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How to buy a nuclear power plant: Procurement contracting in risky long-term projects

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Abstract
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HOW TO BUY A NUCLEAR POWER PLANT? PROCUREMENT CONTRACTING IN RISKY LONG-TERM PROJECTS

OBJECTIVES

The purpose of this thesis is to provide theoretical insight into the procurement of a nuclear power plant. Previous experience has shown that contracting for a risky long-term project is likely to involve unforeseen contingencies that cannot be contractually accounted for. Moreover, the long project duration highlights the discrepancies induced by informational asymmetry between the contracting parties.

THEORETICAL FRAMEWORK

The theoretical framework for static contracting consists of basic bidding and contracting models. The bidding phase incorporates adverse selection issues; the contracting phase is linked to moral hazard issues.

The theoretical framework for dynamic contracting builds on the static theory, accounting for long project duration and the heightened risk. Adding dynamics to the setting creates the risk of underinvestment, and yields more complicated results.

KEY FINDINGS

Simple procurement can be governed by conventional tools: optimal bidding arrangements and monitoring suffice to mitigate adverse selection and moral hazard in the static setting. In contrast, a dynamic long-term procurement setting involves risk of both underinvestment and renegotiations. In order to achieve the optimal outcome, the incentives of the contracting parties must be aligned. Output-dependent ex-post compensation is best organized through an option contract or vertical ownership arrangements.

KEYWORDS

Contract theory; procurement contracting; asymmetric information; adverse selection; moral hazard; nuclear power industry; power industry; holdup; contractual incompleteness; renegotiation.

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KUINKA YDINVOIMALA OSTETAAN? HANKINTASOPIMUKSET KORKEARISKISISSÄ JA PITKÄKESTOISISSA PROJEKTEISSA

TAVOITTEET

Tämän tutkielman tarkoitus on tuoda teoreettinen näkökulma ydinvoimalan hankintasopimuksen valmisteluun. Aiempi kokemus on osoittanut, että pitkäkestoinen korkeariskinen sopimus todennäköisesti sisältää odottamattomia elementtejä, joita ei kyetä sopimuksellisesti kattamaan. Tämän lisäksi projektin pitkä kesto korostaa epäsymmetrisen informaation aiheuttamaa epäsuhtaa sopimusosapuolten välillä.

TEOREETTINEN VIITEKEHYS

Teoreettisen viitekehyksen staattinen osa kattaa tarjousvaiheen ja sopimusvaiheen. Tarjousvaiheessa käsitellään haitallista valikoitumista ja sopimusvaiheessa moraalikatoa.

Teoreettisen viitekehyksen dynaaminen osa pohjautuu staattiseen viitekehykseen lisäten siihen projektin pitkän keston ja kohonneen riskisyyden. Dynamiisuuden lisääminen sopimusmalliin saattaa johtaa optimitasoa pienempiin investointeihin sekä staattista mallia monimutkaisempiin johtopäätöksiin.

TULOKSET

Yksinkertaisia hankintasopimuksia pystytään hallinnoimaan tavanmukaisin välinein: tarjousvaiheen järjestelyjen huolellinen valmistelu sekä monitorointi riittävät eliminoimaan haitallisen valikoitumisen ja moraalikadon riskin staattisessa mallissa. Sitä vastoin dynaaminen malli käsittää sekä optimitason alhaisemman investoinnin että uudelleenneuvottelujen riskin. Parhaan mahdollisen lopputuloksen saavuttamiseksi sopimusosapuolten kannustimien tulee olla yhdensuuntaiset. Lopputulokseen sidottu korvaus toteutetaan optiosopimuksen tai omistusjärjestelyjen avulla.

ASIASANAT

Sopimusteoria, hankintasopimukset, epäsymmetrinen informaatio, haitallinen valikoituminen, moraalikato, ydinvoima-ala, energia-ala, epätäydellinen sopimus; uudelleenneuvottelu

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1 Introduction

Nuclear power has been the subject of rising interest due to the greenhouse gas emission reduction targets and increasing fossil fuel prices since the beginning of the new millennium. There was a long halt in new nuclear construction projects in the 1990s in the aftermath of the Chernobyl nuclear disaster. According to the World Nuclear Association (2011) the increasing electricity demand and the need for sustainable energy have lately induced several new nuclear construction projects, especially in developing countries but also in Europe. The increasing European demand for new nuclear reactors stems also from the fact that a number of first generation reactors are shortly coming to the end of their life cycle, and their generation capacity needs to be replaced. In Western Europe, Finland and France are currently constructing new reactors, and the United Kingdom is in an advanced phase of planning. In Central and Eastern Europe, Poland, Estonia and Latvia are working on a joint nuclear program. There are opposing signs, too: the Fukushima nuclear disaster induced Germany to announce a gradual shutdown of its nuclear reactors by 2020.

The so-called nuclear renaissance has been off to a bumpy start. Current European nuclear projects provide two examples. First, the infamous Olkiluoto 3 project in Western Finland sets an interesting benchmark in a negative sense. The client, Teollisuuden Voima Oyj (TVO), ordered the nuclear power plant from the French nuclear power plant supplier Areva as a fixed-price turn-key contract. The fixed-price contract was intended to fully transfer the design-related risks of the first-of-a-kind project to the supplier. The supplier, Areva, was willing to accept the extensive scope as Olkiluoto 3 was intended to become a showcase of the company's new technology at the dawn of the nuclear renaissance. However, the project has faced costly delays that have so far nearly doubled both the budget and the schedule. The main issues seem to stem from the inflexible contract structure: the fixed-price contract is very rigid when changes are required, and falls short in providing time-related incentives. Moreover, Areva's inexperience from the role of an architect engineer in projects of extensive scope has led to coordination problems. The delays and cost overruns have induced bitter feuds between TVO and Areva, who have entered into an extensive litigation process of claims and counterclaims that are being settled by the International Chamber of Commerce. Currently the value of claims on both sides is estimated to a total of 2−3 billion euros. As a second example, the French Flamanville 3 project has been facing similar issues concerning quality management and subcontractor chain, which have led to costly delays more than doubling the budget and the schedule for the project. (Nuclear Engineering International, 2009; World Nuclear Association, 2011)

The abovementioned recent examples of procurement contracting demonstrate that further insight into nuclear power plant procurement is needed. In particular, the increasing importance of nuclear energy in the Finnish electricity market and the recent challenges in nuclear projects further emphasize this need. The market characteristics that distinguish the nuclear power plant industry from other procurement settings require careful consideration. There is little empirical research on procurement contracting in the particular field, since the number of projects is fairly limited and the information available is scarce. Moreover, contracts are drafted under strictly enforced non-disclosure agreements, which renders gathering of empirical data nearly impossible. Generic procurement literature that explores standard procurement processes such as highways (Bajari & Lewis, 2009), standard power plants (Lewis, 1986) or on a more limited scale repeated contracting e.g. coal provision, is reviewed in chapter 2. In contrast, this section addresses the market features and the regulatory environment that distinguish the nuclear power plant market from other industries. Compared to a generic procurement setting, the nuclear power plant market encompasses the following distinctive features:

1. **Bilateral oligopoly.** Despite the recent boom in nuclear building, the market still consists of few potential suppliers and few potential buyers. In such a setting, the exit of a supplier from the market or the entry of a new client can quickly deteriorate the client's negotiation position. The bilateral oligopoly is supported by the inability of a standard electricity utility to take the construction of a nuclear power plant in-house due to the high degree of specific design requirements. Therefore a nuclear energy company willing to take on nuclear power generation is forced to trade with one of the few existing reactor suppliers.
2. **Risk.** A nuclear power plant differs from other large-scale construction projects in that the project is of very little value before 100% completed. However, both the supplier and the buyer become locked into each other in a very early stage of the project, with an insignificant default option. The risk during this relationship accrues from the following factors, and has to been contractually divided between the contracting parties.
    a. **Immature design.** There are usually only a few units built of each reactor model before the next generation design takes over. Moreover, each power plant needs to be customized to meet the regulatory requirements and the particular client's needs. The immature design also leads to a heightened yet unknown risk profile.
    b. **Long-term commitment.** Even the most hurried nuclear power plant projects have taken 48 months from the first concrete pouring to the beginning of commercial operation − the preceding negotiation and licensing phases included the timeframe

is likely to be twice as long. Costs are incurred throughout the process, whereas the benefits accrue only after the project is completed. Moreover, post-construction liability is likely to lengthen the duration of the supplier-client relationship even further.

c. **High degree of regulation.** The industry is highly regulated both internationally and domestically. As follows, the information flow between the regulator, the client and the supplier needs to be seamless. Moreover, the high degree of regulation brings along a notable risk of changes in design requirements, thus increasing the overall project riskiness. The riskiness of the project is further enhanced by the reform of the Finnish nuclear law that is expected to come into effect in 2013.

Some of the abovementioned features are also identified within defense procurement literature. Rogerson (1994) explores massive uncertainties in defense procurement, dividing them into internal and external threats. Internal threats involve problems in the design and production, whereas external threats focus on changes in the environment, e.g. legislation and external financing. These threats are parallel to the immaturity of design and the high degree of regulation. However, examples from defense procurement tend towards repeated long-term commitment (e.g. Rogerson, 1994; Hiller & Tollison, 1978) instead of extensive one-time project investments. These differences alongside with the industry-specific features indicate a research gap in the existing procurement literature.

1.1 Research questions

The research questions of this thesis concern the optimal contracting for a risky long-term project where asymmetric information is present. In addressing these issues, the thesis employs the classical principal–agent paradigm as presented within contract theory. In the sense of a Stackelberg game (Salanié, 2005, p.5) *principal* is the contracting party who proposes a contract and *agent* is the follower who accepts or rejects the contract. For example, Sappington (1984) determines this relationship such that the principal owns a productive technology that requires as an input the effort of the agent. In the context of nuclear reactor procurement, the client or the nuclear power facility is referred to as *principal* whereas the supplier or the contractor is referred to as *agent*.

As in all contract theory, the assumption of *asymmetric information* is strongly present throughout the thesis. Asymmetric information refers to the realistic assumption that the principal and the agent are unlikely to share the same information about their cost structure and about the future states of world. This leads to discrepancies in both bidding phase and contracting phase – by leveraging on informational asymmetry either party might be capable of reaping most surplus from the bilateral contract. Informational asymmetry occurs both *ex ante* – before the state of the world that affects the outcome of the contract has been realized – and *ex post* − after the state of the world has become known to both parties. It is commonly acknowledged within contract theory that the problems of asymmetric information lead to deviations from the pareto–optimal outcome of a contract (e.g. Baron & Besanko, 1987). These effects and their mitigation are explored with the following research questions:

1. What are the optimal bidding arrangements?
2. What is the optimal contract structure?
3. How to ensure the optimal outcome in case of renegotiation?

The first question is posed for theoretical interest and in order to provide a comprehensive contracting timeline. The theoretical insight provides support to the intuitive results about how an extensive procurement bidding process is optimally arranged. The second research question raises the issue of optimal contract structure. A contract is said to be optimal, when the contracting parties are induced to choose their investment levels so that the joint marginal cost equals the joint marginal benefit. The optimal investment levels are referred to as *ex-ante* efficiency. However, a contracting environment encompasses large uncertainties, which can distort the ex-post efficiency of the contract. The third research question embraces this idea of ex-post inefficiencies and acknowledges that judicially every contract can be renegotiated – or breached. A contracting party should seek to ensure that trade takes place in all circumstances in which it creates value to him. This thesis provides insight into the contracting tools with which the optimal outcome can be achieved.

1.2 Theoretical framework

Within contract theory, a well-established approach is to divide the contracting process into two phases: bidding and contracting. Informational asymmetry is present in both as follows. In the bidding phase informational asymmetry allows for agent's *hidden information* which can induce *adverse selection*. In the contracting phase, informational asymmetry allows for *hidden action*, which can induce *moral hazard.* Contractual incompleteness is closely related to asymmetric information – not even the most extensive contract can account for every possible future contingency. In complex or uncertain environments, the contracting parties are likely to renegotiate the contract at some point. Therefore, this thesis discusses renegotiation as the third phase of a procurement project.

The following figure conceptualizes the theoretical framework of the thesis (Figure 1: Theoretical framework: Contractual issues). A procurement process is divided into three phases: bidding, contracting and renegotiation. The dominating environmental characteristic throughout the contracting period is asymmetric information. Moreover, contractual incompleteness is a major factor allowing for moral hazard and holdups in both contracting and renegotiation phase. The main problems associated with procurement contracting are adverse selection, moral hazard and holdup situations. This thesis discusses theoretical solutions to each of these issues and provides practical insight into how procurement should be conducted in order to ensure an optimal outcome.

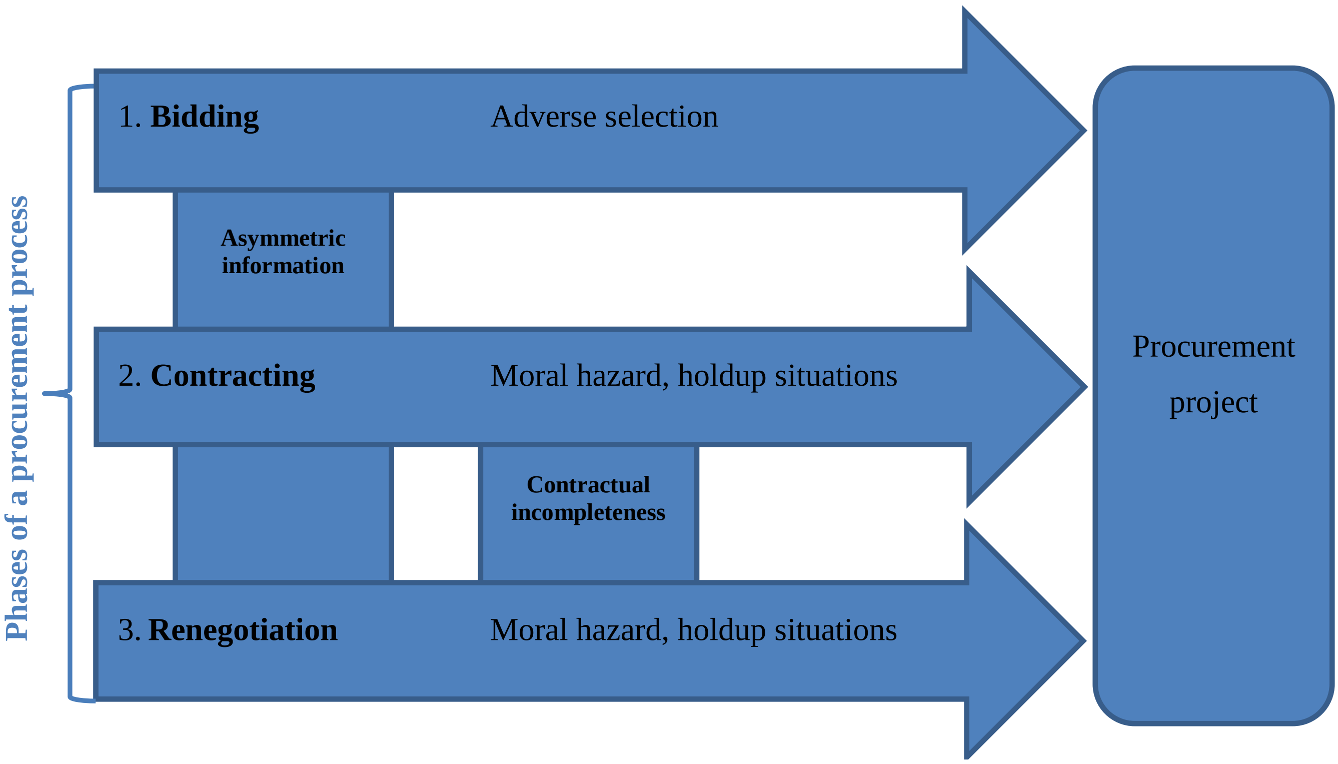

Figure 1: Theoretical framework: Contractual issues

1.3 Related literature

The scope of the literature reviewed in this thesis covers the initial contracting scheme with competing suppliers, the actual contractual negotiations and holdup situations leading to renegotiation. The contract theory literature originates from the 1960s and 1970s when the theory of incentives was first explored, and the concepts of private information and hidden action were introduced. Most literature reviewed in this thesis stems from research from the late 1970s and the early 1980s emphasizing the optimal incentives in static contracts. There is a reasonable understanding about the theoretical framework for the static setting, where environmental characteristics remain stable or have little impact on the outcome of a contract. The second wave in the late 1980s and around 1990s, in turn, shifts focus towards long-term dynamic contracting. Renegotiation and contractual incompleteness are in the center of attention. After 2000, the theory about dynamic contracting in complex environments has been developed further. However, a clear consensus about the theoretical framework still remains to be reached. (Bolton & Dewatripont, 2004)

This thesis explores both elementary contract theory and more specific contracting examples. Whereas the empirical examples and the most relevant industry cases are based on individual articles, the overview of contract theory and the theoretical definitions used in this thesis are largely based on two manuals. The first is *Contract Theory* by Bolton and Dewatripont (2004) and the second is *The Economics of Contracts* by Salanié (2005). *Law & Economics* (Cooter and Ulen, 2004) has also been a source of inspiration.

