the constitutive reference to the formal institutional environment in which relationships are placed. Impersonal power is highly conducive to developing trust in business relationships, whereas the use of personal power makes it less likely that trust will also flourish (Bachmann, 2001). Table 3 outlines four power–trust patterns related to inter-organizational relationships (Bachmann, 2001).

Table 3 – Power and trust related to inter-organizational relationships (Source: Bachmann, 2001)

	Institutional power dominance	**Personal power dominance**
Institutional trust dominance	*Pure Form 1* Fully institutionalized form	*Hybrid Form 1* Institutional trust/personal power
Personal trust dominance	*Hybrid Form 2* Institutional power/personal trust	*Pure Form 2* Fully personalized form

Bachman (2001) differentiate between power and trust that are both either predominantly institution-based or person-based in relation to inter-organizational relationships. One also has hybrid forms of power and trust related to inter-organizational relationships as followed (Bachmann, 2001):

<u>Fully institutionalized form</u>
This form has a tight and coherent system of institutional arrangements that govern the behavior of social actors in inter-organizational relationships. The opportunistic behavior of involved personnel does not occur at large, because power is anonymous and, therefore, they will not use their own competence and power against the power already in the organization. The established rules in the organization are accepted and these create a high level of predictability. Trust in other parties occurs frequently because there is a low risk of opportunistic behavior under this condition.

Fully personalized form

Power and trust can also emerge without constitutive reference to the institutional framework. This occurs when strong and reliable institutions and generalized rules of behavior do not exist, and the involved personnel base their decisions on the resources of power and/or trust that are mobile. Power and trust affects social control differently as they can occur in combination and this makes an important difference to whether power or trust dominates the relationship. Both can affect transaction costs, foster innovation and increase flexibility. In this quadrant, there is a risk of opportunistic behavior from the party with the most power in the relationship because they tend to use their own resources in many situations instead of the collaborating parties' resources.

Institutional trust and personal power

There can be incongruence between institutional trust and personal power. In the upper right quadrant, there will often be strong institutional trust, but at the same time, opportunistic behavior can take place because this situation encourages individualistic strategies. In this quadrant, one can also observe a lot of risk-taking. Trust that has been developed can be reduced by institutional arrangements. Inter-organizational relationships are then created and evolve on joint trust. Power evolves in relation to personal authority when there is an absence of rules.

Institutional power and personal trust

Institutional power operates next to personal trust. Inter-organizational relationships cannot benefit from institutions that generate trust because they have no safeguards against opportunistic behavior at the macro-level. This indicates that they have to develop interpersonal trust at a micro-level. In addition, power is rooted in the institution since it supports cultures and rules because people have the chance to return to their power-related behavior.

All four types affect inter-organizational relationships based on whether they have high or low trust or micro-routines or macro-institutional forms. The reason for relating inter-organizational relationships to our scope is that the thesis objective is to increase the output value between the collaborating partners; therefore, a framework including the power–trust relationship between the involved parties at a personal and institutional level is relevant. This also maximizes transaction value and minimizes transaction costs between the parties (Jeffrey, 1997). In complex industries, this is seen as challenging and receives strong attention from both a strategic and operational level. One of the major challenges is opportunistic behavior. Opportunistic behavior is often avoided through safeguards such as legal contract arrangements, but in inter-organizational relationships this is a static way of handling dynamics between companies. I argue in our papers in part II that contracts can be either static (e.g., fixed price) or dynamic (incentive-based with risks and rewards). The primary purpose of inter-organizational relationships is to encourage parties to work together, with focus on doing the right things together to increase the value for the network participants, and with a focus on the overall common goal, instead of discussing who is going to do what, when and in what way (Jeffrey, 1997).

2.3.2 Transaction cost theory

Transaction cost theory is relevant for inter-organizational collaboration. Its idea is that there are many possibilities to organize transactions and that different governance structures affect transaction costs differently. Further, distinctive company-specific factors are of great importance when deciding what kind of organizational structure is optimal for a particular company in a given situation. In transaction cost theory, the *composition principles* are of great interest. This is recognized by the system (macro) level being prioritized above the individual (micro) level. Further, one can only provide a systematic explanation for transaction costs if the common *human-* and *situation-based* conditions are identified (Williamson, 1975). When transactions are conducted, many related costs occur because of "friction" in the economic system. Those costs can be divided into three groups (Williamson, 1985):

1. *Information cost*, which includes costs related to gathering information and identifying and evaluating potential trading partners;

2. *Bargaining cost,* which includes costs related to negotiating and writing agreements; and

3. *Enforcement cost,* which are costs related to solving conflicts and negotiating with trading partners that have not fulfilled their agreements.

Through transaction cost theory, relationships are seen as an ongoing series of exchanges (of goods, services or money) between parties driven by self-interest where its aim is to maximize the efficiency of those exchanges. Further, the theory argues that the frequency of transactions, uncertainty and asset specificity affects what kind of governance structure, organizational structure and coordination mechanism is the most efficient in any given situation (Williamson, 1985).

Figure 2 is a framework of analysis of an alternative governance structure. This framework shows the relationship between the governance structure and the institutional environment where the relationship is set. Further, the framework shows how the governance structure relates to individual interactions. The solid arrows indicate primary influence and the dotted arrows indicate secondary influence (Williamson, 1996). The solid arrow from the institutional environment to the governance box indicates that changes in the institutional environment influence the comparative costs of alternative government structures. The solid arrow pointing from individual to governance visualizes the involved individuals' behavior that will affect the effectiveness of the governance structure. Williamson (1975) argued that individuals are not completely rational and honest. This is described as *moral hazards* and *adverse selection.* From the transaction cost perspective, moral hazard is often related to poor or lacking information or a lack of capacity processing information. Some partners want to cooperate rationally but are restricted in their capabilities to communicate their point of view to others, and that leads to opportunistic behavior. Adverse selection is information asymmetry that provides conditions under which the principal cannot be certain that the agent accurately performs the work for which it is being paid (Eisenhardt, 1989a; Milgrom & Roberts, 1992). This was explained in the principal–agency theory in section 2.1.3. It is not necessary that involved partners act opportunistically all the time. If they sometimes act opportunistically, that is crucial for the relationship. The circle in the governance quadrant indicates that governance structures can change the course of the relationship (Williamson, 1975). Below, I outline a framework of analysis of an alternative governance structure (Williamson, 1996).

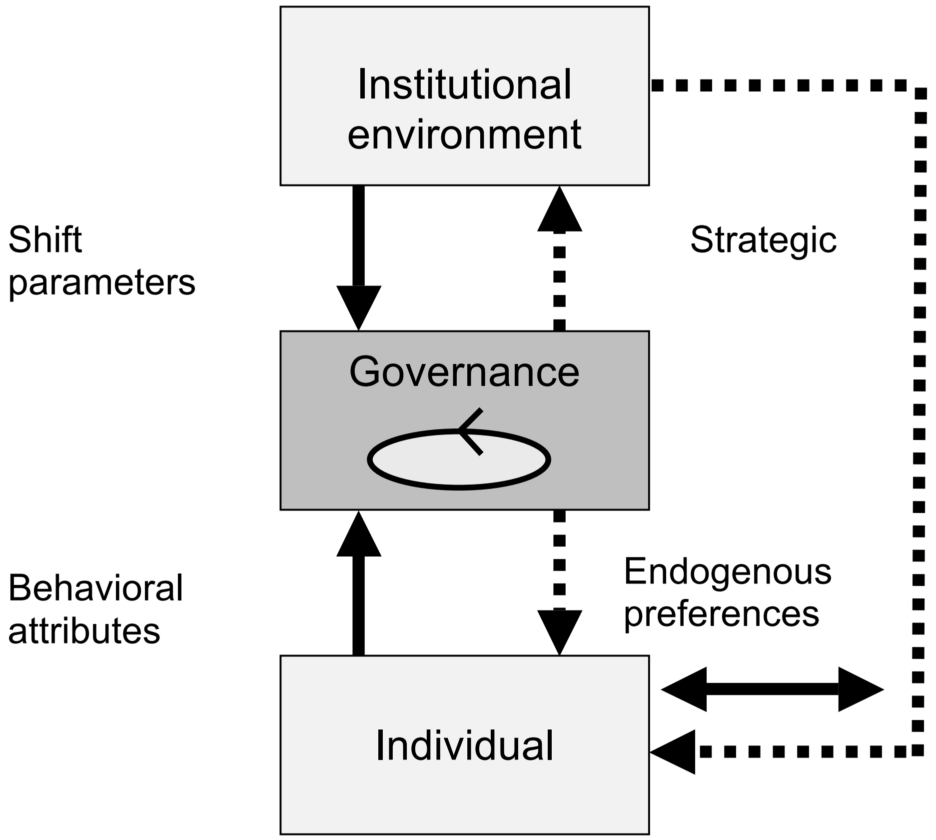

Figure 2 – Williamson's layer scheme- an analysis of an alternative governance structure (Source: Williamson, 1996)

To avoid the two types of opportunistic behavior, one has to establish a safeguard (or governance structure) to protect involved parties. Establishing a complex safeguard increases transaction costs, especially where there is a high degree of asset specificity (Klein, Crawford, & Alchian, 1978; Williamson, 1985). Safeguards can be defined as a control mechanism where the goal is to ensure fairness among parties. The purpose of the safeguard is to create, with a minimum of cost, the control and trust that is important to attract and retain parties in the network (i.e., engaging in this network will make them better off; Williamson, 1985). Further, in addition to cost minimization, involved parties in the network should maximize the value for all involved parties in the value chain. The choice of governance structure (i.e., safeguard) regulating the relationship will affect the value creation for all involved parties. The mechanism regulating this relationship was further explained in the incentive theory in section 2.1.4 and in the mechanism design theory in section 2.1.5.

2.3.3 Network theory

Network theory is characterized by cooperation between individual organizations when producing a product or service. The involved organizations contribute with one or several specialized tasks using their core competences. Network theory has recently gained increased emphasis because of rapid technological changes since it aims to increase flexibility (Lunnan & Haugland, 1996). Further, it has been argued that network theory has become an interesting governance model, with implications for industrial efficiency, industrial development and control over industrial operations. Network theory consists of the relationship between the actors as well as the activities, resources and dependencies between them. It possesses a number of more or less interrelated activities. Each of these activities is dependent on the activities by other contributors (e.g., the result of one activity is dependent on how other activities are performed; Håkansson & Johanson, 1993; Porter, 1980). Collaborating through inter-organizational relationships is often proposed as the relationship between two or more legally independent organizations that has a mission to exchange goods and services. The exchange of goods and services is necessary because network theory argues that organizations depend on resources from other organizations. This relationship is named *dyad* if the relationships involve only two firms and is called an *industrial network* if it involves more than two firms (Skjøtt-Larsen, 1999).

The cooperating company's mission is to produce a product or service. Each of the involved companies specializes in one or several components of the production by cooperating in the network. The development of competences take place between the involved organizations, and the governance of inter-organizational relationships between the involved organizations is of high importance because they want to secure competitive advantages. Resources need to be linked through relationships between the involved parties to gain competitive advantages. The composition of the relationship also affects the competence level and the level of competitive advantages because it better exploits the gain and release of resources as the environment changes. Because the focal company exploits complementary resources, a company can gain competitive advantages by cooperating with other parities to quickly build core competences with others rather than developing the competence for themselves. Because the companies are pooling resources together, they can respond faster to volatility in the industry and gain competitive advantages above the competitors. In industries recognized as having high volatility, competitive advantage is realized by the development of competences across organizations and the development of government mechanisms (incentive schemes) that enhance the optimal handling of these relationships. When companies establish a relationship with other companies there is a risk of being exploited. This opportunistic behavior can be avoided by establishing a governance mechanism (Lunnan & Haugland, 1996).
The strategic core developed between the involved firms is seen as their raison d'être because it defines their economic rationale within an industry (Lunnan & Haugland, 1996). All firms depend on resources controlled by other firms and gain access to resources through interaction with other firms in the network (Skjøtt-Larsen, 1999). The involved firms' relationships in the network are developed through two interaction processes (Johanson & Mattsson, 1987):

Exchange processes, which include the exchange of goods, information, service and money. They also include the exchange of personal interactions such as emotions, feelings, legal, technical and administrative factors; and

Adaptation processes, which include the mutual modifications of work processes and administrative systems with a goal to more efficiently use the resources within the network. Adaptation processes strengthen the relationship between the involved firms. Their willingness to adjust to each other is a good safeguard for a long-lasting relationship and signals stability.

2.4 Comparison of the underlying theories excluded from my papers

In Table 4, I compare the relevant theoretical perspectives that were not used in the papers. I found the described theories relevant for our scope, and a reason to include them in our thesis despite not using them in our papers. I argue that they are of high importance for our research questions and objectives, as outlined in the previous section. The theories' main arguments, scope and relationships with this thesis are described below.

Table 4 – Theoretical perspectives relevant for my research questions and objectives but excluded from the papers

	Main arguments	Scope	Relationship with the thesis
Inter-organizational relationship	• The primary purpose with the inter-organizational relationships is to encourage parties to work together, where the focus is on doing the right things together to increase the value for the participants	• The interaction process and its participants. The environment within which the interaction takes place. The atmosphere affecting and affected by the interaction • Formal inter-organizational relationships • Power and trust in inter-organizational relationships	• Our thesis aims to increase the output value between the collaborating partners, and, therefore, a framework for the power–trust relationship between the involved parties at the micro- and macro-level is relevant (e.g., maximizing transaction value and minimizing transaction costs)
Transaction cost theory	• Transaction cost theory argues that there are many ways to organize transactions • The organization's distinctive factors are important when deciding which kind of organizational structure is best for that particular company	• The relationship is seen as an ongoing series of exchanges of goods, services or money between parties driven by self-interest and the need to maximize the efficiency of those exchanges • Argues that the frequency of transaction, uncertainty and asset specificity related to the relationship decides the most efficient government structure and coordination mechanism	• Highlights the importance of safeguards that should create, with a minimum of cost, the control and trust that is important for attracting and retaining parties in the transaction • The transaction cost framework indicates that changes in the institutional environment will influence the comparative costs of alternative government structures • The framework also visualizes the involved individuals' behavior assumption, which will affect the effectiveness of the governance structure
Network theory	• Characterized by a high degree of cooperation between individual organizations • The involved organizations will contribute with their core competences through one or several specialized tasks	• Highlights the importance of network theory because it has become an interesting governance model, with good implications for industrial efficiency • Network theory consists of the actors and the relationships between them, but also involves activities and resources and the dependencies between them	• Network theory possesses a number of more or less interrelated activities. Each of these activities is dependent on other activities from other contributors e.g., the result of one activity is dependent on how other activities are performed

2.5 The relationship between these theories and the papers in part II

In the previous sections, I outlined the theoretical perspectives used in the papers that are directly related to our research questions and objectives. I also outline those theories relevant for the research questions and objectives but excluded from any papers. In Figure 3, I show how these theories relate to the papers.

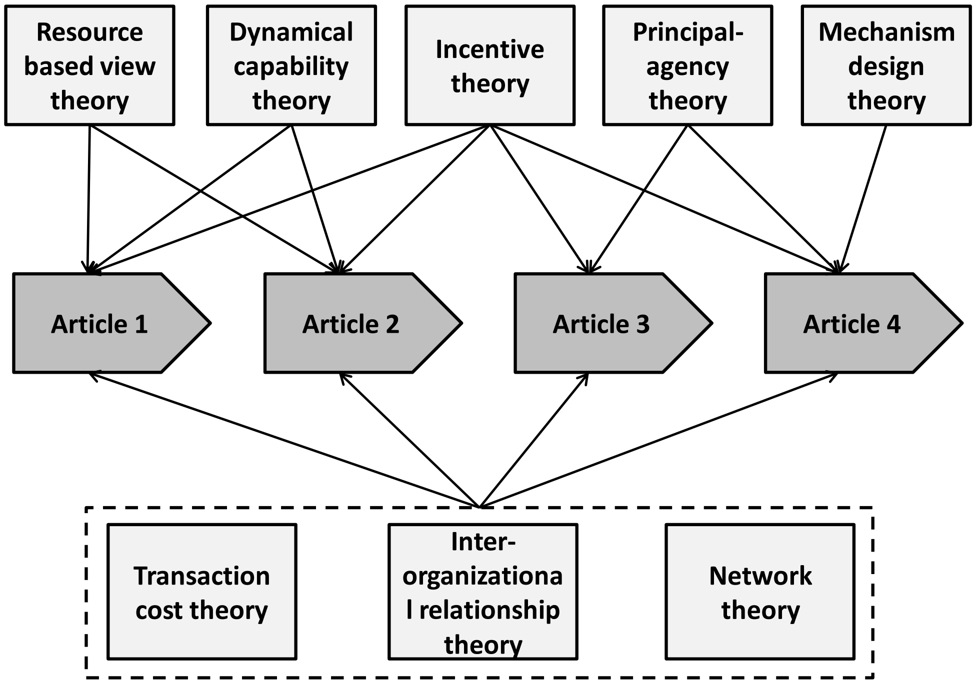

Figure 3 – The relationship between the theories in part I and the papers in part II

I will now outline how the theories excluded from my papers relate to the papers and research questions. The literature review showed that power and trust has a central place in the inter-organizational relationship framework, and has recently received significant attention. I will in the next section argue that one of the main findings in my case study, as outlined in the two first papers in part II, is the power and trust challenges between the operator (principal) and service providers (agents). I argue that power and trust as outlined in the inter-organizational relationship is relevant for all my papers because they focus on the relationship between different parties from their respective angles. Further, Table 3 outlines the dominance between institutional power and trust, and personal power and trust in an inter-organizational relationship. I argue from my case study in paper 1 and 2 that there could be incongruence between institutional trust and personal power. There might exist strong institutional trust but, at the same time, opportunistic behavior can take place because the situation can encourage individualistic strategies between the parties. By contrast, trust that has been developed between individuals over time can be reduced by institutional arrangements. Further, I found in my case study that the implementation of integrated operations in the oil and gas industry has changed much of the work processes and work routines because the service providers have received more of the workload, with the aim of increasing productivity and cost efficiency. The results have not materialized, and the attitude of some key employees with a responsibility for drilling projects has partially been blamed because they gathered and kept information for themselves in order to maintain the traditional dynamics between the operator and service providers. Some of the operator's middle managers were described as displaying this attitude, where they feel that the ownership of and primary investment in information, processes and technology warrant the operator withholding it from third party service providers. The result is that the service providers make decisions based on asymmetric information, which will ultimately affect performance for the operator as well. I argue that inter-organizational relationships evolve through mutual trust. In papers 3 and 4 in part II, I prove this is correct because I design incentive schemes with risks and rewards that change the behavior for all parties. This is because aligning goals and minimizing the moral hazard and adverse selection favors all parties' value realization positively. This jointly creates trust and, therefore, monitoring and controlling costs are minimized.

Transaction cost theory has many similarities to my findings and supports the papers because it focuses on several interesting areas. It argues that many costs occur during transactions because of "friction" in the economic system. These costs can be divided into three groups as previously argued (Williamson, 1985):

1. *Information cost*, which includes costs related to gathering information and identifying and evaluating potential trading partners;

2. *Bargaining cost,* which includes costs related to negotiating and writing agreements; and

3. *Enforcement cost,* which are costs related to solving conflicts and negotiating with trading partners that have not fulfilled their agreements.

These three cost groups are very important. In paper 3, I describe those costs as related to moral hazard, adverse selection, monitoring and controlling. Papers 1 and 2 highlight the importance of those costs related to productivity and cost efficiency in drilling projects. Transaction cost theory sees relationships as an ongoing series of exchanges (of goods, services or money) between parties driven by self-interest, because their aims are to maximize the efficiency of those exchanges (Williamson, 1975). The case study highlights this as important in papers 1 and 2. Further, I outline how to avoid agents being too self-interested through the development of an incentive-based contract with risks and rewards in paper 3. In the literature review, Williamson (1975) argued that costs related to moral hazard and adverse selection can be avoided by establishing and implementing a safeguard (or governance structure) to protect the involved parties. In paper 2, I argue, and in paper 3, I prove, that this statement is correct. I found that this kind of opportunistic behavior could be avoided by implementing an incentive-based contract with risks and rewards instead of a static fixed price contract. In paper 3, I develop a joint welfare analysis and an individual profit maximization analysis, which use an incentive-based contract to minimize moral hazard and adverse selection. Figures 1 and 2 in paper 3 show that the parties can avoid new negotiations by implementing an incentive-based contract. In the fixed price contracts used at large in the oil and gas industry, the parties renegotiate when they use more time than agreed upon. This renegotiation process would be superfluous by implementing an incentive-based contract. They would rather receive risk, (i.e., punishment) if they spend more time than agreed. This downside will affect everyone negatively because the final outcome is shared between everyone involved since the parties are more dependent on everyone. This will benefit all involved positively and work in every parties' best interests. Further, transaction cost theory argues that changes in the institutional environment will influence the comparative costs of alternative government structures. I support this statement. I also argued in section 2.3.3 that the network theory consists of the actors and the relationships between them. In addition, it also involves the activities, resources and the dependencies between them. I have in all my papers argued for the importance of optimal resources, activities, and the dependencies between the activities. My papers argue, to realize better performance one need to involve resources from the agents. A dynamical gain and release of resources between the actors also stress the importance of acceptable incentives for the involved to secure their participation and make sure the network transfer utility across the agents to realize incentive compatibility.

The objectives of this thesis are to investigate the relationship between the principal and the involved agents. However, I outline the importance of industry volatility in section 2.6 and argue for its relevance for involved organizations' dynamic capabilities. Similar to Eisenhardt & Martin (2000), I outline in section 2.6.1 that market dynamism has a large impact on the dynamic capabilities of organizations. In section 2.6.2, I outline how organizations can adopt to market dynamics.

2.6 The importance of market dynamics in inter-organizational relationships

In this section, I outline the importance of market dynamics as it affects inter-organizational relationships. Market dynamics is not the primary objective of the thesis, but still I argue that market dynamics affects inter-organizational relationships (in paper 2 and section 2.1.2 of this thesis I outline the relationship between organization and market dynamics). The optimization in paper 4 is a mechanism for realizing the gain and release of resources, and market dynamism will then be of high importance because new allocation and outside options will affect the involved parties' preferences. The involved parties' preferences and behavior will be different in markets with a high degree of volatility or "high velocity" compared to moderately dynamic markets. In paper 4, I analyzed and optimized the allocation with the involved parties' preferences in mind. In Figure 4, I outline the relationship between market dynamics, adaptation to market dynamics and the findings from the papers in part II.

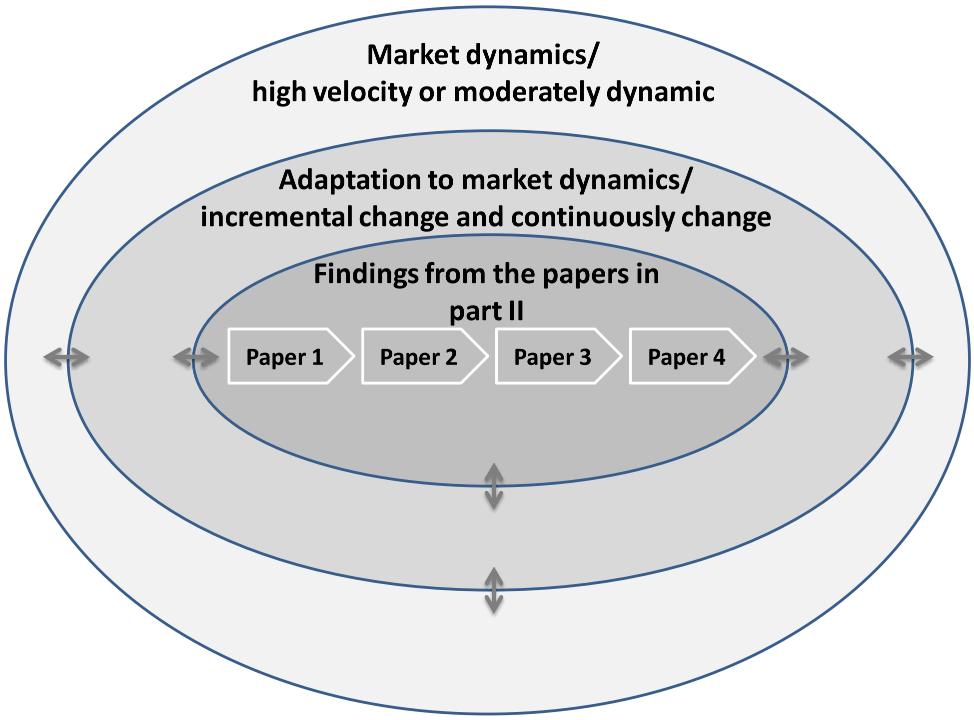

Figure 4 – The relationship among market dynamics, adaptation to market dynamics and the findings in part II

Market dynamics characteristics will affect integration between companies in the oil and gas industry. I.e. the "shape" of the oil and gas industry will be of high importance for how the focal company can succeed with adopting and integrating new resources. Thereby, the industry characteristics will be of high importance and hence outlined.

2.6.1 Market dynamics

Effective dynamic capabilities depend on market dynamism (Eisenhardt and Martin, 2000). Coase (1938) argues that if the aim is to learn how to adopt dynamic capabilities in markets, one has to focus on the dynamics between the markets and the organizations. Further, Barney (1986) argues that assets that can be easily adopted in the market at a fixed price cannot give the organization an competitive advantage. In my case study I outline how specific resource combinations, (adopted from different parties), that cannot be adopted easily by competitors, will increase dynamic capability and competitive advantages for involved parties.

The sustainability of dynamic capabilities varies with the dynamics in the market, and market dynamism has a large impact on dynamic capabilities. Dynamic capabilities are determined by the existing knowledge in a company. In moderately dynamic markets, where change is often predictable and follows a linear path, capabilities seem to follow traditional routines (Eisenhardt & Martin, 2000). Participating companies are often well known to each other if the industrial structure is relatively stable. In moderately dynamic markets, dynamic capability is complicated, predictable and has analytical processes that rely on the knowledge already in the organization. In moderately dynamic markets, change evolves slowly (Eisenhardt & Martin, 2000). If the market is recognized for being "high velocity" as in very dynamic markets, change becomes less linear and predictable. In high velocity markets, one often observe frequently shifting boundaries between organizations which complicate the identification of the most suitable business models. As a result, the industry structure is not easy to define (Eisenhardt & Martin, 2000). Further, the development of dynamic capabilities is a simple, iterative and experimental process in high velocity markets (Eisenhardt & Martin, 2000).

It is important to examine the main drivers for change in the environment and how this affects the need for new resources. Adopting new resources is often a response to changes caused by e.g. technology, volatility in the environment with its aim to sustain or evolve new competitive advantages (Eisenhardt & Martin, 2000). In my case study, it is argued that these resources may be adopted through inter-organizational relationships where one manages to elicit the extra value realized by combining resources from the involved companies.

2.6.2 Adaptation to market dynamics

When adopting new resources, it is interesting to focus on the level of volatility in the market and how this affects the level of change and interaction. If change is seen as moderate, there is less need to involve external resources. If change is seen as more incremental, there is more need for external support and thereby more interaction with outside actors. Network theory argues that the exchange of goods and services is necessary because organizations depend on resources from other organizations (Håkansson & Johanson, 1993).

Anderson and Tushman (1990) saw change as incremental, or a punctuated equilibrium because of technological discontinuities. This kind of change will affect the organization but rarely occurs, which makes it difficult to respond to those changes if the organization is not prepared, and that can cause resistance to change. This kind of change occurs in industries recognized as moderately dynamic. Therefore, it is important to have good internal communication to make sure that employees understand the change and why it has been conducted. Incremental change also involves some risk since it can be both competence enhancing or competence destroying, especially regarding technological changes in the industry (Anderson & Tushman, 1990). Further, Anderson & Tushman (1990) argues competence-destroying changes could lead to resistance to change as one do not use the employees existing competence, which can challenge the adoption of new resources and has to be taken into consideration from the start of the change project.

Compared with the incremental change model, the continuous change model has another level of adoption and leads to a different response. This kind of well-known change is a part of their daily work and has been the way they operate (Brown & Eisenhardt, 1997). If changes occur often (as in high velocity markets) and continuously, this creates an organization that can respond to changes in the industry more smoothly with less resistance. Those changes will be less radical than in the punctuated equilibrium model. As those changes are less radical, those changes are often competence enhancing as one use the employees existing competence in the change process. In this situation, the employees often tend to support the change. The best chance to success when adopting new resources is when there is continuous change in high velocity markets, since it most probably affects the organization on a smaller scale (Eisenhardt & Martin, 2000).

Changes in the environment will affect the need for new resources regardless of the model. The punctuated equilibrium model would have a larger effect on the level of adoption of new resources since it is more radical. By contrast, the continuous change model will evolve continuously and the volume of the adoption of new resources will be less. It will also be easier to adopt new resources because change is continuous and employees are familiar with change (Eisenhardt & Martin, 2000).

2.7 Supply chain management and relationship to my articles

In this section, I want to outline the importance of supply chain management (SCM) literature for my research. I will start with the "triple-A" supply chain, agility, adaptation and alignment. Further, the resilient organization will be outlined and discussed. At the end, I outline and discuss the relevance of supply chain risk management and business continuity to my research.

Hau L. Lee's ground breaking article the "triple-A supply chain", published in the 21st-century supply chain series in the *Harvard Business Review* had a large influence on the evolvement of organization behavior and response to unexpected events (Lee, 2004). The triple-A, or agility, adaptability and alignment has proven itself to be a large contributor to remaining competitive in an industry changing environment. Lee (2004) argued that the most efficient supply chains like Wal-Mart, Dell, and Amazon have not become the most efficient due to streamlining their supply chain through, e.g., speed and cost efficiency. Their competitive edge is due to their agility and their ability to adapt over time as the environment changes. They also align the network parties' preferences to optimize the whole supply chain. Uncompetitive value chains are often streamlined so much that they have no buffers to adapt to changes in markets and forecasts often prove wrong or insufficient scenarios, especially when future volatility is high, e.g., the future deviates too much from the past (Narayanan & Raman, 2004). The organizations that build agile, adaptable, and aligned supply chains can realize higher competitive advantages than their competitors (Lee, 2004). Even further, Lee (2004) argues that agility, adaptability, and alignment have to be developed and implemented together if they should outperform their rival organizations' performance. Below, I have outlined how agility, adaptability and alignment relate to the findings from my qualitative study outlined in paper 1 and 2.

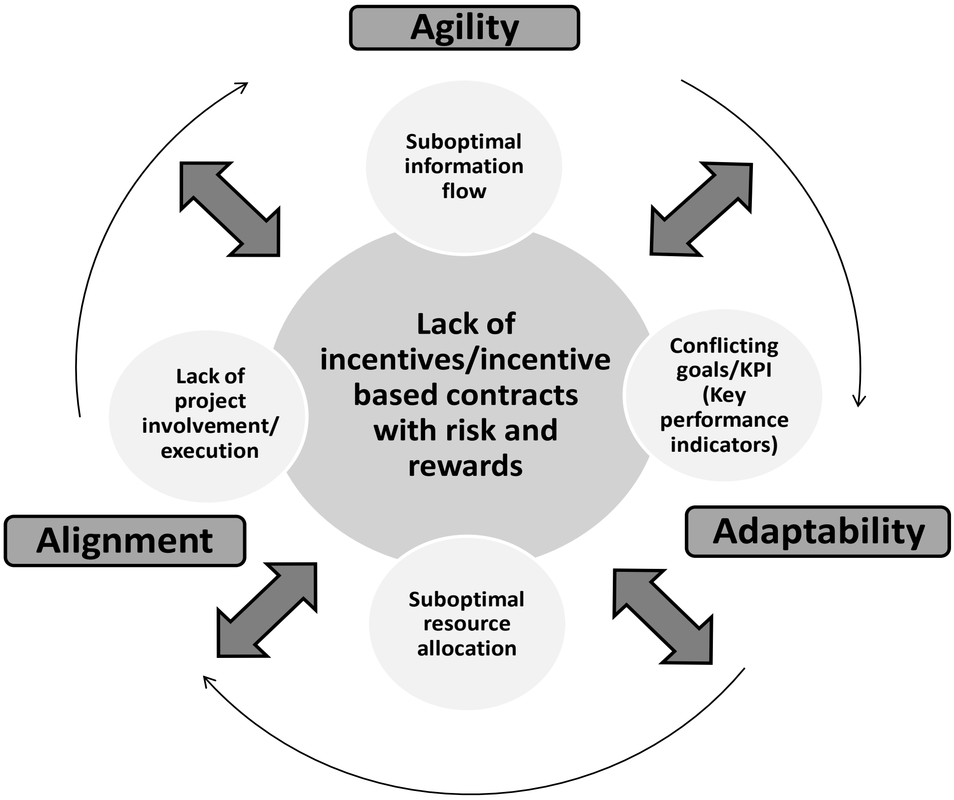

Figure 5 – How the findings from my qualitative study relates to agility, adaptability and alignment

In Figure 5, I have outlined how agility, adaptability and alignment relate to the findings from my qualitative study (based on Figure 1 in paper 2). As I argue below, and in the articles in part II, the goal is to operate in a more dynamic way where the parties share the extra value they create when the project realizes a higher value. This can be done through adapting to project and environmental changes more efficiently. I argue that there are similarities between the agility, adaptability and my research findings, as both try to optimize the supply chain through alignment, and alignment of incentives. I further discuss the relationship below.

2.7.1 Agility

Agility is all about getting the involved organizations in a network to respond quickly and efficiently to volatility and change in the environment. The increased focus on agility within organizations today is due to the increased complexity in the environment (Lee, 2004). The development and implementation of integrated operations in the oil and gas industry has increased the complexity as the numbers of suppliers on drilling projects has increased. As a consequence, the involved parties has started to focus more on their core competences. As argued in the case study in paper 1 and 2, this complexity has not been met by developing and implementing more refined business models. The overall goal of agility, as mentioned, is to handle internal and external volatility quickly and efficiently. It is also to build a relationship where the involved parties can differentiate themselves from their competitor networks and further increase their competitive advantages (Lee, 2004). In paper 4, I argue that if the incentive model is refined enough, the incentives obtained in the relationship can be a mechanism to differentiate this relationship from other relationships. For example, as observed in paper 4, I argue that a participation constraint condition is evident if, and only if, there exists incentive compatibility in the network. Involving those rules and implementing a refined incentive model with risk and rewards can lead the network to generate more value, and as a result, the network may differentiate itself from other networks. Networks that work better together through implementing incentive-based contracts with risk and rewards, may also respond faster to volatility in the industry as it is in all the involved parties' best interests to do so.

To handle external disruptions as smoothly as possible, Lee (2004) came up with six different methods. To respond quickly the parties need good information, therefore information sharing with suppliers and customers is of huge importance. The focal company also needs to develop close cooperation with their suppliers. Outlined in Figure 5 and discussed in my study in paper 2, I outline the importance of sharing information and cooperating closely as some of the single most important areas to focus on within a drilling project, similar to the methods relevant for agility. Even further, Lee (2004) and Sheffi (2009) argue for the importance of the strategy of postponement; for example, developing common products and work processes that can be used by different end products to increase resource utilization. This will lead to increased agility in the value chain, as one can use the resources on another project if one project is terminated. Further, one can decide where to use the resources later when one has obtained better information (Sheffi, 2005; Sheffi 2007; Sheffi 2009). When I conducted my interviews, one respondent stated that they sometimes asked for resources from other offshore installations if they missed resources and there were available resources at another, relatively close installation. As a result, they could avoid costly delays. What I find disturbing is that the service providers do this without gaining any more/better incentives. As a consequence, there is basically nothing that motivates the service provider to take that particular action. Formalizing this kind of resource allocation within drilling projects through defining and formalizing the work practice and tying the new work practice to incentives could be a positive contributor to increase value, and should be further investigated. Another way of dealing with volatility and unexpected change is to keep back small amounts of the most used resources on sight (Lee, 2004). Requiring resources from another offshore installation may avoid costly delays and is, as argued, to be preferred. This is a better alternative than if the project has to stop because of lack of resources, but is still a costly operation. Having a small buffer with the most commonly used resources on-site on the rig to avoid creating bottlenecks and costly delays can be important to ensure business continuity.

Further, Lee (2004) argues that it is not important that the focal company itself define and implement all those new practices, as it can be more easily built up through collaborating with other parties with these kinds of practices already defined and implemented. I argue this would be favorable for the oil and gas industry as well. According to paper 4, I argue one can dynamically on-board and off-board resources and parties as the environment changes and still secure participation as long as the incentives are calibrated correctly. Hereby, one can secure best practice resources to meet future changes. If the incentives are calibrated optimally, one can be sure to attract the best resources for every given situation (see alignment section for further explanation). Lee (2004) argues for the importance of team composition that knows how to develop and implement back-up plans. From my findings in paper 2 and observed in Figure 5, one can observe that there is an arm's length distance between the involved parties on a drilling project. Even further, the findings outline that suppliers are not involved when drilling projects are planned, something that I find disturbing as they have a lot of competence the operator would benefit from. In the alignment section we discuss how incentives can contribute to avoid this to happen.

2.7.2 Adaptation

As the agility outlined above is to respond to short-term volatility quickly, the adaptability concept is to adjust the supply chain to meet structural long-term changes in the market, and further to modify the collaboration partners to the new strategy in terms of product and technology development etc. (Lee, 2004). Further Lee (2004) argues that the best supply chains are those that can spot shifting trends a long time before they actually occur. This is done through developing and implementing best practice technology to capture new and relevant data for better decision making. Better decision making can further lead the focal organization to efficiently change their supply base and other important structural changes to increase their response to structural changes in the environment. To secure those capabilities, one must actively track changes in the environment, so organizations can quickly adapt to those changes. This is important if organizations wish to remain competitive. To avoid running its operation after forecasts (typically when there is a market push strategy), one can start measuring actual performance (typically when there is a market pull strategy). Lee (2004) argues that this strategy will lead the involved parties to decide on better information, as forecasts will lead to the distortion of demand data that fluctuates down the value chain (often addressed as the bull-whip effect) creating the data to be built up and increasing its distortion size between each process.

Further argued, the focal company needs to develop a new supplier base that can step in and compliment an existing one if there is a need for it. This will secure the business continuity if some of the suppliers have to leave. The designers of supply chains further need to design processes, products and technology that can be used in other supply chains to ensure business continuity if one of the supply chains can not operate as planned (Lee, 2004). In my papers, I do not outline the importance of adaptation between drilling projects in the supply chain, but within one drilling process. Yet, I recognize the adaptation between drilling projects to be highly important, and that it should be further investigated. For example, one should analyze the benefit of moving resources between offshore installations as the demand for resources at one installation declines, and that the particular resources can be used at another installation (also argued for in the agility section). As resources can be implemented in the different projects (seen as temporary supply chains), I believe that there can be great benefits if one could develop work processes that formalize the resource allocation between projects.

2.7.3 Alignment

In high-technology sectors, like the information technology (IT) and telecommunications sector in Silicon Valley or similar places, being at the front of product development is seen as being highly important to remain competitive. The importance of gathering a team that responds quickly and efficiently to real time information is seen as important for realizing competitive advantages. This asks for complex contract formats (Williamson, 2008).
To achieve agility and alignment in the extended value chain, one must align the preferences between the involved parties (Sheffi, 2005). If the involved parties optimize their own portfolio without the total supply chain in mind, this will affect the final result of the supply chain negatively (Narayanan & Raman, 2004; Lee, 2004). It is argued one must align the involved parties' preferences with the overall supply chain goal. Misalignment of goals in the value chain can occur within one particular organization (intra-organizational) and between two or more organizations (inter-organizational) (Narayanan & Raman, 2004). Further Narayanan and Raman (2004) argue that one way of aligning interests and preferences is by defining a new incentive with risks, (seen as punishment), and rewards (seen as bonus) equitably between the involved parties. This increases the quality and reliability of suppliers affecting the focal companies' performance positively. As the focal company wants to share

additional value that is created with their suppliers, they further improve the alignment with the suppliers as there is an incentive for the supplier to further improve their performance. This is because everyone in the value chain has the same goal, to optimize performance and let the best positioned party execute decisions (Sheffi 2005). In paper 2, I conducted a qualitative study where the respondents argue for the importance of goal alignment between the operator and the involved service providers on drilling projects. The study also implies that fixed price contracts that are customary in the oil and gas industry do not support optimal operations and create goal conflicts between the involved parties. The service provider will try to optimize its own pay-off by stretching the margins in the contract accordingly rather than optimizing the pay-off for the whole supply chain. Narayanan and Raman (2004) have also argued that if incentives are not aligned, the involved parties will optimize their own revenue, affecting the value of the total value chain negatively. One of their single most important contributions is that all parties will increase their outcome if they align their incentives, instead of working with misaligned incentives where they will optimize their own portfolio despite knowing that it will affect the revenue of the other participants negatively. Further, Williamson (2008) argues that firms that use "muscular" contracting, tend to lose market shares to companies that have a more credible contract similar to the incentive-based contract with risk and reward outlined in paper 3.

Due to the implementation of integrated operations in the oil and gas industry, respondents in the study stated that the contract regulating the relationship has to change because service providers have taken over more of the technology development and responsibility for drilling operations. As a result, incentive-based contracts are needed to secure optimal performance from both sides. Despite the shift in roles the operator remains directly involved. In my study, this was seen as suboptimal not only by service providers but by the operator as well. Further, discussed in paper 2 and outlined in Figure 5, I argue that incentive-based contracts with reward and punishment will better align the involved parties' goals and lead to increased productivity through the bundling of the involved participants' resources because they can utilize each other's core competences better. As there were no incentives related to performance, the respondents answered that the service providers were involved too late in project planning and execution. If they were involved earlier, the overall value on the project would be higher. As there are no incentives that benefit the involved parties when they produce more value, closer collaboration will not materialize. Neither will the involved parties share information with each other, as they will rather optimize their own portfolio, affecting the total value chain negatively.

In the case study, the respondents stated that an implementation of risk and reward contracts would lead the involved parties to share information more openly as the other party's decision and performance also affects themselves as the final extra value is shared by all involved in the project. In paper 3, I evidently show that both the operator and the service provider prefer the incentive-based contract instead of the much used fixed price contract, even thought the fixed price contract is the most commonly used contract on the NCS, and the incentive-based contract is rarely used. Further, in paper 3, I develop models for both contracts to better understand the nature of the two contracts. The models contain 20 parameters accounting for characteristics related to profit, gross income, and operating expenditure for an operator and a service provider. I also involve a free choice variable for the service provider that equals the time to complete the project. To determine which contract is optimal under which conditions, I solve the model by conducting individual profit maximization for the operator and a service provider, and joint welfare analysis. To illustrate the solution, I graphically show how different parameters and the time to complete the project affect both actors' profits. I observe that the fixed price contract and the incentive-based contract affect time usage and profits differently. Examples of disadvantages of the fixed price contract are moral hazard, (post-contractual opportunism where the principal cannot be sure that the agent exerts maximal effort), and adverse selection, (pre-contractual information asymmetry where the principal cannot be certain that the agent accurately performs its work) (Milgrom & Roberts, 1992). The service provider may work for its own goals rather than the operator's goals. The service provider usually knows more about its tasks than the operator, and may exploit the information for its own interest. Divergent goals and interests are huge challenges for the fixed price contract. The operator cannot fully monitor and observe the service provider's actions, as it can only measure its own profit. Since decisions are based on asymmetric information, both the operator and service providers spend resources acquiring information. The fixed price contract usually causes large monitoring and coordination costs, as well as other costs (related to catering, planning, administration of onshore organization, overhead, insurance cost, etc.). The incentive-based contract removes many of the costs common to the fixed price contract, especially related to moral hazard and adverse selection. Monitoring and coordination costs decrease. Various other costs also decrease, e.g., if the service provider through the incentive-based contract completes the project in shorter time. Similar to my results outlined in paper 2, where agreement on goals and key performance indicators (KPIs), and involvement of both actors in planning, may lead to better resource allocation. The drilling process involves balancing quality against time. Whereas a fixed price contract has a strong focus on time, an incentive-based contract has the potential to account for the complex relationship between quality and time by linking incentives to performance.

Narayanan and Raman (2004) have created a stepwise model for how to develop incentive-based contracts in supply chains.