When assessing the literature one has to carefully bear in mind the fact that the majority of procurement projects concern standardized procurement and mass production. This sets limitations to the extent to which the theory can be applied to the nuclear power plant industry, where every project is a tailor-made modification of a relatively young design that might get repeated only a dozen times over its lifetime, and where risk is highly present. The market features of nuclear power industry are considered throughout the thesis to assess which aspects of the literature are relevant in this study.

1.4 Structure of the thesis

The thesis is structured according to the theoretical framework as follows. Chapter 2 presents the case company Fennovoima, and the procurement project at hand. A contracting timeline and assumptions on the risk preferences of the contracting parties are presented. Furthermore, chapter 2 briefly discusses parallels between the procurement project at hand and other fields of industry. Chapters 3–6 present contract theory according to the timeline presented above so that chapters 3 and 4 focus on the static setting, whereas dynamics are introduced into the setting in chapters 5 and 6. In particular, chapter 3 explores the bidding phase, where competition between the bidders is a predominant feature. The first section presents a simple model of adverse selection. Different mechanisms to choose the supplier are introduced in the second section. The final section presents general remarks concerning the bidding phase. Chapter 4 explores the contracting phase that takes place after the preferred bidder has been selected. The first section presents a simple model of moral hazard. The optimal risk-sharing structure is discussed in the second section. The third section presents incentives for achieving quality, and the final section makes general remarks about the contracting phase. As for chapter 5, the focus lies on holdup situations. The first section presents the underlying theory and the second section discusses some contractual solutions to the topic. The final section of chapter 5 presents general remarks about holdup situations. Finally, chapter 6 reviews renegotiation. The first section discusses the underlying theory. Incomplete contracts are described in the second section. The third section presents a few topics in renegotiation literature, and the final section sums up the topic by presenting some general remarks. The findings and practical implications vis-à-vis the case company are discussed in chapter 7. The discussion is completed by noting the limitations of the study and pointing out topics for further research.

2 Procurement project in the case company

Fennovoima Ltd. is the newest entrant in the Finnish nuclear power industry. The company was founded in 2007 by Voimaosakeyhtiö SF (66%), a consortium of Finnish electricity and industrial companies, and the German electricity company E.ON (34%) with the aim of constructing a new nuclear plant that could be operational in 2020. After being granted the decision-in-principle, Fennovoima has proceeded with the project to build a nuclear power plant in North-Western Finland, in the Pyhäjoki municipality. The company sent out a bid invitation specification to two potential reactor suppliers in 2011 after narrowing the choice down from a few major reactor builders. The negotiations with the potential bidders, the French Areva and the Japanese Toshiba, will be held in parallel until the selection of preferred bidder is made. The financial closing is planned for 2015, when the company is expected to be issued the actual construction license. (Fennovoima Project Schedule)

A quarter of Finland's electricity supply is produced by nuclear power. In 2012, there are four reactors in operation, two run by TVO in Olkiluoto and two run by Fortum Plc in Loviisa. TVO is currently constructing a third reactor. TVO and Fennovoima were granted decisions-in-principle by the Finnish Parliament in 2010, which permits the two companies to proceed with the planning of two new nuclear reactors. These projects completed, there will be seven nuclear reactors in Finland, generating up to 50% of the country's electricity supply. (World Nuclear Association, 2012)

In 2012, Fennovoima is negotiating for a contract for the procurement of a nuclear reactor for its first nuclear power plant, Hanhikivi 1. This thesis explores contract theory within this framework. The following three issues are of particular concern. First, the reactor supplier has superior information about his ability, which can affect the ex-post welfare of the contracting parties. Asymmetric information between Fennovoima and the prospective reactor supplier is abundant, which further contributes to the riskiness of the project from the company's point of view. Informational advantage about their cost structure can account for disproportioned bargaining leverage to the agent in the bidding phase, the contracting phase and the plausible renegotiation phase, and thus allow for the agent to reap most of the surplus generated by the bilateral contract. Second, the project involves massive uncertainties, and the related risk needs to be borne by either one or both contracting parties. Risk is highly typical to the nuclear construction projects: nuclear power plant projects are lengthy, the design is likely to change during the project, and the regulatory environment is prone to changes. A contractual failure can lead to costly delays, which in turn can affect negatively the public opinion and the regulatory environment, and thus increase the riskiness of the Fennovoima project and reduce the probability of a positive outcome. Third, the project involves large relationship-specific investments, as a significant part of the design development work that has to be conducted in the early stages of this project may not be applicable in other projects or with another supplier. This might lead to socially suboptimal investment levels.

In addition to the general challenges listed above, the Fennovoima project involves project-specific challenges. Considering the Finnish nuclear regulation practices and the extensive regulatory lags, the project is a unique possibility for the company to enter the Finnish nuclear power industry. Against likelihood, Fennovoima obtained a parliamentary go-ahead for a new greenfield site nuclear project in the parliamentary vote in 2010, whereas the well-established Fortum Plc was refused their application for a third reactor. It is already known that the next vote will not be taking place before the next elections in 2015. Hence the Fennovoima project is regarded as a one-time opportunity. Furthermore, as the company was founded only in 2007 to execute this one particular project, its capabilities are still relatively unknown in the industry. The vast scope of the project, the related investment risks and the one-shot nature of the project, combined with the infamous difficulties of the Olkiluoto 3 project, have created an interest for wider understanding on how to mitigate contractual risks and achieve a pareto-optimal outcome.

This chapter discusses the Fennovoima project from three different angles, shedding more light on the procurement project and the related issues at hand. The first section presents the contracting timeline, and presents a simple figure illustrating the themes of this thesis with regards to the contracting timeline. The second section discusses the risk preferences of the contracting parties and their relevance vis-à-vis the Fennovoima project. Finally, the third section explores parallels with other fields of industry by providing an overview of the related literature.

2.1 Contracting timeline

The procurement process consists of several subsequent phases that are governed by different contracts. The first two Early Works Agreement contracts (EWA 1 and EWA 2) are signed with both supplier candidates in order to secure joint design development and ensure the suitability of each design. The preferred bidder is selected in 2013, and the Front-End Engineering and Design contract (FEED) is signed with one of the two suppliers in order to further develop the design. The potential main contract, the Engineering, Procurement and Construction (EPC) contract will be signed in 2015, and will cover the whole construction process from until the connection to the commercial grid.

For simplicity, the contracting timeline so as to highlight the contractual risk that needs to be borne by either one of the contracting parties. The figure below (Figure 2: Risk vs. investment level) presents the interplay between investment and project completion in the Fennovoima project, and describes how the risk is shared between the contracting parties without any contractual intervention. Three main issues of this thesis are highlighted in the figure: selecting the best supplier before the contract is signed, incentivizing the chosen supplier to duly complete the project, and mitigating the underinvestment from initially low contractual coverage. The timeline is set out as follows:

$t = -1$	Bid invitations sent out, project-specific investments initiated
$t = 0$	Contract is signed
$0 < t < 1$	Contract is renegotiated as contingencies unfold
$t = 1$	Project completion

Before signing the EPC contract, the two competing suppliers bear a significant proportion of the investment-related risk. The degree up to which the contract-specific investments are covered by the contract is low at this early stage, but the design has to be developed so as to be licensable in the Finnish market. Until the contract is signed, this development involves a heavy supplier risk. Therefore, up until date 0, the suppliers' incentives to reach contractual coverage are surprisingly strong, which in turn strengthens the competition between the two competing candidates. As a compensation for this risk, the supplier candidates are granted a bid bond in case the negotiations are unilaterally terminated. Once the contract is signed, the risk can be contractually shared between the two parties. Since the project is of zero value to the buyer until completion, the contract must involve strong incentives for the supplier to finalize the project. Due to the tight regulation and supplier-specific design, the buyer is locked into the supplier until completion. Therefore a procurement contract typically involves high breech clauses.

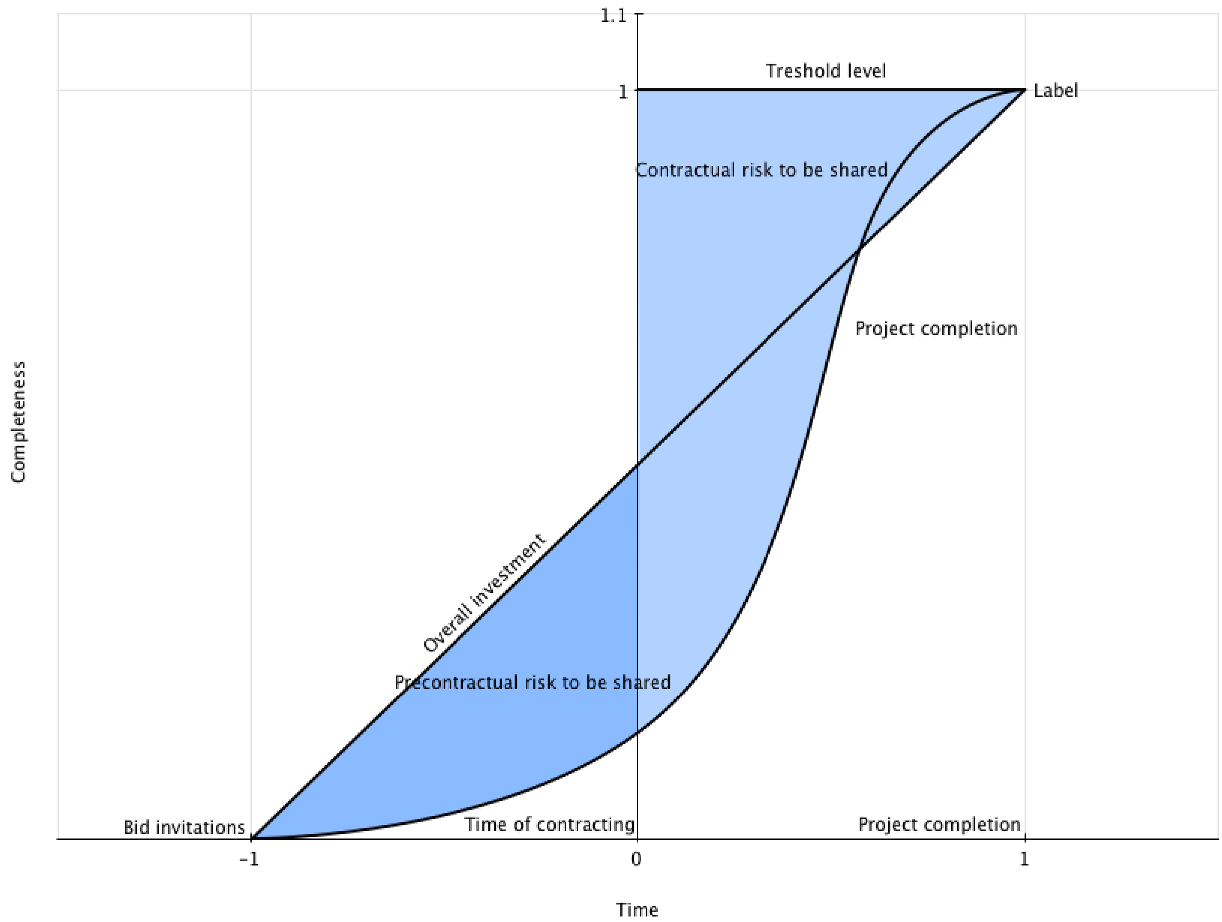

Figure 2: Risk vs. investment level

2.2 Assumptions on risk preferences

It has been stated (Allen & Lueck, 1995) that the standard risk sharing model consists of a situation, where the agent is risk-averse and the only margin for moral hazard is induced by the agent's effort; the principal cannot shirk. Allen and Lueck (1995) argue that the theoretical risk preferences of the contracting parties actually have no influence on the contract structure. They argue that individual risk preferences are not measurable, least dichotomous, and thus the general assumption of risk-neutral principal and risk-averse agent remains weak. Allen and Lueck rely on empirical data in showing that 1) the traditional assumption about contracting parties' risk preferences may be incorrect and 2) the role of risk preferences is less pervasive in determining the contract structure than previously assumed.

The liberal approach of Allen and Lueck (1995) is applied in selecting the model to be presented. It is easy to justify different views on the contracting parties risk preferences in the contractual setting at hand. The principal can be assumed to be risk-averse or risk-neutral. Theoretically, risk neutrality is a safe assumption. Considering the ownership structure, risk-aversion also requires consideration. In reality, the principal’s action can quite easily tend towards risk-loving, due to the one-shot nature of the project. The agent’s preferences, in turn, can be either risk-averse or risk-neutral, depending on the relative weight of the Fennovoima project in their portfolio. As discussed above, defining risk preferences for the procurement project at hand seems redundant, and therefore they have not been allotted significant weight in the model selection in this thesis.

2.3 Parallels with other fields of industry

This section explores some parallels that can be drawn between nuclear power plant procurement and some other industries, and specifies how the empirical procurement literature can support the Fennovoima procurement project. The empirical studies are mainly located within defense procurement and large-scale construction projects such highway projects and building construction industry. John and Saunders (1983) have conducted one of the few empirical analyses about nuclear plant procurement. They conclude that contractors are unwilling to take on fixed-price contracts for nuclear power related procurement, unless the cost variance is reduced through repetition and experience or the customer is able to break the project in smaller parts with greater project and cost definition.

A significant part of procurement literature explores the principal's make-or-buy decision. This refers to the principal's choice of producing the component itself instead of contracting an agent to produce it. It is stated (e.g. Bajari and Tadelis, 2001) that the complexity of the component determines the choice such that a simple component that is straightforward to contract upon will be bought, whereas a complex component with anticipated design changes is more likely to be produced internally. This approach has empirical support from aerospace industry (Masten, 1984) and automobile industry (Monteverde and Teece, 1982) where it has been shown that more complexity increases the likelihood of internal procurement. In the nuclear power industry, however, it is uncustomary that the client take production in-house. There are few examples of projects where the agent has become a partial owner of the project. For example, in the American South Texas Project, the Japanese Toshiba formed a joint venture with an energy company to become a stakeholder in the project (NINA Press release, 2010). Despite the theoretical support for internal production, it remains an interesting question for further research why vertical integration into the supply chain remains an uncommon practice within the nuclear power industry.

2.3.1 Defense procurement

Defense procurement is one of the closest benchmarks to the nuclear power industry. The parallels can be mainly found within the riskiness of the projects, uniqueness of the design and the possibility for holdups due to the limited number of potential suppliers and clients in the market. Similarly, both industries face strict regulation and involve a high level of confidentiality.

Hiller and Tollison (1978) explore the two extremities of the linear form of contract within the context of defense procurement. By the end of the 1970s it had been empirically proven that introducing incentive measures had improved cost measures relative to the target costs. The reasons behind this were twofold. First, in case of a cost overrun with an incentive contract, the principal is obliged to pay only a part of it. Second, since the agent will have to pay a portion of any cost overrun, there is a strong incentive to improve on cost efficiency. However, Hiller and Tollison (1978) list strong counterarguments that support the opposite view on incentive contracts. First, it is possible that the target costs in a fixed-price context are inflated compared to what they could have been in a cost-plus context, where the buyer compensated the supplier for his costs. Second, incentive contracts offer both higher negotiated target profits and higher final profits, and therefore the achieved production efficiencies must exceed the increase in the profit rates. Finally, if an investment involves an incentive for exceeding the targets, the total cost to the supplier might even be increased. However intuitive the increased cost efficiency under an incentive contract might seem, Hiller and Tollison make a convincing case against it. They argue that production costs are often confused with the total costs to the principal, rendering comparison useless. Moreover, higher profit rates of the agent, target value inflation, possible incentive costs and even higher administrative costs can outweigh the reductions in production efficiency.

Baron and Besanko (1988) investigate procurement contracts in the context of defense procurement. In their model the government designs optimal linear contracts for a risk-averse agent in the presence of moral hazard, private information and an imperfect monitor. Crocker and Reynolds (1993) discuss major weapons systems acquisition where government has few, if any, alternative suppliers ex post, and gets thus locked into a contract in an early stage. They argue that the ability of the government to constraint the supplier's opportunism depends on the degree of contractual completeness. They examine six alternative contract types with a varying degree of ex-ante and ex-post negotiations. Contract types vary from a firm fixed-price contract, which allows no room for ex-post negotiations, to a fixed-price incentive contract, which involves an initial target cost and a high cost-sharing rate. Crocker and Reynolds (1993) discover that cost-sharing contracts gain popularity over time. They consider the agent's cumulative reputation as an important factor in this development, and state that long-term repeated contracting allows for less complete contract design.

In a study on the economic incentives in defense procurement, Rogerson (1994) points out four distinguishing aspects: importance of R&D, large uncertainties, holdup problems created by specific investments and long lead-times, and large economies of scale. All but the last can be directly applied to nuclear power plant procurement. First, project specific R&D is necessary due to varying national regulation and requirements, which creates an opening for holdup situations from both agent's and principal's side. Second, both the immaturity of design and the external operational environment contribute to large uncertainties which are likely to involve a considerable cost risk. Third, relationship-specific investments are likely to lead to holdup situations where the contracting parties are locked into each other. Fourth, however, economies of scale are only present in multiple reactor projects, which has been quite unusual in the European context due to stringent regulation. For example, a Finnish nuclear power utility is unlikely to be granted two separate decisions-in-principle within the lifetime of one unaltered design.

Baron and Besanko's (1988) research about defense procurement resonates with Rogerson's (1994) findings that were described above. They define four features that complicate a procurement project. First, the cost-related risk requires specific attention to the risk-sharing structure of the contract. Second, large uncertainties and long lead-times involve private information. Third, the complexity of the projects renders accurate monitoring nearly impossible, and therefore the contract must be designed to mitigate the issue of moral hazard. Finally, it is impossible to separate the direct costs of a project from the overhead costs of the agent, which results in a noisy monitor. Therefore procurement costs are often based on imperfect monitoring of production costs. In fact, Baron and Besanko (1988) argue that due to the features listed above, the optimal contract in defense procurement deviates from the theoretical first-best solution, and that the direction of the deviation depends largely on the monitor, alleviating the moral hazard issues. The article provides parallels to the procurement project at hand: nuclear power industry and defense procurement can be inspected with the same tools. The empirical findings about military procurement by Baron and Besanko (1988, p. 519) support the view that fixed-price contracts are generally used for standardized products and repeated contracting, whereas cost-plus contract is widely used for complex products with severe cost randomness.

One of the key differences between the nuclear power plant industry and defense industry is the relative weight of the parties. In defense procurement the principal, i.e. the state, can usually allocate significant resources to the procurement process. Moreover, the make-or-buy decision is often worth considering, too. In contrast, in nuclear power plant procurement the relation is nearly inversed, especially in the Fennovoima case: the principal is a new entrant in the industry, whereas the potential agents are imposing in their size and scale of operations.

2.3.2 Large-scale highway projects

Bajari and Lewis (2009) assess efficient bidding and contracting in large-scale highway construction processes, aiming at timely completion of the projects. They examine a set of data from projects ordered by the Minnesota Department of Transportation, including both innovative and standard contracts. They argue that contractors respond to incentives as the theory predicts and that significant welfare improvements can be achieved by switching from a standard contract to socially efficient time incentives. The most advanced form of incentive contract involves two parts: a monetary bid for the labor and material costs, and a bid on the total number of days to complete the project. It is shown that these combined contracts result in significantly faster completion of project than the standard contract.

Some parallels can be drawn between an extensive highway project and the procurement of a nuclear power reactor. However, in nuclear power industry quality issues are likely to gain significantly more weight than in a highway construction project. Therefore direct implementation of the advanced incentive contracts, shown to be efficient in highway construction, is likely to be too simplistic for reactor procurement. The most intuitive insight stems from a scoring auction, which is further explored in subsection 3.2.2 . Another distinguishing feature of a highway project is that the winning bidder is required to post a contract bond guaranteeing the completion of the contract according to specifications. Typically this bond is secured through a third party who will take on the bidder's obligations in case of default. Nuclear reactor projects, however, involve extremely high relationship-specific investments - a contract bond is unlikely to be high enough to cover for the financial loss in case of premature project termination and there exists no third party that could be able to take on the construction project in case of default.

2.3.3 Building construction industry

Similarities between large construction projects and building a nuclear power plant are plentiful and quite straightforward. Every project is unique and requires diligent coordination between the architect engineer, subcontractors and suppliers (Bajari and Tadelis, 2001). However, the nuclear power industry involves more regulation per se, and is thus more likely to lead to holdups between the contracting parties. Similarly, the market structure is more rigid, allowing the contracting parties for more negotiation leverage. In construction industry, fixed-price contracts tend to be awarded through competitive bidding, whereas cost-plus contracts are negotiated privately between the principal and the agent. Occasionally cost-plus contracts are complemented with rewarding or penalizing incentives. The risk sharing arrangements are further explained in section 4.1.2 .

The construction industry literature provides important insight into the risk sharing structure, as there is abundant empirical evidence on the topic. It has been found that a fixed-price contract in a complex project frequently leads to renegotiation. The agent is not willing to perform duties beyond those listed in the contract without additional compensation. According to Bajari and Tadelis (2001), there is ample evidence that ex-post changes are the rule rather than the exception. Reasons behind this include incompleteness of design, changes in scope and unpredictable site conditions.

2.4 Linking the case company to the theory

As has been discussed above, Fennovoima is in a challenging position as a newcomer in the nuclear power industry. In particular, the recent negative experiences about Finnish nuclear power projects add up as additional pressure towards the company. This chapter described the procurement situation with a simplified timeframe of the project, and with examples from benchmark industries. Some parallels between nuclear power industry in defense procurement were establishedThe following chapter employ this timeline such that chapters 3 and 4 focus on the static part of contracting theory, providing tools for bidding and contracting, whereas chapters 5 and 6 consider the dynamics of a long-term project.

3 Bidding

In the bidding phase, the buyer's main concern is to select a capable supplier. The main risk during the bidding process is *adverse selection.* Adverse selection takes place when the supplier has private information about his type – whether he is likely or unlikely to perform well - and can induce the buyer to sign a contract which enables the supplier to capitalize on his superior information. Alternatively, adverse selection can occur when the better qualified suppliers get outbid from the competition, and the less qualified supplier wins the bid. A close example can be found within the Finnish nuclear power industry. It is commonly agreed that during the Olkiluoto 3 bidding process the suppliers' bids were pushed so low, and the schedule was drafted to be so tight that the winning supplier could do nothing but fail in fulfilling the targets. With this in mind, it is crucial to reflect on adverse selection and assess the theoretical findings on its mitigation.

This chapter sheds light on the first stage of procurement contracting in which multiple bidders are still involved in the process. The topics include adverse selection and the optimal bidding mechanism design to its mitigation. The first section describes the simple theory: how asymmetric information can cause adverse selection and how it is theoretically mitigated through screening. The second section focuses on literature about the bidding phase, building on the theory from the first section. The question to be answered in this section is: What are the optimal bidding arrangements? The final section sums up the chapter by discussing some general remarks about the bidding phase in the context of the Fennovoima project.

3.1 Adverse selection: A simple model

Adverse selection occurs when the principal accepts the bid of an inefficient agent because it cannot observe the agents' expected production costs before awarding the contract. Typically the agent holds *hidden information.* This section examines bilateral contracts when one the contracting parties has private information. Two cases are generally recognized within adverse selection. In the first case, it is the uninformed principal who suggests a contract. In such a situation the uninformed principal faces a *screening problem*: he must try to screen the agents for their private information. In the second case, in contrast, it is the informed agent who suggests a contract. Here the agent faces a *signaling problem*: he must try to signal his quality to the principal. Adverse selection is typical of employee-employment relationships: the employer screens the potential employees for their characteristics and attracts better qualified workers by offering a higher wage, or the potential employees signal their quality through e.g. education. (Bolton & Dewatripont, 2004)

How efficient can contracting under asymmetric information be? According to the *revelation principle*, the answer is surprisingly simple: to determine optimal contracts under asymmetric information, it suffices to consider only one contract for each type of information the informed party might have, while making sure that each type has an incentive to select the contract that is destined to him. This is called *incentive compatibility*. This reduces the contracting problem under asymmetric information into a standard contracting problem with additional incentive compatibility constraints, and eliminates the need for communication between the contracting parties. (Bolton and Dewatripont, 2004)

Bolton and Dewatripont (2004, pp. 17–19) present a simple contracting problem with hidden information. Their illustration of an employee–employer relationship is modified into a supplier–buyer relationship for the purposes of this thesis. The modification entails excluding employee's preferences for leisure, l, and using a multiplication factor 1 instead of $1 - l$. The buyer's utility function is then given by $U(\alpha\theta) - t$, and the supplier's utility function by $u(t)$, where t is the buyer's monetary transfer to the supplier, α is a positive constant, and θ is the skill level or the type of the supplier. The variable θ is thus the state of nature, learned privately by the supplier before signing the contract. In particular, the supplier knows if he represents the good type, θ_H, or the bad type, θ_L, with $\theta_H > \theta_L$. The buyer knows only that the probability of facing a supplier of the good type is p_H. With a good supplier, the relevant reservation utility is $\bar{u}_H = u(\theta_H)$, and with a bad supplier, it is $\bar{u}_L = u(\theta_L)$. If the buyer could learn the supplier's type, he would offer in state θ_j a contract with transfer $t_j = \theta_j$ in exchange for the delivery of the product. Such a contract would maximize efficiency, and since the supplier's individual rationality constraint $u(t_j) \geq u(\theta_j)$ would be binding under this contract, it would maximize the buyer's payoff.

However, when the supplier's productivity is private information, the buyer is not able to achieve the same payoff as above. If the buyer offers a contract $t_j = \theta_j$ in exchange for the delivery of the product, all supplier types would pretend to be skilled to get the higher wage θ_H. If the output, however, is observable, the buyer can get around the informational asymmetry by including a money-back guarantee in the contract – if the product falls short of the promised quality level, the supplier refunds the difference to the buyer. Therefore the hidden information problems often include an assumption of unobservable quality (Bolton and Dewatripont, 2004). Another assumption is that the supplier cannot be punished ex post for a failure to reach the contracted quality. If this is the case, then the bad type of worker can always pretend that he was unlucky. For simplicity it is thus assumed that the output quality is unobservable (Bolton and Dewatripont, 2004). The definition of quality in the context of this thesis is discussed in detail in section 4.3 In order to proceed with the adverse selection assumption, it is useful to assume quality as a product feature that is defined over the lifetime of the nuclear power plant, and thus unobservable within the contracting period.

Under the assumption of non-observability of quality, the only contract the buyer can offer is a simple transfer t in exchange for one delivered unit of product. According to the revelation principle, there exists a revelation mechanism with anequilibrium where the contracting parties truthfully report their types. It is then sufficient to offer two types of contracts, t_H and t_L, where contract t_j is the contract chosen by the type j. However, each contract has to be incentive compatible. That is, type θ_H must prefer t_H over t_L, and type θ_L must prefer t_L over t_H. Thus the optimal menu of procurement contracts can be represented as the solution to the optimal contracting problem under complete information

$$\max_{t_j}\{ p_L U[\alpha\, \theta_L - t_L] + p_H U[\alpha\, \theta_H - t_H]$$

subject to the individual rationality constraints

$$u(\theta_L + t_L) \geq u(\theta_L)$$

and

$$u(\theta_H + t_H) \geq u(\theta_H)$$

and two additional incentive compatibility constraints

$$u(\theta_H + t_H) \geq u(\theta_H + t_L)$$

and

$$u(\theta_L + t_L) \geq u(\theta_L + t_H).$$

The solution to this constrained optimization problem yields the most efficient contracts under hidden information. Adding incentive compatibility constraints results in a less efficient allocation than could be achieved under complete information. In general, asymmetric information leads to second-best contracts.

3.2 Optimal bidding process

There is abundant mechanism design literature assessing bidding mechanisms. The focus is on mitigating adverse selection, which is commonly achieved through organized competition between several agents. In their study from 1992, Crémer and Khalil explore the agent's ability to gather information before signing a contract. They show that the bidding scheme – competition or no competition – as well as the number of agents involved in the bidding process significantly affect the principal's surplus. This holds if agent's cost of acquiring ex-ante information is low enough. It is shown that instead of informational symmetries or asymmetries, it is rather the agents' market position that affects the contract and the principal's surplus. If an agent is able to acquire information at low cost, the principal is induced into offering a better contract. Therefore, other factors held constant, the principal is better off contracting with the more ignorant agent. Valley et al. (1998) study the effects of communication on the efficiency of a contract. The study combines economic and behavioral analysis, and state that private information held by one party lead to a negative expected value for the uninformed party. Valley et al. argue that mutually beneficial outcomes can be more easily attained, if negotiation strategies include face-to-face communication among other elements of cooperation. They consider pre-bid communication as a means of mitigating adverse selection through a signaling game, and thus contribute to the reputation building literature, following e.g. Lewis (1986).

Asker and Cantillon (2010), in turn, assess the principal's optimal buying mechanism when both price and quality are of importance to the principal. Asker and Cantillon define the optimal procurement mechanism for a single procurement contract. The theoretical optimal mechanism is then compared to simpler bidding mechanisms that are seen more regularly in practice. Whereas the theoretical optimal mechanism allows the principal to extract the whole strategic surplus from the contract, the first one of the simpler mechanisms, scoring auction, allows the principal to extract a significant proportion of the available strategic surplus. In contrast, the second mechanism assessed, a bargaining game, is likely to lead to a less desirable outcome. However, the assumption of contractible and endogenously determined quality sets severe limitations to the practical implications of the findings, since quality in the context of a nuclear power reactor is a multidimensional feature. As such, it can be debated whether quality can be contracted upon.

A simple model of adverse selection and screening was presented in the previous section. This section, in turn, focuses on discussing a few more detailed models with particular attention to the practical implications and possible common features with the bidding situation that Fennovoima has at hand. The first subsection discusses two models with different views on agent's ignorance, concluding that the principal might be better off contracting with the more ignorant agent, and always better off when there is competition between multiple bidders. Whereas the first subsection points out the importance of competition, the second subsection focuses on assessing alternative ways of organizing the bidding process and managing competition. The final subsection briefly discusses the benefits of repeated contracting, which is a theoretically rewarding topic, but unfortunately of little practicality in the context of nuclear reactor procurement.

3.2.1 Asymmetric information in bidding phase

Asymmetric information can take multiple forms in the bidding phase. Three models presented here discuss its effects on contracting. The first model by Lewis and Sappington (1993) states that the agent's enhanced information might lead to a higher surplus. Along the same lines, the findings of the second model (Crémer & Khalil, 1992) encourage contracting with an ignorant agent so that the principal will be able to capitalize on his superior information. The principal can interfere with the agent's informing efforts by encouraging competition between as many agents as possible. A third model by Lewis (1986) suggests contract bonds as a means of mitigating adverse selection.

According to McAfee and McMillan (1986), a standard lowest price bidding process involves several informational asymmetries. Two of these three informational asymmetries are related to adverse selection. First, the principal cannot observe the bidders' expected production costs and is therefore unaware of which one of the bidders is an efficient supplier. Second, the bidders are unaware of each other's bids so that the bidders must place their bids in ignorance of the expected costs of their rivals. In the third case (explored also by e.g. Lewis, 1986), the principal's inability to observe the agent's cost-reduction effort opens a venue for moral hazard, which is explored in section 4.1 . Lewis (1986), in turn, argues that the principal's inability to acquire symmetric information can lead to a situation where the agent initially exerts high effort, resulting in a good outcome that is observable to the principal, until both sides are fully committed to the project. This reputation-building scheme, yet induced by asymmetric information and related to adverse selection, is further explored in the context of contracting in subsection 4.2.2 .