Figure 6 – A step-by-step approach to developing incentives in the supply chain (Source: Narayanan and Raman, 2004)

There are three issues to pay attention to if one wants to realize more value in the value chain (Narayanan & Raman, 2004). First, one needs to avoid opportunistic action. As one cannot observe the service provider's action, one needs to relate performance to incentives as mentioned above. If the model is refined enough, this will align the involved parties' behavior and actions. Secondly, one needs to construct an incentive model so refined that it will lead the involved parties to reveal information others do not have, even though it would benefit them in the short term to hold back the information. Thirdly, if the model is refined enough, the involved parties will reveal information even if it is only short-term information (Narayanan & Raman, 2004). In my case study, I argue for the difference of fixed price contracts and incentive-based contracts with risk and rewards when it comes to efficiency in the value chain. Hence, I outline the companies can challenge their incentive problems by accepting that misalignment exists between the organizations' incentives. Further, it would be beneficial to locate where they have hidden actions, hidden information, or suboptimal incentives. By analyzing those factors, one can start to align and redesign the party's incentives. Then, the focal company can obtain information about the behavior they want from the participants in the network. To upgrade their partnership through closer collaboration, the focal organization should consider to change the much used statically fixed price contract, to a contract format that rewards partners for their contribution and enhances revealing and sharing of information between the involved parties. This kind of contract format will most probably also alter trust in the relationship. When the environment is changing, e.g., one has to adopt to new markets, new technologies or develop and implement new supply chain initiatives. One also needs to audit and renew one's incentive schemes to make sure it is best practice for that particular value chain. I consider the training of key employees and making sure they understand how incentives affect performance to be of high importance.

Lee (2004) outlines an example for increased agility, adaptability and alignment in his paper for seven-eleven Japan. The fundamental success for seven-eleven Japan was the alignment of their interests in their partner's interests. The rules of engagement were clear: make seven-eleven Japan a success, and hereby share the excess profit realized. If the partners fail to deliver as agreed upon, they have to pay a penalty. As a result, the parties start to trust each other, and do not spend resources on controlling each other's actions, as these expensive and unnecessary costs would lead to lower final profit that ultimately would give less to each involved as the final profit is divided between every party. Seven-eleven Japan also work closely with their suppliers if they want to develop new business opportunities, and share the revenue with them. As a result, they get involved more closely and work for the best interests of seven-eleven. Narayanan and Raman (2004) argue that if the involved parties use incentive-based contracts, they will work together to optimize the final value in the value chain. As a consequence, the value chain will create higher value compared to other value chains that work with misaligned incentives. Even further, they will attract the best resources in competition with other value chains competing.

2.7.4 The resilient organization

I hereby want to include the resilient organization in my thesis as I found the resilient literature to be of high importance for the oil and gas industry as well as for my research. When change happens suddenly, organizations are often caught unaware. The focus on lean operations has created smooth and efficient value chains that unfortunately, due to their continuous improvement and focus on streamlined operations, have affected the flexibility negatively (Economist Intelligence Unit, 2010). Often one talks about a trade-off between complexity and the simple supply chain. This is outlined in the figure below (Economist Intelligence Unit, 2010):

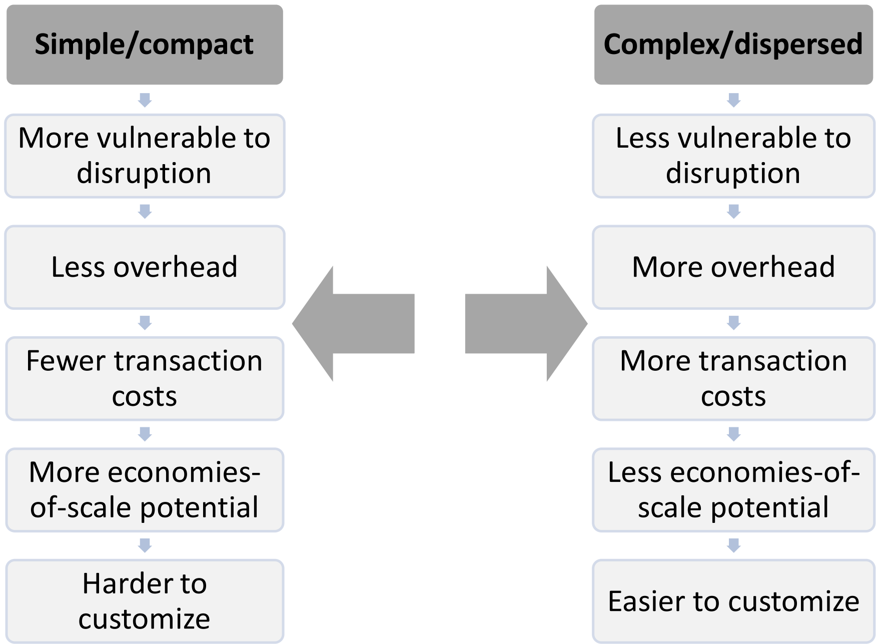

Figure 7 – The traditional trade-off: Simple and compact versus complex and dispersed supply chain (Source: Economist Intelligence Unit, 2010)

The trade-off between efficiency and resilience is often seen as a contradiction in the supply chain literature as one either has to focus on increasing efficiency simultaneously as decreasing flexibility or vice versa (Economist Intelligence Unit, 2010). However, it does not have to be like that. It is possible to increase efficiency and resilience at the same time. As I mentioned in section 2.7., one can use standardized resources in some parts of the final product. As a consequence, the company increases efficiency through standardization of one part of the value chain, but has flexibility in another part of the value chain. This boosts both efficiency and resilience together. In paper 4, I argue that one can increase productivity (efficiency) if one implements an incentive-based contract with risk and rewards that increases flexibility, as increasing the resilience, as one can dynamically change resource allocations between the involved parties as projects change. One starts the project with a clear scope, and involves resources according to that scope. As the scope changes, (as most drilling projects often do), one starts to change the resource allocation between the involved parties. In paper 4, I outline how this on-boarding and off-boarding of resources can be done dynamically with the implementation of an incentive-based contract with some additional "rules". These "rules" are related to incentive compatibility and participation constraints, and is important when the goal is to optimize the resource allocation between the agents. The mechanism can create a Pareto improvement because the players can increase their utility value without compromising the other actors. In contrast, by not involving the constraints, one or more agents can source the total amount of resources by themselves because this generates a marginally increased profit in the short term. This can lead to the agent(s) acting opportunistically and to lower profits for all involved parties in the long run. This will also be negative for the opportunistic agent. An example of how the "rules", (outlined in table 6 in paper 4) support the incentive-based contract is as follows: if some of the agents receive less volume to source when on-boarding new agents, they have to be compensated for their losses. The network can still have incentive compatibility and, as a result, the involved parties will reveal their true preferences and information. If not compensated properly, they will behave opportunistically or leave the network, affecting the network negatively. The new agents' contribution of value needs to be significantly higher than the old networks value *after* the agents receiving less volume have been compensated. If not, the network will not satisfy the requirement of the participation constraint. As a consequence of conflicting these constraints, the agent will value the network less because their social choice function, outlined in paper 4, creates a negative equilibrium. This situation has no incentive compatibility and the agent will probably leave the network because the participation constraint is conflicted. Further, in paper 4 I argue that a resource allocation given the conditions and methods outlined may lead to an attractive and more "democratic" allocation that ultimately leads to higher profits for all involved parties. As a consequence of the increased flexibility, the network may gain a competitive advantage. Further, the network can, as a result of its higher profit, attract the best resources and further strengthen its position. Even further, the flexible value chain ultimately can create a more efficient value chain. In Figure 8, I outline how resilience affects efficiency and vice versa. Expanding the resilience from the thick line to A, one observes from the dotted line that the efficiency increases as well. If the thick line decrease to B, one observes that the resilience decreases and as a consequence the efficiency decreases. The ideal strategy is to move the curve outwards, creating a more resilient and efficient organization (Economist Intelligence Unit, 2010).

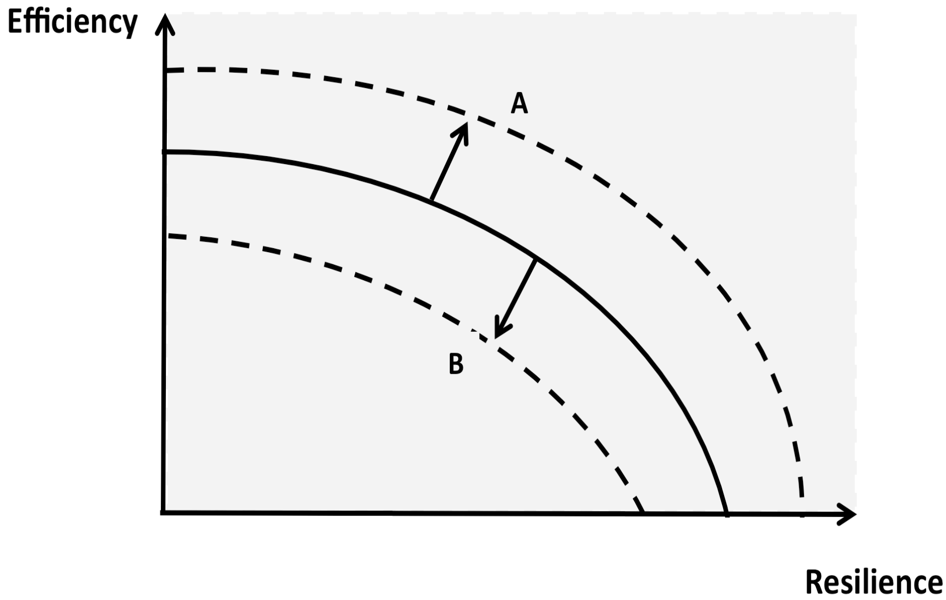

Figure 8 – Relationship between efficiency and resilience in the supply chain (Source: Economist Intelligence Unit, 2010)

To obtain a more resilient organization, the organizations need to be agile enough to adapt to different disruptions and fluctuations. This can be done through the following (Economist Intelligence Unit, 2010):

- Developing partnerships that mutually benefit the involved parties to avoid disruption and secure business continuity;
- A better use of data to increase information sharing between parties. A mix of past and real time data is preferable. This mix is important as happenings that rarely occur but have a large impact can usually not be forecasted due to a lack of historical data (see next chapter for further explanation); and
- It is important that organizations are not too lean and efficient as they get less robust for volatility. If the lean level is too high, that will affect the resilience as outlined in Figure 8.

2.7.5 Supply chain risk management and business continuity

In this section, I outline the importance of supply chain risk management and business continuity. I will outline what to do when disruption strikes, how to avoid it, and the importance of avoiding disruption on operations. One of the scopes of the dissertation is to increase the efficiency as much as possible through becoming more resilient as one on-boards and off-boards resources. Risk management cannot be handled within the focal company. Disruptions affecting companies negatively are often due to disruption further down the value chain, and therefore, risk management is a supply chain issue (Sheffi, 2009). The focal company relies on a myriad of different vendors, and hence the term supply chain risk management (Sheffi, 2007). Sheffi, (2007) outlines two approaches to risk management:

- Based on models and numbers; and
- Based on subjective forecasts for the future.

By following patterns of future happenings with the use of data, probability distribution, and models to make forecast, the value chain can effectuate necessary action to respond to future happenings. This kind of methodology has a weak side as it is difficult to forecast what is known as high-impact and low-probability happenings as they do not appear very often. This is because of the lack of historical data to make accurate forecasts. Hereby, high-impact and low-probability happenings often have a significant impact on supply chains as they occur suddenly without any warning (Sheffi, 2007). If the probability of disruption is high, and the consequences are severe, the value chain probably has historical data to forecast future happenings. Still, vulnerability is at its highest (Sheffi, 2005). Figure 9, depicts the likelihood of disruption probability and consequences (Sheffi, 2007; Sheffi, 2009).

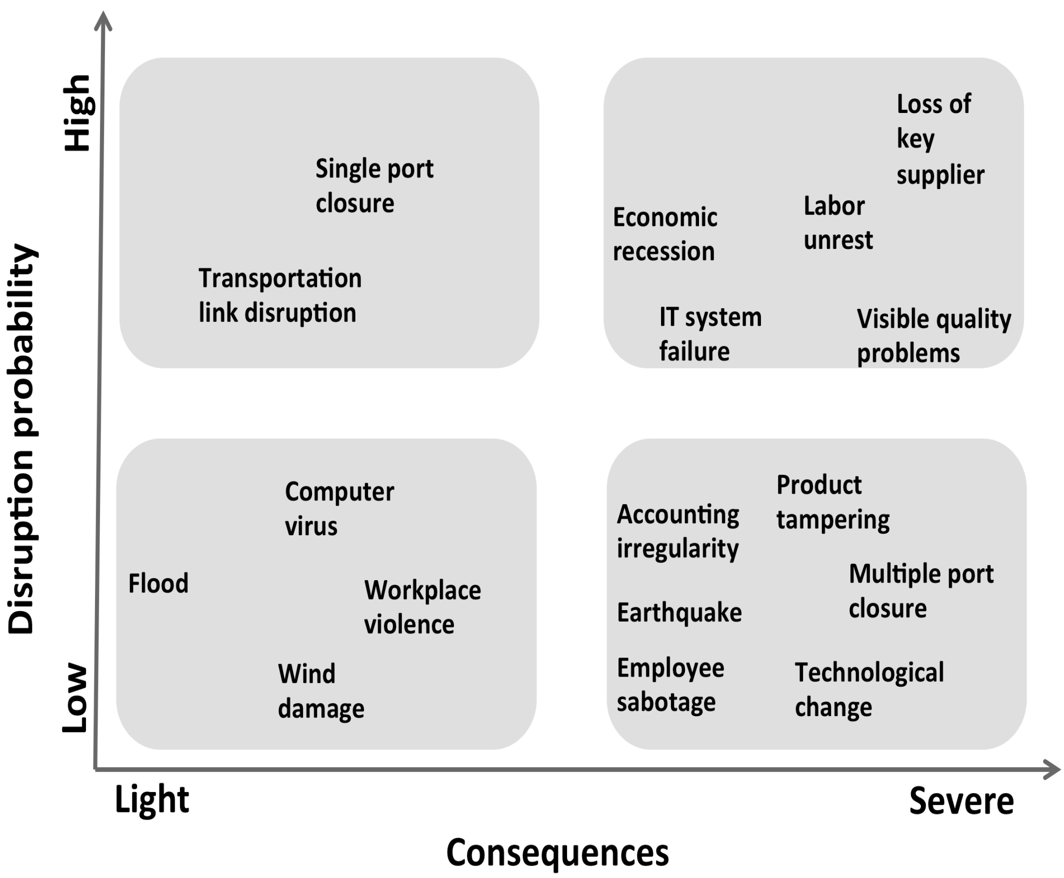

Figure 9 – Supply chain risk management and business continuity priority chart (Source: Sheffi, 2007; Sheffi, 2009)

In Figure 9, I outline the importance of disruption probability and the consequences of disruption. As observed, loss of key suppliers is the occurrence that is most likely to happen and the consequences will be severe. Since the probability of disruption is high, and that the loss of key suppliers is believed to have happened in the past, one can probably obtain historical data to forecast the possible future loss of key suppliers. As the consequences are severe, it is important to do what is needed to hold on to the key suppliers. In my study outlined in paper 1 and 2, one of the respondents replied that another operator (owning a petroleum license) had given better conditions to one of their key suppliers with the result that the supplier switched to that operator. As the operator in my study had spent two years working together with that supplier aiming to interact as smoothly as possible, this had severe consequences for the operator in my study. There existed no safeguard to secure this relationship. If one could implement an incentive-based contract with risk and reward as outlined in paper 3, this contract format would be collectively beneficial for both the operator and the suppliers as the costs associated with moral hazard, adverse selection, monitoring, coordination, etc. decreases. Involving the additional "rules" related to incentive compatibility and participation constraints as outlined in paper 4, one create a mechanism that safeguards the relationship to evolve positively as all parties will favor the network instead of other networks. As a consequence, one can observe the value added by incentive-based contracts regulating organizations to be a contribution to the supply chain risk management and business continuity literature. This is because the contract type supports the two important components; prevention of unexpected happenings and recovery of such happenings (Sheffi, 2009). In papers 3 and 4, I outline that the incentive-based contracts will give better response time when disruption starts to evolve, and in addition, that contract format will also decrease the recovery time if disruption has already happened compared to the fixed price contract.

3. CONTRIBUTIONS TO INTER-ORGANIZATIONAL RELATIONSHIPS, INCENTIVE MODELING AND THE ANALYSIS OF COMPETITIVE ADVANTAGES

Although the research is documented in the papers in part II of this thesis, section 3.1 summarizes the papers' scientific approaches and contributions and outlines the relationship between them. The following section outlines the papers' main contributions:

- The importance of inter-organizational relationships in the upstream oil and gas industry and the importance of new incentive schemes. Even further, the relationship between incentive schemes and other critical success factors in the principal–agent relationship;
- The design of incentive schemes and results of using a fixed price contract versus an incentive-based contract with risks and rewards; and
- The gain and release of resources in an inter-organizational relationship setting.

In section 3.2 I outline the value of a mixed methods research-the balanced approach to research, and in 3.3, I outline the value of the results, and synergies. In section 3.4, I outline the papers contribution to the dissertation.

3.1 The relationship between each paper

I will start this chapter with an outline of the relationship between the papers. Then I will outline a summary and their key contributions. Figure 10 shows the scientific contribution of the papers in the five top boxes and the relationship between them in the bottom three boxes. I will also involve a section commenting on the methodology used in the papers in the beginning of the summary of each paper. I will argue for the choice of methodology, and for the advantages and disadvantages of the methodology.

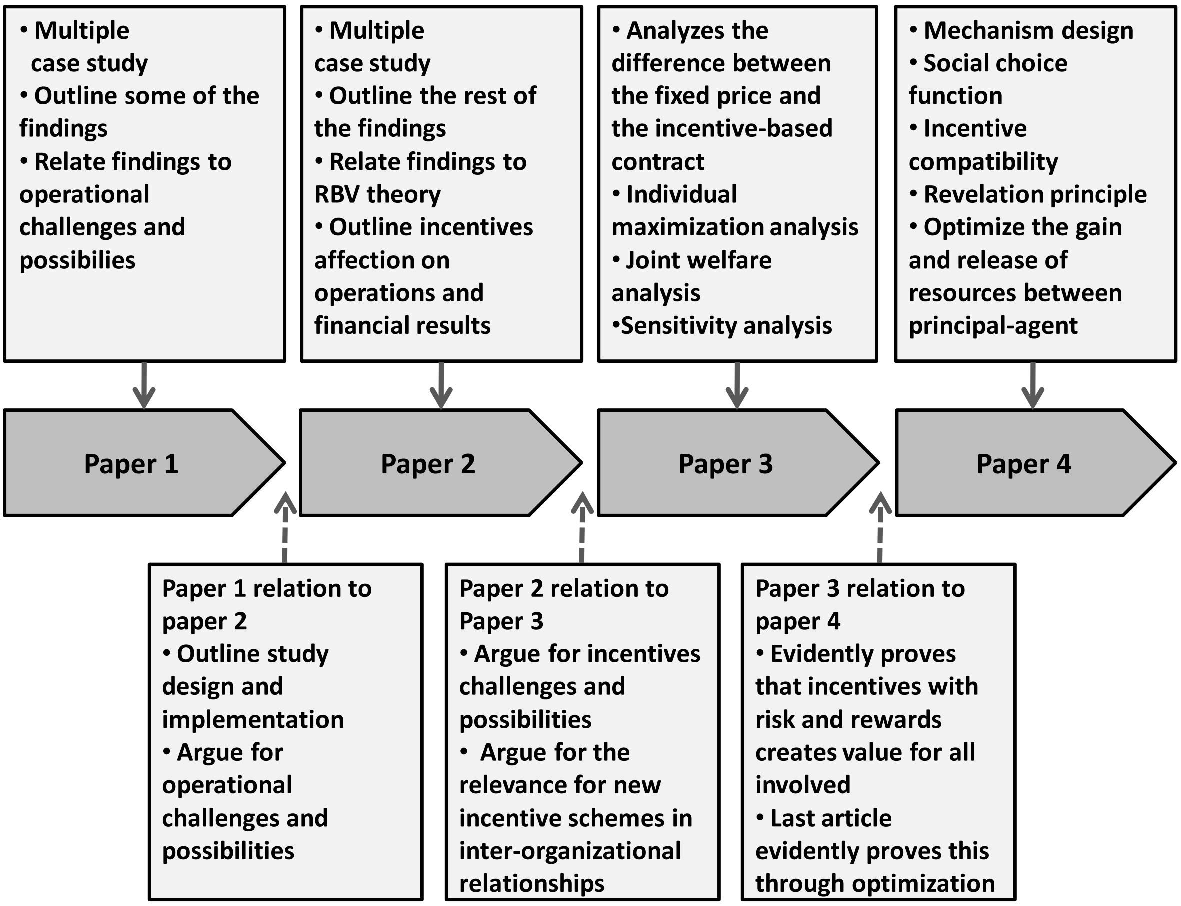

Figure 10 – Scientific contribution in the papers in part II and their relationship

3.1.1 Summary of paper 1

Integrated operations: How effective is the current relationship between operating companies and suppliers?

In the first paper, we focus on the inter-organizational relationship between one operator (operator A) and four service providers (service providers B-E) in the context of integrated operations for the upstream oil and gas industry with specific attention to the drilling environment. We investigate the oil and gas industry's interest in adopting incentive-based contracts with risks and rewards. The paper presents and discusses the main results found in the study. This includes the disconnection between operators and suppliers related to contractual/incentive-based contracts, and the results of using incentive-based contracts are illustrated and possible improvements discussed. Incentive-based contracts with risks and rewards between operating companies and service providers have not been a priority on the integrated operations agenda of the NCS.

A main part of the first paper is to outline the methodology of a qualitative study where the chosen research design is an embedded multiple case study. The case study, and the rationale behind it, is outlined in detail in section 1.3 and papers 1 and 2.
Yin (2003), argues that a side effect of the case study is that it constitutes a flexible and sometimes opportunistic methodology. This may also be a weakness for the case study methodology (Stuart et al., 2002). We recognize the value of flexibility and the potential disadvantages associated with the fact that researchers can be subjective and behave

opportunistically. The case study findings could of course have been strengthened through a triangulation approach (e.g., through a quantitative survey in addition to the qualitative study). The strength of using a triangulation approach is outlined in section 3.2. In Figure 11, the advantages and disadvantages of using a case study methodology (based on Gimenez, 2005) is outlined.

Advantages

- Obtained complete information as data collection was not constrained by limitation of the questionnaire
- Gave creative new insights
- Outlined the relationship between parties
- Obtained good understanding about the objective of the study
- We obtained a close relationship with the respondent and operations
- Respondents liked the objective of the study (all participants received written feedback and some respondents contacted us for further information)

Disadvantages

- We cannot be sure the results can be generalized as there only where 27 respondents
- The study may be subjective (in section 3.2 we outline how the subjectivity in the study is reduced by an triangulation approach as we use other methodologies)
- The study needed a lot of resources, as these kind of studies are time and money consuming

Figure 11 – Advantages and disadvantages of the case study methodology (Modified from Gimenez, 2005)

Figure 11 depicts the advantages and disadvantages of the case study methodology. The findings obtained by using a case study methodology are very valuable for our research. At the same time, the disadvantages of using this kind of methodology are also very evident. We argue that some of the disadvantages can be avoided through a triangulation approach as outlined in section 3.2.

The relevance of the findings in paper 1, where incentives were highlighted as the single most important issue, has been argued to be of high importance when we have presented the findings to the industry as well as to academics. We argue the present incentive model is not optimal and should have been replaced by a more refined incentive model based on risk and reward sharing. The key findings related to incentives are summarized below.

Incentives at an employee level

The study indicates that some service providers increase their incentives at the employee level if the performance is better than expected. We found a difference among the companies in the study. Some service providers would not receive better incentives if they performed better than expected, but some did. Operator A respondents stated that their contribution would probably be higher if they had incentives based on individual performance, but only employees at the management level had such incentives. In paper 3, we include incentives at an employee level when setting up the incentive-based model with risks and rewards. It is argued that if change at the employee level is going to materialize, the employees needs personal incentives as well as company incentives.

Incentives at a company level
At operator A, there were divergent answers on whether the company could receive better incentives depending on the employee's department. From the service providers' point of view, most of them received incentives if employees performed better. In paper 3, we argue for the importance of incentive-based contracts with risks and rewards and show that they realize significantly more value than traditional fixed price contracts and should be preferred. In paper 4, I outline how incentive-based contracts should be calibrated between the involved parties to ensure they will accept the incentives and participate in the network.

Does your company have the right incentives?
We also wanted to know if the operator and service providers had the optimal incentives (e.g., salary, bonuses) for good performance. Operator A and service providers D and E's respondents stated that they received good incentives. Respondents at service provider B answered that they recognize the incentives, but only at some level was satisfied with them. Service provider C's respondents stated they did not got paid according to performance. In paper 4, we outline how incentive-based contracts should be calibrated between the involved parties to ensure they will accept the incentives and participate in the network. Further, in paper 4, we argue that an optimal incentive-based contract can function as a mechanism to on-board and off-board resources to realize higher value and secure participation as the network realizes a higher value than its competitors.

How incentives could be developed to improve the performance for your company
One of the findings from the study relates to how incentives could be developed to improve the performances of the involved companies. One of the core questions concerns how incentive-based contracts that regulate the relationship between operator A and the involved parties (service providers B–E) could be developed further. For the respondents at operator A, keeping business units separate and better use of KPIs were highlighted as important. Further, operator A respondents also stated that incentives had to enhance the value for all parties involved to ensure that they all work towards a common goal. Further, the reciprocal treatment between party and how they contributed to each other's operations were highlighted as important. Service provider B's respondents stated that the contract had to create value for all involved parties. This was highlighted to be the most important issue in the integrated operations environment. Respondents at service provider C argued that in order to increase the value for integrated operations, it is necessary to develop better incentive models for all involved parties. Further, service provider C's respondents argued for increased attention towards avoiding conflicts and they also argued for the need for using KPIs better in operations. Service provider D's respondents highlighted the importance of the involved parties having incentive-based contracts. Further, they argued they had to start to use KPIs on projects more consistently. Respondents at service provider E answered that development of better incentives should be prioritized to materialize better performance in addition to better use of KPIs in drilling projects. Many of the findings are verified in paper 2 which has some of the same results. Paper 3 supports the findings in paper 1, and argues they can reduce much of the problem with cooperation as one implement an incentive-based contract. Papers 3 and 4 argue that the problem outlined in paper 1 is related to the different parties' behavior being based on their opportunistic behavior. Reducing this behavior by implementing incentive-based contracts will ultimately lead to the mentioned challenges being reduced to a minimum, or in the best case, avoided.

3.1.2 Key contributions

In the first paper, we offer some recommendations at the end. Since this paper was the first, the recommendations can be interpreted as rather bold statements. Later, in papers 3 and 4, we argue that the statements in the first paper were quite precise. We argue in paper 1 that more focus is needed on incentive-based contracts for all involved parties in the drilling environment. The study indicates that only two out of four service providers increase their incentives if they perform better. Service provider D uses incentive-based contracts on all drilling projects for operator A, and were the most satisfied with the contract. All companies stated that better use of incentives that increase the value for all involved parties is important for better collaboration in drilling projects. We also observe that nearly all respondents said that they do not receive optimal incentives for their work. Further, incentives have to be implemented on an employee level if one should realize value on corporate level.

We will also argue the service provider has to bear some of the project's risk. In paper 1, one service provider is trying to avoid being burdened with negative consequences if they perform badly in a particular phase. Hence, we argue that this can affect the overall result of the project. This is because the service provider will optimize their respective phases, that further will lead to suboptimal performance because of the lack of incentives to perform optimally on the project in overall. In contrast, service providers also demand different ways of being compensated for their risk. This is a good argument for development and implementing incentive-based contracts.

In the literature it has been argued that it is possible to outsource more or less everything, but not its core competence. Consequently, it has been argued that the focal company can lose their position in the network, and as the other actors behave opportunistic, a likely outcome is that they may lose their competitive advantage (Porter, 1980; Prahaland & Hamel, 1990). Needless to say, the drilling process is considered to be one of the core competences of an operating company. We argue the operators can be exposed for such a behavior from their service providers as they have taken over more and more activities within the drilling process and technology development, and approximately account for 80% of the workload. This may have negative effects for the dynamics between the operator and service providers in the long run.

In this paper, we propose several focus areas to secure and increase the performance between the operator and the service providers with the use of an incentive-based contract. The study argues for goal alignment, and one way to align goals is through incentive-based contracts. The use of incentive-based risk/reward contracts can improve relationships because the involved parties work for common goals. Further, the study states that if all parties are using incentive-based contracts with risk/reward sharing, it is in all their interests to operate with the highest possible productivity and quality. This is evident because the total value created in the project is shared among all parties involved. We believe it would be in the interest of every party to use best practice technology and the resources available to reach its goals, and if possible, even stretch its goals. The consequence of higher quality can lead to shorter drilling time, because the involved parties collaborate more closely and share information more openly. The benefit is realized because the parties avoid mistakes and deliver with optimal first-time quality. This statement was proven through our analysis in paper 3 and in the optimization in paper 4.

3.1.3 Summary of paper 2

Developing new resources: How to gain dynamic capabilities and competitive advantages from integrated operations in the upstream oil and gas industry

The first paper outlines the methodology of an embedded multiple case study and some findings. In paper 2, the goal is to examine how selected companies in the oil and gas industry use incentive-based contracts with risks and rewards to bring about competitive advantages and dynamic capability. I examine inter-organizational relationships in the oil and gas industry resulting from integrated operations. I also create a linkage between resource-based view (RBV) theory and dynamic capabilities. As I relate the findings in paper 2 to the RBV literature, I argue that resources used in specific combinations that lower costs or increase productivity can provide organizations with competitive advantages. It is further argued that if resources create competitive advantages for the involved parties, then these groups of resources must be coordinated through inter-organizational collaboration. These results were obtained by using the case study described in section 1.3 and papers 1 and 2. As I have commented on the choice of methodology and given a short overview of the advantages and disadvantages of the methodology in section 3.1.1, I will not comment on those issues in this section. With respect to the results, my case study showed that competitive advantages can be achieved through better bundling of the involved parties' resources because this produces dynamic capabilities that permit the involved parties to jointly react better and faster with a higher value for all involved. The study showed that it is hard for the involved parties to adapt to the increased volatility in the industry because of the well-established culture and routines. Respondents cited problems in the development of existing competences to respond to market dynamism because there were no incentives for change. I find the study very relevant, and the response I have received both from the industry and academics, argue the findings are very intriguing and highly relevant for inter-organizational relationships within drilling projects.

In the case study, I outline that the operator and involved service providers may in some situations have different preferences regarding collaboration. A surprising finding was that they almost unanimously agreed that this was one of the most important challenges to overcome in order to achieve better collaboration. All parties agreed that better resource allocation was important for better dynamic capabilities. Below, I outline a model describing the five most interesting areas to focus on and those areas receive the most attention in the study by the participants. The focus areas are depicted in Figure 12.

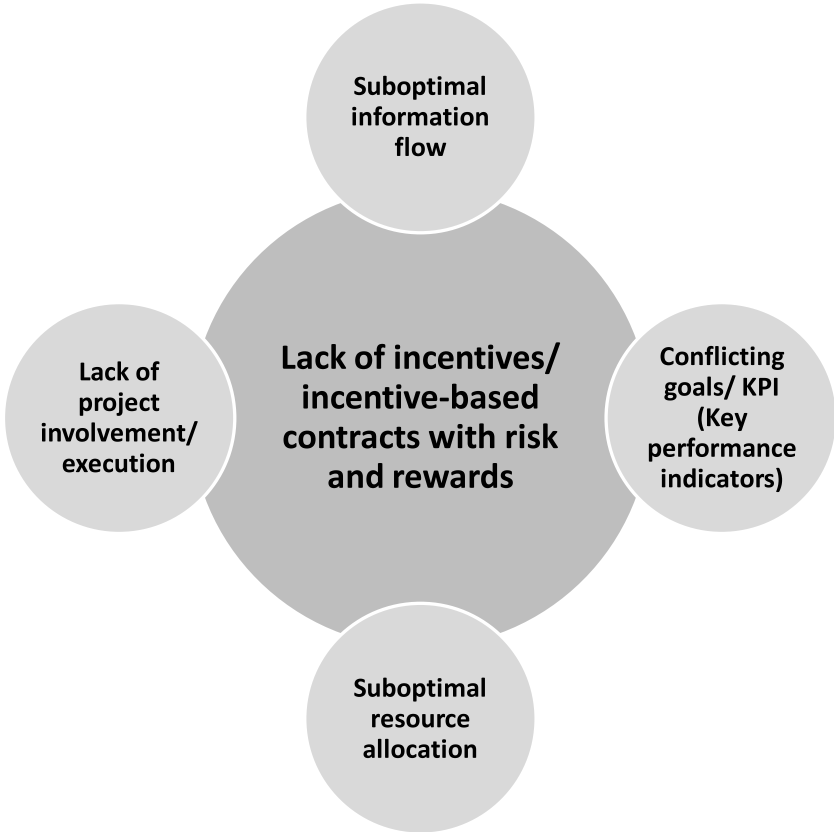

Figure 12 – Overview of the five most important findings in my study

For realizing the value of integrated operations in the oil and gas industry through closer interaction between the involved companies, these five findings were seen as crucial. As illustrated in the figure, the lack of incentive-based contracts was cited as the single most important issue and a constraint for realizing more value. The incentive-based contracts are highlighted as important to achieve the other four findings, as they are seen as closely related. E.g., as some of the parties were not involved in project planning, they were deprived from information they needed to make optimal decisions in the project. As a consequence, this led to goal conflicts due to inaccurate KPIs that further led to opportunistic behavior from both parties because there were no incentives for goal alignment.

Lack of project involvement/execution
These findings suggests that some of the respondents from both the operator and service providers felt that their value from collaborations would probably increase if they could be involved earlier in projects. This is especially relevant in the planning phase. If all the involved parties adopted this approach, they could plan the project in collaboration. This would avoid suboptimal KPIs that create goal conflicts and constraining productive operations that lead the operator and the involved service providers to work against each other. The involved parties stated that this could be realized by integrating an incentive-based contract with risks and rewards. I proved the above mentioned arguments are correct in papers 3 and 4.

Suboptimal resource allocation
The majority of the respondents stated that the involved organizations need to start collaborating more effectively and use each other’s core competences better. As a consequence, the involved parties could then better renew and align their competitive

advantages as the environment is changing. It is often beneficial to let the service providers address a particular task, if some tasks are not a part of the focal company's core competences and could be performed better by the other party.

Competitive advantages are highlighted as important challenges to overcome, but can be avoided through a dynamical gain and release of resources. The case study showed that allowing third parties to make independent decisions because they are closest to the operations and have the best information, is a key factor in order to succeed with inter-organizational relationships. In my case study I found that quite often the service provider is not involved when an operator executes a particular decision relevant for the operations (e.g. decisions concerned with which tools to use on a drilling project). This is not conducive for the value realization of the project. Adopting incentive-based contracts with risks and rewards could help the involved parties freely give away responsibilities related to decision making to achieve a better outcome for all involved. In paper 3, I used a model to analyze the outcome of using incentive-based contracts with risks and rewards and proved that it generates better value than fixed price contracts. In paper 4, I optimized the principal–agent relationship with the aim of finding the optimal resource allocation between the parties. Further, in papers 3 and 4 I showed how incentive-based contracts with risks and rewards create more value for all involved parties. Fixed price contracts function differently because the involved parties behave selfishly and this affects resource allocation and value creation negatively.

Suboptimal information flow

According to the case study, all involved parties stated that best practice knowledge transfer between the parties is important. Integrated operations in the oil and gas industry are recognized to be an information-intensive method. To gain optimal operational performance, real-time information is crucial and is to be considered to be one of the major value drivers. The involved service providers need to receive information on a daily basis in order to perform optimal decisions. The study outline that there is a problem with receiving information because the operator owns this information. The case study show that the involved parties differed greatly when it comes to accessing information from the operator. Some had system interfaces to extract the information they needed, but others could not obtain optimal information. As the operator holds on to the traditional dynamics, this affects the project performance as the service providers also needs to communicate with each other. Consequently, the service providers make decisions based on asymmetric information. In the end, this will also affect the performance for the operator. Some key employees with responsibility in drilling projects were partially responsible as they held back information to maintain the traditional dynamics between the operator and service providers. This strongly suggests there is no well-defined responsibilities and open communication between the parties. As a result, this gives rise to a problem when it comes to decision allocation in the principal-agent relationships. The implementation of an incentive-based risks and rewards contract could stimulate the involved parties to share information more easily because it would reward them all at the end. I argue that this finding is important and explain this in more depth in the following.

Lack of incentives and conflicting goals and KPIs

Given that the service providers gradually have taken over more of the technological development and responsibility for drilling operations, it may be timely to suggest that the contract regulating the relationship ought to change. And as a consequence, one of the incentive-based contracts main objectives should be to secure optimal performance for both the operator and service providers. It is both surprising and interesting to find that despite the shift in roles, the operator remains directly involved. Both the operator and the service providers stated this was not an optimal situation. In papers 3 and 4, I showed that implementing an incentive-based contract will terminate the problem where the operator is not sure the service provider put in maximum effort or behaved opportunistically. Adopting an incentive-based contract with risks and rewards will change and align the behavior for the involved parties because all parties' contributions will affect the final pay-off to everyone involved.

Goal conflicts often occur as a consequence of using fixed price contracts, and this is one of the main findings in the numerical model in paper 3. As argued in the case study and paper 3, the operator often establishes predefined goals, hands over the KPIs to the service providers and expects them to behave at their best. Given a hypothetical situation where the service provider receives payment for the amount of drilled meters per day, they will try to optimize their own pay-off by stretching the margins in the contract for their best interest instead of optimizing the pay-off for the all parties involved.

It could be beneficial for inter-organizational collaboration to involve incentive-based contracts as it would help improve efficiency. In the aftermath of the project, all parties would share the risks and rewards. The parties goals would then be aligned and as a consequence this will ultimately increased productivity as one are bundling resources and core competences. This argument was supported by the numerical model in paper 3 and the optimization of the gain and release of resources in paper 4.

In my study, it is argued that health, safety and environmental features (HSE) will be affected as a consequence of increased productivity. This will not be realized by tight guidelines and the formalization of work processes, but as a positive side effect of the involved parties being more adaptive and responding faster and better to unexpected events in the environment. E.g., the value can be realized by better information flow and closer collaboration in the value chain. As the focus is on first-time quality and this is the overall goal for the involved parties, this will positively affect HSE level, productivity and cost efficiency. The results of papers 3 and 4 outlined in the next sections proved that the arguments in paper 2 are correct. Both the analyses in paper 3 and the optimization of the principal–agent and agent–agent relationships in paper 4 will back up the arguments outlined in paper 2.

3.1.4 Key contributions

One of the findings in paper 2 was that the operator employees do not always share information with the service providers. The middle level managers often regard this information as their own, and as a consequence, information is held back. The operator employees observe that the tasks that they traditionally performed is gradually being conducted by the service providers and as a consequence they hold back information because they are afraid of losing their place in the network. New arrangements may benefit the organizations, but still, the employees often tend to resist the arrangements. Therefore, I found that they try to maintain and preserve the old dynamics in the industry. Only in a few cases does limited information due to technology or knowledge restrain operational results. The respondents stated that this usually were caused by unwillingness of sharing information. Further, I found that resource allocation was seen as a source of conflict between operators and service providers, to which one possible solution is to further involve service providers when operators start to plan drilling projects. This requires the modification of traditional routines and work practices to make use of information-sharing technology and real-time data. The challenges found in the study and outlined above are supported by paper 3, where I outline that goal congruence can be aligned by implementing an incentive-based risks and rewards contract benefiting all parties involved. This is also further outlined and discussed in the summary of paper 3 in the next section.

In my case study I outline how the service providers has to obtain responsibility and ownership of their own processes. Quite often, the operator performed suboptimal because they were taking decisions that service providers were better positioned to take. Both parties stated this was a problem, and this is encouraging news for the relationship. It is argued that this conflict could be eliminated by the use of incentive-based contracts with risk and reward sharing. This is supported by paper 3, where I found that incentive-based contracts with risks and rewards could be a mechanism to avoid conflicts related to decision allocation between the parties. This encourages each party to ensure that decisions are made by the party best able to do so. Conflicts will largely be avoided, as joint establishment of KPIs and profit sharing based on total performance in the value chain will be a motivator for goal alignment between the involved parties. The involvement of service providers in the planning and execution phase could be accelerated by implementing incentive-based contracts. This is also argued in papers 3 and 4. I argued that another side effect of using incentive-based contracts is an improved HSE level because the involved parties would respond better and faster to unexpected events. Papers 3 and 4 stated that delivering best practice quality is within all parties' best interests because it will benefit the pay-off for everyone involved. Better quality, goal alignment, cooperation and communication create a better HSE level.

3.1.5 Summary of paper 3

Fixed price contracts versus incentive-based contracts in the oil and gas industry

The first paper outlines the methodology of a qualitative study and some findings. Further, paper 2 examined how selected companies in the oil and gas industry could use incentive-based contracts with risks and rewards to bring about competitive advantages and dynamic capability. Both papers were based on the same case study. In paper 3, we analyze the difference between the fixed price contracts common in the oil and gas industry, and the more uncommon incentive-based contracts with risk and rewards. To do so, we develop a model based on quantitative data. The scope in paper 3 is based on the findings in papers 1 and 2. In paper 2, (and at some level in paper 1), we argue for the importance of five specific findings, and in paper 3, we model the relationship between operator and service providers with respect to the findings in papers 1 and 2. We model the use of fixed price contracts and incentive-based contracts with risk and rewards. Hence, consider two firms, i.e. one operator, seen as a principal, and one service provider, seen as an agent. We outline how the principal-agent problem affects both the operator's and the service provider's behavior and profits and how the two different contracts impact on value creation differently through inter-organizational relationships. To do so, we have to quantify gross income and operating expenditure and observe that they are affected differently by fixed price and incentive-based contracts. We developed numerical models for the two contracts and used empirical data gathered from the Norwegian Petroleum Directorate (Emhjellen, Hausken, & Osmundsen, 2006) to analyze the contracts. The model involves 20 parameters accounting for characteristics related to profit, gross income, and operating expenditure for both the operator and a service provider. As we want to obtain information about which contract is optimal under which conditions, we conduct individual profit maximization analysis for the operator and a service provider, and in addition, a joint welfare analysis. Using quantitative data, we managed to verify the results obtained in the case study in papers 1 and 2. The value of a triangulation approach is further discussed and argued for in section 3.2.

In Figure 13, we outline the advantages and disadvantages we found using quantitative data for our model. A similar figure has been earlier outlined by (Gimenez, 2005).

Advantages

- We obtained higher precision and reliability
- We ensured objectivity as we were not involved in gathering the data
- We manage to generalize results as we received data from the Norwegian Petroleum Directorate and through a triangulation apporach (outlined in section 3.2)
- Less expencive and time consuming methodology compared to the case study

Disadvantages

- Information obtained from the Norwegian Petroleum Directorate was at some level model limited. We argue, not affecting the results negatively.

Figure 13 – Advantages and disadvantages of using quantitative data (Modified from Gimenez, 2005)

The advantages obtained by using a quantitative approach are very valuable for the research. The disadvantages can be reduced through a triangulation approach as we benchmark the results through verification of the information quality. As stated, the information was at some level model limited. For example, we did not obtained costs of, e.g., moral hazard and adverse selection as the industry does not measure these cost components. We obtained a data set with total costs, and hereby we needed to make a cost forecast with respect to moral hazard and adverse selection based on industry trends and the specific cost levels obtained in the literature for those costs.

In paper 3, we observe that the service provider may work for its own goals rather than the operator's goals as they usually know more about their tasks than the operator. Further, we observe that this occurs because the fixed price contract has a downside related to moral hazard and adverse selection. As a consequence, the service provider may exploit the information for its own interests and create divergent goals and interests. This is the same results as we observe in papers 1 and 2. The fixed price contract thus usually causes large monitoring, coordination and other costs. As the incentive-based contract uses reward and punishment, it compensate for the parties performance. Incentives, such as material rewards, motivate agents to take particular actions. If the agent does not meet the performance criteria, the reward decreases and may become negative which constitutes a punishment. Further, in paper 3, we argue the incentive-based contract removes many of the costs common for the fixed price contract, especially related to moral hazard and adverse selection. In addition, the monitoring, coordination and various other costs also decrease, if e.g. the service provider through the incentive-based contract completes the project in shorter time. Involving both parties in project planning and agreement on goals and KPIs may lead to better resource allocation. An incentive-based contract has the potential to account for the complex relationship between quality and time by linking incentives to performance, and the fixed price contract has a strong focus on time.

3.1.6 Key contributions

As argued in paper 2, incentive-based contracts can increase the value of drilling activities by increasing productivity and cost efficiency for all actors. In paper 3, we outline the cost and benefits related to inter-organizational relationships, we developed as mentioned in the section above, a formal model for the relationship between an operator and a service provider that supports the findings in paper 2. The models outline the results related to profit, gross income and operating expenditure for an operator and a service provider. In addition to an outline of the profits under the two contracts, we determine which contract is optimal under which conditions. Hence, we solve the model by conducting individual profit maximization for the operator and a service provider and a joint welfare analysis for the two parties.