As a contrast to the general assumption about the agent's superior information, Lewis and Sappington (1993) present an adverse selection model where the agent is as ignorant as the principal is. However, the agent is the only one to know whether he merely shares the principal's imperfect beliefs or has superior information. For instance, the reactor supplier and the client can initially share the same imperfect information about the technology. However, the supplier's engineering and design efforts can sometimes provide the company with superior knowledge about the production costs. If these research efforts do not bear fruit, the supplier remains as ignorant as the client is. This is called *bilateral ignorance.*

As opposed to the standard agency problem where principal is the ignorant party, Lewis and Sappington (1993) identify four qualitative changes that arise, when agent’s ignorance is introduced into the standard model. First, with an optimal incentive contract, the informed agent finds a region for pooling, where his costs are below the costs of an ignorant agent, and where the induced performance is insensitive to the superior information. Second, if the costs of an informed agent are above the expected costs of an ignorant agent, the informed agent produces small levels (or alternatively: low quality) of output. Third, the operations of the informed agent are more likely to be terminated by the principal when agent’s ignorance is a possibility. Fourth, the optimal incentive contract induces discontinuous levels of output, since small increases in costs exceeding expected costs of the ignorant agent induce large reductions in the performance of the informed agent. The abovementioned changes occur especially due to the principal’s effort to secure desirable behavior from the ignorant agent. As a consequence, the agent's profits may be substantially lower, when the possibility of ignorance arises. Therefore, the agent may be willing to incur personal costs ex ante to rule out the possibility of ignorance, thus informing himself, and assuring the principal of his ability and therefore securing better performance. This has potentially interesting implications in the context of the thesis: the supplier is able to increase the total surplus from the contract by investing in informing himself, and in signaling that they hold this information.

Crémer and Khalil (1992) argue that in reality the asymmetry exists because principal and agent acquire different pieces of information. Thus the true asymmetry would lie in the ability to acquire information: the signed contract is influenced by the fact that the agent could acquire information ex ante at a very low cost. In the model, firm P wants to buy a component from firm A and offers a contract. A does not know precisely its disutility from producing the component but could determine it at some cost. This timeline presented in Crémer and Khalil (1992) shows that it is always preferable for P to offer a contract attractive enough for A to omit ex-ante cost analysis. After the contract is signed, A will acquire information about the disutility of production at no cost. This implies that acquiring information before signing the contract is socially wasteful, since this information will be discovered ex post in any case.

Following the logic of Crémer and Khalil (1992), it seems obvious that the principal will prefer choosing an agent with a high cost of acquiring information, as the principal is thus likely to gain informational advantage. This increases principal's expected surplus. The model also suggests that the gain to the principal due to a small increase in agent's cost of acquiring ex-ante information is entirely a transfer from the agent – the social welfare remains intact. Moreover, this implies that the principal would be willing to exert a costly effort in order to increase the agent's cost of acquiring information. This feature has interesting implications in the context of nuclear reactor procurement, in particular, as Fennovoima is negotiating in parallel with two potential suppliers. The practical implications of the model are further highlighted by the fact that one of the supplier candidates has experience from a similar nuclear reactor project in Finland, whereas the other lacks experience of building the particular reactor type outside its home country. Since information acquisition potentially yields informational rents to the agent, the principal is likely to prefer the agent with a higher cost of acquiring information. According to Crémer and Khalil (1992, p. 577), the increase in the expected welfare of the principal might be significant when contracting with an uninformed agent.

In addition to the importance of information acquisition, Crémer and Khalil also demonstrate that it pays off to uphold competition between several agents (1992, pp. 575–576). In a comparative analysis of a single-agent game and a multiple-agent game, they show that increasing the number of agents who compete in a bidding process diminishes the benefit that any single agent can reap from ex-ante observation of costs. The principal collects rents from increasing competition. The principal can offer contract to several agents who fulfill the requirements and choose among those who accept the contract. This reduces the agents' value from ex-ante investigation and correspondingly increases principal's surplus.

The main finding in Crémer's and Khalil's model is that if the agent’s cost of acquiring ex-ante information is small enough, the principal's expected surplus is increasing in the number of agents and the marginal value of this increase is proportional to the number of agents. However, this model does not account for the additional cost of including several bidders in a complex bidding process. In the nuclear power industry, and in particular in the Fennovoima case, the bidding process and the parallel negotiations with the bidders are lengthy and require project-specific investments in e.g. design work from both parties. Therefore the principal's surplus may no longer be increasing in the number of agents involved. This analogy holds with the findings of Crémer and Khalil (1992), since in the nuclear power industry the cost of acquiring ex-ante information is likely to be large.

Whereas Lewis and Sappington (1993) suggest that the principal can increase his surplus and mitigate adverse selection by choosing to trade with an agent who is willing to invest in informing himself, and Crémer and Khalil highlight the importance of maintaining competition, Lewis (1986) presents contract bonds as a means of mitigating adverse selection. If the agent is required to place a large enough performance bond, which would be refunded upon completion of the project, fewer contractors wish to be hired on hard jobs, as the project might get cancelled before they can recover their fixed costs. Therefore an agent who is likely to incur high enough costs for the project to get cancelled is likely to withstand from the bidding for a project.

3.2.2 Managing competition

The previous subsection concluded that adverse selection is best mitigated through competition; this subsection, in turn, discusses alternative ways of organizing and managing the bidding process. Asker and Cantillon (2010) present a model that compares alternative ways of organizing competition between agents. The model involves private information concerning the agents' marginal cost for providing quality and their fixed cost of production, which create participation constraints and incentive compatibility constraints for the agent. The buyer's objective is to maximize his expected utility subject to these two constraints. This maximization rule defines the optimal bidding mechanism.

As described by Asker and Cantillon (2010), the first way of managing competition, a scoring auction, is presented as a means to promote both low price and high quality. A scoring auction is organized so that the principal announces the scoring rule, i.e. the way the offers will be ranked. This might take the form of a bid invitation specification, accompanied by a set of scoring criteria. The suppliers submit bids that cover every dimension of the bid invitation, and the contract is awarded to the bidder who scores the highest according to the scoring rule. In their analysis, the principal is able to reap a significant proportion of the strategic surplus through a scoring auction. A scoring auction could be further enhanced by involving a timing rule as presented by Bajari and Lewis (2009). Intuitively, the timing rule must be enforced by amending sanctions for a delayed completion of the project.

Even though scoring auction maximizes competition between two agents, it leaves little room for flexibility in terms of design. However, a scoring auction is only secondary to the optimal bidding mechanism, since the efficient mechanism could be implemented by a scoring auction, but a scoring auction falls short in terms of flexibility. Despite the theoretical superiority of the optimal bidding mechanism, it is hard to implement for two reasons. First, implementation requires precise knowledge about the environment and the realization of the future states. Second, it is impossible to design a simple, easily explained mechanism to implement the optimal bidding arrangements. This limits the principal's ability to explain the mechanism to the agent at a reasonably low cost and to administer the procurement process at a low cost. Therefore it is suggested that the simple second-best solution, i.e. scoring auction, is likely to lead to a better outcome. (Asker & Cantillon, 2010)

The second method listed by Asker and Cantillon (2010), bargaining, is defined such that principal negotiates with the potential suppliers one at a time. The principal approaches the agents sequentially and is allowed to haggle with each of them as much as he wants. However, the principal cannot return to an agent when negotiation breaks down, unless a recall option is introduced into the model. This way the agents do not compete directly against each other. Compared to a scoring auction, bargaining allows for more flexibility in terms of product design as the agent can present improvements during the negotiations. In particular, with a bargaining game the competition is lower since there is room for more variation in the competing products.

The standard bargaining model by Asker and Cantillon is enhanced by allowing the principal to make an offer to one of the agents after negotiations have failed with all candidates. This recall option improves the expected utility of the principal, and also transforms the bidding game more resembling to an auction. In fact, if the recall option can be repeated, the form of the game becomes similar to an auction. Therefore it is straightforward to note that recall option increases the rents the principal extracts from the trade. However, a single recall option actually reduces the principal's commitment power, since the agents expect the principal to come back to either one of them with a more profitable offer. Therefore a higher offer is required for the trade to be accepted on the first round.

Empirically, scoring auctions seem to dominate price-only auctions, whereas bargaining is a more common form of a less-structured bidding design, which is often implemented when quality matters (Asker & Cantillon, 2010). Auctions seem to lead to an efficient outcome only when the fixed costs are highly correlated with the marginal costs, or when the design is unlikely to require changes. Asker and Cantillon refer to defense procurement as an example: the product involves many dimensions with a varying degree of contractibility, and renegotiation of the contract is expected at many stages. It is straightforward to assume that procurement contracting for a nuclear power reactor involves multiple dimensions. The minimum requirements that have to be met are set by the regulating authority. But in a scoring auction the principal should be able to define the tradeoff between the price tag and additional security and usability features, timely execution included. Moreover, these features are often intertwined, so that the security features affect the operational factor of the plant through the downtime required. As the contract involves long-term commitment, it is necessary that the communications and safety culture between the agent and the principal level with each other. However, it is nearly impossible to create metrics for these issues. All this implies that even the most comprehensive scoring rule is likely to fall short of the real-life requirements.

In contrast to the theoretical evidence of Asker and Cantillon (2010), bargaining seems to be surprisingly common in procurement contracting. This is assumed to be partially caused by project managers' will to control the bidding process. The non-contractibility of quality also seems to be an issue: through a bargaining game the principal is more likely to get to know with the potential suppliers, thus giving the supplier a chance to establish reputation and therefore allowing for trust-based contracting. However, such familiarity-induced slackness in contracting is unlikely to take place in a multi-billion project with global competition. The support for either form of organizing competition remains twofold. The buyer faces a tradeoff between cost and quality: auction enhances cost-efficiency, whereas quality is more easily contracted upon by repeated bargaining. Involving a comprehensive list of quality features in a scoring auction may not be possible in the industry context.

John and Saunders (1983) complement the discussion on managing competition by presenting a model where the number of potential bidders is severely limited. This corresponds with the procurement project Fennovoima has at hand, and is therefore worth noting. John and Saunders state that in initial procurement for new plant types and equipment the bidder's premium can be very large due to the lack of competition. They suggest that a bargained contract can actually outperform an auction in this setting. A bargaining process could enable bonding between the companies, joint design development and therefore create better incentives for cost reductions.

3.3 General remarks about the bidding phase

In the bidding phase, the main risk stems from the supplier's private information about his type – i.e. capability to deliver – and hence, adverse selection. The theory offers two main ways to mitigate this: screening, which is conducted by the uninformed buyer, and signaling, which is conducted by the informed supplier.

Signaling provides few practical tools for the procurement project at hand; it is better suited for e.g. employment situations where the applicant signals his intelligence by having acquired higher education. Signaling is based on the agent's initiative, and since the focus is on the buyer's scope in thus study, signaling is omitted in the analysis.

Screening is of more practical importance in the bidding process: the buyer takes the responsibility for selecting a suitable supplier. In theory, screening takes place through a menu of contracts, from which the suppliers select the one that is suitable considering their capability and outside options. The outcome cannot be contractually dictated, and hence the supplier's type affects the probability of a successful project. In practice, screening takes place through the bidding arrangements. The literature recognizes competition as an important tool of screening. Two extremities for managing competition, auction and bargaining, are compared against each other. Bargaining seems to dominate over an auction: bargaining, when enforced with a recall option, allows for relational bonding and cooperation in design development. Even though an auction dominates in terms of cost-efficiency, adding recall options to the basic bargaining scheme increases its benefits. Most importantly, bargaining allows for iterative design development, whereas with an auction the design requirements must be complete at the time of bidding.

As a final remark, it can be noted that if the bidders are likely to be equally capable, the buyer might benefit from contracting with the one who is most ignorant about the environmental characteristics that might occur during the contract so as to gain informational advantage over the supplier. The next chapter takes one step forward, contemplating the optimal contract to be made with the preferred bidder.

4 Contracting

In the contracting phase, the buyer’s main concern is to maximize his utility. The main risk the buyer faces during the contracting process is the risk of *moral hazard.* Moral hazard occurs when the supplier has private information about his action and can use this information to acquire superior rents without exerting an optimal effort. In practice, in order to maximize the buyer’s utility, the contract must be designed so as to limit the supplier’s capability to capitalize on his private information, either by drafting a complete contract or ensuring that the same outcome is optimal for both parties. The structure of an optimal contract is central to the analysis of this chapter. Once the best seller has been chosen in the bidding phase, the seller must be incentivized into exerting an optimal effort, i.e. perform at the level where the marginal cost of an increase in the effort level equals its marginal benefit.

This chapter provides a theoretical overview on the structure of an optimal contract in a risky long-term project such as the procurement of a nuclear power plant. The main questions to be answered are related to informational asymmetry and, more precisely, to the risk of moral hazard. Informational asymmetry enables hidden action, which can negatively affect the outcome of a contract in the form of moral hazard. The first section presents an overview of a simplified theoretical model on these issues. The second section focuses on risk-sharing literature, providing insight into the optimal risk sharing structure for the procurement of a nuclear power plant, and building on the theory from the first section. The question to be answered in this section is: What is the optimal contract structure? The third section, in turn, focuses on quality literature, discussing the interplay between quality and cost. Finally, the chapter is concluded with general remarks about the contracting phase.

4.1 Moral hazard: A simple model

Well, then, says I, what's the use you learning to do right when it's troublesome to do right and ain't no trouble to do wrong, and the wages is just the same? I was stuck. I couldn't answer that. So I reckoned I wouldn't bother no more about it, but afterwards always do whichever come handiest at the time.

*–**Mark Twain,** Adventures of Huckleberry Finn, quoted by Holmström and Milgrom (1987)*

Moral hazard occurs when the principal can only observe the outcome and not the action chosen by the agent. The *hidden action* of the agent enables him to make decisions that are not pareto optimal, allowing him to receive financial coverage for an effort which is less than optimal. Similarly to *adverse selection* (see section 3.1), which is induced by hidden information, moral hazard issues also stem from asymmetric information. In theory, moral hazard is best mitigated through monitoring, so that the principal receives a potentially noisy signal about the agent's effort affecting the compensation scheme, or so that the compensation is based on the outcome rather than the effort level. The model presented here formalizes the moral hazard problem, whereas the following subsections present models of monitoring and effort-based compensation.

Bolton and Dewatripont (2004, pp. 22–23) present a simple contracting problem with moral hazard. Their illustration of an employee–employer relationship is modified into a supplier–buyer relationship for the purposes of this thesis. The modification entails interpreting the amount of time worked, $1 - l$, as the effort exerted by the supplier. Formally, to introduce hidden action into a contracting problem with uncertainty, it is supposed that the effort $1 - l$ is the supplier's private information, i.e. hidden action. Moreover, the effort level $1 - l$ is chosen before the state of nature, θ_j, is realized, and this effort affects the probability of the state of nature. When the supplier chooses action $1 - l$, output for the buyer is simply θ_H with a probability function $p_H(1 - l)$, which is increasing in $1 - l$, and θ_L with a probability function $p_L(1 - l) = 1 - p_H(1 - l)$. The common interpretation is that more effort $(1 - l)$ produces higher expected output at cost e to the supplier. However, it is not guaranteed to induce higher output, since the bad state of world may still occur.

Since the effort $(1 - l)$ is not observable, the agent may be compensated only on the basis of realized output θ_j. The buyer is thus restricted to offering a compensation contract $t(\theta_j)$ to the supplier, i.e. a transfer t contingent on the state of world. The buyer must now account for the fact that $(1-l)$ will be chosen by the supplier to maximize his own expected payoff under the offered compensation scheme. This means that the buyer can only make a best guess that the chosen effort level is the outcome of the supplier's optimization problem:

$$(1-l) \in arg \max_{\hat{l}}\{p_L(1-l)u[t(\theta_L)+l]+p_H(1-l)u[t(\theta_H)+l]\}$$

Now, when the buyer chooses the optimal compensation contract $\{t(\theta_j)\}$ to maximize his expected utility, he must ensure that it is the supplier's best interest to supply the right level of effort. The employer thus solves the optimization problem:

$$\max_{t(\theta_j)}\{p_L[1-l]U[\theta_L-t(\theta_L)]+p_H[1-l]U[\theta_H-t(\theta_H)]$$

subject to the individual rationality constraint

$$p_L(1-l)u[t(\theta_L)+l]+p_H(1-l)u[t(\theta_H)+l] \geq \bar{u}=u(1)$$

and the incentive compatibility constraint

$$(1-l) \in arg \max_{\hat{l}}\{p_L(1-l)u[t(\theta_L)+l]+p_H(1-l)u[t(\theta_H)+l]\}$$

Similar to adverse selection problems with hidden information (see section 3.1 when the supplier's action is unobservable to the buyer, he must take into consideration not only the supplier's individual rationality constraint but also his incentive compatibility constraint.

Bolton and Dewatripont (2004, p. 23) point out that determining the solution to the optimization problem presented above is rather complicated. However, they emphasize the underlying idea of a trade-off between insurance risk, and incentives for exerting effort. In general, this means that the supplier should be rewarded for the outcomes that are most likely to arise when he exerts the required effort level, and punishing him for the outcomes that are likely to occur when he shirks. The application of this principle, however, yields complex compensation contracts, except for the case, where agent is risk neutral. In case of risk neutrality it is efficient to have the agent to take on all risk in order to maximize his incentives for effort provision.

The following two subsections expand on the model presented above. The first subsection presents a simple model on mitigating moral hazard through monitoring the outcome with a costly monitor. The second subsection presents a model where one of the contracting parties is risk-averse, and the outcome of the contract is dichotomous, i.e. it is either a success or a failure.

4.1.1 Mitigating moral hazard through monitoring

Whereas the standard agency problem, as presented above, assumes that actions are unobservable but the output is observable, for some agency problems even the level of output might be difficult to observe (Bolton & Dewatripont, 2004, p. 134). In this case, the contracting parties might choose to base the compensation on the observed effort level. Similarly, in long-term projects where the output cannot be observed until years later, the contracting parties might choose to compensate the agent for his effort already during the project so as to cover the agent's expenses. The monitoring model presented next assumes that contracting on the output q is too costly, but the principal can observe the agent's actions at a cost through monitoring. The effort can be verified at a monitoring expense M. The full monitoring then solves

$$\max_{a,w} p(a) - w - M$$

subject to

$$w - a \geq 0$$

and

$$w \geq 0$$

which yields $w^* = a^*$ and p'$(a^*) = 1$; the agent's compensation equals his effort in equilibrium. Suppose next that the principal can verify the agent's action with probability 0,5 without spending M. If the agent is caught shirking, it is optimal to give him the lowest possible compensation. In this case, with a limited wealth constraint[1], the variable w is set equal to 0 for simplicity. If the principal decides not to spend M, his problem is

$$\max_{a,w} p(a) - w$$

subject to the incentive constraint

$$w - a \geq 0{,}5w.$$

The left hand side of the incentive constraint is the agent's payoff if he chooses the prescribed action a. The right hand side is the agent's maximum payoff is he shirks. In the borderline case it is optimal for the agent not to exert any effort and gamble on the possibility of getting caught. Now

[1] $w \geq 0$

the principal has to give the agent a compensation that is twice his effort level; i.e. the principal gives the agent compensation he would lose when caught shirking. Having to give up rents once again lowers the principal's desire to induce effort, so that the optimal effort is lower than a^*. Therefore the choice of whether or not to employ a costly monitor depends of the size of M.

The model presented above assesses a static contracting situation. However, the assumption of non-observable outcome is surprisingly well-suited for the framework of this thesis. Once dynamics are introduced into the model, it becomes evident that output cannot be observed until the project is fully finished. Therefore monitoring becomes a viable option as a means of mitigating moral hazard, and its costs can be assessed against the framework presented above. In the procurement project at hand, the minimum requirement level is set by the Finnish Radiation Authority (STUK), who is also responsible for the monitoring. However, to ensure swift execution of the project and to avoid unnecessary delay, the principal benefits from employing a proactive monitor that follows the fulfillment of the quality standards.

4.1.2 Dichotomous outcomes with risk-averse agent

Bolton and Dewatripont (2004) improve the standard moral hazard model so that in addition to the agent choosing his effort intensity, the outcome is dichotomous – a success or a failure. The principal only cares about the outcome. However, exerting effort is costly to the agent, so the principal must compensate the agent for his effort. As the effort is unobservable to the principal, the principal cannot do better than to relate the compensation scheme to the agent's performance, i.e. the outcome of the project. Typically, this entails a loss, since performance is only a noisy signal of effort. The dichotomous outcomes encompassed by the model resonate with the reality: a nuclear power plant is either licensable or not – linearity of quality in this sense would therefore be of no additional value. The model is then expanded to cover risk aversion of at least one of the contracting parties. This assumption is similarly in line with reality – the scope of the project is long enough to entail bankruptcy, and neither of the contracting parties is willing to entertain this option.

Bolton and Dewatripont (2004, pp.129–132) present a model where the output q can take two values: $q \in \{0,1\}$. With $q = 1$, the agent's performance is a success; with $q = 0$, the performance is a failure. The probability of success is given by $\Pr(q = 1|a) = p(a)$, which is strictly increasing and concave in effort intensity a. Assume that $p(0) = 0, p(\infty) = 1$ and $p'(0) > 1$. The principal's utility function is given by

$$V(q - w)$$

where w is the agent's compensation, $V'(\cdot) > 0$ and $V''(\cdot) \leq 0$. The agent's utility function is

$$u(w) - \varphi(a)$$

where φ is the agent's cost of exerting effort, $u'(\cdot) > 0, u''(\cdot) > 0,$ and $\varphi''(\cdot) \geq 0$. For simplicity it can be assumed that $\varphi(a) = a$. When the agent' action is observable and verifiable (to the principal or to a third party) the compensation scheme can be made contingent on the agent's action choice. The optimal compensation contract is then the solution to the following maximization problem from the principal's viewpoint:

$$\max_{a,w_i} p(a)V(1 - w_1) + [1 - p(a)]V(-w_0)$$

subject to

$$p(a)u(w_1) + [1 - p(a)]u(w_0) - a \geq \bar{u}$$

where $\bar{u}$ is the agent's outside option, which can be generalized to 1 for simplicity. The Lagrange multiplier for the agent's individual rationality constraint is denoted by λ, the first-order conditions with respect to w_1 and $w_0$yield the following optimal coinsurance between the principal and the agent:

$$\frac{V'(1 - w_1)}{u'(w_1)} = \lambda = \frac{V'(-w_0)}{u'(w_0)}$$

The first-order condition with respect to effort is

$$p'(a)[V(1 - w_1) - V(-w_0)] + \lambda p'(a)[u(w_1) - u(w_0)] - \lambda = 0$$

which, together with the optimal insurance rule, determines the optimal action a.

Next, Bolton and Dewatripont (2004, pp.131–132) assume a risk-neutral agent, $[u(x) = x]$. The optimal action entails full insurance of the principal, with

$$w_1^* - w_0^* = 1 \text{ and } p'(a^*) = 1.$$

The marginal product of effort is thus equal with its marginal cost to the principal. When the agent’s choice of action is unobservable, the compensation of the agent cannot be made contingent on it. Therefore the output-contingent compensation must induce the agent to choose an action that maximizes his payoff:

$$\max_{a} p(a)u(w_1) + [1 - p(a)]u(w_0).$$

The second-best contract is the solution of the following

$$\max_{a,\, w_1} p(a)V(1 - w_1) + [1 - p(a)]V(-w_0)$$

subject to

$$p(a)u(w_1) + [1 - p(a)]u(w_0) - a \geq 0$$

and

$$a \in arg \max_{\hat{a},\, w_1} p(\hat{a})u(w_1) + [1 - p(\hat{a})]u(w_0) - \hat{a}.$$

The first-order condition of the agent's optimization problem is then given by

$$p'(a)[u(w_1) - u(w_0)] = 1.$$

A unique solution exists to this equation for any compensation scheme for the two-performance contract $(w_0; w_1)$ presented above. The agent's incentive constraint can be replaced by the first-order condition. This substitution simplifies the analysis of the following case, where at least one of the contracting parties is risk averse.

If the agent is assumed to be the risk-averse party, achieving the first-best solution requires a constant wage, independent of the agent's performance and any risk associated. This, in turn, completely eliminates effort incentives, in case effort is not observable. If risk aversion is a bilateral feature, optimal risk sharing does not provide for full insurance of the agent, but still prevents the contracting parties from achieving first-best outcomes under moral hazard. In this case, the principal solves

$$\max_{a,\, w_i} p(a)V(1 - w_1) + [1 - p(a)]V(-w_0)$$

subject to

$$p(a)u(w_1) + [1 - p(a)]u(w_0) - a \geq 0$$

and

$$p'(a)[u(w_1) - u(w_0)] = 1.$$

Let λ and μ denote the respective Lagrange multipliers of the individual rationality constraint and the incentive compatibility constraint. Then derivation of the maximization problem with respect to $w_0$and w_1 yields

$$\frac{V'(1-w_1)}{u'(w_1)} = \lambda + \mu \frac{p'(a)}{p(a)}$$

and

$$\frac{V'(1-w_0)}{u'(w_0)} = \lambda - \mu \frac{p'(a)}{1-p(a)}$$

When $\mu = 0$, the optimal coinsurance rule, $\frac{V\prime(1-w_1)}{u\prime(w_1)} = \lambda$, is obtained. However, at the optimum $\mu > 0$, so that the optimal insurance is distorted: the agent gets a larger (smaller) share of the surplus in case of high (low) performance. In order to induce effort, the agent is thus rewarded (punished) for outcomes whose frequency rises (falls) with effort. In the two-outcome setting, the result is simple: $q = 1$ is rewarded, and $q = 0$ is punished.

This rather complex modeling confirms the intuition about compensating the agent according to the outcome: a success is rewarded and a failure is punished. However, this approach fails to account for the exogenous risks that are likely to be faced during a complex long-term project. If, for instance, policy changes induce modifications in the industry regulation, the initial design might turn into a failure, in the sense of being no longer licensable. Therefore, in a long-term project both monitoring and results-based compensation need to be accompanied by a definition of the risk-sharing structure, which is discussed in the next section.

4.2 Optimal risk-sharing

This section discusses optimal risk sharing structure, considering the limitations that the nuclear market specific features impose. More specifically, the section discusses how the risks related to a long-term project, such as the procurement of a nuclear power plant, are optimally shared between the principal and the agent, once the preferred bidder has been selected. Defining whether the principal or the agent bears the risks related to long-term contracting is necessary in order to provide incentives for both low production costs and sufficient production quality. The risk-sharing scale reaches from a fixed-price contract to a cost-plus contract. A fixed-price contract offers the seller strong incentives to cost reduction, but is best suited for products that are simple in design that do not require modification or renegotiation. With a fixed-price contract the seller bears the exogenous risk, which is likely to show as an increase in the price of the original bids. In contrast, a cost-plus contract allows for greater flexibility in terms of design but offers no incentives for cost reduction efforts. With a cost-plus contract, however, the buyer is responsible for the exogenous risk, yielding lower original bids.

The topic is divided into two subsections as follows. The first subsection discusses the optimal risk-sharing rate in a procurement contract, formalizes its presentation and defines the parameters affecting the optimal choice. The second subsection gives an overview of two different models concerning the effects of reputation on the optimal contract. The first model concerns the principal's reputation, and the second concerns that of the agent's. The section is finalized with a brief example from the Japanese nuclear power plant industry, where reputation is highly appreciated by convention.

4.2.1 Linear form of contract

Linear formulation of contract is the simplest way of defining the risk sharing structure. The risk related to a procurement contract stems from the delays involved: the contracting parties make relationship-specific investments long before the outcome is realized. The investments involve a risk, which is typically increasing in contract duration. In particular, the supplier bears a major part of the risk. In order to induce the supplier to accept a contract, he needs to be either compensated for his risk, or the principal has to contractually relieve the agent from this related risk. The first option, compensation, is executed through a fixed-price contract, where the price has to be high enough to compensate for the risk. The second option, transferring the risk upon the principal, is executed through a cost-plus contract.

Asymmetric information complicates the choice of the contract form. If adverse selection is considered a prevalent risk, and the agents have hidden information about their types, a fixed-price contract is not be the best alternative: the good type of agent might be excluded from the bidding process due to his higher bid. In contrast, if moral hazard is a prevalent risk, and the agent can exert hidden action, i.e. the principal cannot observe his effort level, a cost-plus contract is not desirable: principal has no incentive for cost reductions. The following models discuss the choice of the contract form and provide further insight into the characteristics affecting the choice.

In a simple model of procurement contracting, the choice of contractual risk sharing structure takes place on a linear scale (e.g. McAfee & McMillan, 1986; Bajari & Tadelis, 2001). McAfee and

McMillan (1986) present the linear model of the principal's contract payment as follows. For clarity, the notation follows that of Bajari and Tadelis.

$$P(c) = \alpha b + \beta c + \gamma$$

where c is the ex-post cost of the project to the principal, β is the cost sharing parameter, b is the bid of the successful agent and α defines the proportion of the bid to be reimbursed to the agent. Therefore γ is a constant parameter. In case of a cost-plus contract, where the agent is reimbursed for all his costs and the principal bears all related risk, $\beta = 1$, $\propto = 0$ and γ represents the agent's profit. In case of a fixed-price contract, where the agent's compensation is defined ex ante and the principal bears all related risk, $\beta = 0$ and $\propto = 1$. In addition, there exists an intermediate form of the two, so that $0 < \beta < 1$ and $\propto = 1 - \beta$. Despite the three parameters (β, $\propto$, and γ), the only parameter of consequence is the cost-sharing rate β. In case of $0 < \beta < 1$, the agent's realized costs are not entirely covered by the principal. Therefore under an incentive contract, i.e. the agent bears at least a part of the costs, higher expected production costs force the agent to place a higher bid. It can thus be assumed, that in the case of an incentive contract low bids reflect high cost-efficiency. In contrast, in case of a cost-plus contract, $\beta = 1$, a high-cost agent has no incentive to bid any higher than a low-cost agent. Therefore a cost-plus contract can never be optimal if there are multiple bidders: with n bidders, the principal will fail to select the most efficient agent with probability $(n-1)/n$. It is thus argued that the cost-plus contract is of no relevance to the procurement of a nuclear power plant (McAfee & McMillan, 1986).

The model presented above (McAfee & McMillan, 1986) can be further simplified. Parameters γ and $\propto$ are inconsequential. Since any value of γ results in similar bids across the agents and any positivie value of $\propto$ results in similar payments, the notation can be simplified without loss of generality so that $\gamma = 0$ and $\propto = 1 - \beta$. This leads to a simplified form, which is also presented by Cox et al. (1996). With this modification, the price for the trade with agent i as presented by McAfee and McMillan (1986) can be reformulated as follows:

$$P_i = b + \beta(c - b)$$

P_i is the price of the contract to the principal, b is the bid price of the contract, c is the base cost observable to all and β is the cost-sharing rate, i.e. the proportion of cost-overruns (or savings) that will be reimbursed by the principal (Cox & al., 1996, p.149). If $\beta = 1$, the payment consists only of the costs incurred during the project. If $\beta = 0$, they payment consists only of the winning agent's bid. If $0 < \beta < 1$, the payment is dependent on both the bid and the costs. If in this case the costs exceed the bid ($c > b$), the principal's payment is greater than the bidding price. If the bid exceeds the costs ($b > c$), the payment is actually lower than the original bid. Hence the model does not provide any cost-reduction incentive for a cost-sharing contract, and therefore the simplified model by Bajari and Tadelis (2001) seems more realistic. They present the simplest formulation of the linear contract as follows:

$$P(c) = b + \beta c$$

where $\beta \in \{0,1\}$. Similarly to the models presented above (Cox et al., 1996; McAfee & McMillan, 1986) $\beta = 0$ is a fixed-price incentive contract with the agent's bid $b$as the price and $\beta = 1$ is a cost-plus contract that reimburses the contractor for his costs and provides him with an additional compensation of b.

In McAfee and McMillan (1986, p. 328), the bidder's profit π equals the difference between the contract payment p and the sum of the observable costs c and the non-observable effort costs $h(\varepsilon_i)$ of agent *i*. Now the contract profit for the agent *i* is given by:

$$\pi_i = p_i - c_i - h(\varepsilon_i) = (1 - \beta)(b - c_i) - h(\varepsilon_i)$$

Each bidding agent knows their base cost *c*, the contract form β and the probability distributions for the others' base costs and the probability distributions for the others' uncertain costs. After all bids are submitted and the lowest bid is awarded the contract, the lowest bidder decides on the discretionary cost reduction ε_i and learns about the realization of the random component w_i, which is also part of the observable cost of fulfilling the contract c_i. The observable cost of fulfilling the contract, c_i, consists of three components; c_i^* represents the certain base cost.

$$c_i = c_i^* + w_i + \varepsilon_i$$

Cox et al. (1996) follow McAfee and McMillan (1986) in deriving the low bidder's choice for discretionary cost reduction ε_i. By maximizing the contract profit π_i with respect to ε_i and assuming that the non-observable effort cost $h'(0) < 1 - \beta$, one obtains the first order condition for the agent's profit maximizing level of discretionary cost reduction.

$$h'(\varepsilon_i^0) = 1 - \beta$$

Since $h''(\cdot) > 0$, there exists an inverse, $g(\cdot)$, to the function, $h'(\cdot)$, that is strictly increasing. Therefore, the model (Cox et al., 1996, p.150) predicts

$$\varepsilon_i^0 = g(1-\beta) \qquad \text{and} \qquad \frac{d\varepsilon_i^0}{d\beta} = -g'(1-\beta) < 0.$$

From this it can be seen that the discretionary cost reduction ε_i equals $g(1-\beta)$ and it decreases as the cost-sharing rate β increases. The principal's choice of cost-sharing rate β determines the agent's choice of cost-reduction effort. Thus the model predicts inefficiency, i.e. moral hazard, for cost-sharing contracts. From a theoretical point of view, cost-sharing contracts are thus the least efficient in terms of cost-reduction. However, cost-sharing contracts are likely to be more tempting to the bidders, since they ensure that the principal bears a significant proportion of the risk related to unforeseen future contingencies. Therefore a cost-sharing contract might result in lower procurement expense than a cost-plus contract, if the bidding process yields bids that are low enough to offset the adverse selection and moral hazard costs of such contracts (Cox et al., 1996, p. 171). In fact, McAfee and McMillan (1986) go as far as arguing that cost-sharing contract is the procurement cost-minimizing contract form. In contrast with this, Cox et al. (1996) argue that lowering procurement expenses by attracting lower bids with a cost-sharing contract can potentially lead to documentable cost overruns and even a bankruptcy of the principal, in case the costs from moral hazard are high enough.