<u>Joint welfare analysis</u>

Summing the operator and service provider's profits in (9), (10), (11) and (12) in paper 3, the joint welfare for the two actors for fixed price contracts and incentive-based contracts provides the following.

Theorem 1: The joint welfare for the operator and service provider is maximized by choosing incentive-based contracts over fixed price contracts.

Proof: Follows from comparing (13) and (14) in paper 3.

Fixed price contracts introduce additional costs caused by the difference between (13) and (14) in paper 3, and as a consequence we can outline theorem 1. The costs are as followed: First, the operator's costs of monitoring, coordination, moral hazard, adverse selection and other costs including catering, planning, the administration of onshore organization, overheads and insurance costs; the second, the service provider's costs of moral hazard and adverse selection; and third, the more time spent to complete the project, the more these costs will increase. These costs decrease, or can even be eliminated, with the use of incentive-based contracts, but are common for fixed price contracts. This is because the incentive-based contracts realize goal alignment, prevent the parties working against each other, decrease opportunistic behavior, improve resource allocation, cause information to be exchanged more openly, and as a consequence, the parties realize more value between them. Many of the same results were obtained in paper 2. From a joint welfare point of view, one benefit of using an incentive-based contract is that the service providers are closer involved in the project planning phase. As a consequence, the decisions could be taken by the party that is in the best position and has the formal competence, instead of the party with formal ownership to the process. This is relevant with respect to the fact that the operator owns the petroleum license and has formal ownership of the process and is also in a position to exploit the situation. In the operator-service provider relationship, a fixed price contract affects productivity negatively. On the other hand, an incentive-based contract decreases the time to complete the project.

<u>Individual profit maximization</u>

As actors will maximize their own profits, they cannot be expected to focus idealistically on their joint welfare. It does not matter if profits in total or profits per day are compared under the two contracts as they give the same result. This is because it would not matter whether division with used time occurs on either both sides or no sides of an inequality. Therefore, the operator prefers the incentive-based contract as observed when comparing (9) and (10) according to (15) in paper 3. Further, if we compare (11) and (12) in paper 3, we observe that the service provider prefers incentive-based contracts according to (16) in paper 3.

<table>
<tr><td rowspan="2">The actors' contract preferences in (15) and (16) in paper 3 are illustrated in Figure 14 (parameters follow from the nomenclature list in paper 3). When $w \geq w_H$:
The operator prefers the fixed price contract
The service provider prefers the incentive-based contract</td><td>When $C \geq C_H$:
The operator prefers the incentive-based contract
The service provider the prefers fixed price contract</td></tr>
<tr><td>When $C_L \leq C \leq C_H$:
Both actors prefer incentive-based contracts</td></tr>
<tr><td>When $w \leq w_H$:
Both actors prefer incentive-based contracts</td><td>When $C \leq C_L$:
The operator prefers the fixed price contract
The service provider the prefers incentive-based contract</td></tr>
</table>

$T=0$ $T=T_N$ T

Figure 14 – Operator's and service provider's contract preferences as T (time) varies horizontally and w (service provider's variable income) and C (punishment function) vary vertically (for in depth explanation of the parameters, se the nomenclature list in paper 3)

Theorem 2: (a) Both actors prefer incentive-based contracts when the time used is lower than the estimated time and the variable income is set high, or when the time used is higher than the estimated time and the punishment is not too lenient nor too harsh ($C_L \leq C \leq C_H$)*. (b) The operator prefers fixed price contracts and the service provider prefers incentive-based contracts when the time used is lower than the estimated time and the variable income is set low, or when the time used is higher than the estimated time and the punishment is set low. (c) The operator prefers incentive-based contracts and the service provider prefers fixed price contracts when the time used is higher than the estimated time and the punishment is set low. (d) It is not possible for both actors to jointly prefer fixed price contracts.*

Proof: Follows from (15) and (16) in paper 3, and figure 14.

The operator prefers incentive-based contracts when the income needed to complete the project in surplus is not too high, and the project is likely to finish in less than the estimated time. We observe that the service provider will always prefer incentive-based contracts. This result is evident as the service provider increases its incentives if the project is finished earlier than expected. This can be realized if one can provide incentives with not too much cost for the operator. If the cost is too high for the operator to provide these incentives, the operator will prefer fixed price contracts. On the other hand, the service provider will not prefer a fixed price contract. Both parties prefer the incentive-based contract if the project is completed in more than the estimated time and the punishment applied by the operator on the service provider for not delivering according to the estimated time is neither too lenient nor too harsh ($C_L \leq C \leq C_H$). The reason for this is that if the punishment is too lenient, the operator will realize little benefit from the incentive-based contract and prefer a fixed price contract instead. On the contrary, service providers prefer a fixed price contract if the punishment is too harsh as they suffer too much from the arrangement.

Profits under the two contracts

In paper 3, we outline panels that show how the 20 parameters used in the model affect the operator and service provider preferences sometimes similarly and sometimes differently. As a result, we can verify that theorem 2 outlined above is correct. Our objective is to gain insight into how the 20 parameters and the variable time to complete the project impact both the operator's and service provider's preferences for the two contracts. Similar to the results obtained in the individual profit maximization in the last section, we suggest that there are cases where both actors prefer the incentive-based contract, and as a consequences, we argue that the parties can realize better performance by using this kind of contract. On the other side, there are also cases where the actors have opposite contract preferences, and also situations where both prefer the fixed price contract.

In paper 3, we argue for the choice of contract format, and we found that neither the joint welfare analysis, the profits under the two contracts nor the individual profit maximization procedure leads the operator and the service provider to jointly prefer fixed price contracts. These are important findings given the fact that the fixed price contract is the dominant form of contract in drilling operations. With use of fixed price contracts, costs of monitoring, coordination, moral hazard and adverse selection will affect both parties negatively. Further, costs related to divergent goals and interests and asymmetric information are larger for fixed price contracts than for incentive-based contracts. We suggest that contracts used in the oil and gas industry should not be treated as simple rigorous fixed price mechanisms specifying what should be done when and at what cost. The evolvement of future production and technologies cannot be described in the contract upfront, as the industry volatility is not taken into consideration (Laffont and Tirole, 1999). In paper 3, we propose that incorporating incentive-based contracts should support projects to evolve positively, as the external and internal environment changes. We believe this will decrease the time to complete the project and increase profits for all actors. The actors' profits are interrelated and the incentive-based contract allows them to better understand each other's goals, motivations, and value drivers.

3.1.7 Summary of paper 4

Dynamic resource allocation with self-interested agents in the upstream oil and gas industry

The first paper outlines the methodology of a qualitative study and some findings. Further, paper 2 examines how selected companies in the oil and gas industry could use incentive-based contracts with risks and rewards to bring about competitive advantages and dynamic capability. Paper 3 analyzes the difference between fixed price and incentive-based contracts. In paper 4, I optimize the resource allocation between a principal and an agent, and between the involved agents. This optimization was designed to explore the benefit of implementing an incentive-based contract in the oil and gas industry. The examples were chosen based on interviews with key employees in the industry, where resource allocation was highlighted as a problem due to unsatisfying incentive models as outlined in papers 1 and 2. With the collection of field data, I managed to create a detailed description of the phenomenon. Based on the information gathered from the respondents, I managed to determine realistic parameter values for the model. The use of Excel solver gave me the opportunity to visualize graphically changes in resource allocation between agents, and how the on-boarding of new agents affected the other agents' preferences. The methodology was appropriate with respect to the problem, and I argue I manage to obtain innovative solutions with high value for both the industry as well as for academics. I have neither observed that any other paper has been written with the same scope, strengthening the innovation argument of the paper.

My main goal in the paper was to implement a participation constraint and incentive compatibility conditions so the parties would reveal their true preferences and information, and hereby optimize the resource allocation between the agents by use of an incentive-based contract with risk and rewards. As I implemented the participation constraint and the incentive compatibility, I also obtained information about how the involved parties valuate this network compared to outside options. Further, implementing the constraints will ultimately lead to better information sharing, closer cooperation and avoidance of goal conflicts due to inaccurate KPIs, creating values for all involved parties. I managed to verify the results as I triangulated the findings in paper 1, 2 and 3 positively. In addition, I received good feedback from both the industry and academics, where importance and relevance of the findings has been highlighted as exceptionally good.

Paper 4 dealt with opportunistic behavior involving a principal and several agents in the upstream oil and gas industry. The main two strategies to minimize opportunistic behavior are as follows (Ouchi, 1979):

- The measurement of the agents' efforts; and
- The reduction of goal conflicts between the involved parties.

The paper outlines how incomplete contract incentive implications affect the number of agents, and further how incentives related to quality can lower the number of agents (Bakos and Brynjolfsson, 1992). Bakos and Brynjolfsson (1992) also develop a model that optimizes the number of total suppliers. Further, they argue that there is an optimal combination between high coordination cost (transaction cost) when there are many agents, and the risk of been exposed to opportunistic behavior when there are few agents (Bakos and Brynjolfsson, 1992). Bakos & Brynjolfsson (1992) stated that when incentives focus on increased quality, the number of agents decreases. However, Bakos & Brynjolfsson (1992) did not take into consideration the involved agents' preferences. E.g. they analyze neither how the agents valuate the network compared to alternative outside options, nor the resource flow from the agents to the principal.

In paper 3, I argue that if the service provider has no outside options, it may choose to maximize its profits in the long term dependent on which contract is signed. If the service provider has unlimited outside options, it may choose to maximize its profits in the short term, which allows them to continue to the next project upon completion of the current one, and thus maximize profits across a succession of all the projects the service provider is participating on. In paper 3 it is argued that in the real world, the service provider finds itself between these two extremes, and may focus on both profit and profit per day. In paper 4, I argue, regardless of the number of outside options, the service provider will participate in one particular network as long as incentive compatibility exists. If not, they will not participate in the network. Therefore, I argue for the importance of incentive compatibility when an outside option exists. But, what if an outside option does not exist? Will incentive compatibility be superfluous? Hence, I argue that incentive compatibility will not be superfluous if no outside option exists. In an extreme situation, the agent will chose to do nothing rather than participating in a network where the incentives are lower than doing nothing. Hence, incentive compatibility is important in the network even when no outside options exist. Hereby, regardless of the number of alternatives or no alternatives, incentive compatibility is of high importance to secure participation by agents in the network.

The mechanism design theory is outlined in paper 4, as I wanted to analyze how the agents valuate the network compared to outside options and the resource flow from the agents. In the mechanism design theory, I address the decentralized optimization problem with self-interested agents in a situation where there is private information regarding their different outcomes and preferences. There I outline the mechanism design theory's purpose which is to reveal the true information (preferences) in an environment with asymmetric information and also assess how this information-revealing problem is a constraint in social decisions. Incentive compatibility and the revelation principle are found to be of high importance for good cooperation in the mechanism design literature. Further, the revelation principle argues for the value of designing a mechanism where the agent will give away his true information and preferences. When no agents find it advantageous to abort from the mechanism, there is an incentive compatibility situation. If one actor can increase its utility value without compromising other actors, there is a Pareto improvement. Further, in paper 4, I outlined how to secure incentive compatibility and participation on a drilling project in a principal–agent context with the outline of an incentive-based contract with risks and rewards and some additional constraints/"rules". The article’s main contribution is an optimization of resource allocation among four agents that is later extended to six agents. Hence, I analyze the relationship between deviation from the average number of sourced bundles among the agents and the possibility for one or more agents to become dominant. Further, I outlined and analyzed the importance of incentive-based contracts with risks and rewards in relation to the importance of incentive compatibility and participation constraints to regulate the relationship. In the model, I implement a social choice function and incentive compatibility in resource allocation among agents. Given the two constraints with respect to incentives and participation, the mechanism creates a revelation principle. This is evident because the agents will accept new volumes and pay-offs in the network when they optimize an alternative resource allocation, instead of choosing to leave for an alternative relationship.

3.1.8 Key contributions

The purpose of my model in paper 4 is to outline a mechanism to reveal true information (preferences) in an environment with asymmetric information, as this information revelation problem is a constraint for the network to evolve. To start with, I set up a mechanism where all the involved agents find it advantageous to reveal their true preferences. This is done by assigning constraints seen as "rules" related to incentive compatibility and participation. By using incentive-based contracts with risks and rewards, I can optimize the resource allocation between the agents. Further in paper 4, I argue that the agents will decrease their profit only marginally when the deviation between the agents' volumes of sourced items are at a minimum. At the same time, this will prevent one or more agents enjoying a dominant position and also reduce the potential risk of opportunistic behavior. I argue that I have shown a Pareto improvement because the players can increase their utility values without compromising the other actors. On the other hand, if the constraint is not involved, one or more agents can source the total amount of resources by themselves. This is because they can realize marginally increased profit in the short term. Hence, there is an incentive for the agent(s) to act opportunistically and again this can lead to lower profit for all involved parties in the end. This is also negative for the opportunistic agent(s), because opportunistic behavior will not benefit them either in the end.

The model is dynamic in the sense that it is possible to on-board and off-board agents. If some of the agents receive less volume to source after on-boarding new agents, they have to be compensated for their loss. The involved parties will reveal their true preferences and information as the network has incentive compatibility. The new agents' value contributions for the network need to be significantly higher than the old network's value, after those agents receiving less volume have been compensated for their loss. Otherwise, the network will not satisfy the requirement of the participation constraint. A consequence of conflicting the constraints is that the agent will value the network less because their social choice function creates an equilibrium that is negative for the agent. Hence, the agent will most probably leave the network since the participation constraint is conflicted due to lack of incentive compatibility. I consider the mechanism in paper 4 to be strong because it creates an equilibrium that is accepted by all agents after the on-boarding of the new agents. I argue that this solution is a Pareto optimal mechanism that solves the problem with private information, moral hazard and adverse selection between the involved parties. As an example, agent 4 in Table 10 in paper 4 needs to be compensated for its "loss" because it receives less volume than before. This will ensure it will favor the relationship instead of an outside option and still reveal its true information and preferences. If not compensated properly, it will leave the network or behave opportunistically. All involved parties will realize higher profit as a consequence of a resource allocation given the conditions and method outlined in paper 4 as it will lead to an attractive and more "democratic" allocation. The result is that the network will realize competitive advantage above other networks. As a consequence, the network will attract the best resources and further strengthen its position as a result of higher profit than the competitors network since the profit realized is shared by all involved. I argue, similarly to papers 1 and 2, for the importance of incentive-based contracts as a mechanism to realize better performance and value.

3.2 Mixed methods research – the balanced approach to research

The choice of research methodology depends on what kind of information a researcher is seeking for a particular subject matter. More specifically, the choice of research approach has to be determined by the research phenomenon and the nature of the research questions. The qualitative study methodology is suited in situations in which the phenomenon is new, dynamic or complex similar to the overall aim of this thesis. This enables the researcher to get a more "close up" view of the phenomenon in question. On the other hand, when a phenomenon has been rigorously described in the past, the quantitative methodology is often preferable. In these situations, the literature will provide necessary guidance to help discover gaps in the understanding about the phenomenon that need further attention, and also develop measurement methods for the research project (Golicic et al., 2005). Using a triangulation approach with different methodologies on the same phenomenon has given positive synergies worth highlighting. Different research methodologies create validation between each methodology if the same result emerges from studying the same phenomenon. For the present project, the mixed method gave the possibility to do a more balanced validation of the results, as the qualitative and the quantitative methods are utilized sequentially. It strengthens the findings to use a qualitative approach initially to formulate the research questions, ideas and scope, and subsequently define and use a quantitative approach based on the prior qualitative findings (Voss et al., 2002). This particular approach is highly valuable for the dissertation’s research questions.

3.3 The value of the results, and synergies

In the previous section (3.2), I argued for the value and necessity of a triangulation approach when using different research methodologies. In the following I will also argue for the value realized based on synergies between the findings after implementing an incentive-based contract with risk and reward. In papers 1 and 2, I argue that the most important focus area for value maximization in drilling projects, is to develop and use incentive-based contracts with risk and reward. Based on paper 3, I have illustrated how it is possible to reduce the operator's cost of monitoring, coordination, moral hazard, adverse selection, and also to reduce the operator's other costs (including catering, planning, administration of the onshore organization, overhead, insurance cost etc.). This is a direct consequence of implementing an incentive-based contract with risk and rewards. Another consequence of the incentive-based contract can be derived from paper 4, where I outline how both the operator and the involved service providers can realize additional value when implementing an incentive-based contract with risk and rewards. Implementing additional constraints with respect to participation and incentive compatibility to the incentive-based contract will lead the mechanism to realize optimal resource allocation between the involved parties and thus avoiding that the participants are acting opportunistically. The key argument throughout all the papers is that implementing an incentive-based contract with risk and rewards affects these operations positively. The synergies and added value of implementing an incentive-based contract with risk and rewards are in my view convincing, and I argue for the development and implementation of this particular contract format as it increases value in other areas for all involved parties. In Figure 15, it is depicted how the findings from the papers relate and create synergies between each other.

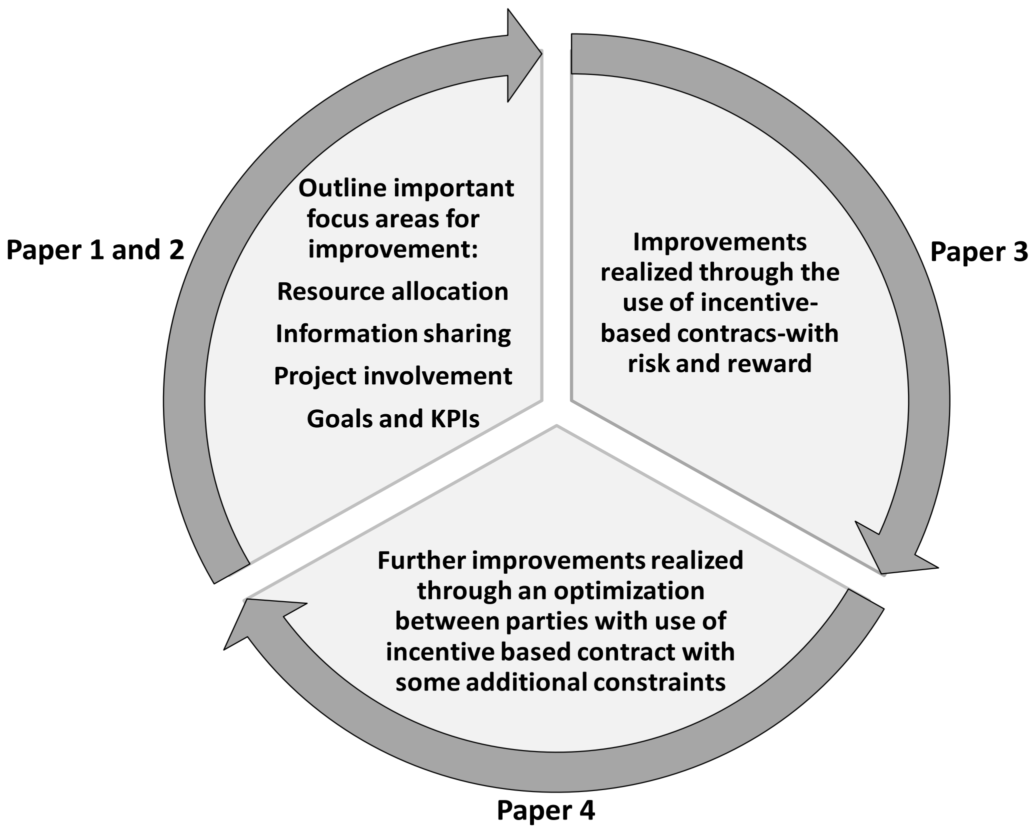

Figure 15 – The papers results, their relationship, and their contribution to synergies

In Figure 15, I illustrate how papers 1 and 2 outline the key factors for realizing higher benefits in the drilling environment. In paper 3, I develop an incentive-based contract with risk and reward, and a fixed price contract, and argue for the increased value of implementing the first contract type. In paper 4 the value increases further by adding some additional constraints to the mechanism. Seen separately, the papers' findings suggests increased value, but the value created by handling problems from different angles is substantial. Not only do they verify each other, they also make synergies between the results. For example, paper 3 clearly shows the extra value realized by implementing an incentive-based contract with risk and rewards with respect to the findings outlined in papers 1 and 2, compared to implementing a fixed price contract. Also, in paper 4 I argue for the more value realized if one fulfill the incentive compatibility condition and the participation constraints. The value is realized if those conditions are implemented in an incentive-based risk and reward contract as outlined in paper 3. As I fulfill the constraints outlined in paper 4, the mechanism also affects the findings in papers 1 and 2 positively. Consequently, it is argued that more value is realized through better resource allocation as well as by sharing information more openly as the total value created on the project is divided amongst everyone involved. Even further, better defined and use of KPIs will give better goal congruence between the involved parties, and in addition, they will collaborate closer.

3.4 The papers' contribution to the dissertation

The findings from the papers is more rigorously discussed in part II and also summarized in section 3.1. In this section, I want to give a more compact description of the key results arising from each paper and also how they contribute to the final results and ultimately form a totality in this dissertation. In order to do so, I outline a model below based on model 10 in section 3.1. In figure 16 and in the following I describe the key contribution from each paper and their results.

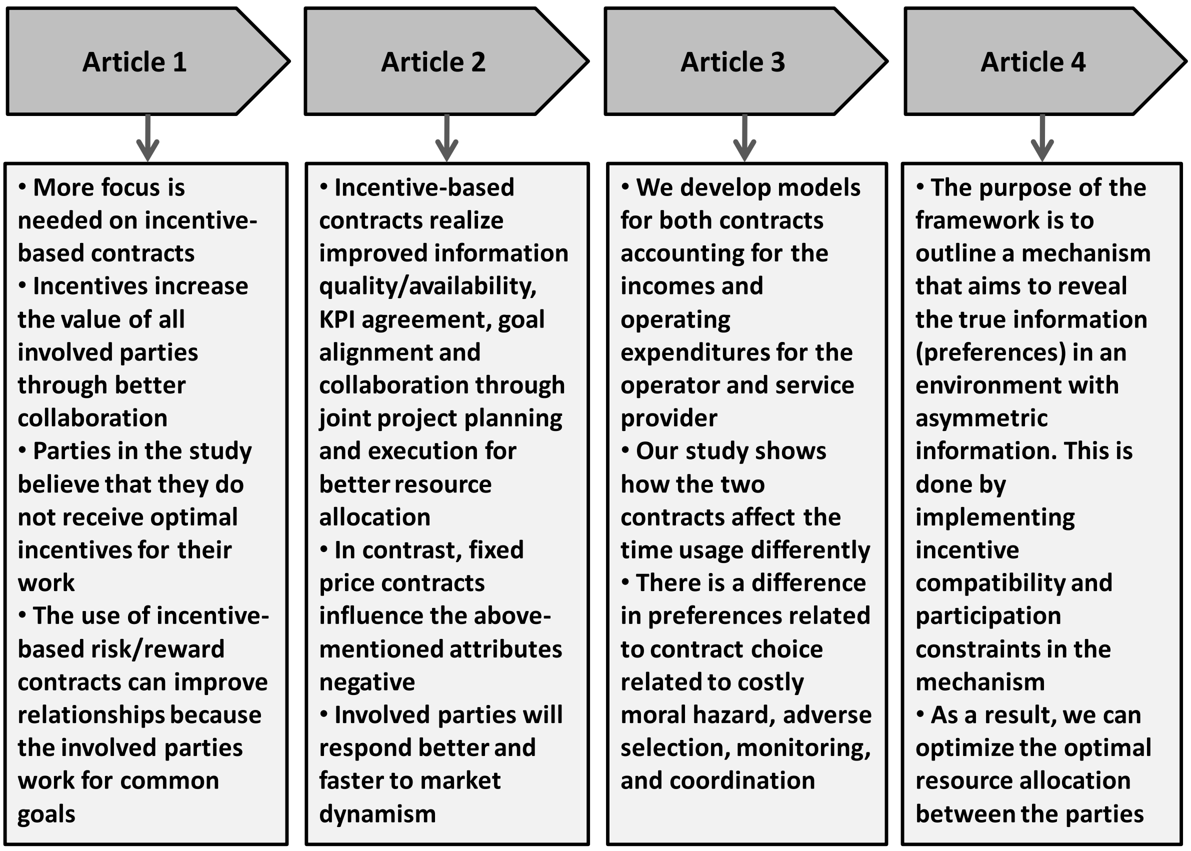

Figure 16 – The papers' results and their contribution to the dissertation

3.4.1 Answering the research questions

The overall aim has been to examine contract development in inter-organizational relationships in the oil and gas industry. The main purpose has been to provide new insights into the interaction of an operator and its service providers within drilling processes and incentive modeling.

What are the most important issues relating to inter-organizational relationships in the oil and gas industry? In paper 1, I outline a case study and the findings related to incentive-based contracts versus fixed price contracts. Crudely summarized, the respondents in the study agree that incentive-based contracts are important for realizing more value in the integrated operations environment. This finding highlights the importance of incentive-based contracts. Incentive-based contracts with risks and rewards between operating companies and service providers have not been a priority on the integrated operations agenda of the NCS. In the study it is further argued for goal alignment, and one way to align goals is through incentive-based contracts. This theme is followed in paper 2, where I describe some additional findings. The lack of incentive-based contracts was highlighted as the single most important issue and was cited as a constraint for increased value realization. Such contracts are considered necessary to achieve the other four findings, which were intertwined. A typical example is the lack of involvement of some organizations in project planning. This deprived those organizations of the information they needed to make optimal decisions in the project execution phase. This also created goal conflicts due to inaccurate KPIs that led to opportunistic behavior from both sides because there were no incentives to work towards the same goals. The involved parties' unwillingness to share information was also highlighted as a problem.

What is the optimal choice of contract and how does it affect the realization of value for the involved parties in an inter-organizational setting under given parameters value? In paper 3, I model the use of an incentive-based contract with risk and reward versus fixed price contracts. Through this study I manage to answer what constitutes the optimal choice contract under given parameters value, and also how this affect value creation for the involved parties. Importantly, incentive-based contracts remove many of the costs common to fixed price contracts, especially related to moral hazard and adverse selection. Monitoring, coordination and various other costs also decrease. Agreement on goals and KPIs, and the involvement of both actors in planning, may lead to better resource allocation. The drilling process involves balancing quality against time. Whereas a fixed price contract has a strong focus on time, an incentive-based contract has the potential to account for the complex relationship between quality and time by linking incentives to performance. Both the operator and the service providers agree that the incentive-based contract is to be preferred compared to the fixed price contract. There are situations where the operator prefers the fixed price contract but not the service provider, or otherwise. This is because either the operator or the service provider has to bear the burden related to moral hazard, adverse selection, monitoring, coordination and various other costs. Implementing an incentive-based contract with risk and reward will reduce this burden, and should be preferred.

What is the optimal mechanism to regulate resource allocation between the principal and involved agents (and between agents) in an inter-organizational setting given some additional constraints to regulate the relationship? In paper 4, I outlined a mechanism that addresses the decentralized optimization problem with self-interested agents where there is private information regarding their different outcomes and preferences. The purpose of the paper is to identify the best mechanism to regulate the resource allocation between the involved agents in an inter-organizational setting. I managed through the mechanism design theory to reveal the true information (preferences) in an environment with asymmetric information and assess how this information-revealing problem is a constraint to social decisions. Further, I optimize the resource allocation between the agents by involving incentive compatibility and participation constraint conditions implemented in an incentive-based contract with risks and rewards. It is argued that a resource allocation, given these conditions and method, will lead to an attractive and more "democratic" allocation that ultimately leads to higher profits for all involved parties. As a consequence, the network will gain a competitive advantage over other networks. Further, the network will, as a result of its higher profit, attract the best resources and further strengthen its position. I argue this mechanism outlined in paper 4 is optimal as it creates a Pareto improvement for the parties.

4. FUTURE RESEARCH

In this section I will provide recommendations for future research. This thesis sought to deliver new insights into the existing literature with respect to the role of incentive theory in the inter-organizational relationship and supply chain management literature for the upstream oil and gas industry. This highlights the differences between fixed price contracts, common in the oil and gas industry, and the uncommon incentive-based contracts. The results are important and do contribute in my understanding of inter-organizational relationship and the supply chain management literature, as they develop and analyze the importance of incentive-based contracts with risks and rewards. Still, it is argued for more research within these research domains related to incentive modeling, inter-organizational relationships and supply chain management.

Given the results in this thesis, I propose some possible research areas related to the research, and hopefully this may form the basis for future research. Admittedly, this is based on my perception of what might be interesting for future research related to the development and implementation of incentive-based contracts with risk and reward in the value chain. In doing so, I outline potential research areas that will be relevant after the incentive-based contract with risk and reward is implemented in the value chain by the involved parties.

In recent years, one of the major priority areas for integrated operations in the drilling area has been the development of new technology, and especially new information systems. It would be interesting to observe how existing information systems support or do not support the implementation of risk and reward mechanisms. Further, it would be interesting to observe if they support or do not support the organizational changes that such an implementation gives the involved actors' value chain. More specifically, what is the probability that existing information systems is adapted optimally and for the best possible flow of information for all the involved parties in the supply chain? Is it possible to assume that the information system is set up solely to ensure information access to one of the parties, e.g. the operator? If so, what about the supplier information access, which accounts for approximately 80% of the workload? If it is shown that the information system is set up to benefit the operator with information, how will the suppliers respond and act in the context of what we have derived previously in terms of opportunistic behavior? Furthermore, it would be interesting to study the importance of the information system in terms of the project's integrity, productivity, cost effectiveness, safety, etc.

It has been argued that integrated operations will generate huge benefits if a number of addressed issues are developed and implemented. Previous attempts to realize these gains have largely been the development of new technology, and to some extent the development of new work processes. The profit potential is estimated to be a formidable 300 BNOK through increased productivity, and it is estimated a potential of 24 BNOK by the reduction of costs (OLF, 2007). However, I would argue that it is not rigorously documented how these values should be realized, and this could form the basis for new research. It would be interesting to study exactly where in the supply chain the profitability occurs in drilling projects. A study focusing on the value chain and where the income is generated will be of great interest. Is it the operator or the supplier that generates the most value? What processes generate the most value, and are there any processes that do not generate any value at all? Could there be some parties who contribute with little or no value? Is there a fair reward-contribution balance for those who contribute a lot or with little value? Is a "fair" reward-contribution balance the best way to set incentives between the parties involved in a drilling project, (or should it discriminate/differentiate the reward)? If so, what is considered to be a "fair" reward-contribution balance? Furthermore, it could be interesting to study various practices in terms of the measurement of cash flow in drilling projects. How does the industry measure cash flow? Can the involved companies give any precise estimates as to how the cash flow evolves in the value chain? Furthermore, it would be interesting to see, e.g., how opportunistic behavior is quantified and further how opportunism evolves and change under the various contract formats. For example, we have previously argued that decisions taken on asymmetric information due to one party holding back information affects productivity and cost efficiency. How can one measure and quantify this? This would be interesting to study when a project evolves and change under the different contract formats during the project.

In the integrated operations literature it has been argued for the need for new technologies, new processes and new decision support systems (OLF, 2007). In my study, I argue for the need for new incentive models. However, it seems to be the case that there is not enough focuses on the organizational consequences of implementing the foregoing, and in particular new incentive models. It would be interesting to see more research related to how organizations have been influenced as a consequence of implementing incentive-based contracts in other industries. Will there be any need to adjust or change the existing organizational model, and if so, to what degree? How will the implementation of incentive-based contracts affect the organizational structures, relations between the parties, decision authority, decision-making procedures, etc? Lastly, it would be interesting to study how existing cultures, practices, history, etc. are affected and affect the implementation of incentive-based contracts.

REFERENCES

Alchian, A. A., & Demsetz, H. (1972). Production, information costs, and economic organization. *The American Economic Review, 62*(5), 777–795.

Amit, R., & Schoemaker, P. J. H. (1990). Key success factors: their foundation and application. *Unpublished working paper, University of British Colombia and University of Chicago*.

Amit, R., & Schoemaker, P. J. H. (1993). Strategic assets and organizational rent. *Strategic Management Journal, 14*, 33–46.

Andersen, G., Grøtan, T. O., Johansen, S. O., Rosness, R., Sivertsen, T., Steiro, T. et al. (2006). Samhandling over avstand – erfaringer av relevans for petroleumsbransjen. *risikoforsk.no,hmsforsk.no*

Anderson, P., & Tushman, M. L. (1990). Technological discontinuities and dominant design: a cyclical model of technological change. *Administrative Science Quarterly, 35*, 604–633.

Arrow, K. J. (1963). *Social choice and individual values* (2nd ed.). New York: John Wiley & Sons, Inc.

Bachmann, R. (2001). Trust, power and control in trans-organizational relations. *Organization Studies, 22*, 337–365.

Bakos, J. Y., & Brynjolfsson, E. (1992). Why information technology hasn't increased the optimal number of suppliers. *Unpublished Working paper. Sloan School of Management*.

Barney, J. B. (1991). Firm resources and sustained competitive advantage. *Journal of Management, 17*(1), 99-120.

Barney, J. B. (2002). *Gaining and sustaining competitive advantage*. Upper Saddle River.

Barney, J. B., & Hesterly, W. S. (1996). Organizational economics: understanding the relationship between organizations and economic analysis. In S. R. Clegg, C. Hardy & W. R. Nord (Eds.), *Handbook of Organization Studies* (pp. 115–147). Thousand Oaks, CA: Sage Publications Ltd.

Bradach, J. L., & Eccles, R. G. (1989). Price, authority and trust: from ideal types to plural forms. *Annual Review of Sociology, 15*, 97–118.

Brown, S. L., & Eisenhardt, K. M. (1997). The art of continuous change: linking complexity theory and time-paced evolution in relentlessly shifting organizations. *Administrative Science Quarterly, 42*, 1–34.

Clark, K. B., & Fujimoto, T. (1991). *Product development performance: strategy, organization, and management in the world auto industry*. Boston, MA: Harvard Business School Press.

Coase, R. (1938). The nature of the firm. *Economica, 4*, 386–405.

Dasgupta, P., Hammond, P., & Maskin, E. (1979). The implementation of social choice rules: some general results on incentive compatibility. *The Review of Economic Studies Ltd, 46*(2), 185–216.

Davis, J. P., Eisenhardt, K. M., & Bingham, C. B. (2006). How do firms manage technology collaborations?. *Working paper*, Stanford University, Stanford, CA.

Davis, J. P., Eisenhardt, K.. M., & Bingham, C. B. (2007a). Complexity theory, market dynamism, and the strategy of simple rules. *Working paper*, Stanford Technology Ventures Program, Stanford University, Stanford, CA.

Davis, J. P., Eisenhardt, K. M., & Bingham, C. B. (2007b). Developing theory through simulation methods. *Academy of Management Review*, *32*(2), 580-599

Day, R. A., & Gastel, B. (2006). *How to write and publish a scientific paper*. Cambridge: Cambridge University Press.

Economist Intelligence Unit (2010), Resilient supply chains in a time of uncertainty, *The Economist*, 1–15.

Eisenhardt, K. M. (1989a). Agency theory: an assessment and review. *The Academy of Management Review, 14*(1), 57–74.

Eisenhardt, K. M. (1989c). Building theories from case study research. *Academy of Management Review, 14*, 532–550.

Eisenhardt, K. M. (1985). Control: Organizational and economic approaches. *Management science,* 31(2), 134–149

Eisenhardt, K. M. (1989b). Making fast strategic decisions in high-velocity environments. *Academy of Management, 32*(3), 543–576.

Eisenhardt, K. M., & Martin, J. A. (2000). Dynamic capabilities: what are they? *Strategic Management Journal, 21*, 1105–1121.

Emhjellen, M., Hausken, K., & Osmundsen, P. (2006). The choice of strategic core-impact of financial volume. *International Journal of Global Energy Issues, 26*(1/2), 136–158.

Eriksen, E., Auseth, J. M., Tømte, Ø., Freeman, I. M., & Jahren, J. (2006). *Oilinfo news* (Vol. Edition no 2).

Fama, E. F. (1980). Agency problems and the theory of the firm. *The Journal of Political Economy*, Vol. 88, No. 2, 288-307.

Gimenez, C. (2005). Case studies and surveys in supply chain management research-Two complementary methodologies. In H. Kotzab, S. Seuring, M. Müller & G. Reiner (Eds.), *Research methodologies in supply chain management* (pp. 315–330). Heidelberg: Physica-Verlag.

Golden, P. A., & Dollinger, M. (1993). Cooperative alliances and competitive strategies in small manufacturing firms. . *Entrepreneurship: Theory and Practice, 17*, 43–56.

Golicic, S. L., Davis, D. F., & McCarthy, T. M. (2005). A balanced approach to research. In H. Kotzab, S. Seuring, M. Müller & G. Reiner (Eds.), *Research methodologies in supply chain management* (pp. 315–330). Heidelberg: Physica-Verlag.

Grant, R. M. (1991). The resource-based theory of competitive advantage. *California Management Review, 33*(3), 114–135.

Grossman, S. J., & Hart, O. D. (1983). An analysis of the principal–agent problem. *Econometrica, 51*(1), 7–45.

Grossman, S. J., & Hart, O. D. (1986). The costs and benefits of ownership: a theory of vertical and lateral integration. *The Journal of Political Economy, 94*(4), 691–719.

Gulati, R. (1998). Alliances and networks. *Strategic Management Journal, 19*, 293–317.

Haragadon, A., & Sutton, R. I. (1997). Technology brokering and innovation in a product development firm. *Administrative Science Quarterly, 42*(4), 716–749.

Hart, O. D., & Moore, J. (1988). Incomplete contracts and renegotiation. *Econometrica, 56*(4), 755–785.

Hedstrom, P., & Swedberg, R. (1998) *Social mechanisms*. Cambridge: Cambridge University Press.

Holmstrøm, B., & Milgrom, P. (1994). The firm as an incentive system. *The American Economic Review, 84*(4), 972–989.

Håkansson, H. (1982). *International marketing and purchasing of industrial goods–an interaction approach*. Hampshire: John Wiley & Sons.

Håkansson, H. (1987). *Industrial technological development – a network approach*. London.

Håkansson, H., & Johanson, J. (1993). The network as a governance structure. *The embedded firm*, 35–51.

Jeffry H. Dyer (1997). Effective interfirm collaboration: How firms minimize transaction costs and maximize transaction value. *Strategic Management Journal*, 18(7), 535–556

Jensen, M., & Meckling, W. (1976). Theory of the firm: managerial behavior, agency costs, and ownership structure. *Journal of Financial Economics, 3*, 305–360.

Jensen, M. (1983). Organization theory and methodology. *The Accounting Review, 58*(2), 319–339.

Johanson, J., & Mattsson, L.-G. (1987). Interorganizational relations in industrial systems – a network approach compared with the transaction cost approach. *International Studies of Management and Organization, 1*(17), 34–48.

Klein, B., Crawford, R. G., & Alchian, A. A. (1978). Vertical integration, appropriable rents, and the competitive contracting process. *Journal of Law and Economics, 21*, 297–326.

Laffont, L., & Tirole, J. (1999). *A theory of incentives in procurement and regulation*. Cambridge, MA: MIT Press.

Lee, H. L. (2004). The triple-A supply chain, the 21st-century supply chain. *Harvard Business Review, 82*(10), 102−112.

Lunnan, R., & Haugland, S. A. (1996). Core competencies in a network organization. *Falkenberg & Haugland: Rethinking the Boundaries of Strategy. Bergen. Eds. Handelshoyskolens forlag*.

Macneil, I. R. (1980). The new social contract. *New Haven: Yale University Press*, 9.

Mas-Colell, A., Whinston, M. D., & Green, J. R. (1995). *Microeconomic theory*. Oxford, NY: Oxford University Press.

Milgrom, P., & Roberts, J. (1992). *Economics, organization and management*. London: Prentice-Hall.

Myerson, R. B. (1981). Optimal auction design. *Mathematics of Operations Research, 6*(1), 58–73.

Narayanan, V. G. & Raman, A., (2004), Aligning incentives in supply chains, the 21st-century supply chain. Harvard Business Review, 82(11), 94−102.

OLF (2006). Potential value of integrated operations on the Norwegian Shelf. 31.

OLF (2007). Oppdatert verdipotensiale for Integrerte Operasjoner på norsk sokkel.

Osmundsen, P., Sørnes, T., & Toft, A. (2008). Drilling contracts and incentives. *Energy Policy*, 3127–3134.

Osmundsen, P., Toft, A., & Dragvik, K. A. (2005). Design of drilling contracts–economic incentives and safety issues. *Energy Policy, 34*(15), 2324–2329.

Ouchi, W. G. (1979). A conceptual framework for the design of organizational control mechanism. *Management Science, 25*, 833–848.

Penrose, E. T. (1959). *The theory of the growth of the firm*. Oxford: Basil Blackwell.

Peteraf, M. A. (1993). The cornerstones of competitive advantage: a resource-based view. *Strategic Management Journal, 14*(3), 179–191.

Porter, M. E. (1980). *Competitive strategy*. New York: Free Press.

Prahaland, C. K., & Hamel, G. (1990). The core competence of the corporation. In B. de Wit & R. Meyer (1994): *Strategy: process, content, context* (pp. 290–301). West Publishing Company.

Ring, P. S., & Van de ven, A. H. (1994). Developmental process of cooperative interorganizational relationships. *Academy of Management Review, 19*(1), 90–118.

Rugman, A., & Verbeke, A. (2002). Edith Penrose's contribution to the resource-based view of strategic management. *Strategic Management Journal, 23*, 769–780.

Salanié, B. (1998). *The economic of contracts*. Cambridge: MIT Press.

Samuelson, P. A. (1984). Second thoughts on analytical income comparisons. *The Economic Journal, 94*(374), 267–278.

Yossi, S. (2005). Building a resilient supply chain, supply chain strategy. *Harvard Business Review, 83*(8) 1–4.

Yossi, S. (2007). Building a resilient organization*, The Bridge – the journal of the National Academy of Science***,** 37 (1): 30-36.

Yossi, S. (2009). Business continuity: a systematic approach. *Global Business and the Terrorist Threat*. Ed. Harry W. Richardson, Peter Gordon, and James E. Moore II, UK: Edward Elgar Publishing Limited, 32-41.

Simon, H. (1947). *Administrative behavior*. New York: MacMillan.

Sine, W. D., Mitusuhashi, H., & Kirsch, D. A. (2006). Revisiting Burns and Stalker: formal structure and new venture performance in emerging economic sectors. *Academy of Management Journal, 49*(1), 13.

Skjøtt-Larsen, T. (1999). Interorganisational relations from a supply chain management point of view. *Logistik Management, 1*(1), 96–108.

Smith, K. G., Carroll, S. J., & Ashford, S. J. (1995). Intra-and interorganizational cooperation: towards a research agenda. *Academy of Management Journal, 38*, 7–23.

Stuart, I., Mc Cutcheon, D., Handfield, R., McLachlin R., Samson, D. (2002). Effective case research in operations management: A process perspective. *Journal of Operations Management, 20*(5): 419–433.

Teece, D. J., Pisano, G., & Shuen, A. (1997). Dynamic capabilities and strategic management. *Strategic Management Journal, 18*, 143–161.

The Research Council of Norway (2000). Quality in Norwegian research – an overview of terms, methods and means.

The United Nations Convention on the Law of the Sea (1982). *The United Nations Convention on the Law of the Sea*.

Tirole, J. (1999). Incomplete contracts: where do we stand? *Econometrica, 67*, 741–781.

Voss, C., Tsikriktsis, N., Frohlich, M. (2002) Case research in operations management research, *International Journal of Operations & Production Management, 22*(2), 195–219

Wernerfelt, B. (1984). A resource-based view of the firm. *Strategic Management Journal, 5*, 171–180.

Williamson, O. E. (1975). *Markets and hierarchies: analysis and antitrust implications: a study in the economics of internal organization*. New York: Free Press.

Williamson, O. E. (1985). *The economic institutions of capitalism. firms, markets, relational contracting.* New York.

Williamson, O. E. (1996). *The mechanisms of governance*. Oxford.

Williamson, O. E. (2008). Outsourcing: transaction cost economics and supply chain management, *Journal of Supply Chain Management*, *44*(2), 5–16.

Yin, R. K. (2003). *Case study research design and methods* (Third ed.). California: Sage Publications.

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Accepted for publication in the Journal of Operations and Supply Chain Management (JOSCM), *3*(2), 78-97.

Part II

Paper I

Integrated Operations: How Effective is the Current Relationship between Operating Companies and Suppliers?

Knut A. Sund & Reidar B. Bratvold

Proceedings of SPE Intelligent Energy Conference and Exhibition, Amsterdam, The Netherlands, 25–27 February 2008.

In the following paper, we outline the oil and gas industry and their interest in adopting incentive-based contracts with risk/reward sharing in a drilling project. As the paper involves a case study, we outline the study design, implementation, data collection and analyses. We interviewed 27 respondents participating in the study where we studied one large operator and some of its largest suppliers within drilling. Then, we analyzed the study results, starting with the study's attributes. We discuss the disconnection between operators and suppliers with respect to contractual issues. Further, the results of using incentive-based contracts are illustrated and possible improvements discussed.

The following words will occur in the paper

- *Incentives*
  Incentives are any factors that enables or motivates a particular course of action. It also functions as a motivator for ones choice of action (Milgrom & Roberts, 1992).

- *Inter-organizational relationship*
  Inter-organizational relationship is a collaboration between several organizations instead of within one organization (i.e. intra-organizational relationship) (Håkansson, 1982).

- *Integrated operations*
  Integrated operations are "the use of information technology to change work processes to reach better decisions, remote-control of equipment and processes, and to move functions and personnel from offshore to onshore" (OLF, 2006).

Paper II

Developing New Resources:
How to Gain Dynamic Capabilities and Competitive Advantages from Integrated Operations in the Upstream Oil and Gas Industry

Knut A. Sund

Proceedings of The Third Annual Meeting of Smart Fields Consortium, Stanford University, California, USA 29-30 April 2008.

In the following paper, I outline how different companies in the oil and gas industry could use incentive-based contracts with risks and rewards with the aim of realizing competitive advantages and dynamic capability. I start with an outline of the Resource Based View theory and the dynamic capability approach. Then, I describe how information is obtained through the use of an embedded multiple case study focusing on the inter-organizational relationships in an integrated operations context. Further, I outline the case study findings and relate the findings to competitive advantages and dynamic capability. The paper also relates the different contract formats to net present value, profit, CAPEX, OPEX and ROI.

The following words will occur in the paper

- *Fixed price contract*
  A contract format with few incentives related to operations. In a fixed-price contract the amount of payment is not related to the resources or time expended (Holmstrøm & Milgrom, 1994).

- *Incentive-based contract*
  The incentive-based contract makes compensation dependent on performance, and is a motivator for the agent not to behave opportunistic (Alchian & Demsetz, 1972; Jensen & Meckling, 1976).

- *Embedded multiple case study*
  Is a specific type of a case study recognized by containing multiple units of analysis. The study design also has the ability to combine different information sources such as interviews, documents, voice recording, presentations, interviews etc. (Yin, 2003).

Developing New Resources: How to Gain Dynamic Capabilities and Competitive Advantages from Integrated Operations in the Upstream Oil and Gas Industry

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ABSTRACT
In this paper, I examine inter-organizational relationships in the oil and gas industry related to integrated operations. I also try to create a linkage between resource-based view theory and dynamic capabilities. Further, I examine how selected companies in the oil and gas industry could use incentive-based contracts with risks and rewards to bring about competitive advantages and dynamic capability. This is gained through better project planning and execution, better information sharing, the avoidance of goal incongruence and wrong key performance indicators and the avoidance of suboptimal resource allocation. The abovementioned factors were found by using an embedded multiple case study focusing on the inter-organizational relationships among one large operator, three large service providers and several small service providers on the Norwegian Continental Shelf. I found that those factors give rise to barriers that are important to overcome if one should succeed in realizing dynamic capabilities and competitive advantages. I relate those barriers to resource-based view theory and dynamic capabilities and discuss how they can be overcome.

JEL codes: D21, D82, D86, L14
Keywords: Incentive-based contract, fixed price contract, embedded multiple case study, resource-based view

1. INTRODUCTION

Competitiveness derives from the ability to build core competences faster than one's competitors. The success factor is management's ability to consolidate technologies and production skills into competencies that enables the business to adapt faster to the volatility in the environment (Prahaland & Hamel, 1990). Productive companies often respond quickly to the market and conduct rapid and flexible product innovations because of management's capability to efficiently coordinate and redeploy internal and external competences (Teece, Pisano, & Shuen, 1997).

The strategic management literature shows that one of the most dominant approaches to staying competitive is the resource-based view of the firm (RBV)—the link between resources and core competence. RBV theory focuses on how an organization can combine its resources to gain a competitive advantage (Barney, 1991; Penrose, 1959; Teece et al., 1997; Wernerfelt, 1984). It is unclear *how* and *why* some organizations can adopt new resources and gain the full potential from them quickly, whereas others struggle to gain any benefit. How and why only some firms gain competitive advantages can be explained by the theory of dynamic capabilities. This theory refers to the capacity to develop (i) the competence to align the firm's competitive advantages with the changing business environment, (ii) strategic management when adapting, integrating and reconfiguring skills and resources and (iii) internal and external functional competences to match the requirements of a changing environment (Teece et al., 1997).

The goal of this paper is to address how selected companies in the oil and gas industry can obtain competitive advantages through dynamic capability. Further, this paper examines how selected companies in the oil and gas industry could use incentive-based contracts with risks and rewards to bring about competitive advantages and dynamic capability. This is gained through better project planning and execution, better information sharing, the avoidance of goal incongruence and wrong key performance indicators (KPIs) and the avoidance of suboptimal resource allocation. Those factors were found using an embedded multiple case study focusing on the inter-organizational relationships among one large operator, three large service providers and several small service providers on the Norwegian Continental Shelf (NCS),[1] in their attempts to bring about integrated operations[2]. Those factors create barriers that are important to overcome to realize dynamic capabilities and competitive advantages. I relate those barriers to RBV theory and dynamic capabilities and discuss how they can be overcome.

The paper is organized as follows. Section 2 introduce a theoretical background, section 3 outline the study design, implementation, data collection and analyses, section 4 outline the study findings, section 5 outline a discussion and conclusion, and at the end, section 6 provides acknowledgements.

2. THEORETICAL BACKGROUND

RBV

RBV is an economic theory to determine an organization's strategic resources (Barney, 1991; Peteraf, 1993; Teece et al., 1997; Wernerfelt, 1984). RBV theory focuses on an organization's competitive advantages that can be attributed to the application of its resources. Strategic resources are those that provide a company with a competitive advantage. To transform an organization into being highly competitive, its resources have to be heterogeneous and not perfectly mobile because this will provide a resource situation preferable to that of its competitors (Barney, 1991; Hoopes, Madsen, & Walker, 2003; Peteraf, 1993; Teece et al., 1997; Wernerfelt, 1984). A company's resources include all company-controlled assets, capabilities, organizational processes, firm attributes, information and knowledge that allow the implementation of strategies that increase efficiency and productivity (Wernerfelt, 1984).

The literature provides several explanations for characterizing and classifying resources. Rugman and Verbeke (2002) decomposed RBV theory into descriptive and normative components. The descriptive component focuses on specific characteristics of the resource profile for each organization and its processes at both an organization and industry level. This

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[1] The NCS is the continental shelf over which Norway exercises sovereign rights. Stretching 200 nautical miles from the Norwegian coast, its major parts are the shelves of the North Sea, Norwegian Sea and Barents Sea (The United Nations Convention on the Law of the Sea, 1982).

[2] Integrated operations has been defined as the use of information technology to change work processes to achieve improved decisions, remote control of processes and equipment, and movement of functions and personnel onshore (Ministry of Petroleum and Energy, 2003-2004).

emphasizes new resource combinations for the involved parties. The normative component is recognized through the following four characteristics, often called VRIN resources: Valuable—the resources must create value, Rare—they are difficult for others to adopt, Imperfectly imitable—they are difficult to duplicate, Non-substitutable—they are difficult to substitute (Barney, 1991; Peteraf, 1993; Rugman & Verbeke, 2002). Possessing VRIN resources can provide an organization with a sustainable competitive advantage if used to implement new value-creating strategies that cannot be easily duplicated by other organizations (Barney, 1991; Crook, Ketchen, Combs, & Todd, 2008; Peteraf, 1993; Wernerfelt, 1984).

Amit and Schoemaker (1993) distinguished between resources and capabilities. In contrast to Wernerfelt (1984), Barney (1991), Peteraf (1993), and Teece et al. (1997), they argued that resources are tradable and non-specific to the firm, whereas capabilities are firm-specific and used to utilize those resources available within the firm. Using resources in specific combinations that lower cost or increase productivity can provide the firm competitive advantages. Explaining an organization's advantages requires analyzing and understanding its competence related to its strategic core activities (Amit & Schoemaker, 1990; Amit & Schoemaker, 1993).

Resources have also been classified as physical (e.g., specialized equipment, geographical location, production facilities), human (e.g., expertise, knowledge, skills) and organizational (e.g., work process, planning, systems for better coordination) (Amit & Schoemaker, 1993; Barney, 1991; Peteraf, 1993; Rugman & Verbeke, 2002). To be considered strategic, a resource must be able to contribute to an organization's increased efficiency (Wernerfelt, 1984).

The term "resource" is often reserved for characteristics that enhance the organization's advantages and efficiency. Indeed, these are not gained from resources alone; they demand coordination between groups of resources. Capability is the capacity of a group of resources that has as its mission to accomplish specific activities. Capability can also mean an internal company-specific characteristic that enables it to coordinate and exploit its own resources (Barney, 2002; Grant, 1991). Capability is not acquiring resources, but coordinating between people and other resources. Capability cannot be easily brought, but must be gradually built up to increase competitive advantages (Teece et al., 1997).

The dynamic capability approach

Organizations often develop organization-specific capabilities and competences to respond to shifting markets (Penrose, 1959; Sine, Mitusuhashi, & Kirsch, 2006; Wernerfelt, 1984). "Dynamic capability" is different organizations' business processes, expansion paths and market positions. The dynamic capability approach tries to provide a framework that can include both conceptual and empirical knowledge (Barney, 1991; Penrose, 1959; Williamson, 1975, 1985).

<u>How to identify dynamic capability</u>

Dynamic capability are identifiable and involves specific routines (Eisenhardt & Martin, 2000). One example is the product development routine, where managers use their skills to create products and services to raise performance. Another example is strategic decision making, where managers combine their personal knowledge and background to make better decisions for the company (Clark & Fujimoto, 1991; Eisenhardt, 1989b).

Some industries have dynamic capability that brings about the gain and release of resources. This enables companies to renew and align their competitive advantages with the changing business environment. Dynamic capability also involves alliances and acquisition routines that bring new resources into the organizations from other companies (Haragadon & Sutton, 1997).

Dynamic capability and their relationships with market dynamism

Eisenhardt and Martin (2000) stated that the pattern of effective dynamic capability depends on market dynamism. Finding out how to adopt dynamic capability in different markets requires looking into the dynamics between markets and firms (Coase, 1938). Not all tasks can be organized internally in the organization, but may entail some kind of exchange with the market (Coase, 1938; Teece et al., 1997). Further, Barney (1986) stated that any assets that can be adopted in the market at a fixed price cannot be strategic.

Market dynamism has a large impact on dynamic capability, which are determined by the existing knowledge in a company. The sustainability of dynamic capability varies with the dynamics in the market. Dynamic capability seems to follow traditional routines in moderately dynamic markets, where change is often predictable and follows a linear path (Eisenhardt & Martin, 2000). If the industrial structure is relatively stable, the participating companies are often well known to each other. Dynamic capability in moderately dynamic markets is complicated and predictable and has analytical processes that rely on the knowledge already in the organization. Also, change evolves slowly (Eisenhardt & Martin, 2000).

In markets that are very dynamic or show “high velocity,” change becomes more nonlinear and less predictable. High velocity markets are recognized by frequently shifting boundaries between organizations, which complicates the identification of the most suitable business model. The whole industry structure becomes more unclear (Eisenhardt & Martin, 2000). In high velocity markets, the development of dynamic capability is a simple, iterative and experimental process. Dynamic capability are often developed through the development of the knowledge of a particular process, through simple boundaries and from rules that are prioritized according to the most important task (Eisenhardt & Martin, 2000).

To understand how organizational dynamics affect the adoption of new resources, one must examine what drives change in the environment and how this affects the need for new resources. This will have an impact on organizational dynamics. Technological changes in the environment often contribute greatly towards adopting new resources as a response to those changes to sustain or evolve new competitive advantages (Eisenhardt & Martin, 2000).

The goal of this paper is to address why and how selected companies in the oil and gas industry adopt competitive advantages through dynamic capability. This paper also presents an embedded multiple case study conducted with one large operator, three of its largest suppliers and several small service providers within the drilling segment. The study aims to understand the dynamics regulating the relationship on different levels in the involved organizations and relate it to RBV theory and dynamic capability. To understand the dynamics present, an embedded multiple case study is the preferred methodology (Eisenhardt, 1989a; Yin, 2003).

3. METHODOLOGY

Case study design and implementation

The case study extract data from several data sources. The study incorporate one operator/principal owning a petroleum license, three of its closest service providers/contractors (seen as agents), and some small service providers/contractors (also seen as agents). When gathering data at different levels in the organization and at its partners, an embedded multiple case study research design is preferable. This research design is appropriate for my study compared to the single case study, as it is considered to yield a wider, more comprehensive and more trustworthy model. This study design is also recommended because it gives a possibility to conduct parallel replication of an experiment (Yin, 2003). As my objective is to study inter-organizational relationships in the oil & gas industry, the embedded case study research design is preferable. The research design is favorable as it has an ability to highlight the importance and the knowledge of varying views that may occur between different parties (Hedstrom & Swedberg, 1998). When the relationship between the research context and the research interest is unclear, the embedded case study shows its strength as the methodology is considered to be effective for focusing on environments.

The interview guides involved both open-ended and possible follow-up questions. Therefore, I used two interview guides for the semi-structured interviews as I wanted to create one for the principal and one for the agents. In addition to the questions itself, it also involved an introduction, a case study proposal, focus, background and case study objectives. I rewrote some of the questions in the interview guide after I obtained better knowledge about the different companies preferences. I used a digital voice recorder on the interviews, as I found it practical. Within 24 hours after each interview, I subsequently forwarded the transcribed interview to the respondents and some of them provided voluntarily written feedback. Some interviews lasted up to 3.5 hours, but the average length of the interviews was 90 minutes.

Data collection

I conducted 27 qualitative interviews with a semi-structured interview guide containing 23 questions. I also obtained data from direct observations, archival records, and participant observations. I spent approximately six months of work to gather relevant information on the organizations before conducting the semi-structured interviews. The employees input were important for the success of the study, as I could better structure the interview guide. I also spent a number of days in the operator's work environment as I wanted to elicit informal information (e.g. information not obtained in formal interviews, printed presentations etc.). Through conversation with employees and observation of employees in their daily work and in their group meetings, I managed to gather valuable information for my case study. In addition, I was also invited to participate in a one-day training session for the onshore drilling centers employees, on an innovation seminar related to integrated operations, and on lunches, coffee breaks and other informal gatherings. As a consequence, I obtained valuable information for the study as I could interact in a more informal setting with employees. The information shared in this setting would not typically be shared in formal settings. As I collected information from a vast number of sources, the multiple data collection methodology was appropriate for the study (Eisenhardt, 1989c; Yin, 2003).

Table 1 – Information gathered from companies for use in the case study

Description of case data	Information source				
	Operator A	Service provider B	Service provider C	Service provider D	Service provider E[1]
High level semi-structured interviews	4	5	4	3	1
Low level semi-structured interviews	3	1	2	n.a.*	4
Meeting with key employees	12	1	4	1	n.a.
Work days on company's site	20	n.a.	n.a.	n.a.	n.a.
One-day ODC training session	1	n.a.	n.a.	n.a.	n.a.
Innovation seminar	1	n.a.	n.a.	n.a.	n.a.
Project reports from the company/companies	Several	Some	Some	n.a.	Some
Strategy reports from the company/companies	Several	One	n.a.	n.a.	Some
Other relevant information such as presentations, speeches, databases, observation of employees, meeting reports	Several	Some	Some	Some	Some

*An "n.a." entry indicates that I did not receive any information.

Data analysis

As the scope in my study aims at employee behavior in an inter-organizational setting and in different levels in the organizations, I found the embedded multiple case study design to be suitable. As I used this research design and the analysis was conducted at different levels in the organization, its collaborating partners and the industry at large, the study design gave me the possibility to conduct analysis on different levels in the organizations. I recognized this to be beneficial for my research having interviewed both personnel in leading positions and employees with no supervisory responsibility. Depicted in table 2, I address this as "high-level and "low-level" positions. It is challenging to define the strategy and best practice techniques when analyzing information from case studies as the methodology is not well defined in the literature. One strategy is to start with prioritizing why and what to analyze (Yin, 2003). All information from interviews, historical documents, and formal and informal meetings where coded and categorized through the computer software QSR NVivo7[2]. I managed to extract high value through the use of this software as I analyzed the usage of particular words and how frequently the words were repeated. As a consequence, the meanings and insights relevant for the study could be derived.

[1] Some interviews were conducted with service providers with small volumes and with long-term relationships with the operator. Their work is performed onsite at the operator, on the same tasks as carried out by the operator's employees. Those service providers are gathered under one column (column E).

[2] http://www.qsrinternational.com/products_nvivo.aspx.

Case study demographics

Table 2. Case study respondents' demographics

Demographic	Comments
Number of companies	One of the companies (operator A) is a large operator on the NCS, and three of them are some of its largest service providers (service providers B, C and D). In addition I summarized the findings from several small service providers (with a small volume for the operator) that are permanently at the operator's site (service providers in column E). See **TABLE 1**.
Number of respondents	A total of 27 respondents were interviewed. Seven were from the operator, six from service provider B, six from service provider C, three from service provider D and five from service provider E. See **TABLE 1**.
Position in the company	In the case study, I defined positions as "high level" or "low level." High level positions consisted of all supervisory positions. Low level positions involved operational tasks and no supervisory responsibility.

Companies	"High level" position	"Low level" position
Operator A	85.7%	14.3%
Service provider B	66.7%	33.3%
Service provider C	80%	20%
Service provider D	66.7%	33.3%
Service provider E	20%	80%

Demographic	Comments
Educational level	For the educational level of the respondents, I chose the following categories: high school/technical high school, college 1–3 years, and college 4–6 years (none of the respondents had more than six years of college).

Companies	High school/technical high school	College 1–3 years	College 4–6 years
Operator A	16.7%	33.3%	50%
Service provider B		50%	50%
Service provider C	100%		
Service provider D		100%	
Service provider E		100%	

Demographic	Comments
Work experience	For the work experience of the respondents, I chose the following categories: 1–10 years of experience, 11–20 years of experience, 21–30 years of experience and 31–40 years of experience.

Companies	1–10 years	11–20 years	21–30 years	31–40 years
Operator A	14.3%		71.4%	14.29%
Service provider B	33.3%	50%	16.7%	
Service provider C		20%	40%	40%
Service provider D		33.3%	66.7%	
Service provider E	40%	40%		20%

4. FINDINGS

The previous chapter noted that organizations need new resources to gain competitive advantages or to stay competitive in a changing environment. This chapter outlines the major findings from our case study. In chapter two, I argued that resources that were used in specific combinations that lower costs or increase productivity can provide organizations competitive advantages. It was also argued that for resources to create competitive advantages for organizations, groups of resources must be coordinated through inter-organizational collaboration. Some of our findings were explained by one of the directors at the operator and summarize much of the challenges. As observed, much of the challenges at the operator are much the same as outlined in the RBV and the dynamic capability approach:

> *If one should define value, one has to see the value between the involved parties, not from one angle. One has to have incentive alignment so all involved parties work for common goals. It could be different sources for value creation for the involved parties. One has to have a clear understanding on what is the common value and common ground for all the involved companies.*
>
> *Resource utilization gives conflicts between operators and service providers. Operators often ask for specific equipment that service companies can't deliver. Operators and service providers have to conduct planning between them. They also need to have better communication, and involved parties should not think only about themselves, but what increases value for all involved parties. What is important when collaborating is to understand each other's value drivers.*
>
> *-Director operator A*

How organizations can adopt resources to gain dynamic capability

In the theoretical discussion, dynamic capability refers to the capacity to develop competence to align the firm's competitive advantages with the changing business environment. The development of ICT related to integrated operations has led to better information quality and availability, and I argue that new resources can and should be involved to more efficiently exploit this information. This can be through the better bundling of the involved parties' resources because this could produce dynamic capabilities that permit the involved parties to jointly react better and faster. The study shows that it is hard for the involved parties to adapt to the increased volatility in the industry because of well-established culture and routines. Respondents cited problems in the development of existing competences to respond to market dynamism because there were no incentives for change.

Our case study found that in some circumstances the operator and involved service providers have different views regarding collaboration. Perhaps surprising was that they largely agreed on the largest challenges for collaboration. They also stated that it was important to exploit the possibility to gain dynamic capabilities through better resource allocation. Five areas were given the most attention by the participants and these are outlined in Figure 1.

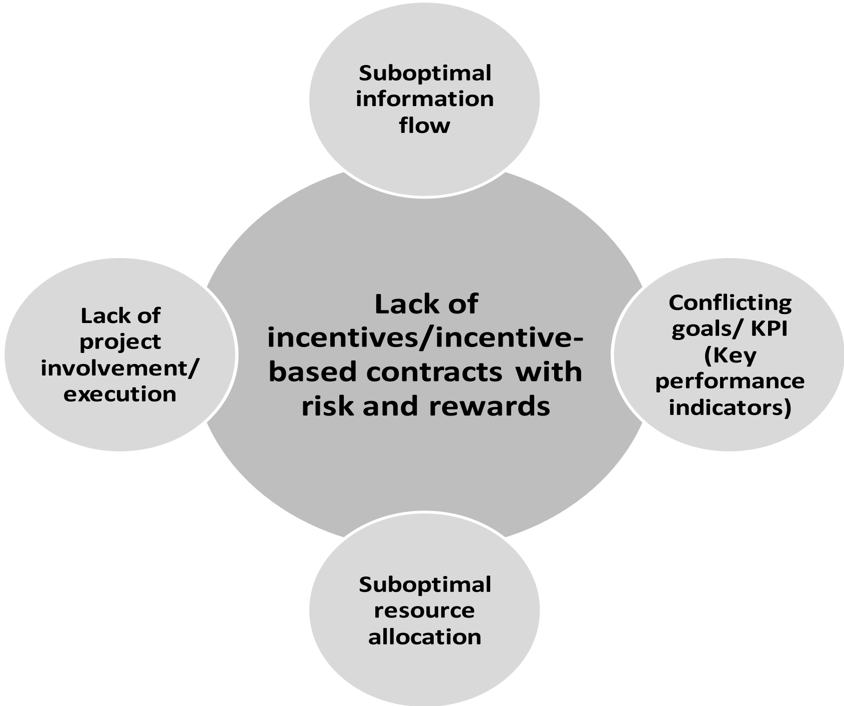

Figure 1 – Overview of the five most important findings in our study

These five findings were seen as crucial to realizing the value of integrated operations in the oil and gas industry through closer interactions between the involved companies. The lack of incentive-based contracts was cited as the single most important issue and affected negatively the other four factors. Such contracts are necessary to achieve the other four findings, which were intertwined. As an example, a lack of involvement in project planning deprived involved organizations of the information needed to make optimal decisions in the project execution phase, created goal conflicts in the phase because of inaccurate KPIs and led to opportunistic behavior from both sides because there were no incentives to work towards the same goals.

Lack of project involvement/execution

Some respondents at both the operator and the service providers stated that their value from collaborations would most probably increase if they could be involved earlier in projects, especially in the planning phase. Some respondents from one service provider reported that another operator has started to involve its service providers more actively in drilling projects, with good results, as stated by a middle manager in service provider B:

> *… Another operator has what they called ”collaborative well planning,” where they gather all the involved people on the projects on a 1-2 day meeting to plan the well in collaboration. At the meeting, KPIs are set jointly with common goals to work toward.*
>
> *-Middle manager, service provider B*

If this approach was adopted, operators and service providers could plan the project in collaboration, avoiding suboptimal or inappropriate KPIs that lead to goal conflict and suboptimal operations. The study reveals that this is an important challenge to overcome because goal conflicts towing to inaccurate KPIs that support only the operator’s performance lead the operator and the involved service providers working against each other.

Suboptimal resource allocation

As the dynamic capability approach outline the concept of "gain and release" of resources to respond to changing business environment, the study shows that the "gain and release" of resources aspect is problematic. The majority of respondents stated that the involved organizations need to start collaborating more effectively and use each other's core competences better. The involved companies could then better renew and align their competitive advantages with the changing business environment. If some tasks are not a part of the focal company's core competences and can be performed better by a service provider, it is beneficial to let involved service providers address that particular task.

This gain and release of resources is seen as highly valuable for realizing competitive advantages. The study shows that succeeding with this kind of inter-organizational collaboration requires allowing third parties to make independent decisions, because they are the closest to operations and have the best information. I found that the operator sometimes makes decisions (such what tools to use on drilling projects) without involving the service provider. One of the service providers stated that its recommendation was often ignored. They said that this had consequences for the service provider's performance and could also affect the operator in the long-term. The following response illustrates this issue:

> *... On a recent well operation on drilling rig N.N., we provided very strong recommendations up front and the potential consequences if they were not followed. Their being ignored resulted in a costly and totally unnecessary sidetrack on this well application. After the sidetrack occurred, we were partially held responsible, which is outrageous.*
>
> -Middle manager, service provider B

Suboptimal information flow

The study states that best practice knowledge transfer is important for all involved parties. "Integrated operations" is an information-intensive method of operating in the oil and gas industry. Real-time information is crucial to gaining optimal performance and is one of the major value drivers within integrated operations. The operator owns this information, and the involved service providers need to receive it daily to make the best possible decisions. The involved parties in the study, as mentioned earlier, differed greatly in their access to information from the operator. Some had system interfaces to extract the information they needed. Others could not obtain optimal information, stating that although they could always call their contact person (at the operator), they felt this would be an intrusion and might result in the information being received only after the decision had been made by the service provider. Respondents answered that information related to the project could be stored and systematized at the operator site, so that everyone involved could easily extract the relevant data. This increase in information quality and availability would increase decision quality. Further, they stated that it would be easier for third parties with a short assignment on the project to extract information on the actions completed, next steps and final goals. It was also stated that involved service providers need to communicate with each other. This is seen as difficult because the operator retains the traditional dynamics, which affects project performance. This was stated by a middle manager at service provider D:

> *... If we have a problem, it can take a long time to solve it. This is mainly because communication with other service providers goes through the operator. The operator is holding back information and we can't go directly to other service providers since we don't know them personally. It would be beneficial to go directly to the involved service providers, but then we need ownership to our processes.*
>
> *-Middle manager service provider D*

The result is that the service provider makes the decision based on asymmetric information, which will ultimately affect performance for the operator as well. It was further stated that the attitude of some key employees with responsibility in drilling projects was partially responsible because they hoard information to maintain the traditional dynamics between the operator and service providers. Some of the operator's middle managers were described as displaying this attitude, where they feel that the ownership of and primary investment in information, processes and technology warrant the operator withholding it from third party service providers. This was stated by one employee at service provider E:

When we work with the operator, we more or less never get the information we need to perform optimally. I have to ask every time I need information. The operator has the tools it needs to share the information, but they don't use them.
-Engineer, service provider E

This indicates a lack of well-defined responsibilities and clear communication, and it constitutes a problem for decision allocation and collaboration. This has long been a problem in the traditionally hierarchical oil and gas industry, with information flowing along strict organizational lines. Respondents revealed that the dynamics between operator and service providers has historically benefited operators because they have controlled the most important strategic assets (petroleum license, technology development, etc.).

Lack of incentives/incentive-based contracts and conflicting goals and KPIs

Respondents stated that the contract regulating the relationship has to change because service providers have assumed more of the technology development and responsibility for drilling operations. As a result, incentive-based contracts are needed to secure optimal performance from both sides, for despite the shift in roles the operator remains directly involved. Surprisingly, this was seen as suboptimal not only by service providers but by the operator as well. This was stated by one leader at operator A:

We (the operator) have traditionally had a lead role in the collaboration with the service providers. Historically this has not been a very good solution for this industry, and therefore we have operated sub-optimally. It's about time we give more responsibility to other involved service providers. It is important that they have the ownership of their own work processes. Often we directly interfere with their work and decide how it should be conducted. This is negative, because they become passive and that could affect operations as well as HSE. When we are interfering in their work, we take their responsibility, and this is the service provider's dilemma. This can lead to prolonged discussions and conflicts. The contract states one thing, but operationally one does something else…
-Leader, Operator A

The majority of the respondents think that the relationship requires a long-term focus to enable core competences to be built within the involved organizations as they jointly develop dynamic capability. This would provide the involved organizations with more sustainability and, as a consequence, the shared resources could create barriers for competitors (as they develop VRIN resources between them that are difficult to duplicate) and result in a competitive advantage. The study implies that one of the most important ways to increase the value of inter-organizational relationships is to adopt incentive-based contracts involving all parties.

The study also implies that fixed price contracts that are customary in the oil and gas industry do not support optimal operations and create goal conflicts between the involved parties. The operator often establishes predefined goals, hands over the KPIs to the service providers and expects them to have the best intentions to reach those goals. The service provider will try to optimize its own payoff by stretching the margins in the contract accordingly rather than optimizing the payoff for the whole supply chain.

In Figures 2 A and B, I have outlined how this is related to drilling time, although I later argue that it is relevant to other variables.

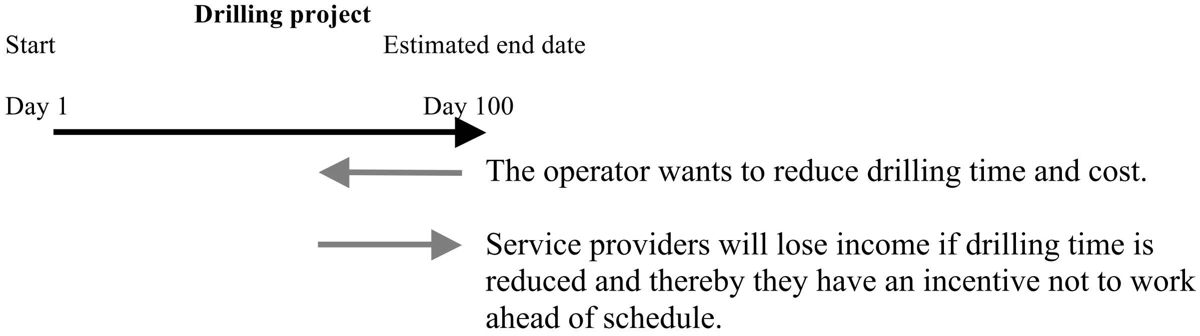

Figure 2 A: Conflicting goals between operators and service providers with fixed price contracts

If incentive-based contracts are used on drilling projects, the incentives would be shared based on participants' involvement (e.g., by percentage). Then, all involved parties would have an incentive to reduce drilling time. This will align the goals of all involved parties, as seen in Figure 2 B:

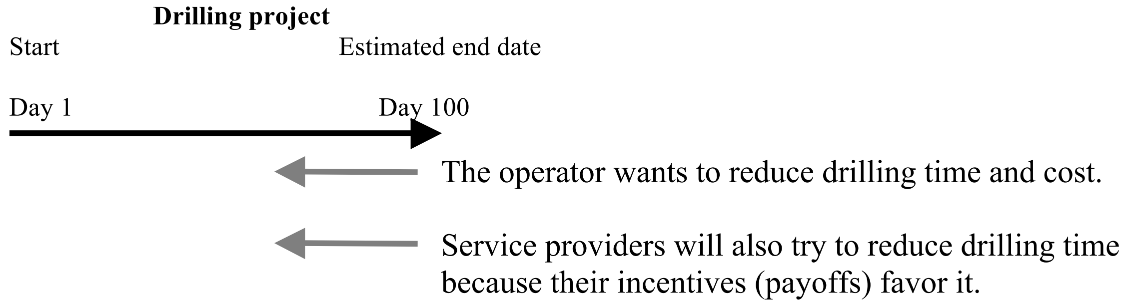

Figure 2 B: Goal alignment between operators and service providers with incentive-based contracts

Incentive-based contracts with risks and rewards would help improve efficiency and create a foundation for inter-organizational collaboration. The parties in the contract that have the lowest risk exposure assume most of the risk (Osmundsen & Olsen, 2005; Osmundsen, Toft, & Dragvik, 2005). Our study included service providers that are financially as strong as the operator and have no difficulty assuming risk. The risks and rewards should be shared between every involved party after their participation in project execution once the project has finished (a well is often accomplished in approximately 100 days). I argue this will better align the involved parties' goals and lead to increased productivity through the bundling of the involved participants' resources because they can thereby utilize each other's core competences. Implementing incentive-based contracts has earlier been argued to increase operational results by reducing moral hazard, adverse selection and the alignment of the involved parties' goals (Laffont & Tirole, 1999; Salanié, 1998).

Figures 2 A and B outlined the consequences of the use of incentive-based and fixed price contracts related to drilling time and goal conflicts. Hence, in addition to drilling time, I argue that our findings (i.e., resource allocation, increased information availability and quality, goal conflicts/conflicting KPIs and improved project planning and execution) could be positively affected by the use of incentive-based contracts. As a consequence of increased productivity, I argue that the HSE level will get affected, not because of strict guidelines and the formalization of work processes, but as a positive side effect of involved parties being more adaptive and responding faster and better to unexpected events because of better information flow and closer collaboration in the value chain. First-time quality will be the overall goal for the involved parties, positively affecting HSE, productivity and cost efficiency.

5. DISCUSSION AND CONCLUSION

Inter-organizational relationships in the oil and gas industry have a huge impact on value creation from integrated operations. Our study reveals that there are five main challenges before realizing the full potential of such relationships.

The service providers on the NCS are mostly regulated through a fixed price contract. A fixed price contract could provide an incentive for the agent not to perform optimally since its compensation could be the same regardless of the results (Eisenhardt, 1985). When an agent lacks incentives to perform optimally, it can be more efficient to replace a fixed price contract with an incentive-based contract affecting the agent's profit. This contract format compensates for actual performance, and is a motivator for the agent's not to behave with moral hazard and adverse selection (Alchian & Demsetz, 1972; Jensen & Meckling, 1976). This contract format is rare and does not occur very often on the NCS.

Laffont & Tirole (1999) and Williamson (1985) argued that the fixed price contract does not increase the companies' adaptability. Similarly, I argued in section 2 for the importance of organizations to renew and align their competitive advantages with the changing business environment. In our study, I find that the fixed price contracts do not support optimal operations and create goal conflicts between the involved parties, and as a result affects the companies' adaptability negatively. An example is that the service provider will try to optimize its own payoff by stretching the margins in the contract accordingly rather than optimizing the payoff for the whole supply chain. This kind of opportunistic behavior can be reduced with implementation of an incentive-based contract with risk and rewards, as this can increase the outcome for all involved parties (Salanié 1998; Tirole 1999). Grossman & Hart (1986) argues that this kind of contract can avoid goal incongruence, similar to our findings in the study.

In Figure 3, I outline how different contract types positively or negatively affect dynamic capability, competitive advantages and financial performance related to market dynamics, RBV theory and the five findings in our study.

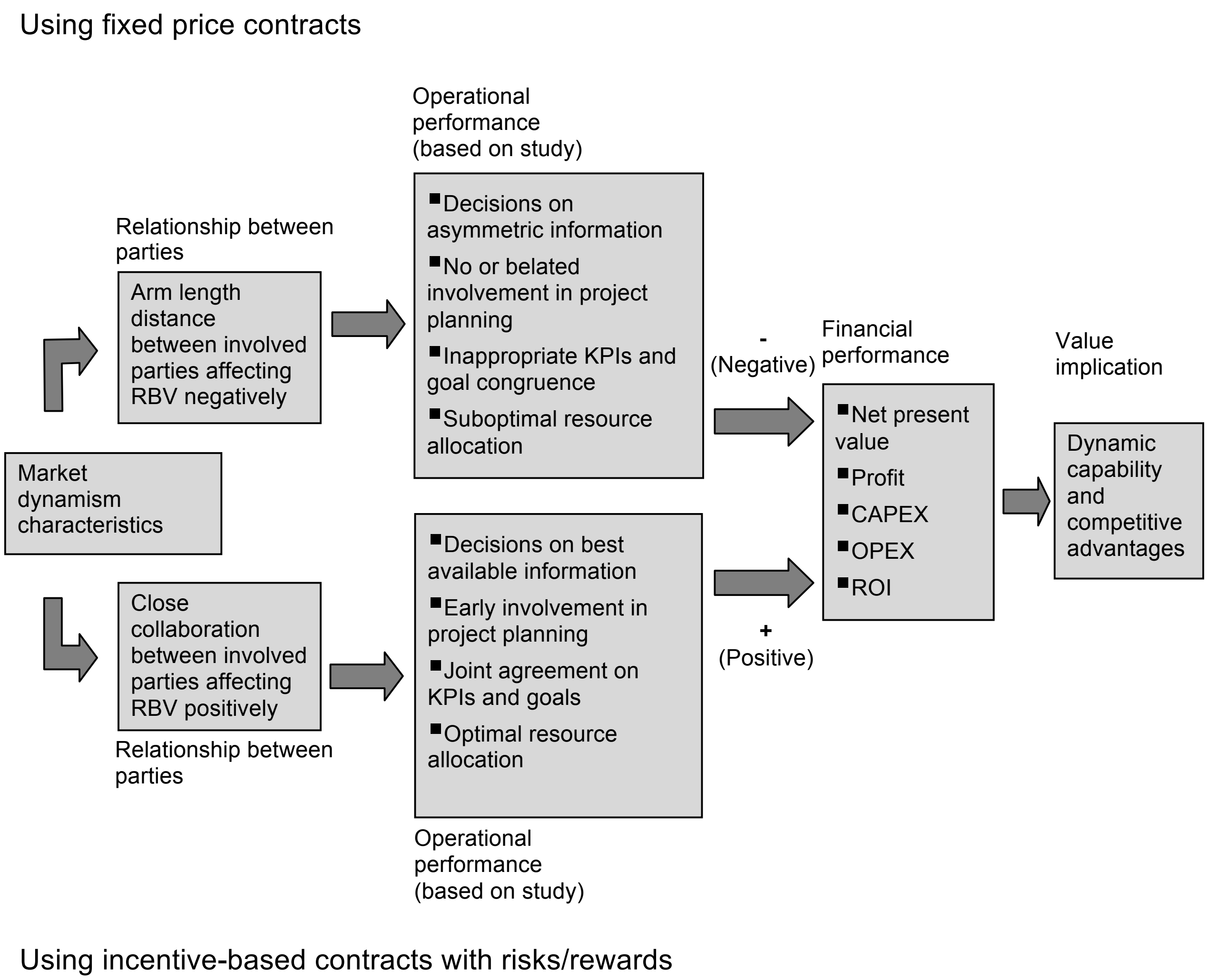

Figure 3 – The relationship between different contract types and operational and financial performance and implied value.

Figure 3 outlines how incentive-based contracts create value by improving information quality and availability, KPI agreement, goal alignment and collaboration through joint project planning and execution because those factors lead to better resource allocation. Further, implementing an incentive-based contract will lead the involved parties to respond better and faster to market dynamism. By contrast, fixed price contracts influence the abovementioned attributes in a negative way. A consequence of implementing an incentive-based contract is that it will lead to better financial performance due to increased operational results (Laffont & Tirole, 1999; Milgrom & Roberts, 1992). Our study proves that it is important to build an efficient mechanism that ensures that companies will avoid the challenges outlined in the study and in Figure 3. Those challenges were seen as the key factor to success with gaining dynamic capability and competitive advantages when collaborating through integrated operations in the oil and gas industry.

Not all tasks should be organized internally in the organization, but should rather entail some kind of exchange with other parties (Coase, 1938; Teece et al., 1997). Hence, I argue for the importance of collaborating with other actors. Information sharing between the parties is then seen as very important. Our study shows that service companies do not always receive optimal information from employees at the operator because some employees, often middle managers, see the information as their own. Their aversion towards information sharing is often because they feel threatened due to outsourcing of tasks that were traditionally theirs. Now these tasks are instead being conducted by third party service providers. If people suffer personal loss from new arrangements, they often resist it even if it benefits the organization. As a result, I found that they try to maintain the old dynamics in the industry. Respondents said that a lack of communication is usually caused by unwillingness to share information, and only in a few cases does it result from technology or knowledge limitations.

Based on our case study, I argue that service providers need to obtain responsibility and ownership of their own processes. Our study showed that in some situations, the operator caused suboptimal performance by making decisions that service providers were better positioned to make. The encouraging news is that study participants representing both parties acknowledge this as a problem. The use of incentive-based contracts with risk/reward sharing eliminates such conflicts. Fixed price contracts do not cover all aspects of the exchange; hence, some areas are left unspecified (Laffont & Tirole, 1999; Salanié, 1998). Implementing incentive-based contracts encourages each party to ensure that decisions are made by the party best able to do so. Respondents in the study argued that conflicts would then largely be avoided since all involved parties have a high level of goal alignment through the joint establishment of KPIs and profit sharing resulting from bilateral dependency. This requires that traditional routines and work practices has to be modified to make use of information-sharing technology and real-time data.

Incentive-based contracts increase the value for all involved parties, making it easier to communicate and foster an acceptance for involvement from different parties. Hence, I argue that they are a key enabler for realizing the benefits within integrated operations for the oil and gas industry.

ACKNOWLEDGEMENTS

I thank Inger Stensaker at the Norwegian school of economics and business administration for thoughtful and detailed comments and suggestions. I also want to thank participants at Stanford University Smart Fields Consortium for their feedback on a presentation of an earlier version of this paper.

REFERENCES

Alchian, A. A., & Demsetz, H. (1972). Production, information costs, and economic organization. *The American Economic Review, 62*(5), 777–795.

Amit, R., & Schoemaker P. J. H. (1990). Key success factors: their foundation and application. *Unpublished working paper, University of British Colombia and University of Chicago*.

Amit, R., & Schoemaker P. J. H. (1993). Strategic assets and organizational rent. *Strategic Management Journal, 14*, 33–46.

Barney, J. B. (1986). Strategic factor markets: Expectations, luck, and business strategy. *Management Science, 32*(10), 1231–1241.

Barney, J. B. (1991). Firm resources and sustained competitive advantage. *Journal of Management, 17*, 21.

Barney, J. B. (2002). *Gaining and sustaining competitive advantage*. Upper Saddle River.

Clark, K. B., & Fujimoto, T. (1991). *Product development performance: strategy, organization, and management in the world auto industry*. Boston, MA: Harvard Business School Press.

Coase, R. (1938). The nature of the firm. *Economica, 4*, 386–405.

Crook, T. R., Ketchen, D. K., Combs, J. G., & Todd, S. Y. (2008). Strategic resources and performance: a meta-analysis. *Strategic Management Journal, 29*(11), 1141–1154.

Eisenhardt, K. M. (1989a). Building theories from case study research. *Academy of Management Review, 14*, 532–550.

Eisenhardt, K. M. (1985). Control: Organizational and economic approaches. *Management Science,* 31(2), 134–149

Eisenhardt, K. M. (1989b). Making fast strategic decisions in high-velocity environments. *Academy of Management, 32*(3), 543–576.

Eisenhardt, K. M., & Martin, J. A. (2000). Dynamic capabilities: what are they? *Strategic Management Journal, 21*, 1105–1121.

Grant, R. M. (1991). The resource-based theory of competitive advantage. *California Management Review, 33*(3), 114–135.

Grossman, S. J., & Hart, O. D. (1986). The costs and benefits of ownership: a theory of vertical and lateral integration. *The Journal of Political Economy, 94*(4), 691–719.

Haragadon, A., & Sutton, R. I. (1997). Technology brokering and innovation in a product development firm. *Administrative Science Quarterly, 42*(4), 716–749.

Hedstrom, P., & Swedberg, R. (1998) *Social mechanisms*. Cambridge: Cambridge University Press.

Hoopes, D. G., Madsen, T. L., & Walker, G. (2003). Guest editors' introduction to the special issue: why is there a resource-based view? Towards a theory of competitive heterogeneity. *Strategic Management Journal, 24*, 889–902.

Jensen, M., & Meckling, W. (1976). Theory of the firm: managerial behavior, agency costs, and ownership structure. *Journal of Financial Economics, 3*, 305–360.

Laffont, L., & Tirole, J. (1999). *A theory of incentives in procurement and regulation*. Cambridge, MA: MIT Press.

Milgrom, P., & Roberts, J. (1992). *Economics, organization and management*. London: Prentice-Hall.

Ministry of Petroleum and Energy (2003–2004). *Storting white paper No. 38. On The Petroleum Activities*.

Osmundsen, P., & Olsen, T. E. (2005). Sharing of endogenous risk in construction. *Journal of Economic Behavior & Organization, 58*, 511–526.