If the design of the product is successful, a fixed-price contract incentivizes the agent to cost-reductions through ex-ante competition between potential contractors (e.g. Bajari & Tadelis, 2001). By allowing the agent to reap all surplus incurred by cost savings, a fixed-price contract strongly incentivizes the agent to efficiency. A fixed-price contract does not require the measurement of construction costs, which renders it a common contract form in procurement contracting.

If the design is likely to fail or require modifications, a cost-plus contract should be preferred. Firstly, with a fixed-price contract some of the surplus will be eroded because of ex-post renegotiation costs. These costs occur since the original contract requires costly modification due to the unanticipated state of the world. Moreover, the ex-ante competition is already initially limited due to the particular market features of the nuclear power plant industry (Bajari & Tadelis, 2001). Thus a fixed-price contract is not necessarily as strong an incentive for ex-ante cost reduction within the context of this thesis: the ex-ante competition is less fierce than in other industries. Therefore, the principal’s utility from a cost-plus contract is increasing in the complexity of the product. John and Saunders (1983, p. 397) support this view in their model about optimal incentives for cost reduction in power plant projects. They conclude that tailor made projects that involve high cost variance minimize their cost of procurement by using a cost-plus contract. However, if the contract is repeated over time, the cost variance should decrease; a transition towards incentive contracts might be observed. Moreover, John and Saunders present a case with potential implications to the Fennovoima project. As a part of their empirical analysis, John and Saunders (1983, p.402) assert that an agent is likely to be reluctant to take on contracts of fixed type unless the cost variance is diminished through experience and repetition, or unless the principal is able to break the procurement into smaller parts, giving each individual procurement greater project and cost definition.

Exogenous risk affects the choice of the contract structure. Both parties share uncertainty about changes in design requirements and regulatory environment that occur after the production begins. Cost-plus contracts account for a high probability of future adaptation, i.e. the degree of contractual completeness is low (Bajari and Tadelis, 2001). As opposed to fixed-price contracts, a cost-plus contract does not erode the principal's ex-post surplus through increased negotiation costs. However, it discourages the agent from ex-ante cost efficiency. Bajari and Tadelis concentrate on problems of adaptation when the initial design is endogenously incomplete, and could thus be enhanced during the contract period. They suggest that high cost-reduction incentives such as a fixed-price contract do succeed in reducing costs, but at the same time dissipate the potential of increased ex-post surplus, due to the increased renegotiation costs that occur under asymmetric information. Fixed-price contracts thus lead to inflexible contracts, which are costly to renegotiate, and are thus ill-suited for complex contracting environments.

McAfee and McMillan (1986) argue that the tradeoff between risk sharing, incentives and information revelation cause contracts that lie between fixed-price ($\beta = 0$) and cost-plus ($\beta = 1$) be generally desirable. In their study, cost-plus contracts are never optimal since they offer no incentive for the suppliers to bid aggressively against potential competitors. This is also relevant to the nuclear power industry. Since contracts are seldom repeated, the threat of losing a contract because of bad performance in the past is weak. Therefore, a cost-plus contract is unlikely to induce cost-aware behavior as the principal bears all cost-related risk.

As seen above, the maturity of product design and regulatory environment, i.e. both endogenous and exogenous risk, affect the contract design and the optimal risk-sharing structure. The next subchapter develops the theme further, discussing the effects of reputation.

4.2.2 The effects of reputation on risk-sharing

Both principal's and agent's reputation from previous projects affect the optimal contract structure. In an empirical study about defense procurement, Rogerson (p. 69, 1994) focuses on the principal's reputation. According to Rogerson, the principal "would often benefit in the short run from reneging on its commitments and negotiating the lowest possible prices for the current period's contracts." In the long run, however, the principal would be worse off, since its partners would no longer be willing to commit to relationship-specific investments. Clearly this approach applies the best to repeated procurement. However, if the principal ever intents to take on a second procurement project, safeguarding its reputation is crucial in order to maintain negotiation power and to render commitment attractive.

Another approach to the reputation issue is presented by Baron and Besanko (1988) and Crocker and Reynolds (1993) as concerning the agent's reputation. A small number of past lawsuits or recorded disputes can be seen as a signal of the trustworthiness of the agent, thus affecting the risk sharing structure as follows. An agent with good reputation is more likely to perform well under a cost-plus contract, in which all the costs are inflicted on the principal. In contrast, bad reputation has a direct linkage to potential moral hazard thus favoring a contract tending towards a more fixed pricing structure, providing the agent with an incentive to reduce costs. The logic is rather intuitive: a supplier with a track record of contractual disagreements can be considered likely to exploit a cost-plus contract in terms of cost efficiency and even false cost reimbursements. Similarly, a supplier with a solid track record is likely to be willing to keep up with its reputation and can thus be induced to cost efficiency even under a cost-plus agreement.

Applying the insight about the effects of reputation to nuclear reactor procurement is an interesting topic. On one hand, Fennovoima is a project company, founded specifically to execute a one-time construction project of a nuclear power plant. From Fennovoima's point of view it is important to establish reliable ex-ante reputation – the company has to be capable of convincing the potential suppliers to commit to relationship-specific investment. In this sense, the presence of the German energy conglomerate E.ON has been a valuable asset to the project, as the company has held a significant position in the European nuclear power industry. However, the Finnish nuclear power policy sets quite clear limitations to the scope of Fennovoima: the Hanhikivi 1 project is a one-of-a-kind opportunity. This, in fact, allows the company for *ex-post* bad behavior – of which the supplier is aware. On the other hand, the supplier is aware of the fact that cooperation with Fennovoima will be over after the Hanhikivi 1 project is complete. Therefore the supplier has no incentive to overplay its contractual responsibilities – on the contrary, it is likely to shirk wherever possible. However, due the thinness of the nuclear reactor market, the supplier has its reputation to safeguard. A poorly performing reactor supplier is likely to suffer from a loss of reputation in the long run.

The Japanese contracting method forms a striking counterexample: the three Japanese nuclear reactor manufacturers – Toshiba, Hitachi and Mitsubishi – have employed a sequential rotation in filling the roles of the reactor supplier, turbine supplier and architect engineer. Combined with the frequency of past nuclear projects, this cooperation has allowed for incomplete contracting and less stringent bidding procedures. The extent to which the flexibility induced by such reputation building has enabled the Japanese nuclear power plant constructors to execute record-fast construction project remains an important question.

4.3 Incentives to achieve high quality

It has been empirically proved that in a procurement process, the principal faces a trade-off between high quality and low cost (Cox et al., 1996). High quality is achieved through a low-incentive cost-plus contract which enables the agent to focus on quality requirements instead of aiming at increasing his own profit through cost reductions. In contrast, low cost can be achieved through a high-incentive fixed-price contract. With a fixed-price contract, however, the agent is more likely to cut corners wherever contractual incompleteness allows. This section discusses three approaches to encouraging quality at a low cost. The section is divided into three subsections as follows. The first subsection focuses on enhancing quality through the principal's monitoring efforts. The second subsection, in turn, introduces third-party verification into the setting, instead of bilateral monitoring. The final subsection makes a general remark about design-related incentives in the empirical context of defense procurement.

4.3.1 Monitoring for quality

Baron and Besanko (1987) assess monitoring as a means to control quality in the context of defense procurement. In their model an imperfect monitor is used to mitigate the risk of moral hazard, stemming from private information. They assess a costly monitor and weigh the monitoring expenses against the payments the principal must make to induce the agent to reveal his private information. In the model, Baron and Besanko (1987, p. 510) consider two special cases. The first case involves a risk-averse agent with random cost and a perfect monitor. The optimal contract in this case relieves the agent of some of the risk from the random cost, and subsidizes the agent for his effort, since he otherwise would exert a suboptimal effort level. The second case involves deterministic costs and a noisy monitor. In this case the principal chooses to impose risk on the agent in order to reduce the information cost associated with inducing the agent to reveal his private information to the principal. Thus, in the case of deterministic costs and a noisy monitor, the payment to the principal is a function of the monitor, and the principal may choose to tax the agent's effort in order to reduce the information costs. The first case comes closer to the Fennovoima project: the monitor technology can come close to perfect at a cost, but the cost structure is certain to include random elements that cannot be pre-specified.

An optimal contract induces the agent to produce such a quality that the marginal benefit from it equals the marginal cost of production (Lewis & Sappington, 1993, p.172). In the case where a monitor is employed in order to mitigate the moral hazard problem, the marginal benefit from quality must equal the modified marginal costs of production, which includes the costs of acquiring information. This implies that the agent's incentive is always to exaggerate the marginal cost in order to increase the marginal benefit. As the highest realizations of marginal cost are extremely expensive to the principal, the production is likely to be terminated in these cases. This corresponds to the case of noisy monitor by Baron and Besanko: the agent’s incentives to exaggerate his costs can be mitigated through an incentive contract or by actually taxing the agent’s excessive effort.

The quality of information obtained through monitoring depends on the resources committed to this activity and on the available technology (Harris & Raviv, 1978). Consequently, the optimal contract structure also depends on the available monitoring technology. In their model, Harris and Raviv (1978) limit the principal's scope. In this case, monitoring is the only way the principal can affect the payoff of the relationship. The analysis focuses on the contract which specifies how this payoff is shared between the two parties. Similar to the simple model in subsection 4.1 .2, they argue that the optimal outcome is dichotomous. If monitoring reveals the actions to be acceptable, the agent is paid according to a pre-specified schedule. Otherwise, the agent receives a less preferred fixed payment (Harris & Raviv, 1978). However, termination of the project is highly unlikely in the context of building a nuclear power plant, since the both parties have committed to relationship-specific investments. This often necessitates renegotiation, further explored in section 6.3 , which is likely to be induced by holdup situations, discussed in section 5 . Instead of dismissal, the principal can resort to penalizing the agent, whenever the effort level is monitored to be suboptimal.

However, according to McAfee and McMillan (1986), imperfect information on the agent's action brings additional uncertainty to the model, and induces ambiguous effects. If both the agent and the principal are risk averse, the uncertainty tends to reduce overall welfare. The risk-aversion of the agent induces the principal to take on a proportion of the risk of cost fluctuations, which reduces the agent's cost-efficiency incentives. The winning bidder makes an unobservable effort decision, and instead of employing a costly monitor of quality or effort level, the principal opts for compensating the agent for the incurred costs, which are easier to detect. Thus a cost-plus contract, which employs a monitor for costs, is an option for mitigating moral hazard (McAfee & McMillan, 1986). On the contrary, if imperfect information induces the principal to employ a credible monitor, the agent can be motivated to make an effort which leads to a pareto-optimal outcome (Harris & Raviv, 1978, p. 248). The credibility of a monitor can be established through investing in the monitoring technology so that the monitor is noise-free. The gains from monitoring decrease to zero as the monitor becomes noisier.

If a credible enough monitor cannot be applied, the buyer has no other means of mitigating moral hazard than resorting to either a complete fixed-price contract or ex-post compensation that depends on the outcome of the project. As there is ample theoretical evidence against fixed-price contracts in the industry context, the following subsection moves on to assessing verifiability of quality, which is required in case of ex-post compensation.

4.3.2 Verifiability of quality

Lewis and Sappington (1991) discuss the impacts of the verifiability of quality, which can be used as an instrument to better incentivize the agent to provide the desired quality level. The essential task of the principal is to motivate the agent to provide a high-quality product while limiting the agent’s rents (Lewis & Sappington, 1991). The verifiability of quality reduces the cost of producing quality, which in turn benefits the principal. Instead, if quality is not verifiable, the agent does not benefit from producing quality. With verifiability, the agent is compensated for the enhanced quality and thus for the underlying effort level. As producing quality is now less costly, more quality is secured by the agent, which further increases the principal's welfare. In applying the model to the nuclear reactor procurement setting, the notion of quality requires further consideration. The quality requirements as such are exogenously given, and enhancing quality over this threshold level does not necessarily increase the buyer's utility. The long-term operational performance of the power plant can be interpreted as quality, but most of the commercial operation takes place after the contracted period. Quality, as understood on the company level, encompasses multiple dimensions, including ISO standard-based features, requirement by the radiation authority and timely delivery. In assessing the model by Lewis and Sappington, it can be assumed for simplicity that quality refers to the timely delivery of a licensable product, i.e. a reactor the features of which comply with the threshold requirements. Timely delivery, interpreted as quality in the model, increases the buyer's valuation, due to the buyer's discount factor and preference for connecting the reactor to the commercial grid rather sooner than later.

In the analysis of Lewis and Sappington (1991, pp. 374–375), quality is unverifiable, and the buyer faces an incentive problem as the compensation cannot be explicitly linked to the quality delivered. In this case the buyer must be aware that the quality level cannot be contractually defined. Instead, the supplier provides the level of quality he finds to be most profitable. Therefore, in order to induce the supplier to provide a higher level of quality, the compensation must be set above the supplier's marginal cost. It is well justified to assume that in nuclear reactor procurement the level of quality is observable, to the buyer as well as to third parties, especially if the timeliness of delivery is considered as the primary quality feature. Therefore the mathematical presentation of motivating optimal quality is omitted in this context. In comparing the two cases (Lewis and Sappington, 1991, pp. 376–377), however, it is pointed out that the tradeoff between low cost and high quality implies that when the quality is unverifiable, the principal settles with lower level of quality. Verifiability of quality, instead, allows for all but non-pricing decisions to be left out of the contract and does not exclude cost efficiency. In a comparison of the two versions of the model, verifiable and non-verifiable quality, Lewis and Sappington (1991, p. 377) conclude that even though the verifiability increases supplier's rents, the total surplus increases even more. Numerical comparison of the model reveals that when quality is verifiable, the price is set at the level of production costs. In contrast, with unverifiable quality, price tends to be significantly higher.

Verifiability of quality brings along undisputable benefits. However, creating a compensation scheme based on quality brings along additional considerations, as all desired quality features would need to be accounted for. In fact, it is generally acknowledged that an incomplete compensation scheme might shift the agent’s focus towards maximizing the verifiable part of the effort at the expense of the unverifiable part. In the context of this thesis, this risk speaks in favor of a comprehensive ex-post compensation scheme that is based on the timeliness of the project completion and the operational factor of the nuclear facility over its lifetime.

4.3.3 Designing for quality

Another example of the tradeoff between high quality and low cost concerns the design. Similarly to Rogerson's (1994) idea about defense procurement, nuclear power companies also face a problem of providing incentives for R&D, since these companies are unable to move the production in-house. This is largely due to the vastness of the scope as well as regulatory reasons. There are very few examples worldwide of nuclear power plant companies that would have had a major role in the research and development of a new product. More precisely, a small new entrant in the market is very likely to be excluded from most of the design process. Moreover, in contrast with defense procurement, where a government is willing to incentivize innovation, the design of a nuclear power plant must be near-to-complete by the time of contracting in order to be granted permissions to proceed. However, internalizing some of the R&D related risks is identified as way of simultaneously incentivizing high quality through more mature design and lower costs through better goal alignment of the cooperating parties (Rogerson, 1994).

In a procurement setting for a nuclear reactor, it is commonplace for the design to be close-to-complete by the time of the bidding phase. The bid invitations as well as the bids are based on at least preliminary design, most of which has been conducted independently of the potential buyer. However, come the time of bidding, an early works agreement (EWA) is signed. The purpose of EWA is specifically to engage the parties in joint design development, so that the design would comply with the local regulation. Despite the cooperation at late stages of the R&D work, the supplier still bears a major proportion of the investment risk. Nonetheless, the EWA procedure stands as an example of how a part of the R&D related risk is internalized by the principal in order to achieve higher quality in the spirit of Rogerson (1994).