Osmundsen, P., Toft, A., & Dragvik, K. A. (2005). Design of drilling contracts – economic incentives and safety issues. *Energy Policy, 34*(15), 2324–2329.
Penrose, E. T. (1959). *The theory of the growth of the firm*. Oxford: Basil Blackwell
Peteraf, M. A. (1993). The cornerstones of competitive advantage: a resource-based view. *Strategic Management Journal, 14*(3), 179–191.
Prahaland, C. K., & Hamel, G. (1990). The core competence of the corporation. In B. de Wit & R. Meyer (1994): *Strategy: process, content, context*. (pp. 290–301) West Publishing Company.
Rugman, A., & Verbeke, A. (2002). Edith Penrose's contribution to the resource-based view of strategic management. *Strategic Management Journal, 23*, 769–780.
Salanié, B. (1998). *The economic of contracts*. Cambridge: MIT Press.
Sine, W. D., Mitusuhashi, H., & Kirsch, D. A. (2006). Revisiting Burns and Stalker: formal structure and new venture performance in emerging economic sectors. *Academy of Management Journal, 49*(1), 13.
Teece, D. J., Pisano, G., & Shuen, A. (1997). Dynamic capabilities and strategic management. *Strategic Management Journal, 18*, 143–161.
The United Nations Convention on the Law of the Sea (1982). *The United Nations Convention on the Law of the Sea*.
Tirole, J. (1999). Incomplete contracts: where do we stand? *Econometrica, 67*, 741–781.
Wernerfelt, B. (1984). A resource-based view of the firm. *Strategic Management Journal, 5*, 171–180.
Williamson, O. E. (1975). *Markets and hierarchies: analysis and antitrust implications: a study in the economics of internal organization*. New York: Free Press.
Williamson, O. E. (1985). *The economic institutions of capitalism. Firms, markets, relational contracting.* New York.
Yin, R. K. (2003). *Case study research design and methods* (Third ed.). California: Sage Publications.

Paper III

Fixed Price Contract Versus Incentive-Based Contract in the Oil and Gas Industry

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Submitted for possible publication in the International Journal of Global Energy Issues (IJGEI).

This paper starts with an outline of the principal-agency theory. Then we involve a section describing the current situation and contracts used on the Norwegian Continental Shelf. Next section develops models of the two contracts, and analyzed in the upcoming section. We analyze the difference between the fixed price contract and the incentive-based contract. Further, we develop a model containing 20 parameters accounting for characteristics related to profit, gross income, and operating expenditure for an operator and a service provider. To decide what contract is best under different conditions, we conduct an individual profit maximization and a joint welfare analysis. We graphically show how different parameters and the time to complete the project affects both actors' profits. We visualize graphically the operator's and the service provider's contract preferences dependent on the time used to complete a project, and dependent on changes in parameter values.

The following words will occur in the paper

Nomenclature
Nomenclature is a list of terms or names that assigns a word, phrase or in our example a letter to one object.

Baseline
Baseline is a logical basis for comparison. A given situation used as benchmark.

Principal
An individual, or a group of individuals, who has delegated authority to an agent to achieve predefined goals, where its profit is influenced by the agent's behavior (Eisenhardt, 1989; Jensen, 1983).

Agent
An individual, or a group of individuals gathered together to execute tasks or some activities to reach the principal's goals or objectives (Eisenhardt, 1989; Jensen, 1983).

Moral hazard
Moral hazard is post-contractual opportunism. As a consequencee, the principal cannot be sure that the agent has put forth maximal effort, as its effort is difficult to observe. The agent may then pursue its own interests (Eisenhardt, 1989; Milgrom & Roberts, 1992).

Adverse selection
Adverse selection is a pre-contractual information asymmetry. Hence, the principal cannot be certain that the agent accurately performs the work for which it is being paid (Eisenhardt, 1989; Milgrom & Roberts, 1992).

Fixed Price Contract Versus Incentive Based Contract in the Oil Industry

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ABSTRACT
This paper analyzes the difference between the fixed price contract, common in the Oil & Gas industry, and the uncommon incentive based contract. Our study shows how the two contracts affect the profits and time usage differently. Both the operator and service provider prefer the incentive based contract when the project is completed in less than the estimated time and the service provider's variable income is low, or the project is completed in more than the estimated time and the punishment is intermediate. The operator prefers the fixed price contract and the service provider prefers the incentive based contract when the project is completed in less than the estimated time and the service provider's variable income is high, or the project is completed in more than the estimated time and the punishment is lenient. The operator prefers the incentive based contract and the service provider prefers the fixed price contract when the project is completed in more than the estimated time and the punishment is harsh. Both actors never jointly prefer the fixed price contract. The two actors collectively always prefer the incentive based contract. That neither individual maximization nor joint welfare analysis causes both actors to jointly prefer the fixed price contract is remarkable given its current prevalence. This result follows since costs associated with moral hazard, adverse selection, monitoring, coordination, etc. decrease with the use of an incentive based contract.

JEL codes: D21, D82, D86, L14
Keywords: Incentive based contract, fixed price contract, moral hazard, adverse selection, profit, cost.

1. INTRODUCTION
The Oil & Gas industry on the Norwegian Continental Shelf (NCS)[10] currently experiences cost increases and reduced productivity. Costs related to rig-hire and oil services are among the largest cost drivers in drilling projects combined with a reduction in drilling productivity (Osmundsen, Sørnes, & Toft, 2008). Main challenges for Integrated Operations[11] on the NCS are moral hazard, adverse selection, and high monitoring and coordination costs. Unfortunately, contracts that tie actual performance to incentives are practically absent on the NCS. Questions emerge whether this absence has affected the recent cost increases and productivity decreases.

Uncertainty often exists in inter-organizational relationships. Information is often asymmetric. The principal can obtain information by inspecting or evaluating the distinctive tasks

[10] NCS is the continental shelf over which Norway exercises sovereign rights. Stretching 200 nautical miles from the Norwegian coast, its major parts are the shelves of the North Sea, Norwegian Sea and Barents Sea (The United Nations Convention on the Law of the Sea, 1982).
[11] Integrated Operations has been defined as the use of information technology to change work processes to achieve improved decisions, remote control of processes and equipment, and movement of functions and personnel onshore (Ministry of Petroleum and Energy, 2003-2004).

performed by the agent, or by developing incentive based systems which ensure that the agent's behavior is in the principal's best interest. This means designing incentive systems that favor all collaborating actors to contribute for the best of those involved (Eisenhardt, 1989). Principal-agent analysis has two distinctive challenges. The first is moral hazard related to post-contractual opportunism, where the principal cannot be sure whether the agent has put forth maximal efforts as its action is difficult to observe. The agent may then pursue its own interests. The second is adverse selection, which is a pre-contractual situation with asymmetric information where the principal cannot be certain that the agent accurately performs the work for which it is paid. The agent's action can be difficult to observe and the agent may pursue its own interests. Moral hazard and adverse selection occur with the use of a fixed price contract, which has a fixed payment per day for one unit of work.

Further, Eisenhardt (1985) argues that a fixed price contract could give an incentive for the agent not to perform optimally since its compensation could be the same regardless of profits. When an agent lacks incentives to perform optimally, it can be more efficient to replace a fixed price contract with what we refer to as an incentive based contract, which is a residual claimant based contract affecting the agent's profit. The latter contract makes compensation dependent on performance which reduces the incentive for the agent's moral hazard and adverse selection (Alchian & Demsetz, 1972; Jensen & Meckling, 1976).

Laffont & Tirole (1999) and Williamson (1985) argue that the fixed price contract does not increase the companies' adaptability which is often seen as a key to success. For example, evolvement of future production and technologies cannot be described in a contract upfront, and therefore the industry volatility is not taken sufficiently into consideration in a fixed price contract. This disturbs the transaction negatively. The actors may not agree from whom various kinds of new resources should be adopted, and they therefore have a possibility to exploit the situation for their own interest. The literature tries to find solutions to eliminate opportunistic behavior through the use of incentive mechanisms. Both Salanié (1998) and Tirole (1999) have focused on reduction of opportunistic behavior through adopting reward and punishment contracts. Further, Grossman and Hart (1986) argued that the use of an incentive based contract should increase the value for all actors and be a major contributor to create goal congruence and avoid opportunistic behavior in operations.

The fixed price contract is the most common contract on the NCS, and the incentive based contract is practically not used. To better understand the nature of the two contracts, this paper develops models for both contracts. The models contain 20 parameters accounting for characteristics related to profit, gross income, and operating expenditure for an operator and a service provider. The free choice variable for the service provider is the time to complete the project. To determine which contract is optimal under which conditions, we solve the model by conducting individual profit maximization for the operator and a service provider, and joint welfare analysis. To illustrate the solution, we graphically show how different parameters and the time to complete the project affect both actors' profits. We visualize graphically the operator's and the service provider's contract preferences dependent on the time used to complete a project, and dependent on changes in parameter values. To determine realistic parameter values we used data received from the Norwegian Petroleum Directorate obtained for a previous study conducted on the NCS (Emhjellen, Hausken, & Osmundsen, 2006).

Section 2 discusses relevant literature. Section 3 describes the current situation and contracts used on the Norwegian Continental Shelf. Section 4 develops models of the two contracts, analyzed in Section 5. Section 6 evaluates how the actors' profits for the two contracts depend on the time to complete the project, and on the model parameters. Section 7 illustrates graphically in two dimensions how the time and parameters affect whether the operator and service provider prefer the fixed price contract versus the incentive based contract. Section 8 concludes.

Nomenclature

Table 1a Parameters and baseline for fixed price contract

Baseline	*Parameters*	*Baseline*	*Parameters*
500,000	*M* operator's cost of monitoring, coordination, moral hazard, and adverse selection	240,000	*h* service provider's cost of moral hazard
250,000	*L* operator's other costs including catering, planning, administration of onshore organization, overhead, insurance cost etc., excluding *M, w, f*	260,000	*z* service provider's cost of adverse selection
		1,450,000	*A* renegotiation parameter

Table 1b Parameters and baseline for incentive based contract

Baseline	*Parameters*	*Baseline*	*Parameters*
345,000	*w* service provider's variable income	100,000	*y* service provider's observed exogenous effect on income
1.5	*B* service provider's intensity of incentives	1.5	γ weight given to y
55,000	*e* service provider's unobserved effort	300,000	*C* punishment function
25,000	*x* service provider's unobserved exogenous effect on income	1.5	*c* scales the punishment when $T \geq T_N$
		1.55	*b* scales the income when $T \leq T_N$

Table 1c Parameters and baseline for both contracts

Baseline	*Parameters*	*Baseline*	*Parameters*
1,500,000	*f* service provider's fixed income	80	*P* oil price in US$ per barrel
1,800,000	*d* service provider's other income excluding fixed and variable income	7,000,000	*Q* production in barrels for the project
750,000	*v* service provider's other cost including catering, planning, administration of onshore organization, overhead, insurance cost etc.	100	T_N estimated time to complete the project

Table 2 Variables for two time values *T*=90 and *T*=110 of completing the project

T=90	*T=110*	*Variables*

90	110	T variable time to complete the project
560,000,000	560,000,000	G gross income for the operator for both contract types
297,000,000	344,500,000	g_F gross income for the service provider with fixed price contract
309,241,062	353,513,167	g_I gross income for the service provider with incentive based contract
364,500,000	427,000,000	O_F operator's OPEX with fixed price contract
309,241,062	353,513,167	O_I operator's OPEX with incentive based contract
247,500,000	302,500,000	o_F service provider's OPEX with fixed price contract
202,500,000	247,500,000	o_I service provider's OPEX with incentive based contract
195,500,000	133,000,000	$\prod_F$ Operator's profit with fixed price contract
250,758,938	206,486,833	$\prod_I$ Operator's profit with incentive based contract
49,500,000	42,000,000	π_F Service provider's profit with fixed price contract
106,741,062	106,013,167	π_I Service provider's profit with incentive based contract

2. RELEVANT LITERATURE

Principal-agent analysis is described by Jensen & Meckling (1976) as "the theory of organizational structure of the firm", by Barney & Hesterly (1996) as trying "to understand the causes and consequences of goal incongruence and principal- agent problems", and by Eisenhardt (1989) and Jensen (1983) as attempts to describe an organization as a nexus of contracts between the principal and agent, giving surviving contracts which are those that best solve the problem of minimizing agency costs.

Principal: An individual, or a group of individuals, who has delegated authority to an agent to achieve predefined goals, where its profit is influenced by the agent's behavior.

Agent: An individual, or a group of individuals gathered together to execute tasks or some activities to reach the principal's goals or objectives.

Principal-agent analysis is the study of problems of motivating and controlling cooperative action. The agency problem arises when the agent works for its own goals rather than the principal's goals. One particular challenge in principal-agent analysis is to get the agent to act the way the principal wants to when the agent has an information advantage over the principal. This challenge arises especially when the principal and agent have divergent goals or interests. It is difficult for the principal to monitor and observe the agent's actions, as it can only measure its own profit (Barney & Hesterly, 1996). It is also difficult to monitor the agent's actions and impact as other exogenous factors outside the principal's control also affect the profit of the operation (Grossman & Hart, 1983).

The agent often knows more about the tasks that should be performed than the principal due to asymmetric information. That is, the two actors have different information available. Traditional neoclassical economics simplifies by assuming that the market has full information, but in the real market information is often asymmetric. Information asymmetry can lead to strategic misrepresentation. To prevent misrepresentation it is important that both actors avoid opportunistic behavior. As trade is voluntary, actors don't have to interact if they don't find it advantageous. Therefore it is important that each actor in the transaction gets at least a minimum amount of surplus for its contribution. A common formulation is that the principal maximizes its profit subject to an individual rationality constraint (participation constraint) and an incentive compatibility constraint for the agent. The agent must find it individually rational to contribute rather than delivering its services elsewhere (outside option), and the agent must have incentives to participate. In the literature this is also addressed as informational rent, which is the actor's return as it shares its private information (Milgrom & Roberts, 1992). Informational rents are often regulated by a contract. Some argue that low-powered contracts, e.g. fixed price contracts, can create constraints for employees to act as they find necessary. This can also create costly and inefficient solutions for the actors (Holmstrøm & Milgrom, 1994). Lack of rent can affect the transaction as there is not enough surplus for the transaction to evolve, even if some actors see the transaction as feasible (Milgrom & Roberts, 1992). The principal can obtain information by inspecting or evaluating the distinctive tasks that have been performed, or develop incentive systems that ensure that the agent's behavior and actions are in the principal's interests. Eisenhardt (1989) argues for designing incentive systems that will favor all collaborating actors to contribute to the best profit for all actors. Regarding asymmetric information and uncertainty, principal-agent analysis holds two problems (Eisenhardt, 1989; Milgrom & Roberts, 1992):

Moral hazard: Moral hazard is post-contractual opportunism, or a condition under which the principal cannot be sure that the agent has put forth maximal effort, as its effort is difficult to observe. The agent may then pursue its own interests.

Adverse selection: Adverse selection is a pre-contractual information asymmetry that gives conditions under which the principal cannot be certain that the agent accurately performs the work for which it is being paid.

Moral hazard and adverse selection occur with the use of fixed price contract and is therefore argued to not always be the best method of organizing relationships between principals and agents (Jensen & Meckling, 1976). A fixed price contract could give an incentive for the agent not to perform optimally for the principal, or with respect to joint welfare, since its compensation will be the same regardless of the quality and effort level of its work (Eisenhardt, 1985). When the agent lacks incentives to perform optimally, it can be more efficient to replace the fixed price contract with an incentive based residual claimant based contract related to the firm's profit (Alchian & Demsetz, 1972). This latter contract reduces the incentive for the agent's moral hazard and adverse selection since it makes its compensation dependent on its performance (Jensen, 1983). Eisenhardt (1989) has stated that an outcome-based contract (e.g. profit based) is a contract that is used to align goals between the principal and the agent. Further she argues that if the agent were rewarded for success rather than for work performed, the productivity and cost efficiency would be better.

3. CURRENT SITUATION AND CONTRACTS USED ON THE NCS

The cost of rig lease on the NCS has increased dramatically, from approximately $140,000 per day in 2004 to nearly $500,000 per day in 2007. At the same time falling oil prices have lead operators to postpone projects awaiting better conditions, i.e. lower cost or higher oil price. In 2002 average drilling per day was 102 meters, 111 meters in 2003, and has stayed at around 80 meters per day since 2004. Cost composition of drilling costs on the NCS is mostly confidential. Osmundsen et al. (2008, p. 3139) apply closed sources to develop a graphic figure from which we estimate 36% for rig hire, 32% for oil services, 14% for logistics, 10% for equipment and consumables, and 8% for administration.

Some specific contracts on the NCS regulate the lease of the drilling rig. These are usually related to drilling time, with a day-rate payment for the rig lease. A more general contract which is the focus in this paper is the service contract which regulates the general relationship between the operator and service provider. Both contracts are tied to time as a critical performance indicator. The service contract additionally accounts for other performance criteria, such as quality of drilling, health, environment, and safety, etc. Quality and time are often seen as contradictory, but can affect each other positively. A number of input factors in the drilling process are time-critical as their recovery rate upon failure depends on the use of existing infrastructure and losses may occur if the input factors are delayed. On the other hand, high drilling speed can imply losing the drill string, or can cause failures in the well, which cause delays. High first time quality can avoid damaging the formation. A non damaged formation gives better well integrity and decreases reservoir leakage. High pressure can lead to fractures in the formation and leakage from the well, and low pressure can lead to collapse and leakage into the well. A non damaged well is more robust to pressure in the well. Reduced reservoir leakage into the well has a positive impact on the resource utilization in the production phase on the well. After a section in the formation has been drilled, it needs to be quickly cemented to prevent the formation from fracturing or collapsing. A non-cemented formation weakens rapidly with time. Quality and time should thus be considered jointly. Whereas a fixed price contract has a strong focus on time, an incentive based contract has the potential to account for the complex relationship between quality and time by linking incentives to performance.

We consider two kinds of service contracts. For the first we use the term fixed price contract. We could alternatively have used the term cost-price contract which is also often used on the NCS. Almost all service providers on the NCS have a fixed price contract, with no or few incentives related to operations. To some degree a contract with some kind of incentives (as a cost-plus contract) is used creating low-powered or weak incentives that are costly and ineffective (Holmstrøm & Milgrom, 1994). A cost-plus contract has often renegotiation opportunities that can weaken the incentives. As the renegotiation will occur later, this affects the form of the original contract and creates difficulties for later renegotiations, or the actors take the later renegotiation process into consideration when negotiating the original contract (Hart & Moore, 1988; Tirole, 1999).

Another type of contract, which is uncommon and almost never used on the NCS, is the incentive based contract. It is sometimes referred to as a residual claimant based contract related to the firm's profit (Alchian & Demsetz, 1972). Applying reward and punishment, it incorporates compensation for actual performance according to targets, budget, schedule and/ or quality. An incentive is a mechanism that motivates agents to take a particular action. One typical incentive is a material reward (for an example a financial reward, often addressed as remunerative incentives). If the agent does not meet the performance criteria, the reward decreases and may even become negative which constitutes a punishment. An incentive based contract is risky in the sense that the agent gets punished when not performing as specified.

From a joint welfare point of view, one benefit of the incentive based contract to regulate completion of projects in the oil industry is that it could involve the service provider more thoroughly in the project planning phase. Decisions could be taken by the actor that is best suited and has the best competence, rather than the actor with formal ownership of the process.

The operator owns the petroleum license and has formal ownership of the process. This ownership affects the productivity negatively with a fixed price contract, but not with an incentive based contract which decreases the time to complete the project.

4. THE MODEL

In order to determine the optimal contract as preferred by an operator, a service provider, or an external actor, we develop two kinds of contracts. The first is a fixed price contract that is commonly used to regulate the relationship between operators and service providers on the NCS, elsewhere in the oil industry, and also outside the oil industry. It pays the service provider per drilled meter. The second is an incentive based contract, which is uncommon and almost never used on the NCS, though it gradually gains terrain elsewhere in our economies.

Sund (2008) has argued that an incentive based contract increases the value of drilling activities as it increases productivity and cost efficiency for all actors. In order to be more specific about the cost and benefits related to inter- organizational relationships, we develop a formal model for the relationship between an operator and a service provider (Grossman & Hart, 1986).

Consider two firms, i.e. one operator, seen as a principal, and one service provider, seen as an agent. We outline how the principal-agent problem affects both the operator's and the service provider's behavior and profits, and how two different contracts impact value creation differently through inter-organizational relationships in the Oil & Gas industry. To do so, we need to quantify the gross income and Operating Expenditure (OPEX), and see how gross income and OPEX are affected by two different contracts, i.e. fixed price contract and incentive based contract. We develop models for the two contracts and use empirics gathered from the Norwegian Petroleum Directorate, and used in an earlier study on the NCS (Emhjellen et al., 2006), to analyze the contracts. Milgrom & Roberts (1992) and Holmstrom (1979) propose

$$w = B(e + x + \gamma y) \tag{1}$$

as the service provider's variable income without perfect information, where B is the intensity of incentives, e is unobserved effort, x is unobserved exogenous effect, y is observed exogenous effect, and γ is the weight assigned to y. We do not include base income in (1), as we include fixed income as a separate parameter later.

Gross income for operator and service provider

Operator:

Gross income (G) with the use of fixed price and incentive based contract

To determine the gross income for the operator, P is the expected oil price per barrel in US$, and Q is the expected production in barrels for the project. The operator's gross income is negative when considering the drilling operation in isolation, but seen in a longer time span the project gets justified through increased expected future gross income. When evaluating a project, the industry usually considers the total cost and return over the entire life span of the oil project (Emhjellen et al., 2006). The expected future gross income (ignoring costs) is positive from the day the well is complete and starts producing oil. We assume that actual sale equals production. The operator's gross income is the same using both contracts, as the contract type does not affect future gross income, i.e.

$$G = PQ \tag{2}$$

Service provider:

Gross income (g_F) with the use of fixed price contract

For a fixed price contract we assume a fixed income f, other income d, and an estimated time T_N to complete the project. If the service provider completes the project using time T less than the estimated time T_N, where $T \leq T_N$, the gross income is $(f+d)T$. This shows that the service provider has no incentive to complete the project before time T_N since less income will be earned. If the service provider completes the project for example three days before T_N, it can choose to do nothing for three days, deliver on day T_N, and earn income for the entire estimated contract time T_N. This illustrates the basic problem with the fixed price contract. Although the problem is severe enough to search for alternative contracts, such alternatives have hardly been implemented on the NCS.

On the other hand, if the service provider uses more time than T_N, $T \geq T_N$, the old contract no longer applies and must be replaced with a new contract which we refer to as renegotiating the old contract. This illustrates a second problem with the fixed price contract. There are no clear rules for how the new contract shall be designed. In praxis, the involved parties scrutinize the reasons for exceeding the estimated time, and try to develop a new contract which is acceptable to everyone. If the service provider is clearly at fault for the delay, low income or even punishment may apply, intended as stimulation to create change in behavior. If the operator is clearly at fault for the delay, the income may be higher. If external factors such as a third party or weather are at fault for the delay, some intermediate compromise is usually worked into the new contract. To allow for sufficient generality for the event that $T \geq T_N$, we assume that the service provider earns a renegotiation parameter A multiplied with the time exceeding T_N, where $A \geq 0$ means additional income and $A \leq 0$ means punishment. Whether A is positive or negative depends on the renegotiation. The service provider may argue that T_N was unrealistically low so A should be positive, though usually lower than $f+d$, or else the operator may argue that the service provider has wasted time, hence A should be negative. Usually, A is substantially lower than $f+d$ which is earned if $T \leq T_N$. This illustrates a third problem with the fixed price contract. The service provider usually has outside options exceeding the value of $f+d$ when $T \geq T_N$. This complicates and introduces uncertainty into the intensive renegotiations around time T_N. Applying this reasoning, the service provider's gross income is

$$g_F = \begin{cases} (f+d)T \text{ if } T \leq T_N \\ (f+d)T_N + A(T-T_N) \text{ if } T \geq T_N \end{cases} \tag{3}$$

Fig. 1 sets T_N=100 and shows the service provider's incentives to decrease versus not decrease the time to complete the project.

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Gross income (g_I) with the use of incentive based contract

The three problems discussed under the fixed price contract are handled by introducing an incentive based contract which accounts for reward and punishment. If the service provider completes the project in exactly the estimated time T_N, its income is $(f+d)T_N$, and the two contracts give the same income. For the incentive based contract we assume that the service provider continues to earn the benchmark income $(f+d)T$, regardless of whether $T \leq T_N$ or $T \geq T_N$, but earns a reward or suffers a punishment relative to this benchmark if T differs from T_N. First, the service provider can earn a reward or bonus $w(T_N-T)^b$ by decreasing the time to complete the project below T_N, where w is the variable income in (1) and b is an income scaling parameter. $b \geq 1$ means convex reward and $0 \leq b \leq 1$ means concave reward. Second, assuming as in the fixed price contract that $A \leq f+d$, the service provider suffers a punishment $C(T_N-T)^c$ if the time to complete the project exceeds T_N, where $C \geq 0$ is a punishment function and c is a punishment scaling parameter. $c \geq 1$ means convex punishment and $0 \leq c \leq 1$ means concave punishment. Applying this reasoning, the service provider's gross income is

$$g_I = \begin{cases} [f+d]T + w(T_N - T)^b \ if \ T \leq T_N \\ [f+d]T - C\,(T - T_N)^c \ if \ T \geq T_N \end{cases} \tag{4}$$

Appendix C discusses an alternative to (4). Fig. 2 sets T_N=100 and shows the service provider's incentives to reduce the time to complete the project regardless of whether $T \leq T_N$ or $T \geq T_N$. The strength of the incentives depends on the parameters.

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OPEX (Operating Expenditure) for operator and service provider

Operator:

OPEX with the use of fixed price contract

The operator's OPEX with fixed price contract is

$$O_F = g_F + (M+L)T \tag{5}$$

where g_F is the service provider's gross income in (3) causing a corresponding expense for the operator, and $(M+L)T$ are costs affecting monitoring, coordination, moral hazard, adverse selection (due to asymmetric information and lack of goal alignment), and other costs affecting the project, assumed proportional to the time used.

OPEX with the use of incentive based contract

The operator's OPEX with incentive based contract is

$$O_I = g_I \tag{6}$$

which simply equals the service provider's gross income in (4), which accounts for all expenses.

Service provider:

OPEX with the use of fixed price contract

With fixed price contract, the service provider's OPEX is

$$o_F = (f + v + h + z)T \tag{7}$$

which includes fixed income f, other cost v, moral hazard h, and adverse selection z, assumed proportional to the time used. The fixed income f is first paid by the operator to the service provider, which transfers the payment further to its employees, and thus f is present in both (3) and (7). In contrast, other income d is paid by the operator to the service provider, which does not transfer the payment further to its employees, and thus d is present in (3), but not present in (7).

OPEX with the use of incentive based contract

With incentive based contract, the service provider's OPEX is

$$o_I = \left(f + v\right)T \tag{8}$$

which corresponds to (7), but we exclude moral hazards *h* and adverse selection *z,* which are already built into the apparatus of incentives.

Profits for operator and service provider
The profit equals gross income minus OPEX.

Operator:
Profit with the use of fixed price contract
The operator's profit for fixed price contract is

$$\Pi_F = G - O_F = \begin{cases} PQ - \left(f + d + M + L\right)T \text{ if } T \le T_N \\ PQ - \left(f + d\right)T_N - A\left(T - T_N\right) - \left(M + L\right)T \text{ if } T \ge T_N \end{cases} \tag{9}$$

subtracting (5) from (2), which decreases in *T*, $\partial \Pi_F / \partial T < 0$.

Profit with the use of incentive based contract
The operator's profit for incentive based contract is

$$\Pi_I = G - O_I = \begin{cases} PQ - \left[f + d\right]T - w(T_N - T)^b \text{ if } T \le T_N \\ PQ - \left[f + d\right]T + C(T - T_N)^c \text{ if } T \ge T_N \end{cases} \tag{10}$$

subtracting (6) from (2).

Service provider:
Profit with the use of fixed price contract
The service provider's profit for fixed price contract is

$$\pi_F = g_F - o_F = \begin{cases} \left(d - v - h - z\right)T \text{ if } T \le T_N \\ \left(f + d - A\right)T_N + \left(A - f - v - h - z\right)T \text{ if } T \ge T_N \end{cases} \tag{11}$$

subtracting (7) from (3). We require that $d\text{-}v\text{-}h\text{-}z \ge 0$ so that the service provider's profit increases when T increases toward T_N.

Profit with the use of incentive based contract
The service provider's profit for incentive based contract is

$$\pi_I = g_I - o_I = \begin{cases} \left[d - v\right]T + w(T_N - T)^b \text{ if } T \le T_N \\ \left[d - v\right]T - C(T - T_N)^c \text{ if } T \ge T_N \end{cases} \tag{12}$$

subtracting (8) from (4). Since *f* is paid by the operator to the service provider and then transferred further to the service provider's employees, it is not present in (12), and is not present in (11) when $T \le T_N$. When $T \ge T_N$, π_F decreases in *f* since the service provider transfers larger payment to its employees than it receives from the operator. Hence *f* is not designed as a driver for increased productivity and cost efficiency for the service provider. In contrast, *d* is positively present in both (11) and (12) and encourages improved resource utilization under both contracts.

5. ANALYZING THE MODEL

The 12 equations in section 4 complete the model description with 20 parameters (Table 1) and one free variable T which the service provider chooses. Among the parameters the operator has at least some control of $M,L,A,B,\gamma,C,c,b,f,d,Q$, the service provider has at least some control of h,z,e,x,y,v, both impact w,T_N, and external factors impact P. Several of the parameters can be conceived as free choice variables for the operator, for example the service provider's fixed income f which impacts whether the service provider accepts the contract or chooses an outside option, or the renegotiation and punishment parameters A,C,c. A main objective of this article is to analyze how the service provider chooses the time T to complete the project. The service provider cannot complete the project in zero time, so some constraints exist in the choice of T. The service provider nevertheless has substantial leeway in choosing T, for example by hiring and firing employees, requiring overtime, or requiring that employees do not work. If the service provider has no outside options, it may choose to maximize its profits π_F or π_I, dependent on which contract is signed. At the other extreme, if the service provider has unlimited outside options, it may choose to maximize its profits π_F/T or π_I/T per day, which allows it to proceed quickly to the next project upon completion of the current one, and thus maximize profits across a succession of projects. In the real world the service provider is between these two extremes and may focus on both profit and profit per day. In this paper we analyze both. We thus analyze four optimization programs for the service provider:

<u>Maximizing π_F for fixed price contract</u>

The service provider differentiates its profit π_F in (11) with respect to its free choice variable T, i.e.

$$\frac{\partial \pi_F}{\partial T} = \begin{cases} d-v-h-z \ \ if \ \ T \le T_N \\ A-f-v-h-z \ \ if \ \ T \ge T_N \end{cases} \tag{13}$$

The requirement d-v-h-$z\geq 0$ implies $\partial \pi_F / \partial T \geq 0$ when $T \leq T_N$. We have allowed A to be positive or negative. When A is not only positive, but $A \geq f+v+h+z$, we get $\partial \pi_F / \partial T \geq 0$ when $T \geq T_N$, and then the service provider chooses to spend infinitely large time $T=\infty$ to complete the project. For the more common case that $A \leq f+v+h+z$, we get $\partial \pi_F / \partial T \leq 0$ when $T \geq T_N$, and then the service provider chooses to spend exactly the estimated time $T=T_N$ to complete the project.

<u>Maximizing π_I for incentive based contract</u>

Differentiating π_I in (12) with respect to T gives

$$\frac{\partial \pi_I}{\partial T} = \begin{cases} d-v-bw(T_N-T)^{b-1} = 0 \ \ if \ \ T \le T_N \\ d-v-cC(T-T_N)^{c-1} = 0 \ \ if \ \ T \ge T_N \end{cases} \Rightarrow \begin{cases} T = T_N - \left(\dfrac{d-v}{bw}\right)^{\frac{1}{b-1}} \ \ if \ \ T \le T_N \\ T = T_N + \left(\dfrac{d-v}{cC}\right)^{\frac{1}{c-1}} \ \ if \ \ T \ge T_N \end{cases} \tag{14}$$

which is inserted into (12) to give the profit

$$\pi_I = \begin{cases} [d-v]\left(T_N - \left(\frac{d-v}{bw}\right)^{\frac{1}{b-1}}\right) + w\left(\frac{d-v}{bw}\right)^{\frac{b}{b-1}} & if\ \ T \le T_N \\ [d-v]\left(T_N + \left(\frac{d-v}{cC}\right)^{\frac{1}{c-1}}\right) - C\left(\frac{d-v}{cC}\right)^{\frac{c}{c-1}} & if\ \ T \ge T_N \end{cases} \tag{15}$$

The second order conditions are

$$\frac{\partial^2 \pi_I}{\partial T^2} = \begin{cases} b(b-1)w(T_N - T)^{b-2} & if\ \ T \le T_N \\ -c(c-1)C(T - T_N)^{c-2} & if\ \ T \ge T_N \end{cases} \tag{16}$$

which means, when $b \ge 1$ and $c \ge 1$, that π_I decreases convexly from a maximum $\pi_I = wT_N^b$ when $T=0$, reaching a local minimum when $T \le T_N$, increasing toward a local maximum when $T \ge T_N$, and finally decreasing toward minus infinity $\pi_I = -\infty$ when $T = \infty$. As we will see when we illustrate the solution in the next section, the local minimum and local maximum are relatively close to the estimated time T_N and the changes in profit are not substantial. The reason for the local minimum and local maximum is the service provider's gross income in (4) where the reward is relatively small when T is slightly below T_N, and the punishment is relatively small when T is slightly above T_N.

Maximizing π_F / T for fixed price contract

Using (11) to differentiate gives

$$\frac{\partial(\pi_F / T)}{\partial T} = \begin{cases} 0 & if\ \ T \le T_N \\ \frac{(A - f - d)T_N}{T^2} & if\ \ T \ge T_N \end{cases} \tag{17}$$

Hence when $T \le T_N$, the service provider chooses any T, $0 \le T \le T_N$, which means that the service provider is indifferent regarding when to complete the project when $T \le T_N$, since the same profit per day is earned over this time period. When $A \ge f+d$, we get $\partial \pi_F / \partial T \ge 0$ when $T \ge T_N$, and the service provider chooses $T=\infty$. For the more common case that $A \ge f+d$, we get $\partial \pi_F / \partial T \le 0$ when $T \ge T_N$, and then the service provider chooses not to exceed the estimated time $T=T_N$ to complete the project, consistent with Fig. 1.

Maximizing π_I / T for incentive based contract

Using (12) to differentiate gives

$$\frac{\partial(\pi_I / T)}{\partial T} = \begin{cases} -\frac{w(T_N + (b-1)T)}{(T_N - T)^{b-1} T^2} \le 0 & if\ \ T \le T_N\ \ and\ \ b \ge 1 - \frac{T_N}{T} \\ -\frac{C(T_N + (c-1)T)}{(T - T_N)^{c-1} T^2} \le 0 & if\ \ T \ge T_N\ \ and\ \ c \ge 1 - \frac{T_N}{T} \end{cases} \tag{18}$$

which means that profit per day decreases throughout when $b \ge 1 - T_N/T$ and $c \ge 1 - T_N/T$. Hence the optimal solution is $T=0$, which means that the service provider prefers to complete the project as quickly as possible, consistent with Fig. 2.

Joint welfare analysis

Summing the operator's and service provider's profits in (9) and (11), the joint welfare for the two actors for the fixed price contract is

$$\Omega_F = \Pi_F + \pi_F = PQ - \left(f + v + M + L + h + z\right)T,$$

$$\frac{\Omega_F}{T} = \frac{\Pi_F + \pi_F}{T} = \frac{PQ}{T} - \left(f + v + M + L + h + z\right) \tag{19}$$

Summing the operator's and service provider's profits in (10) and (12), the joint welfare for the two actors for the incentive based contract is

$$\Omega_I = \Pi_I + \pi_I = PQ - (f + v)T,$$

$$\frac{\Omega_I}{T} = \frac{\Pi_I + \pi_I}{T} = \frac{PQ}{T} - (f + v) \tag{20}$$

Theorem 1: The joint welfare for the operator and service provider maximizes by choosing the incentive based contract rather than the fixed price contract, $\Omega_I \geq \Omega_F$.

Proof: Follows from comparing (19) and (20).

Theorem 1 follows since the fixed price contract introduces additional costs $(M+L+h+z)T$ caused by the difference between (19) and (20). First, M and L are the operator's costs of monitoring, coordination, moral hazard, adverse selection, and other costs including catering, planning, administration of onshore organization, overhead, insurance cost etc. Second, h and z are the service provider's costs of moral hazard and adverse selection. Third, these costs increase proportionally with the time T used to complete the project. Common for these costs is that they apply for the fixed price contract and are decreased or eliminated with the use of an incentive based contract. The incentive based contract introduces goal alignment, prevents that the actors work against each other, decreases opportunistic behavior, improves resource allocation, causes information to be exchanged more openly, and enhances joint value creation. From a joint welfare point of view, one benefit of the incentive based contract to regulate completion of projects in the oil industry is that it could involve the service provider more thoroughly in the project planning phase. Decisions could be taken by the actor that is best suited and has the best competence, rather than the actor with formal ownership of the process. The operator owns the petroleum license and has formal ownership of the process. This ownership affects the productivity negatively with a fixed price contract, but not with an incentive based contract which decreases the time to complete the project.

Individual profit maximization

Actors cannot be expected to focus idealistically on their joint welfare, but are instead likely to maximize their own profit. Whether profits, or profits per day, are compared under the two contracts yield the same result since it does not matter whether division with T occurs on both sides or no sides of an inequality. Therefore, comparing (9) and (10), the operator prefers the incentive based contract when

$$\Pi_I \geq \Pi_F \Rightarrow \begin{cases} w \leq \dfrac{\left(M + L\right)T}{(T_N - T)^b} = w_H \; if \;\; T \leq T_N \\ C \geq \dfrac{(f + d - A)(T - T_N) - \left(M + L\right)T}{(T - T_N)^c} = C_L \; if \;\; T \geq T_N \end{cases} \tag{21}$$

Comparing (11) and (12), the service provider prefers the incentive based contract when

$$\pi_I \geq \pi_F \Rightarrow \begin{cases} always \;\; if \;\; T \leq T_N \\ C \leq \dfrac{(f+d-A)(T-T_N)+\left(h+z\right)T}{(T-T_N)^c} = C_H \;\; if \;\; T \geq T_N \end{cases} \tag{22}$$

The actors' contract preferences in (21) and (22) are illustrated in Fig. 3.

<table>
<tr><td rowspan="2">$w \geq w_H$:
Operator prefers fixed price contract
Service provider prefers incentive based contract</td><td>$C \geq C_H$:
Operator prefers incentive based contract
Service provider prefers fixed price contract</td></tr>
<tr><td>$C_L \leq C \leq C_H$:
Both actors prefer the incentive based contract</td></tr>
<tr><td>$w \leq w_H$:
Both actors prefer the incentive based contract</td><td>$C \leq C_L$:
Operator prefers fixed price contract
Service provider prefers incentive based contract</td></tr>
</table>

T=0 T=T_N T

Fig. 3- Operator's and service provider's contract preferences as *T* varies horizontally and *w* and *C* vary vertically

Theorem 2: (a) Both actors prefer the incentive based contract when $T \leq T_N$ and $w \leq w_H$, or when $T \geq T_N$ and $C_L \leq C \leq C_H$. (b) The operator prefers the fixed price contract and the service provider prefers the incentive based contract when $T \leq T_N$ and $w \geq w_H$, or when $T \geq T_N$ and $C \leq C_L$. (c) The operator prefers the incentive based contract and the service provider prefers the fixed price contract when $T \geq T_N$ and $C \geq C_H$. (d) It is not possible for both actors to jointly prefer the fixed price contract.

Proof: Follows from (21) and (22) and Fig. 3.

When the project is completed in less than the estimated time, $T \leq T_N$, the operator prefers the incentive based contract when the income needed to furnish it is not too high, $w \leq w_H$, while the service provider always prefers the incentive based contract. The intuition behind this result is that the service provider earns incentives to complete the project early, which is possible when providing these incentives is not too costly for the operator. In contrast, when providing these incentives is too costly for the operator, $w \geq w_H$, the operator prefers the fixed price contract, but not the service provider.

When the project is completed in more than the estimated time, $T \geq T_N$, both actors prefer the incentive based contract when the punishment inflicted by the operator on the service provider for not complying with the time estimation is neither too lenient nor too harsh, $C_L \leq C \leq C_H$. The intuition behind this result is that if the punishment is too lenient, the operator earns little benefit from it and prefers the fixed price contract instead. In contrast, if the punishment is too harsh, the service provider suffers too substantially from it and prefers the fixed price contract instead.

That neither the joint welfare analysis nor the individual maximization procedure cause both actors to jointly prefer the fixed price contract is remarkable given its current prevalence. The reason for this result is the high costs of monitoring, coordination, other costs, moral hazard and adverse selection which affect both the operator and the service provider under the fixed price contract. Dysfunctional costs caused by divergent goals and interests, and asymmetric information, are larger for the fixed price contract than for the incentive based contract.The burdens of these costs under the fixed price contract can be shifted disproportionally on one actor or the other so that one, or the other, prefers the fixed price contract, but not such that both prefer it.

6. PROFITS UNDER THE TWO CONTRACTS

Table 1 shows 20 parameters, where all incomes and costs are per time unit. Some of these, such as oil price P, are determined by factors outside the operator's and service provider's control. Some parameters, such as fixed income f, are determined by the operator. Some parameters, such as unobserved effort e, are determined by the service provider. Finally, some parameters, such as the renegotiation parameter A and the estimated time T_N, are determined jointly by the operator and service provider. In this and the next section we show how these 20 parameters affect the operator and service provider, sometimes similarly, sometimes differently. Five of the 20 parameters apply only for the fixed price contract. Of these, M,L,h,z pertain to moral hazard and adverse selection regardless of whether the project is completed on time, while the renegotiation parameter A applies if $T \geq T_N$. Nine of the 20 parameters apply only for the incentive based contract. Of these, w,B,e,x,y,γ,b pertain to the service provider's income if the project is completed on time, $T \leq T_N$, while the punishment parameters C and c apply if $T \geq T_N$. The remaining six parameters, f,d,v,P,Q,T_N apply for both contracts, and regardless of whether $T \leq T_N$ or $T \geq T_N$.

Table 2 shows one independent variable T, which is the time to complete the project, determined by the service provider. Table 2 also shows 11 dependent variables, which are functions of the 20 parameters and T, as specified in the previous section. These are three incomes, four OPEX variables, and four profits.

Our objective is to gain insight into how the 20 parameters and T impact the operator's and service provider's preferences for the two contracts. Illustrating the results in the previous section, we show that there are cases where both actors prefer the incentive based contract, which means that efficiency can be gained by implementing this uncommon contract. But, there are also cases where the actors have opposite contract preferences, and no cases where both prefer the fixed price contract.

To standardize the analysis, Table 1 shows the 20 baseline parameter values used in the simulations. We systematically alter one parameter and T relative to the baseline. Table 2 shows the values of the 11 dependent variables for two time values T=90 and T=110 of completing the project. The time T=90 means that $T \leq T_N$, so 17 of the parameters determine the variables (A,C,c do not apply). The time T=110 means that $T \geq T_N$, so 13 of the parameters determine the variables (w,B,e,x,y,γ,b do not apply).

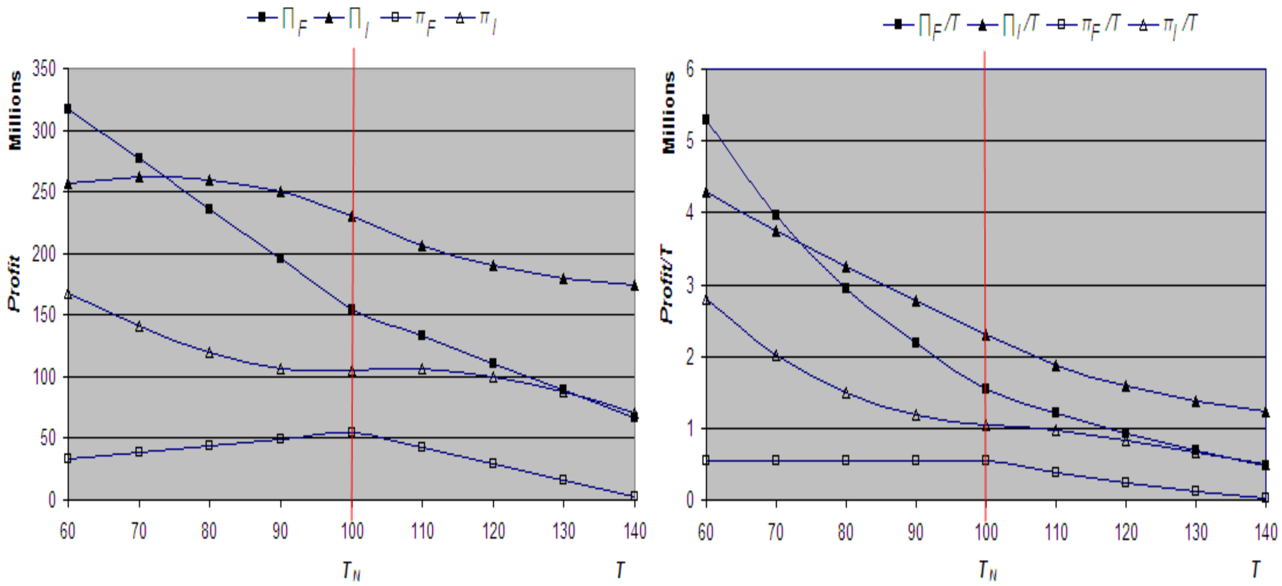
The software @risk (www.palisade.com/risk) was used to simulate. Fig. 4 shows the profits for the operator and service provider for the two contracts as functions of time in the upper left panel, profits divided by time T in the upper right panel, and how profits are composed of gross income and OPEX in the two lower panels.

For the operator, the profit with the fixed price contract Π_F always decreases with T as shown in (9). With the fixed price contract, the service provider has no incentive to decrease T below T_N. Hence the operator can not expect the high profits shown for $T \leq T_N$, but may instead expect

Π_F=155,000,000 for T=T_N, or lower profit if the service provider does not complete the project by time T_N. Also, the operator's profit Π_I for the incentive based contract decreases with T when T≥73.6 with these parameter values. When exceeding T_N, which means that the service provider has not delivered as agreed in the contract, the contract is renegotiated. This affects performance negatively (Osmundsen et al., 2008).

The renegotiation parameter A in (3) is assumed lower than the sum f+d of the fixed income and the other income, and hence the service provider's gross income g_F increases more moderately when T≥T_N compared with when T≤T_N. Hence the service provider's profit π_F increases with T up to T_N, benefiting from wasting time until T_N, and thereafter decreases with T, as punishment in the form of a low renegotiation parameter A starts to operate.

With an incentive based contract, the service provider benefits from using substantially less time than T_N, and suffers from punishment when exceeding T_N substantially. When T≤T_N, the service provider's gross income g_I is U formed whereas its OPEX o_I increases linearly, causing the service provider's profit π_I to be U formed reaching a local minimum when T=97. As T increases through T_N, the gross income g_I increases more moderately and concavely, while o_I is still linear. This causes the service provider's profit π_I to be inverse U formed for T≥T_N, to reach a local maximum when T=105, and to decrease when T>105. The upper right panel shows profits divided by time. Using (11), the service provider's π_F/T for the fixed price contract is constant when T≤T_N, and decreases when T≥T_N. The other three profits divided by time decrease throughout.



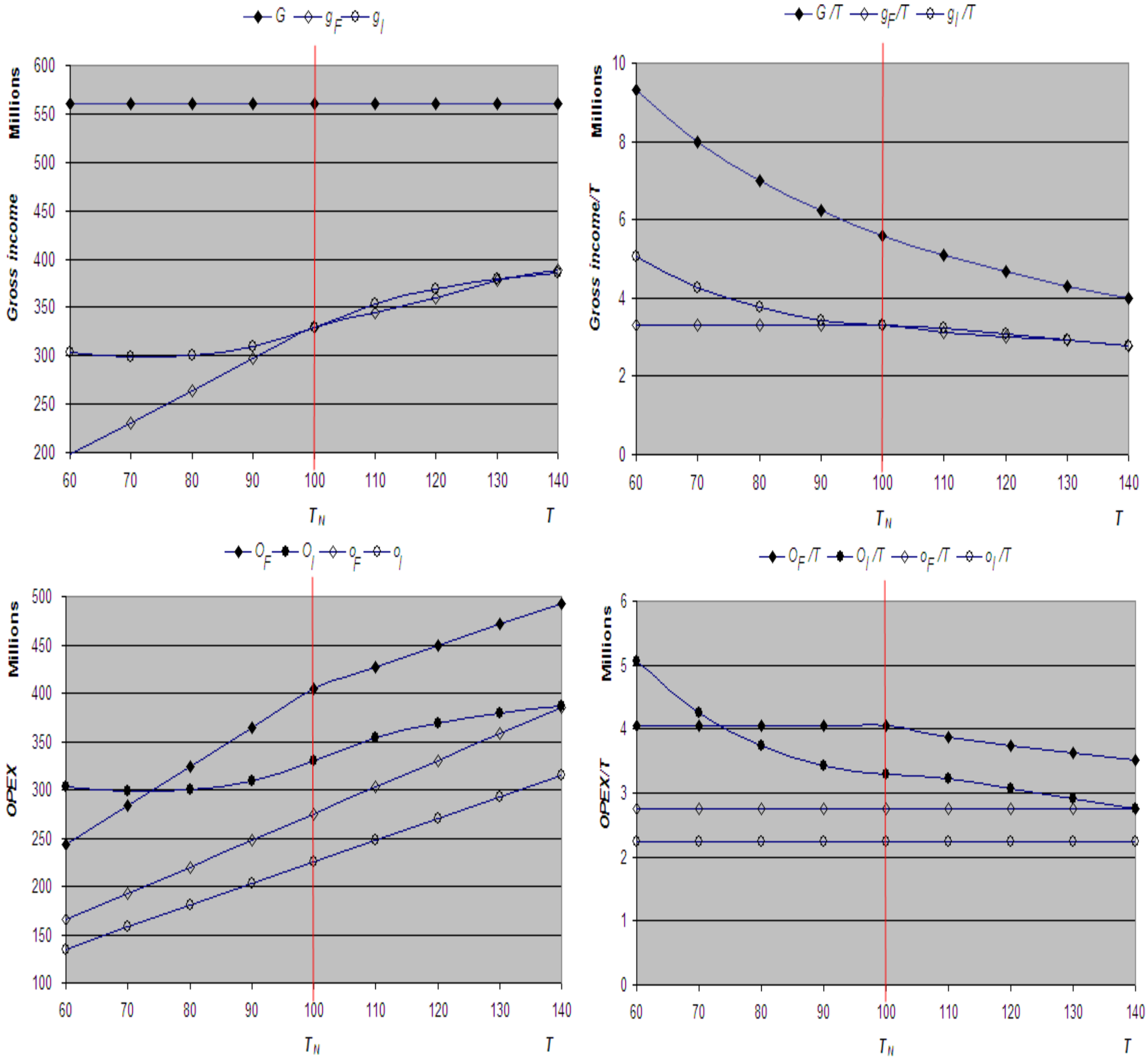


Fig. 4- How time affects the operator's and the service provider's profits, gross income and OPEX.

Fig. 5 sets T=90 so that the equations for $T \leq T_N$ apply, and plots the profits as functions of the service provider's income w and the income scaling parameter b. These do not affect the fixed price contract. For the incentive based contract, the operator suffers and the service provider benefits from increased w and b when the project is completed 10 days ahead of the estimated time. As seen in (10) and (12), the changes are moderate for w and substantial for the exponential b. This gives us the flexibility we need to adjust incentives arbitrarily much, which allows the incentive based contract to be fully operational.

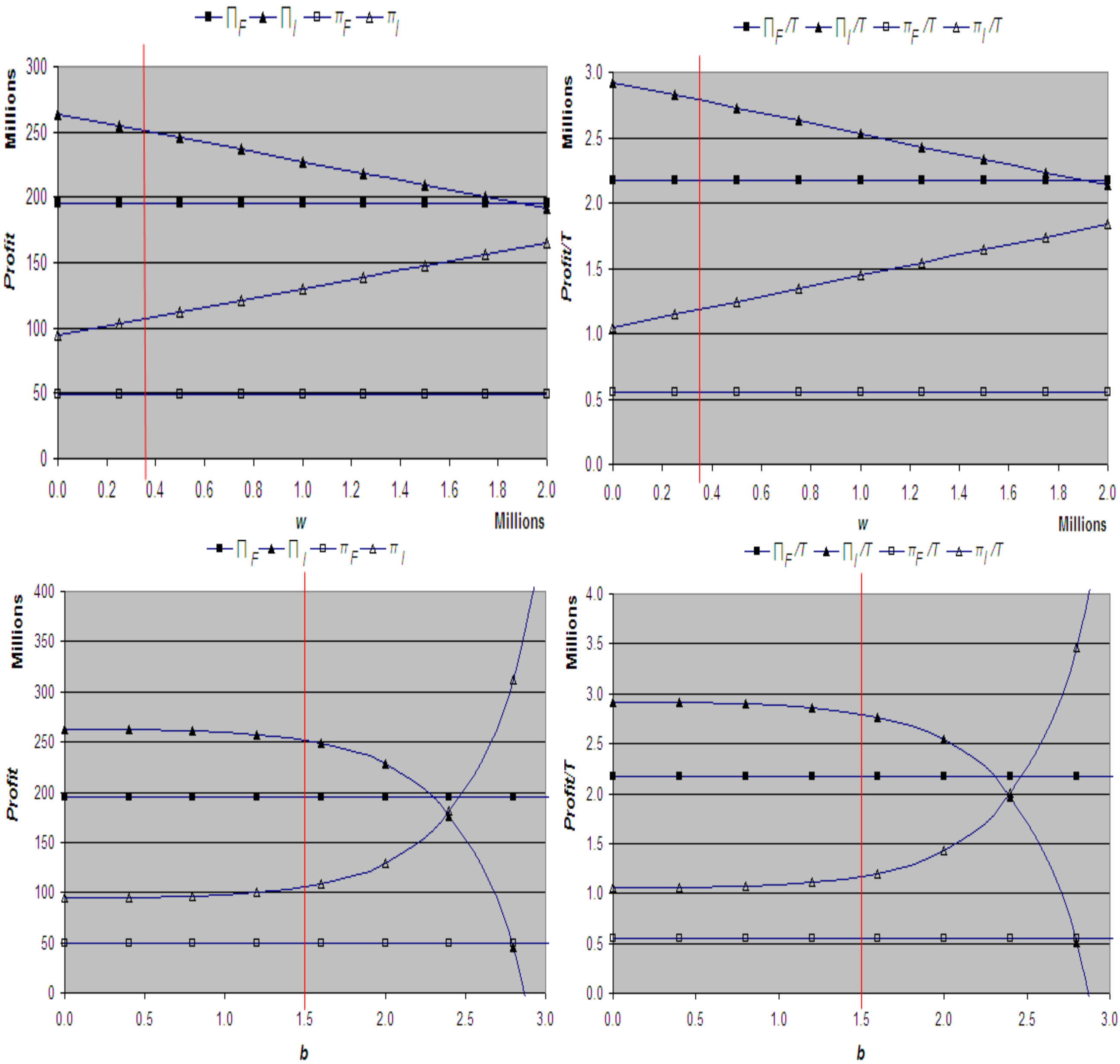


Fig. 5- How the service provider's income *w* and the income scaling parameter *b* affect profits when the project is completed 10 days ahead of the estimated time.

Fig. 6 sets T=110 so that the equations for $T \geq T_N$ apply, and plots the profits as functions of the renegotiation parameter A (which affects only the fixed price contract) and punishment parameters C and c (which affect only the incentive based contract). Using (9) and (11), the operator suffers while the service provider benefits from increasing A under the fixed price contract when the project is completed after the estimated time. Using (10) and (12), the operator benefits while the service provider suffers from increasing C under the incentive based contract when the project is completed after the estimated time. The benefit and suffering increase substantially as the punishment scaling parameter c increases. This again gives us the flexibility we need to adjust incentives, which allows the incentive based contract to be operational also when the project is completed after the estimated time.

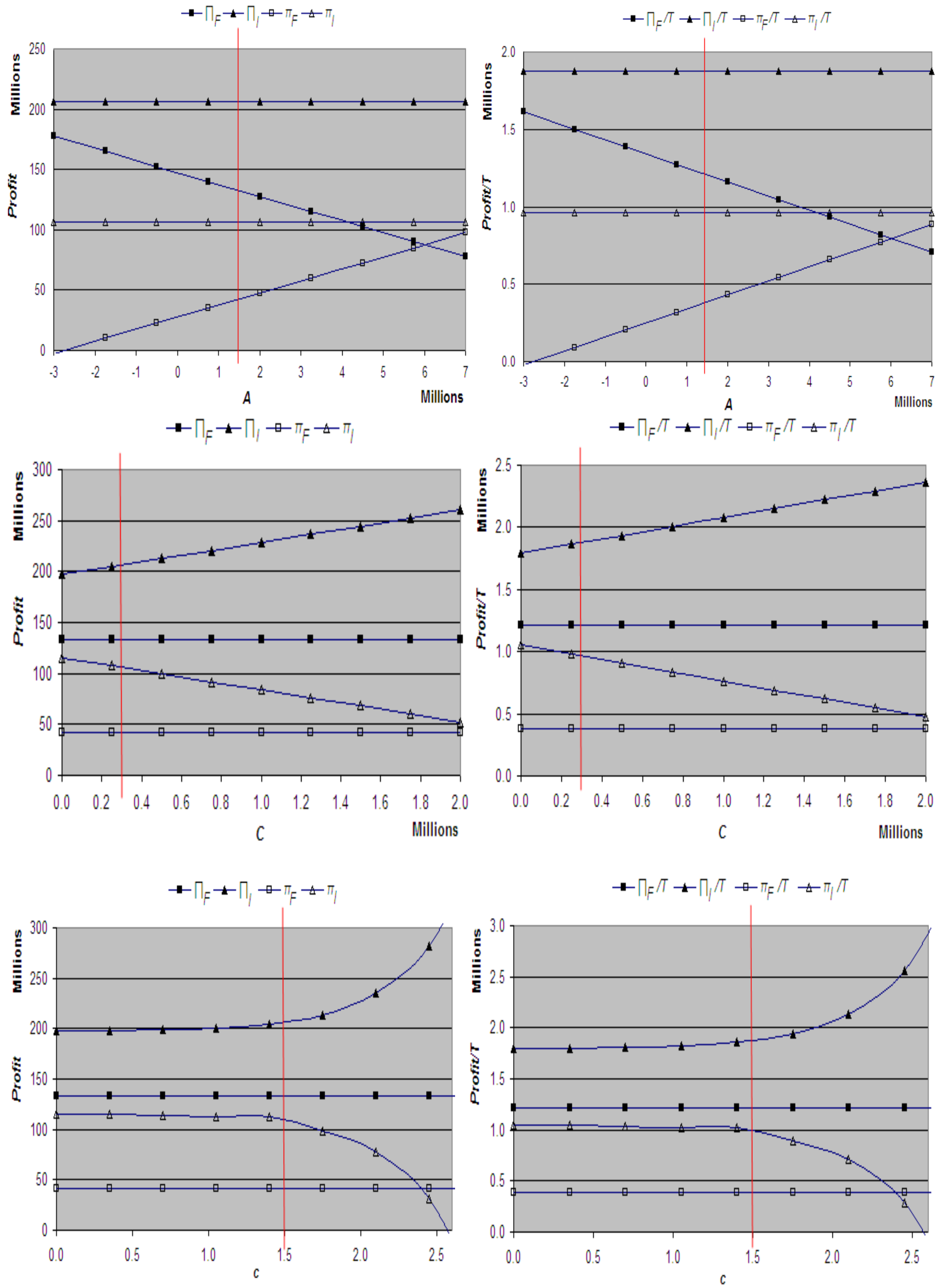
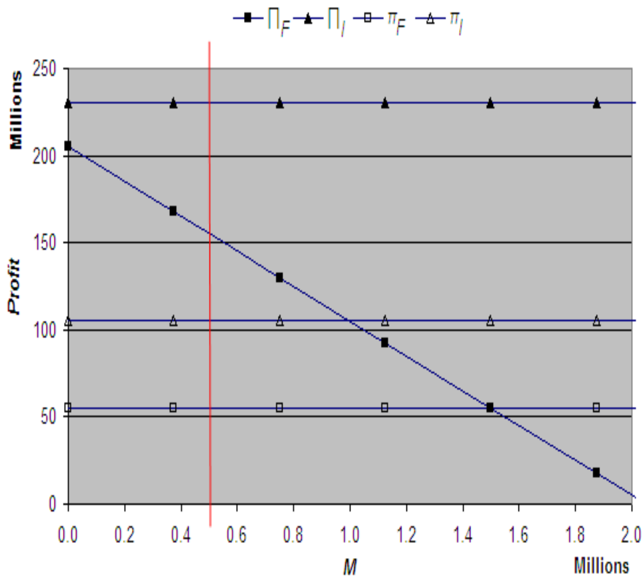


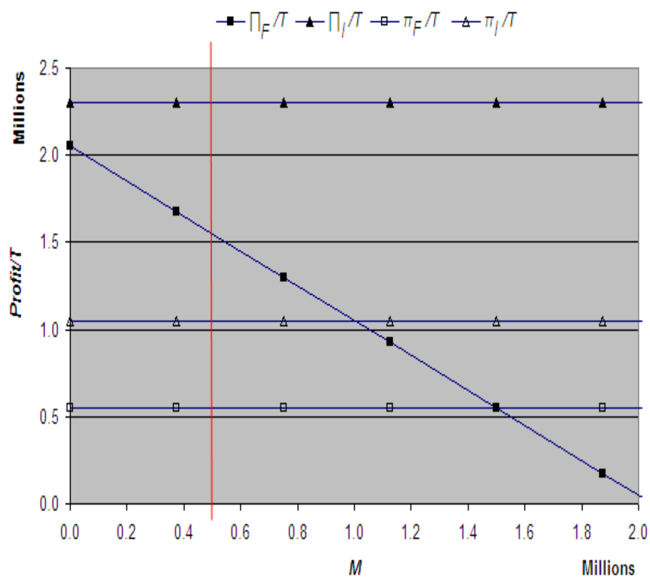
Fig. 6- How the renegotiation parameter *A* and punishment parameters *C* and *c* affect profits when the project is completed 10 days after the estimated time.

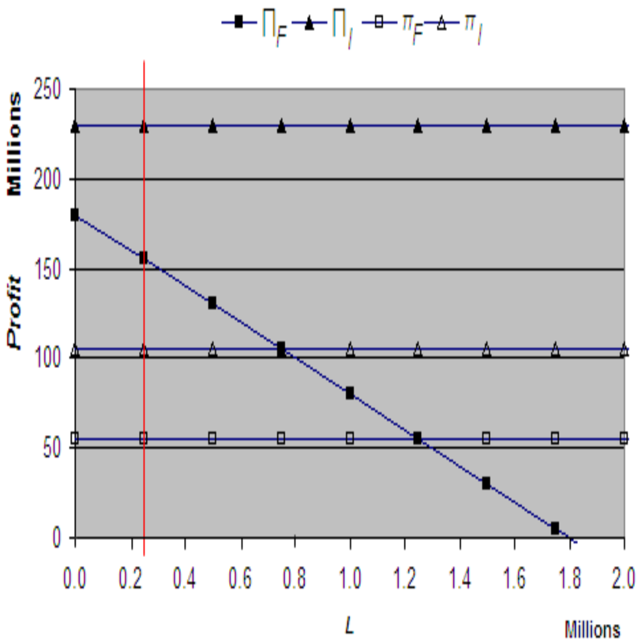
Whereas Figs. 5 and 6 show the profit dependence on w (which depends on B,e,x,y,γ),b,A,C,c dependent on whether or not the project is completed on time, Fig. 7 plots the profits as functions of the remaining 10 parameters M,L,h,z,f,d,v,P,Q,T_N when the project is completed on time, $T=T_N$. Using (9), the main costs M of monitoring etc and other costs L of catering etc affect the operator negatively for the fixed price contract, and do not affect the other profits. Analogously, using (11), the costs h and z of moral hazard and adverse selection affect the service provider negatively for the fixed price contract, and do not affect the other profits. As seen from (9) and (10), fixed income f and income d affect the operator's profit negatively under both contracts. In contrast, as discussed after (12) when $T=T_N$ for both contracts, f does not affect the service provider while d affects the service provider positively. The service provider's other cost v affects the service provider negatively, and does not affect the operator.

The oil price P and production Q affect the operator positively and are not designed to affect the service provider. The operator earns negative profits when P or Q are too low. When Q has its baseline value, the operator needs oil prices of at least \$58 and \$47 per barrel, respectively, for the fixed price contract and incentive based contract, to earn positive profits. If the oil price doubles from \$80 to \$160 per barrel, the profit increases with a factor 4.6 from \$155,000,000 to \$715,000,000 for the fixed price contract, and with a factor 3.4 from \$230,000,000 to \$790,000,000 for the incentive based contract. When P has its baseline value, the operator needs production of at least 5,100,000 barrels and 4,100,000 barrels, respectively, for the fixed price contract and incentive based contract, to earn positive profits. Doubling the production from its baseline has the same impact on operator profits as doubling the oil price from its baseline.

The last two panels show the profits as the estimated time $T=T_N$ to complete the project increases from 0 to 200. Both actors prefer the incentive based contract rather than the fixed price contract in both panels. In the left panel the operator suffers from increasing $T=T_N$, and more so for the fixed price contract. The service provider benefits from increasing $T=T_N$, and more so for the incentive based contract. In the right panel, focusing on profit per day, the operator benefits exponentially from decreasing $T=T_N$, while the service provider is indifferent across time since the same profit is earned every day regardless of $T=T_N$.






Π_F Π_I π_F π_I
Millions
Profit
0 50 100 150 200 250
0.0 0.2 0.4 0.6 0.8 1.0 1.2 1.4 1.6 1.8 2.0
L
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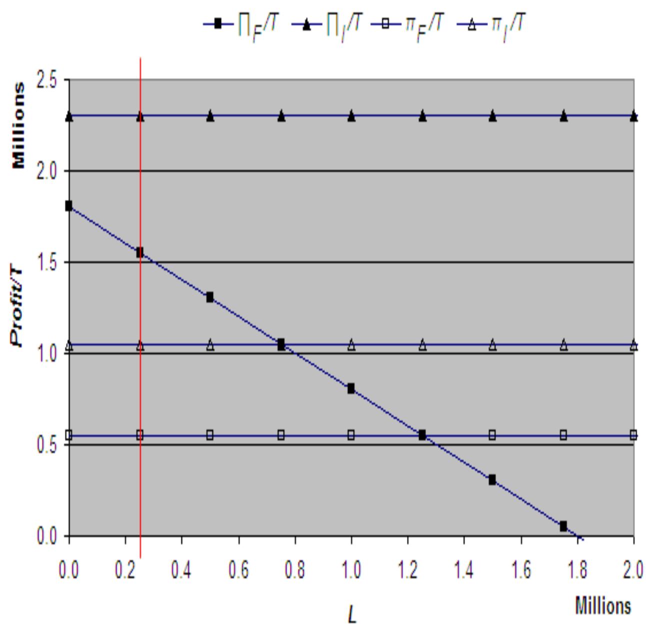
Π_F/T Π_I/T π_F/T π_I/T
Millions
Profit/T
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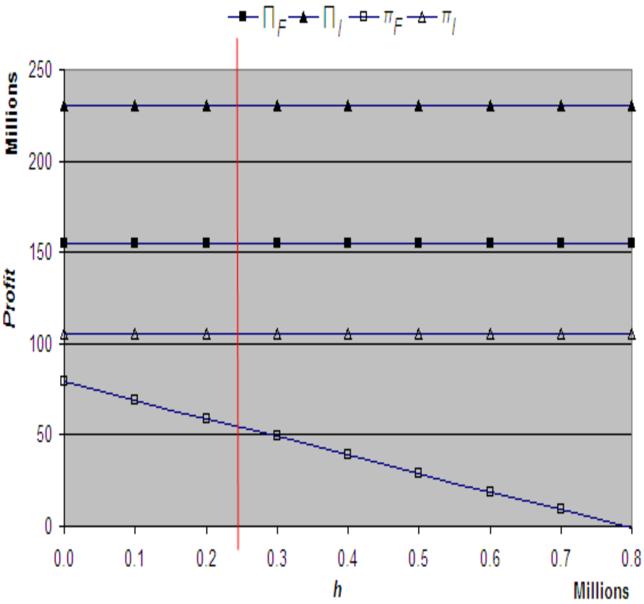
Π_F Π_I π_F π_I
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Profit
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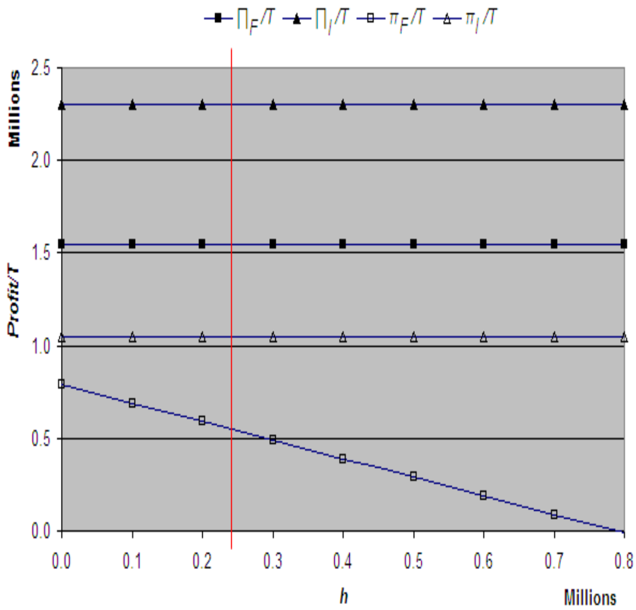
0.0 0.1 0.2 0.3 0.4 0.5 0.6 0.7 0.8
h
Millions


Π_F/T Π_I/T π_F/T π_I/T
Millions
Profit/T
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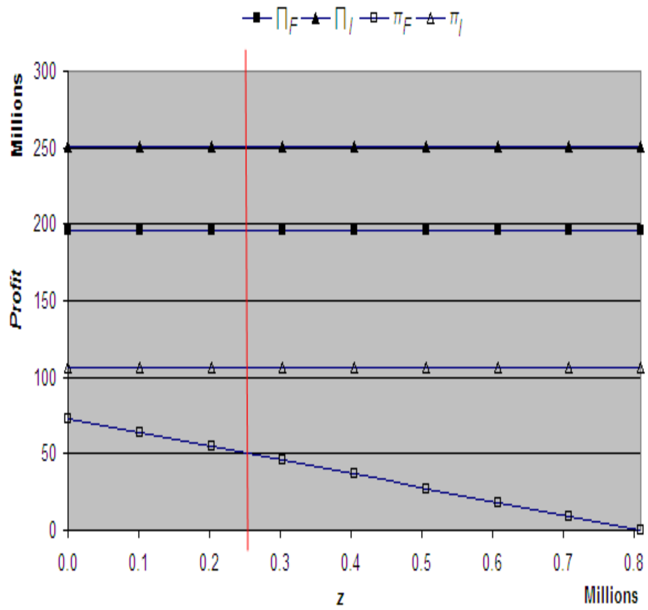
Π_F Π_I π_F π_I
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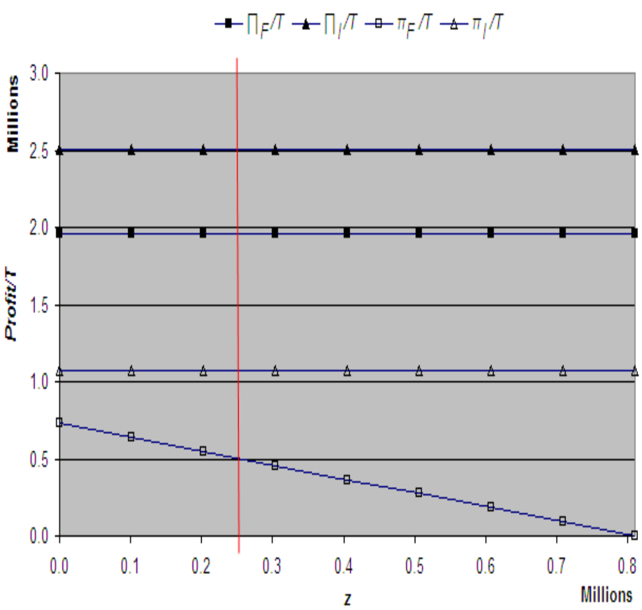
Millions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Millions
Profit/T
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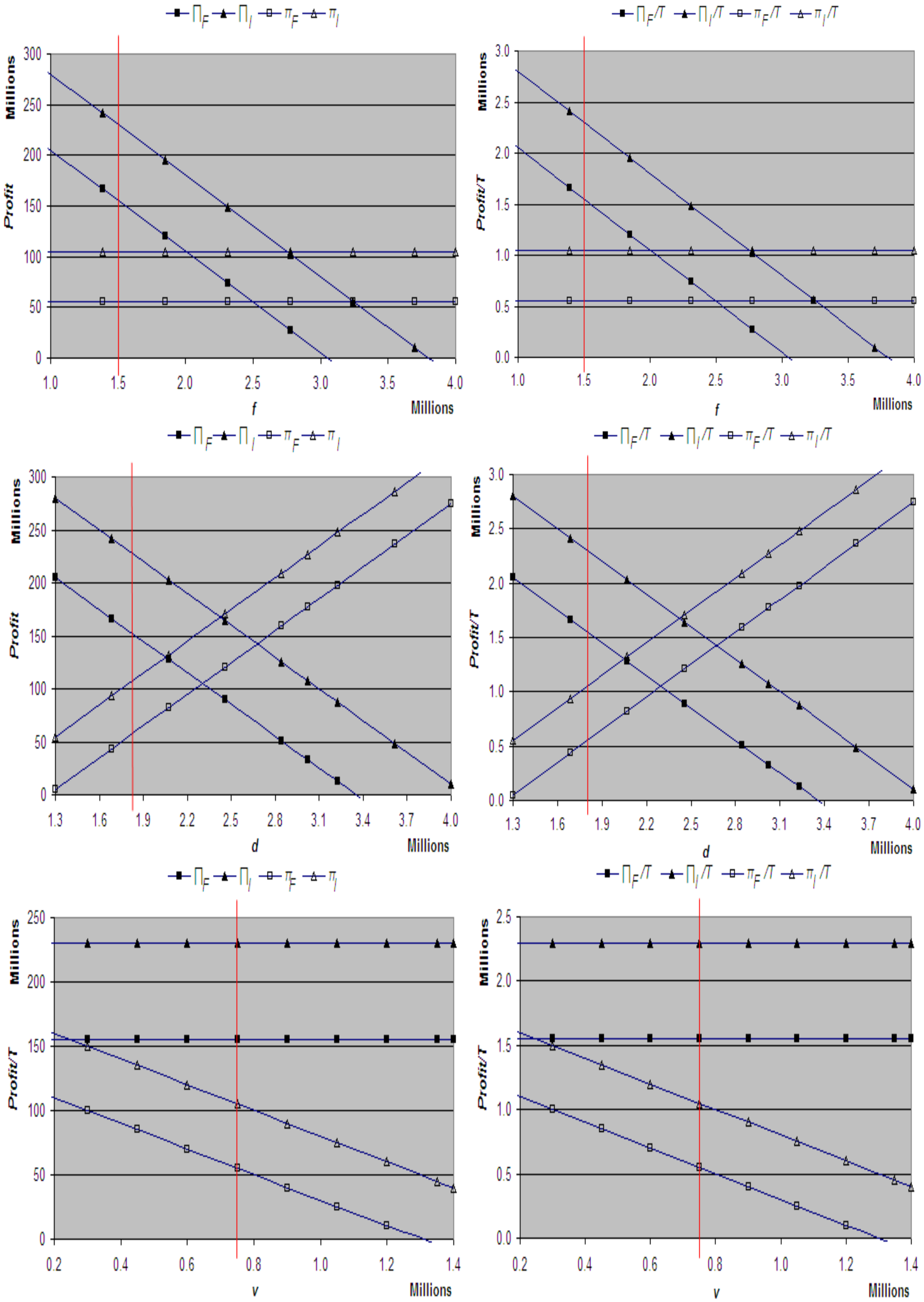
z
Millions


Π_F Π_I π_F π_I
Millions
Profit
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1.0 1.5 2.0 2.5 3.0 3.5 4.0
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Millions
Π_F/T Π_I/T π_F/T π_I/T
Millions
Profit/T
3.0 2.5 2.0 1.5 1.0 0.5 0.0
1.0 1.5 2.0 2.5 3.0 3.5 4.0
f
Millions
Π_F Π_I π_F π_I
Millions
Profit
300 250 200 150 100 50 0
1.3 1.6 1.9 2.2 2.5 2.8 3.1 3.4 3.7 4.0
d
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Millions
Profit/T
3.0 2.5 2.0 1.5 1.0 0.5 0.0
1.3 1.6 1.9 2.2 2.5 2.8 3.1 3.4 3.7 4.0
d
Millions
Π_F Π_I π_F π_I
Millions
Profit/T
250 200 150 100 50 0
0.2 0.4 0.6 0.8 1.0 1.2 1.4
v
Millions
Π_F/T Π_I/T π_F/T π_I/T
Millions
Profit/T
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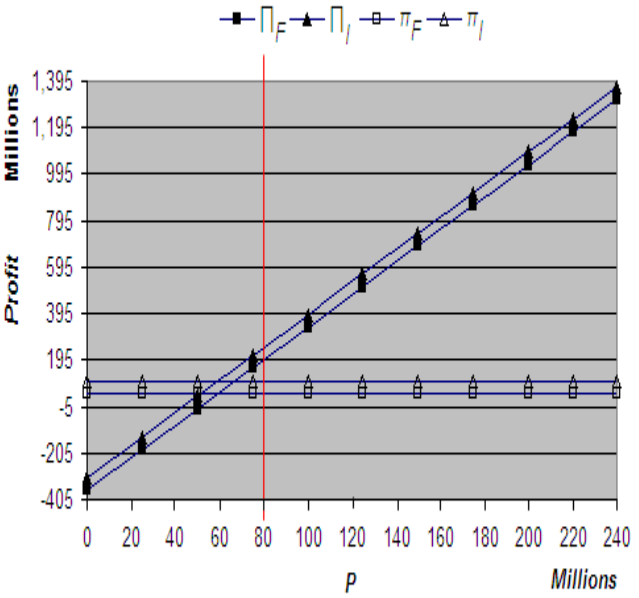
v
Millions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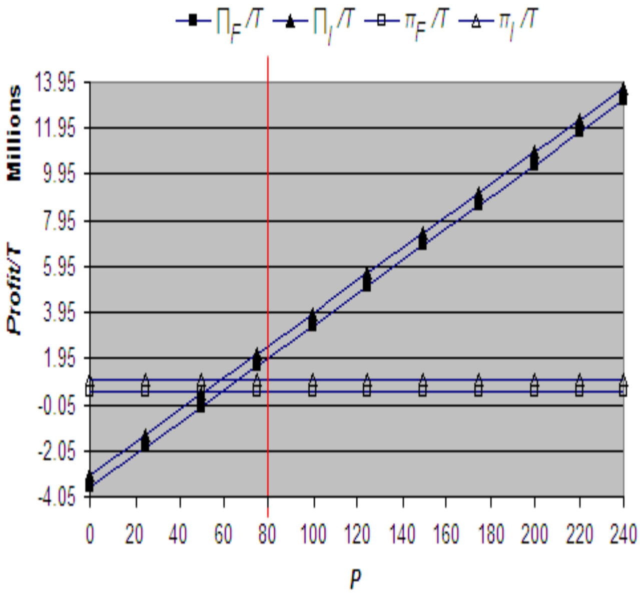
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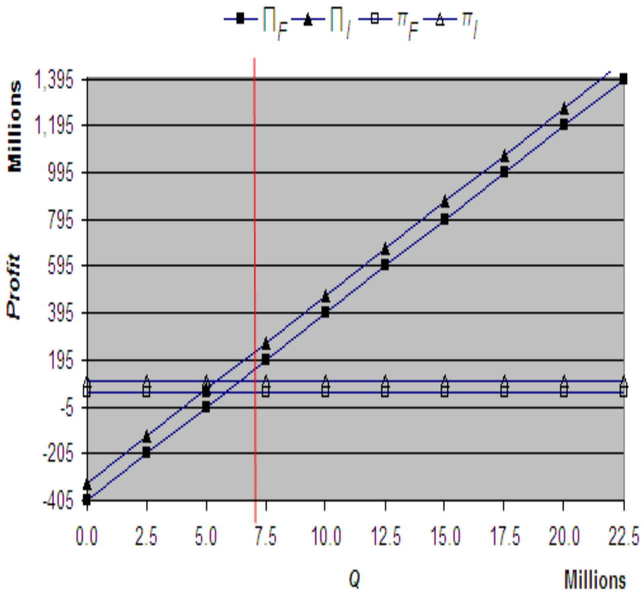
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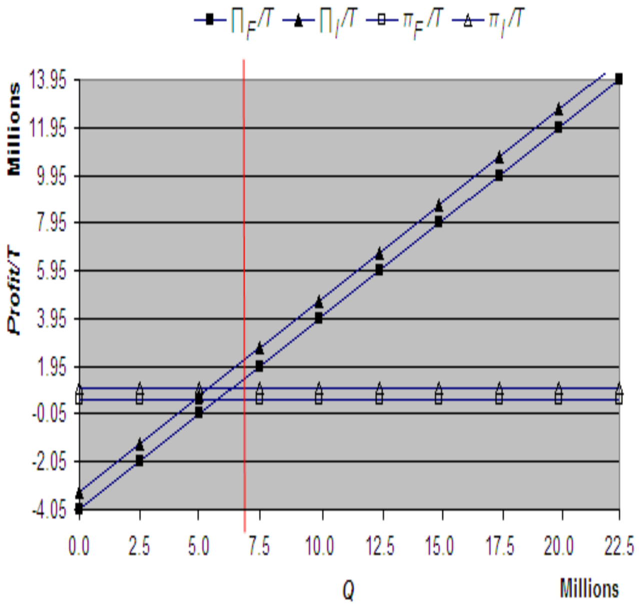
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Profit/T
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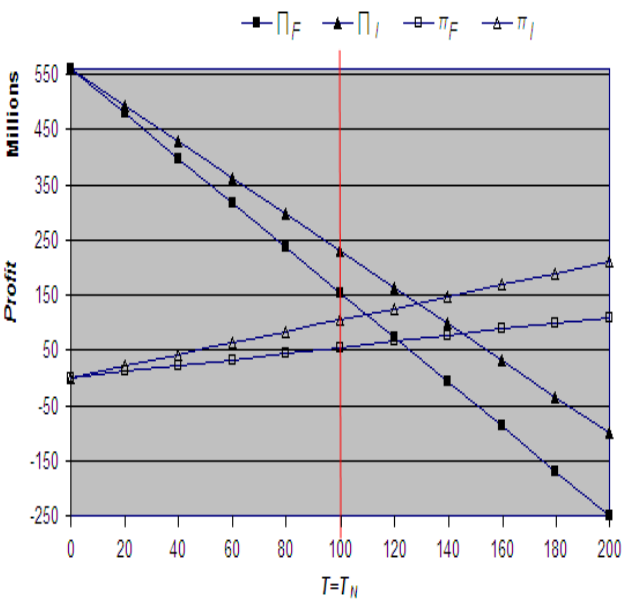

Π_F Π_I π_F π_I
Millions
Profit
$T=T_N$

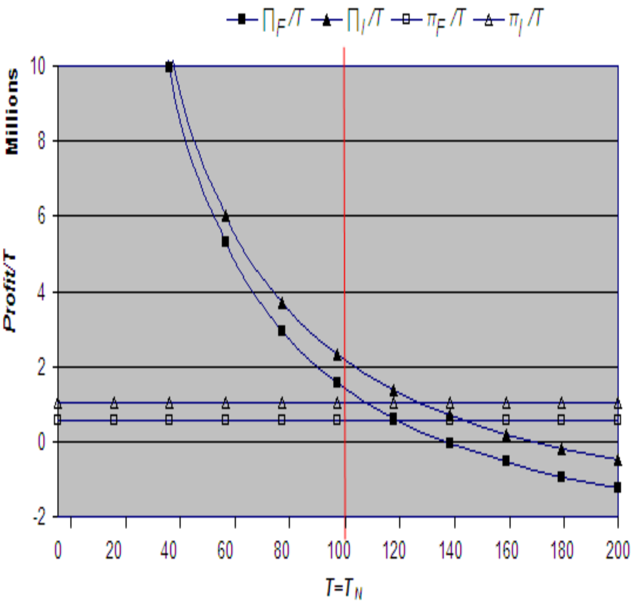

Π_F/T Π_I/T π_F/T π_I/T
Millions
Profit/T
$T=T_N$

Fig. 7- How the 10 parameters M,L,h,z,f,d,v,P,Q,T_N affect profits when the project is completed on time, $T=T_N$.

7. SENSITIVITY ANALYSIS OF CONTRACT CHOICES

The previous section analyzed how the four profits depend on the time T to complete the project, and on 15 parameters allowed to deviate from their baseline values. This section analyzes how the time T and the parameters affect whether the operator and service provider prefer the fixed price contract versus the incentive based contract. We illustrate graphically with sensitivity analysis in which two-dimensional areas the two actors prefer the two contracts. The time T varies along the horizontal dimension, while the following 13 parameters vary along the vertical dimension: T_N, w, $f+d$, v, $M+L$, A, b, C, c, $h+z$. The impact of the oil price P and the production Q is not considered in this section since these impact the operator equivalently in both contracts, see (9) and (10), and do not impact the service provider, see (11) and (12). We also do not consider the impact of the remaining five parameters B,e,x,γ,y since these affect w, which we analyze the impact of. We join parameters that operate together so that we get 10 panels for each actor. $M+L$ and $f+d$ operate together in the operator's profits. $h+z$ operate together in the service provider's profits. $f+d$ do not operate together in the service provider's profits, but setting $\pi_F=\pi_I$ implies an equation as a function of $f+d$. Hence from the $f+d$ panel we can analyze the impact of changing f when d is fixed, and analyzing the impact of changing d when f is fixed.

In Fig. 8 the operator's preference is shown to the left, and the service provider's preference is shown to the right. Equating the profits in (9) and (10) specifies when the operator is indifferent between the two contracts, see Appendix A. Equating the profits in (11) and (12) specifies when the service provider is indifferent between the two contracts, see Appendix B. Fig. 8 shows the indifference curves, shows with white areas where the two actors prefer the fixed price contract, and with grey areas where the two actors prefer the incentive based contract. The stapled horizontal and vertical lines show the baseline parameter values.

Let us start with the general observations. We have intentionally chosen the baseline parameter values such that both actors prefer the incentive based contract for that baseline, shown with a grey area where the two stapled lines cross in each panel. From the 10 left panels we observe that the operator for the baseline parameter values prefers the fixed price contract when the project is completed in sufficiently short time T, that is $T\leq 73.6$. The reason is that the design of the operator's profit in (10) is such that it costs $w(T_N-T)^b$ for the operator to provide the service provider with incentives to complete the project in sufficiently less time than $T_N=100$. At some point, for low T, the costs of incentives take their toll on the operator, who then prefers the fixed price contract.

From the 10 right panels we observe that the service provider prefers the incentive based contract when the project is completed in less time than the estimated time, that is $T\leq T_N$. The service provider enjoys receiving $w(T_N-T)^b$, as seen from the service provider's profits in (11) and (12) which show that $\pi_I \geq \pi_F$ when $T\leq T_N$. Conversely, the service provider prefers the fixed price contract for the baseline parameter values when completing the project substantially after the estimated time, that is $T\geq 192.7$. The reason is seen from (11) and (12). The service provider benefits from the renegotiation parameter A for the fixed price contract, and suffers increasingly by the punishment $C(T-T_N)^c$ as T exceeds T_N for the incentive based contract.

Let us start with the T_N panels. For the baseline T_N=100, the operator is indifferent between the two contracts when T=73.6, earning a profit \$262,000,000, and prefers the incentive based contract when T≥73.6. The indifference curve is almost linear and above the point (T,T_N)=(100,100). For example, when T_N =132.2, the operator prefers the incentive based contract when T≥100. When T_N=100, the service provider is indifferent between the two contracts when T=192.7, suffering a negative profit -\$65,500,000, and prefers the incentive based contract when T≤192.7. Again the indifference curve is almost linear, but below the point (T,T_N)=(100,100). For example, when T_N =28.0, the service provider prefers the incentive based contract when T≤100. Consistent with Theorem 2, there is a broad band from lower left to upper right where both actors prefer the incentive based contract. In the upper left area where T<<T_N only the operator prefers the fixed price contract. In the lower right area where T>>T_N only the service provider prefers the fixed price contract. There is no area where both actors jointly prefer the fixed price contract.

Proceeding with the w panels, the operator's indifference curve for w in (A2) increases exponentially from 0 to infinity when T increases from T to T_N. Again the operator prefers the incentive based contract when T≥73.6. When the service provider completes the project too quickly, the incentive based contract becomes too costly for the operator. As the income w paid to the service provider increases above \$345,000, the service provider can spend more time to complete the project while making the operator indifferent between the two contracts, and conversely as w decreases below \$345,000. The service provider prefers the incentive based contract when T≤192.7 regardless of w. This is seen from (11) and (12) when T≤T_N, where moral hazard h and adverse selection z are too costly for the service provider under the fixed price contract.