4.4 General remarks about the contracting phase

In the contracting phase, the primary endogenous risk stems from the supplier's private information about his action choice – i.e. the exerted effort – and hence, moral hazard. Theoretically, moral hazard is mitigated through monitoring, which enables rewarding or punishing the supplier for his effort. However, as the effort is unlikely to be observable by the buyer or a third-party monitor, the compensation should be based on the ex-post outcome. In this case a monitor is no longer actually needed.

Whereas monitoring or the division the ex-post surplus act as tools to mitigating the endogenous risk of moral hazard, the exogenous risks are best covered through defining the risk-sharing structure. The risk-sharing scale reaches from a fixed-price contract to a cost-plus contract. A fixed-price contract offers the seller strong incentives to cost reduction, but is best suited for products of simple design that do not require modification and renegotiation. With a fixed-price contract the seller bears the exogenous risk, which is likely to show as an increase in the original bids. In contrast, a cost-plus contract allows for greater flexibility in terms of design but offers no incentives for cost reduction efforts. With a cost-plus contract, however, the buyer is responsible for the exogenous risk, yielding lower original bids.

It is important to notice that moral hazard cannot be fully mitigated through the risk-sharing structure. Instead, the risk-sharing rate reflects whether costs or quality are of greater importance to the buyer. Similarly, a monitor is only a tool of compensating the supplier for his effort or for his costs. Moral hazard can only be fully eliminated if the supplier's payoff is made contingent to the outcome of the procurement process, i.e. the contract involves sharing of the ex-post outcome. This conclusion is a step towards a more dynamic setting, in which the contracting parties participate in a sequential game, thus enriching the theory. The following two chapters consider additional dynamic features, namely holdups and renegotiation, adding to the findings supporting ex-post compensation.

5 Holdups

When long project duration is added to the basic procurement setting, *holdup situation* becomes a relevant threat. Holdups arise in bilateral trade in the contracting phase when the unavoidable contractual incompleteness leads to investments that are below the socially optimal level. In a complex long-term project, the initial relationship-specific investment is likely to exceed the degree of contractual coverage. If investment-related information could be specified, and complete contingent-proof contracts could be written, the holdup problem would not arise. However, specific investments are involved and contracting is incomplete (Che & Hausch, 1999). In the procurement of a nuclear reactor, the supplier's initial investment to the design is unlikely to be covered by the contract. Moreover, as the design requires country-specific modifications, the supplier's investment becomes in reality relationship-specific. Therefore the related underinvestment problem requires careful consideration.

This chapter provides a theoretical overview on holdup situations in risky long-term projects, introducing dynamics into the static setting of the previous chapters. Allowing for changing contingencies brings the setting closer to the contracting reality. At the same time, the results are less general, which complicates determining practical implications. Modeling a multi-stage game with exogenous risk is a challenging task. Chapters 5 and 6 are devoted to assessing a simple formulation of the problems at hand, and providing insight into the optimal contracting with descriptive models about the optimal characteristics of the contracting parties. The first section of this chapter presents a simple model of holdups and a definition for the abovementioned underinvestment problem. The second section introduces some theoretical findings about mitigating underinvestment and circumventing the holdup problem. The articles reviewed are selected so as to provide insight into the contracting challenge Fennovoima is facing. Finally, the third section makes general remarks about the holdup literature and its practical implications.

5.1 Holdup: A simple model

A holdup situation leading to *underinvestment* occurs when relationship-specific investments are introduced in a contracting situation. This means that the supplier's default payoff increases less than the gain from trading with the buyer: the supplier's marginal return to his investment is no longer the same independent of whether he sells to the buyer or on the spot market. Thus the first-best investment level is not automatically achieved. The formal presentation of this problem is central to this section.

Bolton and Dewatripont (2004 pp. 560–562) present the holdup problem by a simple model as follows. There are two contracting parties, a prospective buyer and a prospective supplier, who can enter a relationship in which they can end up trading a quantity $q \in [0,1]$ at a price P. At this point it is important to note, that in order to apply the model in the context of nuclear reactor procurement, *quantity* must be interpreted as *quality.* From now on, the notation is referred to as *level of trade.* Their utility from the trade depends on the buyer's valuation v and the supplier's production cost c. These utilities are uncertain at the time of contracting and can be influenced by specific investments made by each party at an earlier date. The following assumptions are made:

$$v \in \{v_L, v_H\}, \qquad v_L < v_H, \qquad \mathrm{Pr}(v_H) = j$$

where the buyer's cost of making an investment j is $\omega(j)$, and

$$c \in \{c_L, c_H\}, \qquad c_L < c_H, \qquad \mathrm{Pr}(c_H) = i$$

where the supplier's cost of making an investment is $\varphi(i)$. The investment functions are increasing and convex, and the investments are sunk whatever the ex-post level of trade. The ex-post payoffs are thus

$$vq - P - \omega(j)$$

for the buyer, and

$$P - cq - \varphi(i)$$

for the supplier. The timing is as follows. First, the parties contract; second, they simultaneously choose their investment levels i and j; third, the both learn the state of nature, $\theta = (v, c)$, affecting the buyer's valuation and the supplier's cost, and fourth, the contract is executed.

For simplicity, it is assumed that $c_H > c_L > v_H > v_L$. Under this assumption, the ex-post efficient level of trade is $q = 1$ if $\theta = (v_H, c_L)$ and 0 otherwise. Since the parties are assumed to be risk neutral, the ex-ante efficiency is equivalent to investment efficiency, i.e. i and j must result from

$$\max_{i,j}\{ij(v_H - c_L) - \omega(j) - \varphi(i)\}$$

The first-order conditions yield the optimal investment levels i^* and j^*:

$$i^*(v_H - c_L) = \omega'(j^*)$$

and

$$j^*(v_H - c_L) = \varphi'(i^*).$$

In the standard contracting problem the state of nature $\theta = (v, c)$ and the investment levels i and j are not contractible, although the state of nature is observable to both parties ex post. If ex-post spot contracting is possible, and if the gains are evenly divided between buyer and supplier, there will be underinvestment in equilibrium after θ is realized and investments i and j are sunk. Figure 3: Underinvestment with holdup problem below illustrates this. The black curves represent the optimal investment functions i^* and j^*, and the grey curves represent the best response functions under spot contracting, given by

$$\frac{1}{2} i(v_H - c_L) = \omega'(j^{BR})$$

and

$$\frac{1}{2} j(v_H - c_L) = \varphi'(i^{BR})$$

The difficulty faced by the contracting parties in a dynamic setting with uncertainty is how to formulate an optimal long-term contract that is independent of the state of nature, which mitigates this underinvestment problem, moving the investment levels from the second-best equilibrium toward the first-best equilibrium.

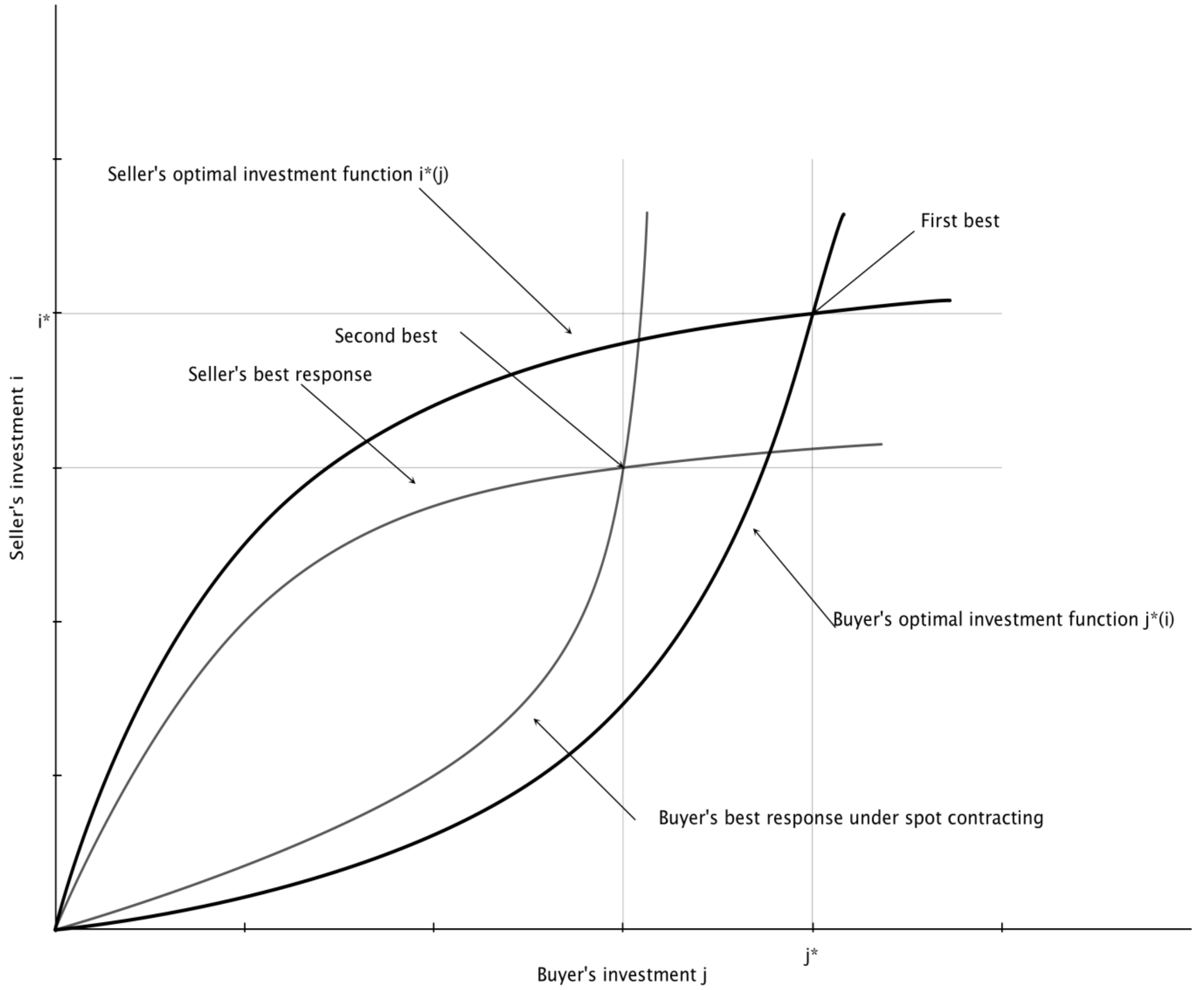

Figure 3: Underinvestment with holdup problem

The following subsection presents one approach to mitigating the underinvestment problem. Bolton and Dewatripont expand on the model above, and present a solution where underinvestment is avoided by awarding one of the two contracting parties full bargaining power.

5.1.1 Mitigating underinvestment with bargaining power

Bolton and Dewatripont (2004, pp. 563–564) present a positivistic solution to mitigating underinvestment. In the model, it is assumed that the parties can specify default options whenever trade is possible. The level of trade, $\tilde{q}$, is defined such that

$$\tilde{q}(c_H - c_L) = \varphi'(i^*)$$

where $\varphi(i)$ is the supplier's payoff. The following contractual mechanism can be considered: Once the state of the world θ has been realized, the parties play the following game: in stage 1, the buyer can make an offer (P, q) to the supplier; in stage 2, the supplier accepts the offer and trade takes place at these terms, or rejects it, in which case $\tilde{q}$ is traded at a prespecified price $\tilde{P}$ designed to share ex-ante surplus according to initial bargaining shares. The buyer has full bargaining power in this first version of the two-stage game; he will therefore offer to trade the ex-post efficient quantity while leaving the supplier indifferent between trade and his default option. This is sufficient to guarantee ex-post efficiency. However, as described in section 5.1.1 this is not a sufficient condition for the investments to be efficient. The supplier anticipates obtaining his default option payoff whatever the ex-post level of trade, so he solves

$$\max\{\tilde{P} - ic_L\tilde{q} - (1-i)c_H\tilde{q} - \varphi(i)\}$$

Given the interpretation of $\tilde{q}$, investment level i^* is the supplier's optimal choice, whatever the buyer's investment. Finally, as the buyer has full bargaining power, he is the residual claimant on her investment and solves

$$\max\{i^*j(v_H - c_L) - [\tilde{P} - i^*c_L\tilde{q} - (1-i^*)c_H\tilde{q} - \omega(j)].$$

The buyer thus maximizes total surplus minus the payoff of the supplier, which does not depend on the investment of the buyer, and minus his own investment. Consequently, the buyer chooses $j = j^*$ and the supplier chooses $i = i^*$.

The mechanism described above induces efficient bilateral investments. For the buyer, the efficient investment level is achieved by making him the residual claimant. The supplier, in turn, is incentivized into efficient investment behavior despite having no bargaining power at all. The supplier's incentive to invest stems from the default option, whose attractiveness rises when his production cost decreases. The existence of the default option thus makes the supplier sensitive to his investment. In the context of nuclear power reactor procurement, however, the existence of a default option is an unrealistic assumption – a half-built nuclear power plant is hardly of any value. Therefore it is straightforward to assume that a default option alone is not a sufficient incentive for the supplier to make first-best investment decisions. The following section focuses on a variety of other contractual solutions.

5.2 Contractual solutions to the holdup problem

Rogerson (1992) sums up the holdup literature, and presents a set of assumptions under which first-best solutions can be found even in the dynamic contracting setting. He follows e.g. Hart and Moore (1988) in listing the three main conclusions of the holdup literature. First, the absence of any contract is likely to lead to underinvestment. Second, even simple contracts can lead to complicated outcomes, if the contract is viewed as affecting subsequent bargaining rather than as a complete description of the outcome. Third, even in simple environments optimal contract can still result in inefficient investment, if a fixed renegotiation game is present.

This section discusses a few articles regarding contractual solutions to the holdup problem in the context procurement contracting. The first subsection presents a model by Che and Sákovics (2004) discussing the importance of patience in solving holdup problems. The second subsection considers cooperative investments as opposed to purely selfish investments (Che and Hausch (1999). The third subsection describes how a holdup situation can be created by reputation building (Lewis, 1986). Finally, the fourth subsection introduces a model where holdups can be prevented via a simple option contract (Nöldeke & Schmidt, 1995; Nöldeke & Schmidt, 1998).

5.2.1 Patience

Che and Sákovics (2004) present a model that allows risk-neutral parties to continue invest until they agree on the terms of trade. The model suggests that a holdup situation, created by relationship-specific investments, do not need to entail underinvestment. In the model, ex-post negotiation allows for the contracting parties to split the ex-post trading surplus. From this it follows that an investor is able to appropriate only half of the marginal return to his investment, which in turn leads to underinvestment. Che and Sákovics study the effect of patience and present a model, where investment dynamics alone can solve the incentive problem, paying particular attention to the individual rationality constraint (p. 5-7, 2004). In the simplified model the supplier faces a binary choice: to invest or not to invest. Investment costs him $C > 0$. The gross surplus from the trade is φ_I if he invests and φ_N if he does not invest. Assume that it is always efficient to invest, $\varphi_I - C > \varphi_N$. The parties have equal bargaining power: each party becomes the proposer of trade with equal probability. In a static model, the supplier would not invest if

$$\frac{1}{2}\varphi_I - C < \frac{1}{2}\varphi_N.$$

In a dynamic version of the model, where sequential investment is allowed, there exists an equilibrium in which the supplier invests if the parties' common discount factor δ is sufficiently close to 1 and the investment is individually rational for the supplier:

$$\frac{1}{2}\varphi_I - C > 0.$$

If the supplier now chooses to invest, the trade results in a standard bargaining game with a fixed surplus, and in the equilibrium the parties will on average split φ_I equally. Hence, the supplier's equilibrium payoff will be $\frac{1}{2}\varphi_I - C$, just as in the static case, i.e., the supplier would be held up in terms of the absolute payoff in both the dynamic and the static model. If the supplier deviates and chooses not to invest in period 1, he will invest in period 2, given a one-period deviation possibility. Therefore, the buyer's continuation payoff following supplier's first-period deviation is $\delta\left(\frac{1}{2}\varphi_I\right)$. Thus the buyer never agrees to trade unless he receives at least this amount. The supplier's payoff from choosing not to invest in the first period is thus $max\left\{\varphi_N - \delta\left(\frac{1}{2}\varphi_I\right),\ \delta\left(\frac{1}{2}\varphi_I - C\right)\right\}$. The former payoff is received if the supplier offers $\delta\left(\frac{1}{2}\varphi_I\right)$; the latter if the offered amount is lower, which the buyer rejects, or if the buyer becomes the proposer, in which case he would offer the supplier's net continuation value, $\delta\left(\frac{1}{2}\varphi_I - C\right)$. For $\delta \rightarrow 1$, both payoffs are less than $\frac{1}{2}\varphi_I - C$, i.e. the payoff the supplier would receive by investing in the first period. Therefore one-period deviation is not profitable, it is in the supplier's interest to invest, when δ is sufficiently close to 1. Thus the mere possibility of adding investment later can create an additional investment incentive compared to the static model, as long the individual rationality constraint is present.