For the f+d panels, again the operator prefers the incentive based contract when T≥73.6, except for the upper right white area where it prefers the fixed price contract. This white area follows since the term f+d in (10) is multiplied with time T and is paid to the service provider also when T≥T_N under the incentive based contract, which is costly for the operator for the baseline punishment parameters C and c. In contrast, f+d in (9) is multiplied with time T_N and is not paid to the service provider when T≥T_N under the fixed contract where the baseline renegotiation parameter A applies instead. The reverse logic applies for the service provider giving a lower right white region. When f+d is low, the income from the operator under the incentive based contract becomes too low when the service provider wastes time beyond T=T_N, and the punishment parameters C and c become too harsh, and hence the service provider prefers the fixed price contract.

For the v panels, the service provider's other cost v does not affect the operator, and affects the service provider equally under the two contracts, and hence under a broad vertical band independent of v, 73.6≤T≤192.7, both actors prefer the incentive based contract. As before, to the left of the band only the operator prefers the fixed price contract, to the right of the band only the service provider prefers the fixed price contract, and nowhere do both actors prefer the fixed price contract.

For the M+L panels, the operator's costs M of monitoring etc and other costs L of catering etc affect the operator and not the service provider. Observe from (A2) and (A4) that M+L incurred under the fixed price contract and w incurred under the incentive based contract are inverse functions when T≤T_N. Hence increasing M+L above \$750,000 corresponds to decreasing w below \$345,000, and both changes allow the service provider to spend more time to complete the project while making the operator indifferent between the two contracts, and conversely when $M+L$ decreases below \$750,000 and w increases above \$345,000.

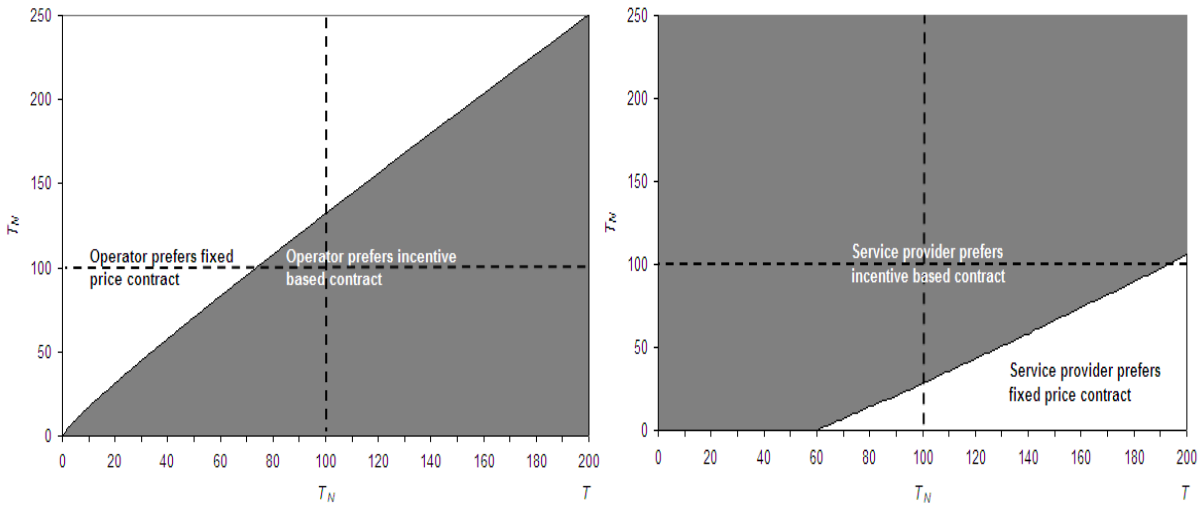
For the A panels, observe from (A3),(A5),(B2),(B3) that the indifference curves for A for both actors equal $f+d$ minus a function. This explains the mirror images of the A and $f+d$ panels. In the lower right white area for the operator the renegotiation parameter A is so negative that the service provider is severely punished for exceeding the time T_N to complete the project, and then the operator prefers the fixed price contract. Conversely, in the upper right white area for the service provider the renegotiation parameter A is so large that the service provider is rewarded for exceeding the time T_N to complete the project, and then the service provider prefers the fixed price contract.

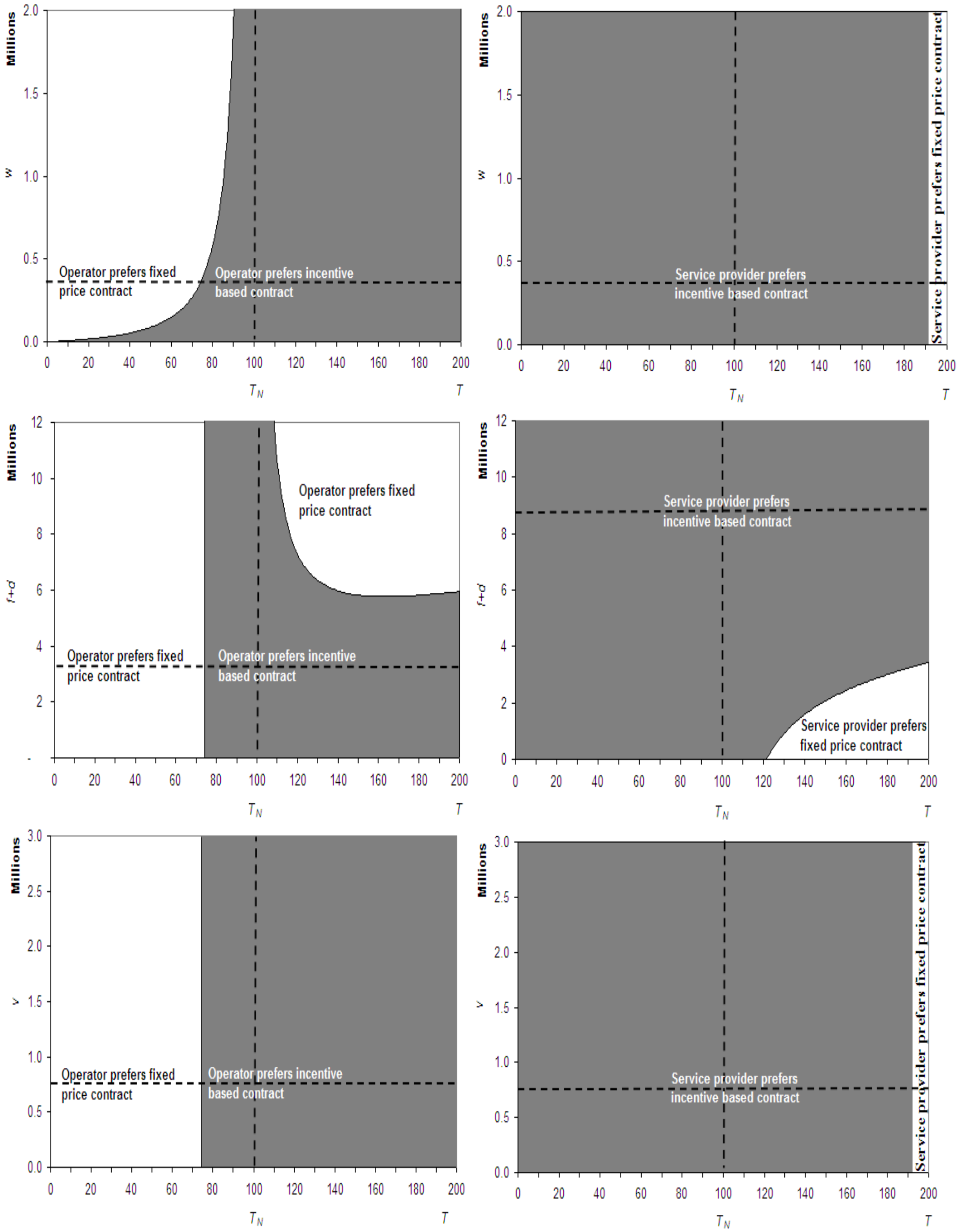
The b panels are reminiscent of the w panels, but the operator's indifference curve for b is inverse S shaped rather than exponential when $T \leq T_N$. As seen from (A2) where w is the service provider's income and b scales the income, convex indifference curve follows from concave reward when $0 \leq b \leq 1$, and concave indifference curve follows from convex reward when $b \geq 1$.

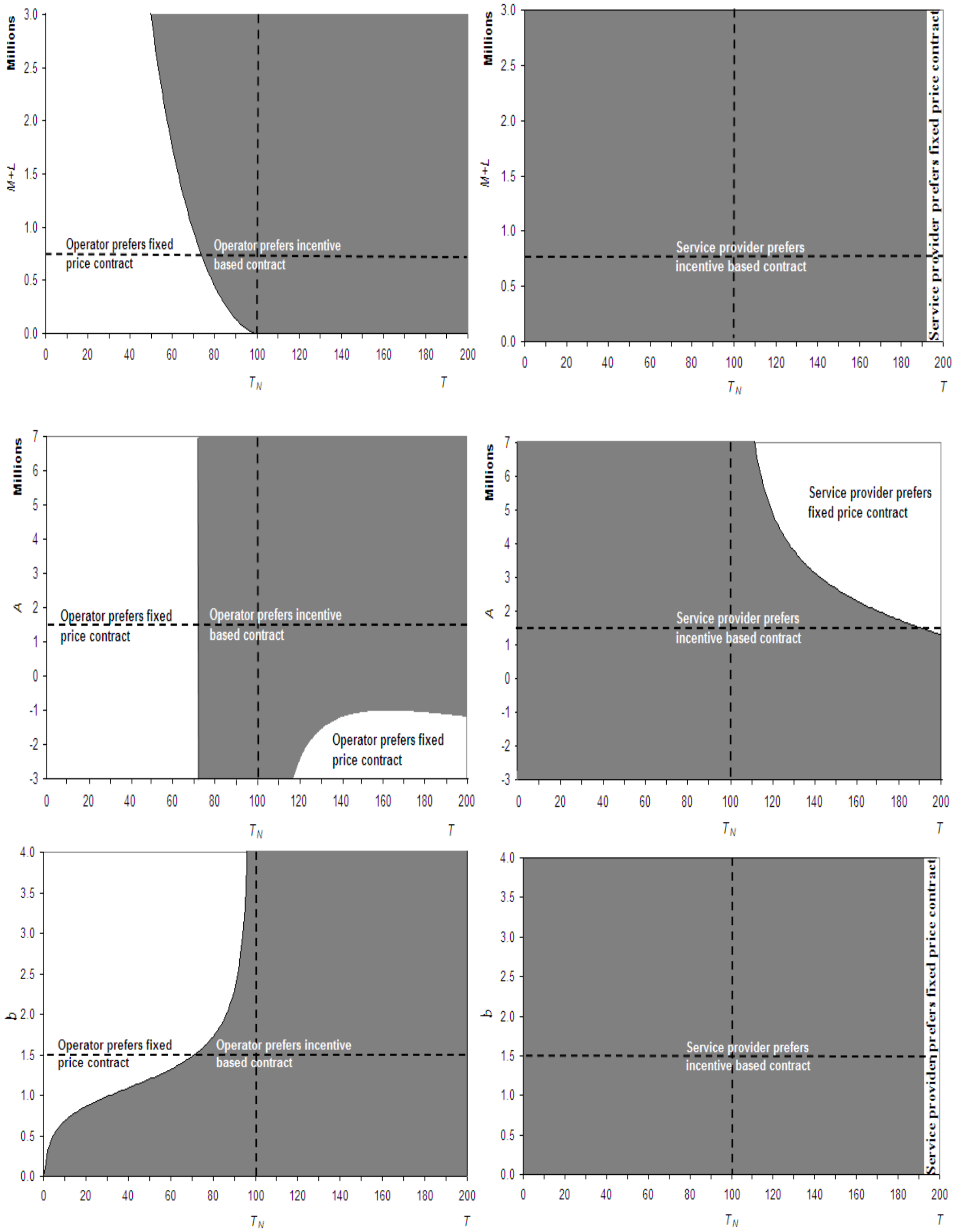
The C panels are reminiscent of the A panels which is reasonable since C is punishment under the incentive based contract, and positive A is reward under the fixed price contract, if the service provider does not complete the project on time. Hence the operator prefers the fixed price contract when the punishment C is lenient (small lower right white area), and the service provider prefers the fixed price contract when the punishment C is harsh (upper right white area).

The parameter c scales the punishment and hence the c panels are similar to the C panels.

Finally, the service provider's costs $h+z$ of moral hazard and adverse selection under the fixed price contract do not affect the operator, but do affect the service provider. As these costs decrease, the value of T where the service provider is indifferent between the two contracts decreases, making the service provider prefer the fixed price contract for shorter times T of completing the project.




Millions
w
Operator prefers fixed price contract
Operator prefers incentive based contract
T_N
T
Service provider prefers incentive based contract
Service provider prefers fixed price contract
f+d
Operator prefers fixed price contract
Service provider prefers fixed price contract
v


Millions
M+L
Operator prefers fixed price contract
Operator prefers incentive based contract
Service provider prefers incentive based contract
Service provider prefers fixed price contract
A
Operator prefers fixed price contract
Service provider prefers fixed price contract
b
T_N
T

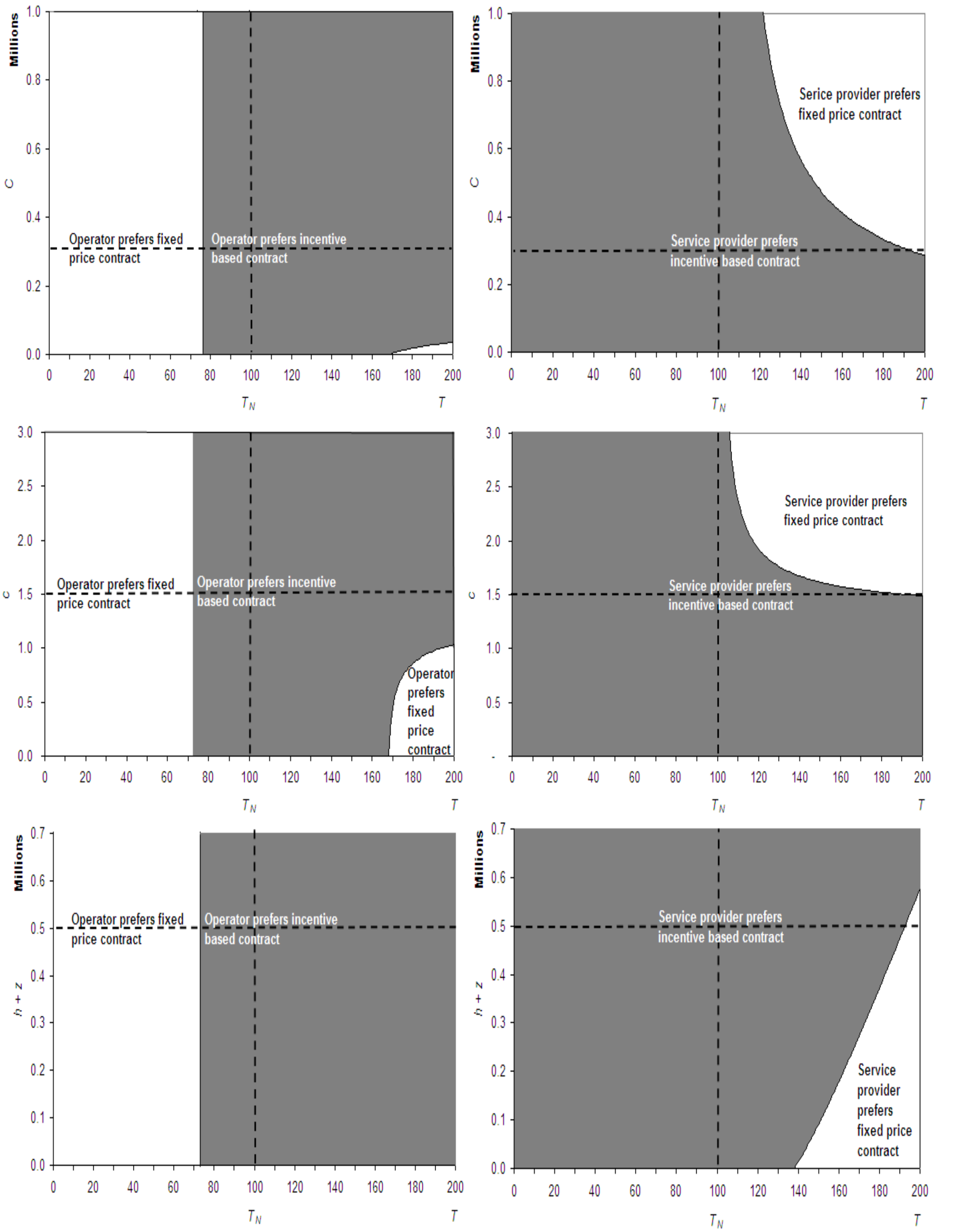


Fig. 8- Operator's and service provider's contract preferences as *T* varies horizontally and T_N, *w, f+d, v, M+L, A, b, C, c, h+z* vary vertically

8. CONCLUSION

The fixed price contract is the common contract on the Norwegian Continental Shelf (NCS). The operator pays the service provider a fixed price per day for completion of a project within a specified time. If the service provider exceeds the specified time, the contract is renegotiated causing lower payment to or punishment for the service provider. The fixed price contract is simplistic, has evolved naturally over time for historical reasons, but displays a certain rigor and exhibits disadvantages which gradually become more apparent.

Examples of disadvantages of the fixed price contract are moral hazard, which is post-contractual opportunism where the principal cannot be sure that the agent exerts maximal effort, and adverse selection, which is pre-contractual information asymmetry where the principal cannot be certain that the agent accurately performs its work. The service provider may work for its own goals rather than the operator's goals. It usually knows more about its tasks than the operator, and may exploit the information for its own interest. Divergent goals and interests are a huge challenge for the fixed price contract. The operator cannot fully monitor and observe the service provider's actions, as it can only measure its own profit. Since decisions are based on asymmetric information, both the operator and service provider spend resources acquiring information. The fixed price contract thus usually causes large monitoring and coordination costs, as well as larger other costs related to catering, planning, administration of onshore organization, overhead, insurance cost, etc.

The incentive based contract (sometimes called residual claimant based contract) is uncommon and almost never used on the NCS. Using reward and punishment, it incorporates compensation for actual performance according to targets, budget, schedule and/or quality. Incentives, such as material rewards, motivate agents to take particular actions. If the agent does not meet the performance criteria, the reward decreases and may become negative which constitutes a punishment.

The incentive based contract removes many of the costs common for the fixed price contract, especially related to moral hazard and adverse selection. Monitoring and coordination costs decrease. Various other costs also decrease e.g. if the service provider through the incentive based contract completes the project in shorter time. Agreement on goals and key performance indicators, and involvement of both actors in planning, may lead to better resource allocation. The drilling process involves balancing quality against time. Many input factors in the drilling process are time-critical, but high drilling speed can imply losing the drill string causing delays (Osmundsen et al., 2008). High first time quality can avoid damaging the formation. Whereas a fixed price contract has a strong focus on time, an incentive based contract has the potential to account for the complex relationship between quality and time by linking incentives to performance.

We develop models for both contracts accounting for the incomes and operating expenditures for the operator and service provider dependent on the time used, which is a free choice variable for the service provider. For the fixed price contract, the service provider earns a fixed payment per day regardless of the time used until the estimated time, and thereafter the contract is renegotiated. For the incentive based contract, the service provider earns a payment per day which increases (decreases) when using less (more) time than the estimated time.

Our study shows how the two contracts affect the time usage differently. When maximizing profit per day for the fixed price contract, we find that the service provider has no incentive to complete the project more quickly than the estimated time. If the renegotiated contract is sufficiently favorable for the service provider, it prefers to use infinitely much time. When maximizing profit per day for the incentive based contract, the service provider prefers to complete the project as quickly as possible.

The joint welfare analysis shows that the two actors collectively always prefer the incentive based contract rather than the fixed price contract. This result follows since costs associated with moral hazard, adverse selection, monitoring, coordination, etc. decrease with the use of an incentive based contract, which is collectively beneficial.

With individual profit maximization we find four results. First, both actors prefer the incentive based contract when the project is completed in less than the estimated time and the service provider’s variable income under the incentive based contract is below a certain level, or the project is completed in more than the estimated time and the punishment is neither too harsh for the service provider nor so lenient that the operator does not benefit from inflicting it. Second, the operator prefers the fixed price contract and the service provider prefers the incentive based contract when the project is completed in less than the estimated time and the service provider’s variable income is above a certain level (making incentives costly for the operator to provide), or the project is completed in more than the estimated time and the punishment is so lenient that the operator does not benefit from inflicting it under the incentive based contract. Third, the operator prefers the incentive based contract and the service provider prefers the fixed price contract when the project is completed in more than the estimated time and the punishment of the service provider under the incentive based contract is too harsh. Fourth, it is not possible for both actors to jointly prefer the fixed price contract.

That neither the joint welfare analysis nor the individual maximization procedure causes both actors to prefer the fixed price contract is remarkable given its current prevalence. The high costs of moral hazard and adverse selection which affect both the operator and the service provider are too high under the fixed price contract. The burdens of moral hazard and adverse selection can be shifted either on the operator or the service provider so that one, or the other, prefers the fixed price contract, but not such that both prefer it.

That the operator and the service provider never jointly prefer the fixed price contract follow from costly moral hazard, adverse selection, monitoring, and coordination. We propose that contracts used in the oil & gas industry should not be treated as simple rigorous fixed price mechanisms specifying what should be done when and at what cost. Laffont & Tirole (1999) argue that evolvement of future production and technologies can’t be described in the contract upfront, and then the industry volatility is not taken into consideration. Incorporating incentives, we propose that contracts should support projects to evolve positively, as the external and internal environment changes. We believe this will decrease the time to complete the project and increase profits for all actors. The actors’ profits are interrelated and the incentive based contract allows them to better understand each other’s goals, motivations, and value drivers.

APPENDICES

Appendix A Equations for when the operator is indifferent between the two contracts

Equating the operator’s profits in (9) and (10) implies

$$
\begin{aligned}
T_N &= T + \left(\frac{(M+L)T}{w}\right)^{1/b} \quad if\ T \le T_N \\
T - T_N &= \frac{A(T-T_N) + C(T-T_N)^c + (M+L)T}{f+d} \quad if\ T \ge T_N
\end{aligned}
\tag{A1}
$$

$$w = \frac{(M+L)T}{(T_N - T)^b} \; if \; T \le T_N \tag{A2}$$

$$f + d = A + \frac{C(T-T_N)^c + (M+L)T}{T-T_N} \quad if \quad T \ge T_N \tag{A3}$$

$$M + L = \begin{cases} \dfrac{w(T_N - T)^b}{T} if \; T \le T_N \\ \dfrac{(f+d-A)(T-T_N) - C(T-T_N)^c}{T} if \; T \ge T_N \end{cases} \tag{A4}$$

$$A = f + d - \frac{C(T-T_N)^c + (M+L)T}{T-T_N} \quad if \quad T \ge T_N \tag{A5}$$

$$b = \frac{1}{Ln(T_N - T)} Ln\left(\frac{(M+L)T}{w}\right) if \; T \le T_N \tag{A6}$$

$$C = \frac{(f+d-A)(T-T_N) - (M+L)T}{(T-T_N)^c} \quad if \quad T \ge T_N \tag{A7}$$

$$c = \frac{1}{Ln\;(T-T_N)} Ln\;\left(\frac{(f+d-A)(T-T_N) - (M+L)T}{C}\right) \; if \quad T \ge T_N \tag{A8}$$

Appendix B Equations for when the service provider is indifferent between the two contracts

Equating the service provider's profits in (11) and (12) implies

$$T - T_N = \frac{A(T-T_N) + C(T-T_N)^c - (h+z)T}{f+d} if \; T \ge T_N \tag{B1}$$

$$f + d = A + \frac{C(T-T_N)^c - (h+z)T}{T-T_N} \quad if \quad T \ge T_N \tag{B2}$$

$$A = f + d - \frac{C(T-T_N)^c - (h+z)T}{T-T_N} \quad if \quad T \ge T_N \tag{B3}$$

$$C = \frac{(f+d-A)(T-T_N) + (h+z)T}{(T-T_N)^c} if \; T \ge T_N \tag{B4}$$

$$c = \frac{1}{Ln(T-T_N)} Ln\left(\frac{(f+d-A)(T-T_N) + (h+z)T}{C}\right) if \; T \ge T_N \tag{B5}$$

$$h + z = \frac{A(T-T_N) + C(T-T_N)^c - (f+d)(T-T_N)}{T} if \; T \ge T_N \tag{B6}$$

Appendix C An alternative gross income function for the service provider

An alternative to the service provider's gross income function in (4) for the incentive based contract is

$$g_I = \begin{cases} [f+d]T_N & if\ T \le T_N \\ [f+d]T_N - C\,(T-T_N)^c & if\ T \ge T_N \end{cases} \tag{C1}$$

When $T \ge T_N$, the service provider is punished as before, but is guaranteed $(f+d)T_N$ if $T \le T_N$, which removes the term $w(T_N - T)^b$ obliterating the parameters w and b. The service provider's reward is that OPEX runs only until time T, allowing the service provider to start other projects at time T. Equation (C1) means that the service provider is paid for work completed, regardless of time used, as long as the estimated time T_N is not exceeded, but is punished if exceeding T_N. Contracts based on work completed rather than time used provide incentives to complete the work early. With (C1), all other equations in section 4 are as before except (10) and (12) which become

$$\Pi_I = G - O_I = \begin{cases} PQ - [f+d]T_N & if\ T \le T_N \\ PQ - [f+d]T_N + C(T-T_N)^c & if\ T \ge T_N \end{cases} \tag{C2}$$

$$\pi_I = g_I - o_I = \begin{cases} [f+d]T_N - [f+v]T & if\ T \le T_N \\ [f+d]T_N - [f+v]T - C(T-T_N)^c & if\ T \ge T_N \end{cases} \tag{C3}$$

Equating the profits gives

$$\Pi_F = \Pi_I \Rightarrow \begin{cases} T = \dfrac{[f+d]T_N}{f+d+M+L} & if\ T \le T_N \\ C(T-T_N)^c = -A(T-T_N) - (M+L)T & if\ T \ge T_N \end{cases} \tag{C4}$$

$$\pi_F = \pi_I \Rightarrow \begin{cases} T = \dfrac{[f+d]T_N}{f+d-h-z} & if\ T \le T_N \\ C(T-T_N)^c = -A(T-T_N) + (h+z)T & if\ T \ge T_N \end{cases} \tag{C5}$$

Observe that $(f+d)T_N\,/(f+d+M+L)$=81.5, and hence in Fig. 8 the vertical line for T=73.6 occurs for T=81.5 instead, and the vertical line for T=192.7 occurs for T=121.4 instead.

Equation (C1) can be explored in future research. This paper has considered both profit and profit per time unit. No exact answer exists for which focus is best. When focusing on profit, observe in Fig. 4 how the service provider's profit π_I for the incentive based contract decreases to a local minimum when T=97, then increases to a local maximum for T=105, and thereafter decreases. Hence using T=T_N=100 as an anchoring point, the service provider locally prefers to increase T to T=105, contrary to Fig. 2. Furthermore, the service provider does not prefer to decrease T to T=97 unless T can be increased further below T=97 where profit again increases. The reason for this is (4) where the punishment is too small when T is slightly above T_N, and the reward is too small when T is slightly below T_N. Whereas some service providers may choose such an anchoring point at T=T_N=100, others may not and may instead focus on profit earned over the entire time T to complete the project, or may focus on profit per time unit.

REFERENCES

Alchian, A. A., & Demsetz, H. (1972). "Production, Information Costs, and Economic Organization". *The American Economic Review, 62*(5), 777-795.

Barney, J. B., & Hesterly, W. S. (1996). Organizational Economics: Understanding the Relationship Between Organizations and Economic Analysis. In S. R. Clegg, C. Hardy & W. R. Nord (Eds.), *Handbook of Organization Studies* (pp. 115-147). Thousand Oaks, CA: Sage Publications Ltd.

Eisenhardt, K. M. (1985). "Control: organizational and economic approaches". *Management Science, 31*(2), 134-149.

Eisenhardt, K. M. (1989). "Agency Theory: An Assessment and Review". *The Academy of Management Review, 14*(1), 57-74.

Emhjellen, M., Hausken, K., & Osmundsen, P. (2006). "The Choice of Strategic Core-Impact of Financial Volume". *International Journal of Global Energy Issues, 26*(1/2), 136-158.

Grossman, S. J., & Hart, O. D. (1983). "An Analysis of the Principal-Agent Problem". *Econometrica, 51*(1), 7-45.

Grossman, S. J., & Hart, O. D. (1986). "The Costs and Benefits of Ownership: A Theory of Vertical and Lateral Integration". *The Journal of Political Economy, 94*(4), 691-719.

Hart, O. D., & Moore, J. (1988). "Incomplete Contracts and Renegotiation". *Econometrica, 56*(4), 755-785.

Holmstrøm, B. (1979). "Moral Hazard and Observability". *The Bell Journal of Economics, 10* (1), 74-91.

Holmstrøm, B., & Milgrom, P. (1994). "The Firm as an Incentive System". *The American Economic Review, 84*(4), 972-989.

Jensen, M. (1983). "Organization Theory and Methodology". *The Accounting Review, 58*(2), 319-339.

Jensen, M., & Meckling, W. (1976). "Theory of the Firm: Managerial Behavior, Agency Costs, and Ownership Structure". *Journal of Financial Economics, 3*, 305-360.

Laffont, L., & Tirole, J. (1999). *A Theory of Incentives in Procurement and Regulation*. Cambridge, MA: MIT Press.

Milgrom, P., & Roberts, J. (1992). *Economics, Organization and Management*. London: Prentic-Hall.

Ministry of Petroleum and Energy. (2003-2004). *Storting White Paper No. 38. On The Petroleum Activities*.

Osmundsen, P., Sørnes, T., & Toft, A. (2008). "Drilling Contracts and Incentives". *Energy Policy*, *36*(8), 3138-3144.

Salanié, B. (1998). *The Economic of Contracts*. Cambridge: MIT Press.

Sund, K. A. (2008). *Developing New Resources: How to Gain Dynamic Capabilities and Competitive Advantages from Integrated Operations in the Upstream Oil & Gas Industry.* Paper presented at the Third Annual Meeting of Smart Fields Consortium, Stanford, USA.

The United Nations Convention on the Law of the Sea. (1982). *The United Nations Convention on the Law of the Sea*.

Tirole, J. (1999). "Incomplete Contracts: Where do we Stand?" *Econometrica, 67*, 741-781.

Williamson, O. E. (1985). *The Economic Institutions of Capitalism. Firms, Markets, Relational Contracting.* New York: Free Press.

Paper IV

Dynamic Resource Allocation with Self-Interested Agents in the Upstream Oil & Gas Industry

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Accepted for publication in the Journal of Operations and Supply Chain Management (JOSCM), *3*(2), 78-97.

In this article, I start with a short outline of the mechanism design theory. Further, I outline a methodology section. Then, I describe a general introduction to the oil & gas industry. The paper describes the mechanism design theory in more detail, and relates it to the study of adverse selection. The paper also outlines the study of moral hazard using the principal-agent model under incentive-based contract with risk and rewards. The main part of the paper contains the following:

- Analysis of the resource allocations between principal-agent (and between agent-agent) in the upstream oil and gas industry. One of the paper's main contributions is an example of performing an optimization of resource allocation among four agents, and later extending it to six agents.

- A principal-agent model for how incentive-based contracts with risk and rewards can be used to secure incentive compatibility and participation on a drilling project.

The following words will occur in the paper

Mechanism design theory
Mechanism design theory is a concept where one is trying to set up a mechanism when there are several self-interested agents with private information regarding their preferences. The theory outlines an optimal system-wide solution to a decentralized optimization problem (Dasgupta et al., 1979; Mas-Colell et al., 1995; Maskin, 2007; Myerson, 1981).

The revelation principle
The revelation principle is used to simplify the identification of all the available social choice functions that can be implemented (Mas-Colell et al., 1995; Maskin, 2007).

The social choice function

The social choice function is a system-wide goal in mechanism design, and its purpose is to create a mechanism that selects the optimal outcome given agent types (Dasgupta, Hammond, & Maskin, 1979; Mas-Colell et al., 1995).

Incentive compatibility

An incentive compatible mechanism captures the value of designing a mechanism, as the agent will give away their true information and preferences. Incentive compatibility is present if every agent finds it disadvantageous to abort from the mechanism (Mas-Colell et al., 1995; Maskin, 2007).

Participation constraint

The participation constraint is consistent with the incentive compatibility problem. The participation constraint argues the incentives should be positive for all involved parties, or some of the participants would consider joining other relationships (Milgrom & Roberts, 1992).

Dynamic Resource Allocation with Self-Interested Agents in the Upstream Oil & Gas Industry

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ABSTRACT

This paper analyzes resource allocation between principal-agent (and between agent-agent) in the upstream oil & gas industry. In the model, I incorporate the parties' preferences as I outline a principal-agent model. Further, I optimize the resource allocation between the parties as they are self-interested with the use of incentive-based contracts with risk and rewards. My optimization determines that to realize the highest profit, the principal and the involved agents should avoid any agents' becoming dominant. Hence, the volume of sourced items from the agents should not vary too much. I further outline the on-boarding process of new agents in the network and how the network needs to compensate for the potential loss for some of the agents if the network should fulfill the incentive-compatibility condition.

JEL codes: D21, D82, D86, L14
Keywords: Resource allocation, incentive-based contract, mechanism design theory, principal-agent theory, optimization.

1. INTRODUCTION

This article deals with opportunistic behavior involving a principal and several agent's (and between the involved agent's) in the upstream oil & gas industry. There are two main strategies to minimize opportunistic behavior: (a) measurement of the agents' effort and (b) reduction of goal conflicts between the involved parties (Ouchi, 1979). This paper addresses both. Bako and Brynjolfsson (1992) outlined how incomplete contracts' incentive implications will affect the number of agents, and further how incentives related to quality can lower the number of agents. Further, they outlined a model that optimizes the number of total suppliers, where they found an optimum between high coordination cost (transaction cost) when there are many agents, and the risk of opportunistic behavior when there are few agents. They also argued that the number of agents decreases when incentives focus on increased quality (Bakos & Brynjolfsson, 1992). However, that study does not take into consideration the involved agents' preferences, e.g., they analyze neither how the agents valuate the network compared to alternative outside options nor the resource flow from the agents to the principal.

As I want to analyze how the agents valuate the network compared to outside options, and analyze the resource flow from the agents, I start with mechanism design theory. I outline the mechanism design literature that addresses the decentralized optimization problem with self-interested agents where there is private information regarding their different outcomes and preferences. The mechanism design theory purpose is to reveal true information (preferences) in an environment with asymmetric information, and how this information-revealing problem is a constraint to social decisions. In the mechanism design literature, incentive compatibility and the revelation principle will be of high importance for good cooperation. The revelation principle argues for the value of designing a mechanism where the agent will give away his true information and preferences. Incentive compatibility is present if no agent finds it advantageous to abort from the mechanism. Then I have a Pareto improvement, meaning that an actor can increase his utility value without compromising other actors. In this paper, I outline two theorems. The first theorem emphasize that the relationship is at risk if one or more agents hold a dominant position. The additional value the workload deviation between the agents creates is only marginally, strengthening the arguments that one or more dominant agent is not optimal. Ensuring a low deviation from the average resource allocation (e.g., 10–20%) allows the relationship to evolve without any parties becoming dominant and behaving opportunistically. This ensures that the network evolves positively without any significant reduction in profit.

Further, I have outlined a principal-agent model for how incentive-based contracts with risk and rewards can be used to secure incentive compatibility and participation constraint on a drilling project. One of the paper's main contribution is an example of performing an optimization of resource allocation among four agents, and later extending it to six agents. Theorem 2 shows how the on-boarding of new agents affects the level of sourced items for the other agents. The existing agents will accept the new agents if the relationship fulfills the requirements of incentive compatibility and participation constraints.

This article is organized as follows. Section 2 gives a briefly introduces mechanism design—a game-theoretical approach. Section 3 outlines the methodology. Section 4 outlines a general introduction to the Oil & Gas industry. Section 5 introduces the mechanism design theory, using the study of adverse selection. Section 6 outlines the study of moral hazard using the principal-agent model under incentive-based contract with risk and rewards. Section 7 outlines an optimization example. Section 8 concludes.

2. A BRIEF INTRODUCTION TO MECHANISM DESIGN-A GAME THEORETICAL APPROACH

Game theory can be employed to study a system of agents acting opportunistic or agents who are bounded rational (the rationality of individuals is limited by their information, their lack of time, and their cognitive limitations of their minds) when participating in some form of bilateral cooperation. Game theory and economic theory often involve Pareto improvement. Pareto improvement is when a player increases his utility value without compromising other actors. If a player increases his utility so that it affects other players negatively, it signals Pareto inefficiency. The goal in game theory is often to aim for a Pareto optimal allocation of resources, meaning that none of the involved actors can increase their utility by forming alliances.

3.1 Basic definitions

I will now explain the basic definition regarding game theory through an example involving a principal and an agent working together. The definitions and terms are based on Fudenberg & Tirole (1991), Osborne & Ariel (1994) and Maskin (2007).

The *type* of an agent determines the preferences of an agent, and is influenced by the different outcomes of a game. I outline the importance of *type* when I discuss mechanism design in the next section, as *type* will affect the design of the mechanism. Suppose an operator who owns a petroleum license (a principal) is collaborating with a service company (agent *i*) that performs dedicated work related to a drilling project for this operator, where agent *i* receives a particular outcome (outcome x_1). Let $\theta_i \in \Theta_i$ be the type of agent *i*, for a set of possible *types* Θ_i. The preferences of agent *i* in relation to outcome $x_1 \in X$ can be expressed as a utility function that can be further expressed as a parameter of the *type*. Let $u_i(x_1, \theta_i)$ be the utility for an agent *i* in outcome $x_1 \in X$ given type θ_i. Suppose agent *i* chooses to leave the present relationship for the benefit of a collaboration having a different relationship with a different outcome (outcome x_2). If the payment to agent *i* from x_2 is better than the payment from x_1, I say that x_2 "dominates" x_1 in the first collaboration. A specific collaboration "dominates" agent *i* if he can benefit by leaving the partnership for another partnership. Hence, agent *i* prefers outcome x_2 above x_1 when $\upsilon_i(x_1, \theta_i) \langle \upsilon_i(x_2, \theta_i)$. Otherwise, agent *i* prefers x_1.

The agent's choices for all given situations constitute a *strategy*. Hence, let $s_i(\theta_i) \in S_i$ be the strategy of agent *i* given type θ_i, where S_i is a set of all possible strategies available to agent *i*. In addition to the above-mentioned *pure* strategy (e.g. agent *i* interact with one operator), agent *i's* strategy can be mixed (e.g., agent *i* interacts with other operators (principals) at the same time and can obtain outside information used to benchmark and valuate the situation differently). Hence, obtaining individual information can give them an advantage over the operator. However, I argue that the core of a Pareto cooperative game evolves based on the fact that no subgroups within the partnership can do better by leaving the partnership. Hence, using the information for his own interest will not benefit the agent. This is evident in the next sections, where I further outline the mechanism design problem with focus on the social choice function, incentive compatibility, and the revelation principle.

3. METHODOLOGY

This optimization was designed to explore the benefit of implementing an incentive-based contract in the oil & gas industry. Further, the study aims to optimize the resource flow from involved agents to the principal. The examples were chosen based on interviews with key-employees in the industry, where resource allocation was highlighted as a problem due to unsatisfying incentive models. This has been outlined in an earlier paper where the problem was described in more detail through an embedded multiple case study (Sund, 2008). Multiple case studies are particularly useful when studying relationships between companies because they provide an understanding of the latent factors that can produce contradictory views between parties (Hedstrom & Swedberg, 1998). The optimization conducted in this paper is a replication of that study and the purpose of our framework is to outline a mechanism that aims to reveal the true information (preferences) in an environment with asymmetric information. I challenge this problem by setting up a mechanism where all the involved agents find it advantageous to reveal their true preferences because of the constraints related to incentive compatibility and participation. Hence, I can optimize the resource allocation between the agents by involving some additional constraints and regulating the relationship with the use of incentive-based contracts with risks and rewards. I choose this study approach because of the limited understanding of how inter-organizational collaboration occurs and evolves (Davies et al., 2006). It is a preferred methodology when the theories are well known and understood, but the underlying theoretical logic (and the relationship between the theories) is limited (Davis et al., 2007a; Davis et al., 2007b). The results depicted in table 8 and 11 in section 7 will be analyzed using Excel solver. Hence, I want to find specific values for specific cells in a spreadsheet model that optimizes a certain object. In our examples, this means to optimize the number of resources that has been allocated from the agents based on their total profit of contributions. Hence, I need to define the target cells, often described as objective or goal, and further define the changing cells, or cells that can be changed to optimize the target cells (Winston, 2007). At the end, I involve the constraints depicted in table 6 in section 7.

4. GENERAL INTRODUCTION TO THE UPSTREAM OIL & GAS INDUSTRY

This paper models an optimal bilateral inter-organizational strategy for the upstream oil & gas industry, hence referred to as the drilling environment. The relationship between the operator (defined as a principal owning a petroleum license) and the agent (defined as a significant service provider for that principal) can greatly affect productivity and cost efficiency. The study of motivating and controlling cooperative action is known in the literature as principal-agent analysis (Salanié, 1998). The principal-agent literature addresses problems arising when the agent works for his own goals rather than the principal's (Milgrom & Roberts, 1992; Salanié, 1998). This is especially relevant if the agent has private information, and the principal finds it hard to monitor and observe the agent's actions, as the principal can only evaluate its own outcome (Barney & Hesterly, 1996).

As the drilling environment is recognized to have asymmetric information, the service provider knows more about the tasks that should be performed than does the operator. The principal-agent literature argues that this can lead to strategic misrepresentation and opportunistic behavior. This can be avoided by the principal's offering an incentive scheme that pays the agent according to the value realized (Gintis, 2009). Further, the principal-agent theory argues that there has to be at least a minimum surplus to the actors, or they will consider joining other collaborative environments. The service provider often experiences an incentive constraint as the operator maximizes its profit subject to an individual rationality constraint (participation constraint). For example, lack of incentive compatibility between the parties may force the service provider to consider outside options. On the other, if the parties have incentive compatibility, they may be willing to share their private information with other involved parties (Milgrom & Roberts, 1992).

Our paper focuses on the mechanism (service contract) that regulates the general relationship between the operator and the service provider in drilling activities. In this much used mechanism, quality and speed are often seen as conflicting, but can affect each other positively. An input factor is considered time-critical in the drilling process if their recovery rate upon failure depends on the use of existing infrastructure, and losses may occur if the input factor is delayed (Sund & Hausken, 2009).

On the Norwegian Continental Shelf (NCS[1]), almost all service provider relationships with the operator are regulated through a fixed-price contract, with no or few incentives related to operation. Incentive-based contract that incorporate risk and reward (e.g. financial payment) related to performance are not common used. This contract pays a negative reward (penalty) if

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[1] NCS is the continental shelf over which Norway exercises sovereign rights. Stretching 200 nautical miles from the Norwegian coast, its major parts are the shelves of the North Sea, Norwegian Sea and Barents Sea (The United Nations Convention on the Law of the Sea, 1982).

the agent does not meet the standards been agreed up on, and pays a positive reward if the agent reach the goals been agreed up on. As the agent financial results are related to performance, the agent becomes more dependent of the other parties. Hence, the party that can contribute with the highest value will be the decision maker rather than the actor with formal ownership of the process (Sund & Hausken, 2009).

Cost, investment, and production level on the NCS

The drilling environment is recognized to pose increased complexity with time, as there are often up to 40 different teams involved in a drilling project. Complexity is believed to be one of the main reasons for the increase in drilling costs for one field completion from $140,000 in 2004 to nearly $500,000 in 2007. At the same time, the daily productivity increased from 102 average drilled meters in 2002 to 111 meters in 2003, before leveling off at around 80 meters since 2004 (Osmundsen, Sørnes, & Toft, 2008).

Below, I outline the investment level and production level on the NCS. Further, I give an example for how the production level can develop and how it differentiates production and gross income. Table 1 depicts the investment level on the NCS.

Table 1 Accrued and estimated investment costs for extraction of crude petroleum and natural gas 2005-2010 (In NOK million)[2]

	2005	2006	2007	2008	2009	2010*
Field development	19,518	21,316	30,762	35,184	40,104	28,833
Fields on stream	34,395	39,013	46,003	57,617	65,222	73,485

* Estimates

The quality of the drilling process, which might last 100 days, affects the productivity of the well for possibly 15 years.[3] A possible relationship between quality and productivity is depicted in table 2:

Table 2 Hypothetical estimated production of barrels of oil per day (b/d)

Quality of drilling	Estimated production in b/d for 15-year life of well
High	12,000 b/d
Middle	10,000 b/d
Low	8,000 b/d

The effect of the implied cumulative production on gross income is depicted in table 3:

Table 3 Effect of production level on gross income

Estimated b/d per day	High = 12,000		Middle = 10,000		Low = 8,000
Number of barrels in 15 years of production	65.700,000		54,750,000		43,800,000
Differentiation in barrels		10,950,000		10,950,000	
Differentiation in gross income*		$686,565,000		$686,565,000	

* Average oil price in 2009 is $62.7. Source: www.ssb.no

[2] www.ssb.no

[3] Average length of operation before shutdown is 13.75 years on the NCS. Source: www.npd.no

This example considered only the result of the drilling process and how it affects the production phase, and did not take into consideration later investments that might increase productivity at an additional cost. The well's productivity might also be influenced by the geological structures and maturity of the field, for example, shale production/brown fields. However, this paper's focus is the influence of the drilling process on production for new fields (green fields). Table 4 depicts how the net total petroleum production on the NCS has declined,[4] despite the increased investment and cost of drilling activities as shown in table 1.

Table 4 Net total production of oil on the NCS from 2002 to 2009

Year	Net total petroleum production in Sm^3 (thousands)
2002	173,649
2003	165,475
2004	162,777
2005	148,137
2006	136,577
2007	128,277
2008	122,673
2009	115,453

Tables 1 and 4 demonstrate asymmetry between investment in the drilling phase and productivity in the production phase. For example, higher investment in the drilling phase does not necessarily lead to better productivity in the production phase. In table 3, I argue that the different quality in the production phase will affect gross income. This statement has been verified through discussion with several key employees from different operators and service providers on the NCS. In this paper, I argue for the importance for the incentive-based contract with risk and rewards as a mechanism to increase the productivity on drilling projects, and thereby affect the productivity in the production process.

5. MECHANISM DESIGN-THE STUDY OF ADVERSE SELECTION

Mechanism design has received increased attention since its noteworthy contributors Leonid Hurwicz, Eric Maskin, and Roger Myerson were awarded the 2007 Nobel Memorial Prize in Economics. The theory of mechanism design affects adverse selection positively as the mechanism tries to reduce opportunistic behavior to a minimum. Adverse selection is defined as a pre-contractual information asymmetry that gives conditions under which the principal cannot be certain that the agent accurately performs the agreed-upon work. Some authors refer to the application of adverse selection models as the "mechanism design problem" (Salanié, 1998). Central to mechanism design is the decentralized optimization problem, in which self-interested agents possess private information regarding their own outcomes and preferences. In many situations, collective decisions are made without the involved agents' personal preferences, as they are not publicly observable. This indicates that the agents must be relied upon to reveal their private information, as the setting is characterized by incomplete information (Salanié, 1998). Later in this paper I evidently outline how there is a motivation for the agent to reveal their private information. The agents private information is revealed through implementation of an optimal system-wide solution. As noted earlier, $\theta_i \in \Theta_i$ is the

[4] Net total petroleum production in 1000 Sm^3. Source: www.npd.no, www.ssb.no

agent *i* type and determines his preferences over different outcomes; i.e., $\upsilon_i(x,\theta_i)$ is the utility of agent *i* given type θ_i for outcome $x \in O$.

Therefore, I seek to understand how the agent's private information is elicited and if and how this information revelation problem constrains how social decisions can respond to individual preferences. I define this as the mechanism design problem (Mas-Colell, Whinston, & Green, 1995).

5.1 The Social Choice Function
The social choice function is a system-wide goal in mechanism design, and its purpose is to create a mechanism that selects the optimal outcome given agent types. Hence, I outline some definitions related to the social choice function and their properties (Arrow, 1963; Dasgupta, Hammond, & Maskin, 1979; Mas-Colell et al., 1995; Myerson, 1981; Parkes, 2001).

Definition 1.1 Social choice function f: $\Theta_1 \times ... \times \Theta_I \rightarrow X$ that, given the agent types $\theta_1,...,\theta_I$, assigns a collective choice $f(\theta_1,...,\theta_I) \in X$.
Hence, given the agent types, $\theta = \theta_1,...,\theta_I$, it would be proper to choose outcome $f(\theta)$.
The goal of mechanism design is to implement "game rules," i.e., possible methods and strategies to try to select an outcome based on the agents' strategies, and thereby implement this solution to the social choice function regardless of the agents' self interest.

Properties of Social Choice Functions
The properties of the social choice function will affect mechanism design. The social choice function has to be Pareto optimal, indicating it implements outcomes none of which is strongly preferred (compared to other outcomes) by a subset of agents. The social choice function is important to mechanism design as it has to be Pareto optimal, even the agents have quasi-linear utility functions.

Definition 1.2 Agent *i* quasi-linear utility function with type θ_i is of the following form

$$u_i(o,\theta_i) = \upsilon_i(x,\theta_i) - p_i$$

where *o* defines the choice $x \in \kappa$ from the relevant set and the payment from agent p_i . The valuation function, $u_i(x)$, for an agent with quasi-linear preferences is defined by its type. Hence, each choice value is defined by $x \in \kappa$, where κ represents their allocations, and the payment is represented by the transfer. For example, side-payment makes it easy to transfer utility across the involved agents. I argue that the agent is risk neutral because the agent is willing to pay as much as he valuates the item and therefore his utility will be the same as his expected value.

5.2 Mechanisms
The mechanism design concept tries to set up a mechanism where there are a number of self-interested agents with private information regarding their preferences, and thereby come up with an optimal system-wide solution to a decentralized optimization problem. Below are some definitions related to mechanism design and their properties (Dasgupta et al., 1979; Mas-Colell et al., 1995; Maskin, 2007; Myerson, 1981).

Definition 1.3 A mechanism $\Gamma = (S_1, \ldots, S_I, g(\cdot))$ defines the set of strategies S_1 available to each agent, and an outcome function g: $S_1 \; x \ldots x \; S_I \rightarrow X$, hence, $g(\cdot)$ is the outcome from the mechanism implementation for the strategy profile $s = (s_1, \ldots, s_I)$.
The mechanism defines available strategies, and based on agents' strategies, a method is used to select the final outcome.
Given mechanism Γ, with the outcome function $g(\cdot)$, I say that a mechanism implements a social choice function $f(\theta)$ if the outcome with equilibrium agent strategies is a solution for the social choice function that is aligned with the agents' possible preferences.

Properties of Mechanisms
Describing the properties of a mechanism requires defining the solution concept and each agent's domain of preferences as quasi-linear, risk neutral, etc. With respect to the implementation of a mechanism (see definition 1.5) and the properties of a social choice function (see definition 1.1), I argue that the property of a mechanism is the same as the property of a social choice function when implemented in a mechanism. That is, a mechanism Γ is Pareto optimal if it involves a Pareto optimal social choice function $f(\theta)$. Another property of a mechanism is the individual-rationality often addressed as the "voluntary participation/participating constraint." This constraint indicates that the agent is not forced to participate in the mechanism. This constraint will affect the expected utility the agents receive from participating.

Let $\bar{v}_i(\theta_i)$ be the expected utility of agent *i* realized through an outside option instead of the mechanism of type θ_i. The most common definition of individual rationality is interim individual rationality, in which the agent knows his own expected utility and has little if any information regarding the preferences of the other agents, but can expect them to be at least its own expected outside utility. When the agent can withdraw from participation once it has knowledge about the outcome, an *ex post* individual rationality is the most appropriate solution. In this situation, the agent's utility from participating has to be at least the same as the outside utility for all agents involved in the mechanism. Often agents must chose to participate before they know their true preferences, which is addressed as *ex ante* individual rationality. Hence, the expected utility, average preferences for participating in the mechanism must be at least the agents' expected utility when he is not participating. If not, the agent may choose not to participate.

5.3 Mechanism Implementing the Social Choice Function
Hence, I outline an mechanism Γ with an outcome $g(\cdot)$ where Γ involves the social choice function $f(\theta)$ as long as the social choice function creates an equilibrium positive for all the involved agents' preferences (Mas-Colell et al., 1995):
Definition 1.4 A mechanism Γ is considered to be rational for all the agents' preferences, θ_i, when it implements a social choice function $f(\theta)$.

$$u_i(f(\theta_i, \theta_{-1})) \geq \bar{u}_i(\theta_i)$$

Hence, $u_i(f(\theta_i,\theta_{-1}))$ is expected utility of agent *i* resulting from his outcome given knowledge about the other agents' preferences θ_{-1}, and $\bar{u}_i(\theta_i)$ is the expected utility for the agent if he decides not to participate. E.g., the mechanism is individual rational if the agent can at any given time realize more utility when participating compared to not participating if the agent has prior knowledge about the other agents preferences.

Definition 1.5 A mechanism $\Gamma = (S_1,\ldots,S_{I,}g(\cdot))$ implements social choice function $f(\cdot)$ if there exists an equilibrium strategy profile $(s_1^*(\cdot),\ldots,s_1^*(\cdot))$ of the game created as a consequence of Γ so that $g(s_1^*(\theta_1),\ldots,s_1^*(\theta_I)) = f(\theta_1,\ldots,\theta_I)$ and this is relevant for all $(\theta_1,\ldots,\theta_I) \in \Theta_1 \; x \ldots x \; \Theta_I$.

Hence, I argue that a mechanism implements a social choice function $f(\cdot)$ if the equilibrium realized through the game is created by using the mechanism that has the same output $f(\cdot)$ for every given types profile $\theta = (\theta_1,\ldots,\theta_I)$.

The problem with definition 1.5 is that it assumes that there exist multiple equilibriums and that the agents will select the equilibrium that the mechanism designers prefer. Also, with respect to the social choice function $f(\cdot)$, an agent may find it disadvantageous to reveal their information truthfully. I show in section 7 that this is not correct, as this problem can be treated as an optimization problem.

5.4 Incentive Compatibility and the Revelation Principle

The revelation principle simplifies the identification of all the available social choice functions that can be implemented. Under weak conditions, the revelation principle can be set up as a mechanism that is incentive compatible and directly reveals the agent's type (direct-revelation mechanism). This captures the value of designing a mechanism, as the agent will give away their true information and preferences. The direct mechanism that always has an equilibrium should be preferred to one that does not create an equilibrium, because the latter may permit free-riding by some of the agents. If the agent's dominant strategy is truth telling, there is a straightforward mechanism. Incentive compatibility is present if every agent finds it disadvantageous to abort from the mechanism. In the revelation principle, each agent is asked to reveal their true type, and as I know $(\hat{\theta}_1,\ldots,\hat{\theta}_I)$, the agent will choose $f(\hat{\theta}_1,\ldots,\hat{\theta}_I) \in X$. Hence, the agent will reveal their direct type and create a mechanism as defined (Dasgupta et al., 1979; Hurwicz, 1973; Mas-Colell et al., 1995; Maskin, 2007; Myerson, 1981; Parkes, 2001; Vickrey, 1961):

Definition 1.6 The direct revelation mechanism is one where $\Gamma = (\Theta_1,\ldots,\Theta_{I,}g(\cdot))$ is a constraint for the strategy set $\sum_i = \Theta_i$. This is relevant for all *i*, and involves an outcome rule $g = \Theta_1 \times \ldots \times \Theta_I \rightarrow O$, as it choose an outcome $g(\hat{\theta})$. The direct revelation mechanism is realized based on the agents' reported preferences $\hat{\theta} = (\hat{\theta}_1,\ldots,\hat{\theta}_I)$.

Hence, the agent will reveal his true preferences θ_i, based on his reported type $\hat{\theta}_i = s_i(\theta_i)$. I can now outline the mechanism where truth telling is an optimal strategy for the agent.

Definition 1.7 A social choice function $f(\cdot)$ is implemented truthfully and is to be considered to be incentive compatible when $\left(s_1^*(\cdot),\ldots,s_I^*(\cdot)\right)$ as $s_1^*\left(\theta_i \in \Theta_i\right)$ and I can find all $i = 1,\ldots,I$. This is evident if the involved agents' truth telling gives equilibrium according to the mechanism $\Gamma = \left(\Theta_1,\ldots,\Theta_{I,}g(\cdot)\right)$.

The next section presents an example where I model the principal-agent relationship using an incentive scheme to outline how payment amount affects the agent's effort.

6. THE PRINCIPAL-AGENT MODEL-THE STUDY OF MORAL HAZARD

The last section outlined the impact of adverse selection and how it affects the involved agents' behavior when cooperating. This section examines the impact of moral hazard in a principal-agent model. Moral hazard is post-contractual opportunism, or a condition under which the principal cannot be sure that the agent has put forth maximal effort, as its effort is difficult to observe. Hence, I want to outline and include a worked example and use the drilling environment for the oil & gas industry as a case example. As adverse selection and mechanism design define the possibilities and constraints that regulate the relationship between principal-agents and agent/agents pre-contractual, the moral hazard (post-contractual) opportunistic behavior is that occurring within the project, and hence similar to a principal-agent model. Because the two different opportunistic behaviors, adverse selection and moral hazard, are interrelated, I argue that adverse selection must be considered when modeling the principal-agent solution.

6.1 Worked example

This section explores a dynamic transaction model seen as a bilateral cooperation process between a principal and an agent. Consider a situation on a drilling project where the operator (principal) will hire a service provider (agent) to perform some kind of work. The Norwegian Continental Shelf often has up to 40 different teams working on one drilling project (Osmundsen et al., 2008). As the different team members has different preferences, this has lead to increased complexity, and this complexity is believed to largely account for cost's having more than tripled from 2004 to 2007 (Osmundsen et al., 2008).

Therefore, I argue that the implementation of an incentive-based contract binding the parties on a drilling project will lead to higher first-time quality due to reduction of moral hazard and adverse selection.

The case model

Our model defines a principal-agent problem and determine a Pareto optimal contract where there are problems with information revelation and challenges with respect to moral hazard between an operator and a service provider. I also want to show that the principal-agent model needs to consider challenges related to adverse selection addressed in section 4. Hence, the social choice function, incentive compatibility, and the revelation principle outlined in section 4 will be addressed, especially in section 6. The general principal-agent model used in our example was developed by Milgrom and Roberts (1992) and further modified to fit our example.

Example
Our example assumes the principal to be risk-neutral, hence concerned with the quality and the final payoff from the project overall. I assume the agent to be risk-averse. (The risk-neutral agent is considered at the end of this section, where I take into consideration a small financial risk.) Hence, the agent will try to contribute as little as possible if there is no upside benefit.

The agents wage *w* (income) and contribution *b* give the following utility function:

$$u(w,b) = \sqrt{w} - (b-1) \qquad (1)$$

Hence, *w*'s decreasing marginal utility function is

$$1/(2\sqrt{w}) \qquad (2)$$

Our model uses two levels of contribution: $b = 1$ and $b = 2$. The former indicates that the agent's contribution is costly when exceeding 1 and represents a risk-averse agent. The principal goal is to get the agent to accept an appropriate level of contribution of work, and not consider outside options. This is done by rewarding the agent with at least as much as he could receive by participating in an outside collaboration, similar to the methodology outlined in the mechanism design concept in the last section. The agent's expected utility is defined as *u*. Our example sets *u* to 1. I also align the agent's income with the value he creates for the principal. Other factors that affect the contribution that either the principal or the agent can observe or affect should also be considered.

In our example, I set $b = 1$ and the income equal to 15 with a probability 2/3, $b = 2$ with income of 45 with a probability of 1/3, as observed in table 5.

Table 5 Probability of outcome

Behavior	Income	
	I = 15	I = 45
b = 1	p = 2/3	p = 1/3
b = 2	p = 1/3	p = 2/3

When $b = 1$, I calculate the income to be (2/3) x 15 + (1/3) x 45 = 75/3, and when I increase the level to b = 2, the expected income rises to (1/3) x 15 + (2/3) x 45 = 105/3. Hence, the contribution *b* effectively increases the probability of a higher outcome realized by the agent.

The agent bears no risk because he would receive a fixed payment *w* irrespective of outcome or even if he does not contribute with contribution level $b = 1$. If the principal could observe *b*, he would demand $b = 2$, and pay nothing for $b = 1$. Eq. 3 gives the payment needed for the agent to accept the contract instead of joining an outside option.

$$\sqrt{w} - (b-1) = \sqrt{w} - (2-1) \geq 1, \quad or \quad w \geq 4 \qquad (3)$$

As observed, if the agent should accept the contract, the payment *w* has to be at least 4. In our model, the principal will not give away more than necessary, hence the agent receives 105/3 - 4 = 93/3. If the principal wants the lowest contribution from the agent, the principal would pay $b = 1$ to the agent, and the agent would receive utility of 72/3. The additional *w* for the extra contribution is 4 – 1 = 3 to the principal, but the alternative payoff would be (105 - 75) = 30/3 > 3. Hence, the principal will find it feasible to pay for the extra contribution from the agent.

In a situation where the level of outcome is observable but not the level of effort, the principal cannot determine the outcome based on the agent's effort. Still there can be some relation between effort and outcome as effort affect outcome. Their affection on each other could also be a misrepresentation, as the outcome could be higher through luck, or lower as outside disturbance out of the agents control can affect the outcome negatively. Creating a purpose for the agent to work hard can be done by giving him better payment for high effort then low effort (measured by outcome as effort affect outcome), indicating the agent needs to take on some financial risk.

In this next example, the agent needs to receive b = 2 when the principal wants high effort, and the outcome needs to be better compared to when the agent chooses b = 1.
Under an incentive-based contract, the agent receives:
l, when the outcome is 15 and,
h, when the outcome is 45

The agent's expected utility by choosing *b* = 1 is

$$(2/3)\left(\sqrt{l}-0\right)+(1/3)\left(\sqrt{h}-0\right) \tag{4}$$

Or, the agent's expected utility by choosing *b* = 2 is

$$(1/3)\left(\sqrt{l}-1\right)+(2/3)\left(\sqrt{h}-1\right) \tag{5}$$

The agent must receive at least as much or more for the high contribution compared to low contribution level. Expression 6 addresses the agent incentive compatibility constraint, the same constraint as outlined in the incentive compatibility model (mechanism design/adverse selection) outlined in definitions 1.1 to 1.7. Incentive compatibility means that the agent must not be worse off by exerting extra effort, the same principle I outlined in section 4 were I argued that the incentives should be positive for all involved parties, or some of the participants would consider joining other relationship.

$$(2/3)\left(\sqrt{l}-0\right)+(1/3)\left(\sqrt{h}-0\right)\leq(1/3)\left(\sqrt{l}-1\right)+(2/3)\left(\sqrt{h}-1\right) \tag{6}$$

Expression 6 shows a constraint in the incentive scheme, affecting high contribution negatively. In addition, I will make the participation constraint consistent with the incentive compatibility problem. If the participation constraint is violated, the agent will reject the contract and will not participate in the collaboration. As the incentive constraint increases, the participation constraint decreases, as seen in fig. 1.

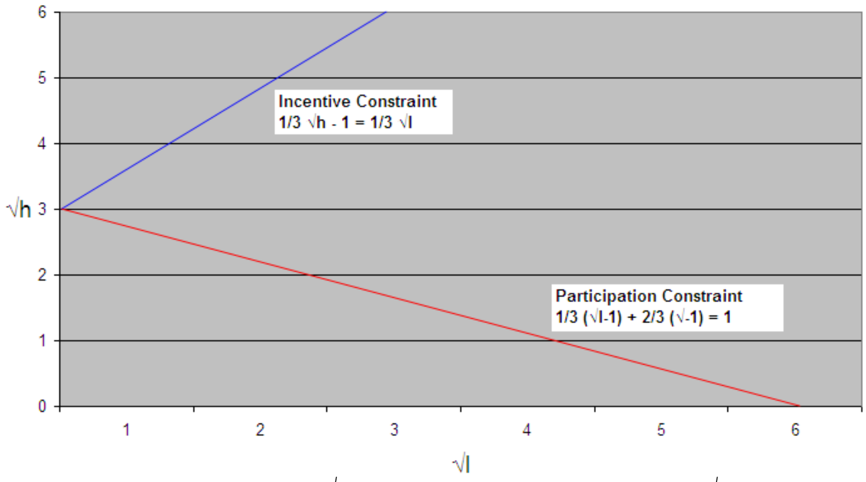

Fig. 1- Incentive constraint (√h) and participation constraint (√l)

The incentive constraint can be reduced to the following form.

$$(1/3)\sqrt{h} - 1 \geq (1/3)\sqrt{l} \tag{7}$$

The payoff needs to increase significantly higher when contribution increases (b = 2), compared to (b = 1).

Expression (6) can also be reduced to a simpler term for the participation constraint, where the outcome with low utility needs to be higher than the outside option. Hence, I set the outside option equal to 1.

$$(1/3)(\sqrt{l} - 1) + (2/3)(\sqrt{h} - 1) \geq 1 \tag{8}$$

The challenge for the principal is to find two positive values of l and h, as the agent is risk adverse, that will lead the agent to accept downside (negative) incentives. Downside risk for agents can be included in a principal-agent model, and be seen as an incentive for increased cost efficiency and productivity (Sund & Hausken, 2009).

Above the top (blue) line in the upper left area in fig. 1, the combination of h and l meets the incentive constraint. At this point, the agent will be motivated to perform at the expected level with a combination of h and l payment. Above the lower (red) line and below the top line, the combination of h and l satisfies a participation constraint. The principal wants l = 0 and h = 9, with a return of (1/3) x (15 – 0) + (2/3) x (45 - 9) = 87/3. The return is less than the earlier return of 93/3. This is because the principal has to pay additional 2 (from 4 to 6) to the agent. Using b = 2 will impose extra cost for the principal, as the agent has to take on performance risk.

If the principal is comfortable with b = 1, there are no incentives for the principal to provide extra payment to the agent. The agent will accept the payment as long as the payment, b = 1, is at least equal to any outside option. The principal will use the incentive scheme with b = 2 as long as the output is higher than an incentive scheme where b = 1. As the agent has a payment of b = 1 the principal's payoff is (2/3) x (15 - 1) + (1/3) x (45 - 1) = 72/3. This is lower than when applying b = 2. Therefore b = 2 contribution level should be preferred.

In this example, I evidently show that there is a positive payoff for the principal to use $b = 2$ in relationship with the agent as it motivates for higher contribution level. In the next section, I want to optimize the resource flow among multiple agents in a drilling project having a principal-agent relationship.

7. OPTIMIZATION EXAMPLE

This section extends the example in section 6. I will outline a principal–agent relationship with the aim of optimizing the resource allocation among multiple agents in a drilling project. Further, I want to analyze how the agents evaluate the network compared to outside options, and analyze the resource flow from the agents. I will do this by implementing a social choice function and incentive compatibility in the resource allocation among the agents. Given these two constraints, the mechanism will create a revelation principle. This will be evident given that the agents accept a new volume and payoff in the network when they optimize an alternative resource allocation rather than choosing to leave for an alternative relationship.

The additional constraints are outlined in Table 6. The operator sets these constraints in conjunction with the service providers. To achieve optimization, they need to be satisfied. For example, there should at any time be at least four agents involved, so that no agent can become too dominant. Too few agents can lead to opportunistic behavior as they enter a dominant position because of economics of scale, whereas too many agents could lead to high coordination and transaction costs (Bakos & Brynjolfsson, 1992). Another constraint is that no agent's resource allocation can deviate from the agreed number of sourced items by more than a predefined percentage (e.g., if there are four agents and the principal wants to adopt 800 units, the average is 200 (800/4) per agent. If the maximum deviation is set to 10%, an agent could source at maximum 220 and at minimum 180 units to the principal). I will later argue that the allowed deviation affects incentive compatibility and the participation constraint. Conflicting with these two constraints could lead some of the involved parties to optimize the resource bundle value, and thereby only one agent would source all the volume. I will also show how this optimization will encourage the on-boarding of new resources. Moreover, agents will still reveal their preferences because the mechanism creates incentive compatibility and offers a secure participation by implementing an incentive-based contract with risks and rewards where the final payoff is shared by all involved parties.

Table 6 – Additional constraints

Minimum of four service providers involved
Maximum and minimum % deviation from average resource allocation for every four agents (average resource allocation is 1000/4 = 250)

To make our example as realistic as possible, the agents need to bundle resources and sell resource packages to the principal. Table 7 depicts an example of how agents might combine resources to form bundles. The principal asks for resource bundles consisting of 12 resource units. The specific terms of the bundle decides what kinds of resource units the agent has to choose. The revenue is set from historical data and/or in conjunction with the principal and agents. I argue that this will mean they reveal their true information because trying to hold back true information or bluff would affect not only the other agents but also themselves given that their payoff depends on the overall performance on the project.

Table 7 – The four agents' resource revenue, profit, cost and combination of resources to form a resource bundle

	Agent 1	Agent 2	Agent 3	Agent 4
Agents' resource revenue				
Revenue of resource 1	$220 00	$140 00	$160 00	$220 00
Revenue of resource 2	$140 00	$160 00	$140 00	$110 00
Revenue of resource 3	$160 00	$180 00	$155 00	$130 00
Agents' resource costs				
Cost of resource 1	$80 00	$65 00	$90 00	$80 00
Cost of resource 2	$100 00	$120 00	$75 00	$95 00
Cost of resource 3	$140 00	$130 00	$135 00	$120 00
Agents' use of different resources to create a bundle				
Use of resource 1	2	4	3	4
Use of resource 2	4	3	3	4
Use of resource 3	6	5	6	4
Total profit of resource bundle	$560 00	$670 00	$525 00	$660 00

Table 8 illustrates how resource allocation can be optimized by using Excel solver. Further, in Table 8, I outline how any change in the percentage deviation from the number of average sourced bundles affects the profit and how much the resource allocation will deviate between the involved agents. Below, I relate the results to incentive compatibility and participation constraint as outlined in the mechanism design theory in section 5. The numbers in Table 8 follow the numbers in Table 7. I have excluded the revenue and costs of the resource bundle in our table.

Table 8 – The four agents' profit contributions and the result of the bundle allocation optimization with 0–50% deviation from the average number of sourced resource bundles

Principal requested sourcing volume is 1000 bundles in total

Agents	Agent 1	Agent 2	Agent 3	Agent 4	Total
Result of resource bundle optimization with 0% deviation from the average (250 bundles)	250	250	250	250	1000 bundles
Total profit of contribution from the agents*	$140000	$167,500	$131,250	$165,000	**$603,750**
Result of resource bundle optimization with 10% deviation from the average (250 bundles)	225	275	225	275	1000 bundles
Total profit of contribution from the agents	$126,000	$184,250	$118,125	$181,500	**$609,875**
Result of resource bundle optimization with 20% deviation from the average (250 bundles)	200	300	200	300	1000 bundles
Total profit of contribution from the agents	$112,000	$201,000	$105,000	$198,000	**$616,000**
Result of resource bundle optimization with 30% deviation from the average (250 bundles)	175	325	175	325	1000 bundles

Total profit of contribution from the agents	$98,000	$217,750	$91,875	$214,500	**$622,125**
Result of resource bundle optimization with 40% deviation from the average (250 bundles)	150	350	150	350	1000 bundles
Total profit of contribution from the agents	$84,000	$234,500	$78,750	$231,000	**$628,250**
Result of resource bundle optimization with 50% deviation from the average (250 bundles)	125	375	125	375	1000 bundles
Total profit of contribution from the agents	$70,000	$251,250	$65,625	$247,500	**$634,375**

* The total profit contribution from the agents is the agents' total profit from the resource bundle in Table 7 multiplied by the result of the resource bundle optimization from each agent outlined in Table 8.

Figure 2 follows the data in Table 8 regarding the number of units in each agent's bundle under each deviation constraint. There is a major deviation from the average when the percentage increases from 0% to 50%. I argue that an increase in the percentage deviation from the average sourced volume conflicts with the constraints outlined in Table 6 because it can lead one or more service providers to enter into a dominant position and exploit their economics of scale. I argue that one should have as little deviation related to sourced volume from the agents as possible because it ensures stability in the relationship. Opportunistic behavior through one or more agents gaining a dominant position could affect negatively the total profit.

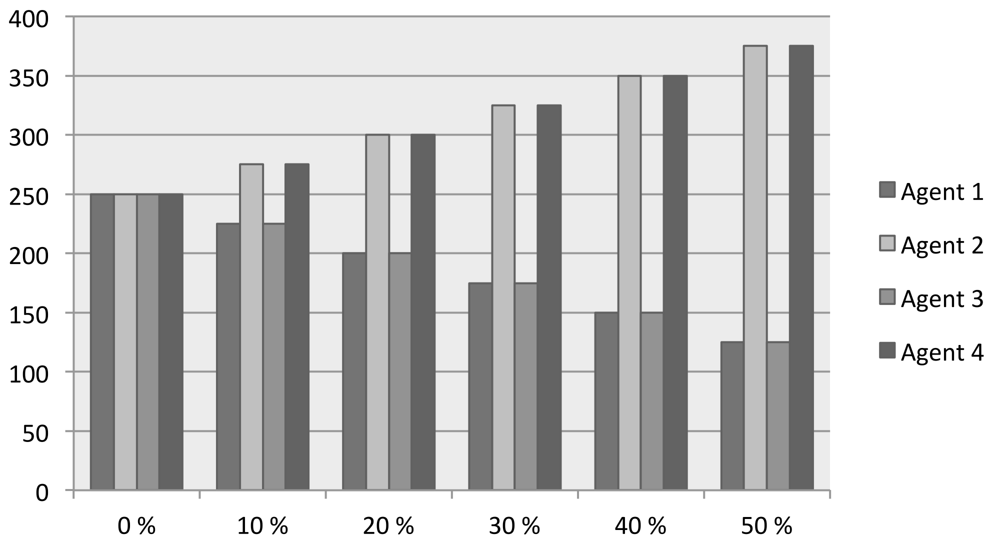

Figure 2 – Number of units in each agent's bundle under each deviation constraint

In Table 9, I outline how the total profit changes as the deviation from the average sourced resource bundles change in percentage terms. In addition, I outline how the increase in profit evolves as a percentage.

Table 9 –The four agents' profit contribution and change in profit as the allowed deviation increases

Deviation from average	0%	10%	20%	30%	40%	50%
Total profit	$603,750	$609,875	$616,000	$622,125	$628,250	$634,375
Change in profit (%)		1.0101%	1.0100%	1.0099%	1.0098%	1.0097%

When change in deviation from the average resource allocation increases by 10%, profit only increases by approximately 1%. I argue that one should not risk the relationship by placing one or more agents in a dominant position since the profit only increases marginally.

Theorem 1: The relationship is at risk if one or more agents hold a dominant position. The additional value the workload deviation creates is only marginal, strengthening the argument that one or more dominant agents is not optimal. Ensuring a low deviation from the average resource allocation (e.g., 10–20%) allows the relationship to evolve without any parties becoming dominant and behaving opportunistically. This ensures that the network evolves positively without any significant reduction in profit.

Proof: Follows from Figure 2 and Table 9.

Theorem 1 follows from Figure 2 and Table 9, where I outline how the profit increases only marginally when the deviation increases significantly (from 0%–50%). Hence, I argue that the risk of the involved parties being exposed to opportunistic behavior by one or more dominant parties grows as the deviation increases. Keeping a low deviation (e.g., 10–20%) prevents any of the involved parties exploiting the situation for their own benefits.

Our next example follows Table 7 but increases the number of agents from four to six to analyze a situation for on-boarding new resources on the project. Hence, the principal asks for additional resource bundles from 1000 (average: 1000/4 = 250) to 1350 (average: 1350/6 = 225).

Table 10 follows Table 7 with the same constraints and conditions as in Table 6 (except total sourced bundles have increased from 1000 to 1350). Our goal in this example is to analyze a situation where two additional agents are involved. I earlier argued that there has to be incentive compatibility for agents to reveal their preferences. If there is no incentive compatibility, the incentive will create a participating constraint. Participation constraints because of a lack of incentive compatibility in this situation occurs when the new incentives are lower than the old ones. For example, if one agent receives better conditions before the new agents were on-boarded, it can be a participation constraint for the agent and he could decide to join other networks.

Table 10 – The six agents' resource revenue, profit, cost and combination of resources to form a resource bundle

	Agent 1	Agent 2	Agent 3	Agent 4	Agent 5	Agent 6
Agents' resource revenue						
Revenue of resource 1	$220 00	$140 00	$160 00	$220 00	$145 00	$110 00
Revenue of resource 2	$140 00	$160 00	$140 00	$110 00	$145 00	$180 00
Revenue of						

resource 3	$160 00	$180 00	$155 00	$130 00	$210 00	$190 00
Agents' resource costs						
Cost resource 1	$80 00	$65 00	$90 00	$80 00	$90 00	$80 00
Cost resource 2	$100 00	$120 00	$75 00	$95 00	$95 00	$100 00
Cost resource 3	$140 00	$130 00	$135 00	$120 00	$120 00	$120 00
Agents use of different resources to create a bundle						
Use of resource 1	2	4	3	4	6	3
Use of resource 2	4	3	3	4	3	4
Use of resource 3	6	5	6	4	3	5
Total profit of resource bundle	$560 00	$670 00	$525 00	$660 00	$750 00	$760 00

Table 11 illustrates how resource allocation can be optimized by using Excel solver. Further, in Table 11, I outline how any change in the percentage deviation from the number of average sourced bundles affects the profit and how much the resource allocation will deviate between the involved agents. Below, I relate the results to incentive compatibility and participation constraint. The numbers in Table 11 follow the numbers in Table 10. I have excluded the revenue and costs of the resource bundle in our table.

Table 11 – The six agents' profit contribution and the result of the bundle allocation optimization with 0–50% deviation from the average number of sourced resource bundles

Principal requested sourcing volume is 1350 bundles in total

Agents	**Agent 1**	**Agent 2**	**Agent 3**	**Agent 4**	**Agent 5**	**Agent 6**	**Total**
Result of resource bundle optimization with 0% deviation from the average (225 bundles)	225	225	225	225	225	225	1350 bundles
Total profit of contribution from the agents*	$126,000	$150,750	$118,125	$148,500	$168,750	$171,000	**$883,125**
Result of resource bundle optimization with 10% deviation from the average (225 bundles)	203	247	203	203	247,5	247,5	1350 bundles
Total profit of contribution from the agents	$113,400	$165,825	$106,313	$133,650	$185,625	$188,100	**$892,912**
Result of resource bundle optimization with 20% deviation from the average (225 bundles)	180	270	180	180	270	270	1350 bundles
Total profit of contribution from the agents	$100,800	$180,900	$94,500	$118,800	$202,500	$205,200	**$902,700**

Result of resource bundle optimization with 30% deviation from the average (225 bundles)	157	293	157	157	292,5	292,5	1350 bundles
Total profit of contribution from the agents	$88,200	$195,975	$82,687	$103,950	$219,375	$222,300	**$912,488**
Result of resource bundle optimization with 40% deviation from the average (225 bundles)	135	315	135	135	315	315	1350 bundles
Total profit of contribution from the agents	$75,600	$211,050	$70,875	$89,100	$236,250	$239,400	**$922,275**
Result of resource bundle optimization with 50% deviation from the average (225 bundles)	112	337,5	112	112	337,5	338	1350 bundles
Total profit of contribution from the agents	$63,000	$226,125	$59,063	$74,250	$253,125	$256,500	**$932,063**

* Total profit of contribution from the agents is the agents' total profit from the resource bundle in Table 10 multiplied by the result of the resource bundle optimization from each agent outlined in Table 11.

Table 11 follows Table 9 because the profit increases only marginally (by approximately 1%) for every 10% deviation from the average number of sourced resources. Incentive-based contracts with risk and rewards can ensure future participation even if the network chooses to on-board new agents. They would also ensure that the agents reveal their true preferences and information because there are benefits for all involved parties to do so. This would only occur if the incentive creates an incentive compatibility situation. The optimization outlined above, I argue, creates incentive compatibility under the given conditions because the agents generate significantly more profit and the relationship is regulated by an incentive-based contract with risk and rewards. In the mechanism design theory in section 5, I argue for the importance of the "voluntary participation constraint." This constraint indicates that the agent is not forced to participate in the mechanism, and further that this constraint will affect the expected utility the agents receive from participating. Hence, the expected value for the agent must be equal or greater than it will if not participating. Otherwise, the agent may choose not to participate. Incentive compatibility is present if every agent finds it disadvantageous to abort from the mechanism. Table 11 depicts that agent 4 receives less bundles to source than before the new agents were on-boarded. When the percent deviation is, e.g. set to 10%, agent 4 could source 275 bundles. However, after the network on-boarded the two new agents, agent 4 receives less bundles to source (203 bundles). Sharing the profit after their contribution will most probably lead agent 4 to resist the new solution according to the mechanism design literature outlined in section 5. Hence, I argue that to ensure Pareto improvement, agent 4 needs to be compensated for its loss as in the principal–agent model outlined in section 6 (at a level implying agent 4 will still find it advantageous to participate in the network). If on-boarding the two new agents affects negatively agent 4, it signals that the partnership is Pareto inefficient and, as a consequence, the agent could leave the network to find more profitable outside options.

Theorem 2: On-boarding new agents affects the level of sourced items for the other agents. The existing agents will accept the new agents if the relationship fulfills the requirements of incentive compatibility and participation constraints.

Proof: Follows from Tables 8 and 11 and sections 5 and 6.

Theorem 2 follows from the central design problem outlined in section 5 and deals with the decentralized optimization problem with self-interested agents where there is private information regarding their different outcomes and preferences. Our goal is to create a mechanism in an environment with asymmetric information involving the involved agents' preferences.

If the new agents contribute significantly more value, the existing agents will accept the new agents because the final profit is shared by all involved parties. If they contribute with less value, they would probably not be on-boarded. If some of the agents receive less volume to source when on-boarding new agents, they have to be compensated for their loss. If they are properly compensated for their loss, the network can still have incentive compatibility and, as a result, the involved parties will reveal their true preferences and information. If not compensated, they will leave the network, hold back information, bluff or behave opportunistically, affecting the network negatively. The new agents' value contribution for the network needs to be significantly higher than the old network's value after the agents receiving less volume have been compensated. If not, the network will not fulfill the requirement of the participation constraint.

I consider this mechanism to be strong because it creates an equilibrium that is acceptable to all agents after on-boarding the two new agents as they still want to participate in the network. This solution is a Pareto optimal mechanism that solves the problem of private information, moral hazard and adverse selection between the involved parties.

8. CONCLUSION

I wanted to deal with the two main challenges related to opportunistic behavior: (a) the measurement of the agents' effort and (b) the reduction of conflicts of interests between the involved parties (Ouchi, 1979). In this article, I have managed to do so through a framework that deals with the decentralized optimization problem with self-interested agents.

The purpose of our framework is to outline a mechanism that aims to reveal the true information (preferences) in an environment with asymmetric information. This information revelation problem is a constraint for the network to evolve. To do so, I set up a mechanism where all the involved agents find it advantageous to reveal their true preferences because of the "rules" related to incentive compatibility and participation constraints. Hence, I can optimize the resource allocation between the agents by involving some additional constraints and regulating the relationship with the use of incentive-based contracts with risks and rewards. I argue that the agents decrease their profits only marginally when the deviation between their volumes of sourced items is small. At the same time, this will prevent one or more agents entering into a dominant position, thereby risking that they will behave opportunistically. I argue that there is a Pareto improvement because the players can increase their utility value without compromising the other actors. By contrast, by not involving the constraint, one or more agents can source the total amount of resources by themselves because this generates a marginally increased profit in the short-term. This can lead to the agent(s) acting opportunistically and lead to lower profits for all involved parties in the long run. This is also ultimately negative for the opportunistic agents.

If some of the agents receive less volume to source when on-boarding new agents, they have to be compensated for their losses. The network can still have incentive compatibility and, as a result, the involved parties will reveal their true preferences and information. If not compensated properly, they will behave opportunistically or leave the network, affecting negatively the network. The new agents' value contribution needs to be significantly higher than the old network's value after the agents receiving less volume have been compensated. If not, the network will not satisfy the requirement of the participation constraint. As a consequence of conflicting these constraints, the agent will value the network less because their social choice function creates a negative equilibrium. This situation has no incentive compatibility and the agent will most probably leave the network because the participation constraint is conflicted.

I argue that a resource allocation given the conditions and method outlined in this article will lead to an attractive and more "democratic" allocation that ultimately leads to higher profits for all involved parties. As a consequence, the network will gain a competitive advantage over other networks. Further, the network will, as a result of its higher profit, attract the best resources and further strengthen its position.

Finally, I need to consider important limitations. First, I could use quantitative data obtained from the industry (relevant companies). This could lead us to verifying the input data in our models. I agree this would be helpful for our analysis. Yet, I argue that the lack of quantitative data from the industry does not affect the quality of our findings as our goal is to optimize the resource flow between parties on a drilling project with constraints. The constraints would function the same way regardless of the information (if it was obtained from the industry or not). Secondly, I can use other methodologies to complement the optimization. If I conduct a case study, I can elicit the parties preferences and benchmark their preferences with the result of our optimization. I agree that this will benefit our study, but it is not necessary. In the methodology section I argue that our results are verifiable as I refer to similar results obtained in an embedded multiple case study.

REFERENCES

Arrow, K. J. (1963). *Social choice and individual values* (2nd ed.). New York: John Wiley & Sons, Inc.

Bakos, J. Y., & Brynjolfsson, E. (1992). Why information technology hasn't increased the optimal number of suppliers. *Unpublished working paper. Sloan School of Management.*

Barney, J. B., & Hesterly, W. S. (1996). Organizational economics: understanding the relationship between organizations and economic analysis. In S. R. Clegg, C. Hardy & W. R. Nord (Eds.), *Handbook of organization studies* (pp. 115–147). Thousand Oaks, CA: Sage Publications Ltd.

Davis, J. P., Eisenhardt, K. M., & Bingham, C. B. (2006). How do firms manage technology collaborations?. *Working paper*, Stanford University, Stanford, CA.

Davis, J. P., Eisenhardt, K.. M., & Bingham, C. B. (2007a). Complexity theory, market dynamism, and the strategy of simple rules. *Working paper*, Stanford Technology Ventures Program, Stanford University, Stanford, CA.

Davis, J. P., Eisenhardt, K. M., & Bingham, C. B. (2007b). Developing theory through simulation methods. *Academy of Management Review*, *32*(2), 580-599

Dasgupta, P., Hammond, P., & Maskin, E. (1979). The implementation of social choice rules: some general results on incentive compatibility. *The Review of Economic Studies, 46*(2), 185–216.

Eisenhardt, K. M. (1989). Agency theory: an assessment and review. *The Academy of Management Review, 14*(1), 57–74.

Fudenberg, D., & Tirole, J. (1991). *Game theory*. Boston, MA: MIT Press.

Gintis, H. (2009). *Game theory evolving* (2nd ed.). Princeton, New Jersey: Princeton University Press.

Hedstrom, P., & Swedberg, R. (1998). *Social mechanisms*. Cambridge: Cambridge University Press.

Hurwicz, L. (1973). The design of mechanisms for resource allocation. *The American Economic Review, 63*(2), 1–30.

Lambert, D. M., Cooper, M. C., & Pagh, J. D. (1998). Supply chain management: implementation issues and research opportunities. *International Journal of Logistics Management, 9*(2), 1–19.

Mas-Colell, A., Whinston, M. D., & Green, J. R. (1995). *Microeconomic theory*. Oxford, NY: Oxford University Press.

Maskin, E. S. (2007). Mechanism design: How to implement social goals. *Nobel price lecture*, Stockholm, Sweden.

Milgrom, P., & Roberts, J. (1992). *Economics, organization and management*. London: Prentice-Hall.

Myerson, R. B. (1981). Optimal auction design. *Mathematics of Operations Research, 6*(1), 58–73.

Osborne, J. M., & Ariel, R. (1994). *A course in game theory*. Boston, MA: MIT Press.

Osmundsen, P., Sørnes, T., & Toft, A. (2008). Drilling contracts and incentives. *Energy Policy*, 3127–3134.

Ouchi, W. G. (1979). A conceptual framework for the design of organizational control mechanism. *Management Science, 25*, 833–848.

Parkes, D. C. (2001). *Iterative combinatorial auctions: achieving economic and computational efficiency.* University of Pennsylvania, Pennsylvania.

Salanié, B. (1998). *The economic of contracts*. Cambridge: MIT Press.

Sund, K. A. (2008). *Developing new resources: How to gain dynamic capabilities and competitive advantages from integrated operations in the upstream oil & gas Industry.* Paper presented at the third annual meeting of smart fields consortium, Stanford, USA.

Sund, K. A., & Hausken, K. (2009). Fixed price contract versus incentive-based contract in the oil and gas industry. *Institutional paper 31*, 35.

Vickrey, W. (1961). Counterspeculation and competitive sealed tenders. *Journal of Finance, 16*(1), 8–37.

Winston, W. L. (2007) *Microsoft office Excel 2007: Data analysis and business modeling*. Redmond, Washington: Microsoft press.