The result of the above-described model is rather intuitive: if the contracting parties are indifferent between investing now and investing later, it is easy for the principal to induce the agent to invest already in the first period since one-period deviation is not profitable to the supplier. The threat of the buyer becoming the proposer is a sufficient incentive for the supplier to invest as soon as possible if the discount factors tend to one.

5.2.2 Cooperative investments

Che and Hausch (1999) challenge the incomplete contract – holdup -paradigm by arguing that a simple contract can solve the holdup problem by achieving an efficient outcome. Most holdup literature assumes that the supplier invests to reduce his cost, and the buyer invests to increase his benefit. This is called *selfish investment*. Instead, the focus of Che and Hausch lies within *cooperative investment* that generates direct benefit to the trading partner. A cooperative investment can be either *pure* in the sense that it offers no benefits to the investors, or it can be *hybrid* in the sense that it offers direct benefits to both trading partners. In practice, e.g. quality-enhancing R&D or enhancing the working conditions of the trading partner can be seen as cooperative investments. Contractual incompleteness results in the threat of holdup with both selfish and cooperative investments. As a first result, Che and Hausch show that regardless the degree of cooperativeness, efficiency can be achieved if the parties can commit not to renegotiate. However, since such a commitment is impossible to execute in complex procurement contracting, the results of a model that accounts for renegotiation are of more importance. The second result is obtained when bargaining shares are exogenously determined. In the presence of renegotiation, it is shown that if investments are sufficiently cooperative, there exists a range of bargaining shares for which contracting brings no additional value over ex-post negotiation. As the investments tend towards pure cooperativeness, the range of worthless ex-ante contracting covers the full range of bargaining shares. The findings revolve around the efficient bargaining shares. A cooperative investment worsens the investor's status quo position by improving the trading partner's status quo position. The party with a smaller bargaining share is more sensitive to a change in his status quo position, and less sensitive to his partner's status quo position. Thus a cooperative investment has less adverse effect on the behavior of the investing party with a smaller bargaining share. It is therefore stated that the first-best outcome may be attainable when the investing party has least bargaining power (Che & Hausch, 1999).

The findings of Che and Hausch (1999) yield interesting implications. The ability to avoid renegotiation is identified as an important condition for achieving efficiency. Since such ability cannot be legally enforced in interfirm trade, it offers some perspective on the theory of organization. Two examples are identified. First, the insight gives strong support to intrafirm trade resulting from vertical integration: commitment not to renegotiate and thus erode surplus from cooperative investment is more easily supported within the firm. Second, some remarks can also be drawn about the judicial attitude towards enforcing nonmodification clauses in interfirm contracting. Courts are reluctant to enforce commitment not to renegotiate, even though nonmodification clauses are likely to enhance efficiency in trades where cooperative investments are important. Therefore the implications are of significance only in the case the contracting parties can credibly commit to a voluntary non-renegotiation clause. As for the second result of Che and Hausch, the effect of the bargaining shares is of little practical importance. As stated above, bargaining shares are exogenously determined, and therefore the less powerful party is automatically induced to invest.

5.2.3 Reputation building

Lewis (1986) discusses reputation and contractual performance in long-term projects. A long-term relationship is modeled as a sequential game to which neither of the parties can credibly commit. It is argued that the contractors typically work hard in the initial phase to keep costs down until both parties are locked into finalizing the project. Lewis distinguishes four attributes of long-term projects. First, the procurement occurs over an extended period. Second, the projects involve untried technologies. Third, the market for such projects is naturally thin which constitutes for the lack of outside options. Finally, costs are incurred throughout the process whereas benefits only accrue once the project is finalized. These features are similar to the nuclear power market. Contractual incompleteness stands as a starting point of the analysis. Lewis (1986) justifies both contractual incompleteness and the high probability of renegotiation with these attributes. First, the extended period of contracting renders writing complete contracts impossible. Second, the lack of outside options combined with the delayed benefits from the project creates a holdup situation which is likely to lead to the renegotiation of the contract.

Lewis (1986, p. 142) describes a holdup problem as the main goal of an agent's initially good performance. In the model i is the number of tasks left to complete the project. The cost history of a project up to period i is summarized by a reputation value for the project, denoted by $q_i \in [0,1]$. In equilibrium there exists a sequence of acceptable reputation levels q_i^* such that the project is cancelled in period i unless $q_i \geq q_i^*$. This implies that the project is continued for one more task, if the benefits yet to be received exceed the perceived future costs to the principal. Lewis (1986) shows that the acceptable reputation levels are strictly declining as the number of task left decreases to some period d, where $q_i^* = 0$ for all $i \leq d$. Therefore at period d the principal is locked in, i.e. committed to finish the procurement process because the benefits from the project exceed even the largest possible costs remaining to be incurred. Similarly, it is shown that the expected cost of completing each task increases as the project nears completion. Even though the threat of cancellation directs the agent's effort in the earlier stages of a project, the incidence of project terminations may be negligible. It is shown that efficient firms will always produce at low cost, so that cancellations actually never occur. In this instance, the efficient agent's investment in his reputation prevents the principal from cancelling the project until he is fully committed to finishing the project at any possible cost.

This model by Lewis (1986) presented above forms a plausible framework for holdups within nuclear construction. The model is actually surprisingly well-suited for the Fennovoima case: the contracting process consists of a sequence of contracts, beginning with an early works agreement, moving on to a front-end engineering design contract and ending up with an engineering, procurement and construction contract. Moreover, the relative weight of the contracts increases logarithmically. It would thus be relatively easy to the supplier to create a holdup situation with a relatively insignificant initial investment. The model resonates with the adverse selection models presented in chapter 3: sequential contracting opens an avenue for a signaling game, which can potentially end up harming the principal, when sequential contracting is introduced into the model. As a result, the two parties of the contract are locked into each other, greatly reducing the appeal of an outside option, i.e. contracting with another supplier or withdrawing from the project. Outside competition has little impact on the relationship, which implies that the contracting parties are likely to enter renegotiation.

5.2.4 Option contracts

Option contracts are theoretically a very powerful tool in aligning the incentives of the two contracting parties and thus to fully relieve the principal from the fear of moral hazard. Option contracts are also identified by Bolton and Dewatripont as a tool of pushing the best-response relationship-specific investment curves toward the first-best equilibrium (see Figure 3: Underinvestment with holdup problem). Schmidt (2001) suggests other than simple governance structures as a means of mitigating the underinvestment-problem, created by a holdup situation. He refers to e.g. Nöldeke and Schmidt (1995), who consider a simple solution to the holdup problem. Nöldeke and Schmidt argue that the underinvestment problem can be overcome with a simple option contract. An option contract gives the supplier the right – not an obligation – to deliver a fixed quantity of the good, and makes the buyer's payment contingent on the delivery decision. Option contract is feasible only if it is possible to enforce payments conditional on the supplier's delivery decision, i.e. if it is verifiable by a court whether it is due to the supplier's refusal to deliver or the buyer's refusal to take delivery that the trade did not take place. This condition is sufficient for efficient investment decisions to be made and to assume the holdup problem away. Unfortunately, the simple form of an option contract can hardly be enforced in the context of nuclear reactor procurement. The regulatory uncertainty faced by the supplier ensures that the supplier has already made sunken investments and is no longer indifferent between "taking delivery" and "refusing delivery".

Nöldeke and Schmidt (1998) consider also a more sophisticated holdup problem where the two contracting parties make sequential relationship-specific investments. The basic assumption is that the only long-term contracts that can be written concern ownership rights, and that efficient investment decisions cannot be contractually forced. Moreover, it is noted that technological progress and regulatory changes make it increasingly difficult to write a complete contingent contract on the required investments. In the model, the first-best investment level is achieved through an option-to-own contract. Instead of a conventional ownership structure, they suggest that firm A could own the company initially, but firm B is given the option to buy the firm at a predetermined price at some later date. Nöldeke and Schmidt present a set of conditions under which this could be sufficient to induce both parties make efficient sequential investments. In the Fennovoima case, the setting can be interpreted so that the reactor supplier owns the venture initially, and has to make an investment in country-specific reactor design. The more the reactor supplier invests, the higher Fennovoima's valuation; Fennovoima will exercise the option-to-own only if the initial investment is sufficiently high. If the option price is chosen appropriately, Fennovoima will buy the venture if and only if the supplier invested the efficient amount. The supplier is thus induced to invest at least the efficient amount, because if Fennovoima does not exercise the option, its investment incentives are similarly diluted, and the venture is not worth much to the supplier. Moreover, the supplier will not overinvest either, because Fennovoima will reap most of the marginal benefits. Finally, it is assumed that Fennovoima-ownership is a sufficient incentive to induce Fennovoima to invest efficiently.

5.3 General remarks about holdups

When dynamics is introduced into the contracting phase, a holdup situation becomes a relevant risk. Theoretically, a holdup is simple to understand: why should the supplier invest more if the thus created additional surplus flows to the buyer? Even if the ex-post surplus were to be equally divided between the contracting parties, the incentive to invest the socially optimal amount may not be sufficient.

In the nuclear reactor procurement setting the situation is somewhat different. The combined investment of the two contracting parties must result in a plant that is licensable and can be connected to the commercial grid. Any output level below this yields a negative payoff. However, the parties can greatly increase their net present value from the project the sooner it is completed. Therefore the supplier and the buyer optimally reach a contract that not only defines bid price and the risk sharing structure, but also equates the marginal costs of accelerated project execution with the marginal benefit from it. The contract must also allot a sufficient proportion of the additional ex-post payoff to the supplier so as to compensate for his investment.

In general, option contracts seem to offer a remedy to the holdup–underinvestment problem. An option to own would ensure the efficient investment by the original owner, so that he would maximize the value of his ownership by the time the trade takes place. Other kinds of option arrangements are worth considering and possibly more easily feasible in the industry context, as long as the additional surplus for the supplier equates his additional investment. For instance, the option contract for the procurement project at hand could be designed so as to incentivize the supplier for timely project completion. This could be achieved by granting the supplier a fixed proportion of the net income generated within the target schedule. If the commercial use of the plant is delayed, net income and thus the additional compensation falls to zero.

6 Renegotiation

In a long-term project, the contracting parties are likely to modify the contract at some point. *Renegotiation* may take place if the contracting environment or the design of the product has changed so that pareto-improvements can be made through revised contract design. The fact that a contractual relation is enduring of nature has fundamental consequences on the effects of asymmetric information and the incentives for an optimal outcome. For instance, in the early stages of a relationship, the agent may hold back on revealing information that could be used against him in later stages of the relationship. Alternatively, the agent may engage in reputation building in order to convince the principal into committing to a long-term relationship. Moreover, unforeseen contingencies introduce an additional challenge into the dynamic setting of renegotiation. Repeated interaction complicates the incentive schemes, but also allows for more refined contractual responses.

For instance, the Finnish Radiation and Nuclear Safety Authority reassessed some of their safety requirements in the aftermath of the Fukushima accident. This introduced exogenous changes into the ongoing construction of Olkiluoto 3, as well as the specifications of the Fennovoima bidding process. Similarly, unspecified design issues have propelled the contracting parties of Olkiluoto 3 into an extensive litigation process over the non-contracted requirements. It is justified to state that the contracting parties are likely to enter into renegotiation at some stage of the contracted period. As a matter of fact, in risky long-term projects renegotiation can be considered as an industry practice, rather than a deviation from the normal contracting procedure.

This chapter provides an overview on dynamic contracting, discussing how changing circumstances and contractual incompleteness induce the contracting parties to renegotiate in order to achieve an optimal outcome. The chapter consists of three sections. The first section presents a simple model of renegotiation. The second section discusses contractual incompleteness, which is identified as a main reason for the need of renegotiation. Finally, the third section focuses on renegotiation literature, discussing some important considerations. This section sheds light on the third research question: How to ensure the optimal outcome in case of renegotiation? In all, this chapter highlights how adding dynamics to the static contracting model increases the complexity of the contracting setting. Unlike the first two themes of this thesis – bidding and contracting – the dynamic theory of contracting is based on fairly recent research. Therefore, there exists no canonical framework for reviewing the topic, and much of the material in this section and its presentation has been synthesized for the purposes of this thesis.

6.1 Renegotiation design: A simple model

Renegotiation takes place when the ex-ante contract no longer yields an optimal outcome. In a model by Bolton and Dewatripont (2004, pp. 565–566), the contracting parties enter in pareto-improving renegotiations after the changing contingencies have induced underinvestment. They present a model of simple renegotiation design for specific-performance contracts. The notation follows that of the simple holdup model presented in section 5.1

The two contracting parties bargain in the absence of contract, beginning at date t when the state of the world θ has been observed. They bargain about the terms of trade in an alternating-offer bargaining game. In state $\theta(v_H, c_L)$ there is a unique equilibrium for any pair of discount factors $\delta_B > 1$ for the buyer and $\delta_S > 1$ for the supplier. When it is the buyer's turn to make an offer P^B, he solves

$$\min P^B \text{ such that } \quad P^B - c_L \geq \delta_S(P^S - c_L)$$

Similarly, when it is the supplier's turn to make an offer P^S, he solves

$$\max P^S \text{ such that } v_H - P^S \geq \delta_B(v_H - P^B)$$

At the optimum these inequalities are binding, and yield a unique outcome. If the supplier makes the first offer, the price is

$$P^S = \frac{1-\delta_B}{1-\delta_B\delta_S} v_H + \delta_B \frac{1-\delta_S}{1-\delta_B\delta_S} c_L$$

If instead the buyer makes the first offer, the price is

$$P^B = \delta_S \frac{1-\delta_B}{1-\delta_B\delta_S} v_H + \frac{1-\delta_S}{1-\delta_B\delta_S} c_L$$

Since $v_H > c_L$, the price offered by the buyer is lower than the price offered by the supplier. If, however, both discount factors tend to 1, then both prices tend to $(v_H + c_L)/2$, so that gains from trade are shared equally. If one party becomes very patient relative to the other ($\delta_k \to 1$, while δ_k is bounded away from 1), he obtains the entire surplus from trade.

6.1.1 Equilibrium renegotiation

The above-presented model described the contract as a result of a bargaining game. In order to assess its impact on the bargaining game, Bolton and Dewatripont (2004, pp. 565–566) present a contract that specifies default options $(\widetilde{P}, \tilde{q})$ that each party can enforce when it is his turn to react to the offer by the other party. As a reaction to an offer, the parties can either accept the offer; wait one period to make a counteroffer or request for their default options. This turns the bargaining game into an alternating-offer game with an outside option. According to the outside-option principle, the parties payoffs associated with the outside option are $(\widetilde{U_B}, \widetilde{U_S})$. The parties ex-post efficient payoffs without the outside option then are (U_B^*, U_S^*). If (U_B^*, U_S^*) pareto-dominates $(\widetilde{U_B}, \widetilde{U_S})$, the equilibrium payoffs are (U_B^*, U_S^*). If (U_B^*, U_S^*) does not pareto-dominate $(\widetilde{U_B}, \widetilde{U_S})$, the outcome of the game is ex-post efficient and gives party k for whom $\widetilde{U_K} > U_K^*$ his outside option payoff.

In order to limit the supplier to his default-option payoff, this payoff has to be higher than the outcome of bargaining without the default option. This outcome is ensured with a penalty for delayed trade that the supplier pays to the buyer. If the penalty is high enough, the supplier immediately accepts any offer (P, q) that is better for him than $(\widetilde{P}, \tilde{q})$, in order to avoid delay. the first-best contract can thus be implemented through a relatively simple contract. This simplicity is achieved as the contract form allows for equilibrium renegotiation.

MacLeod and Malcomson (2001) formalize renegotiation by a bargaining game. The four possible outcomes for the contracting parties are: trade with each other under the terms of original contract, no trade at all, trading with outside options, and renegotiation. The continuation of the relationship, i.e. the first and the last options, requires both parties to agree on the same contract. Breaching the contract, i.e. the second and the third options, may involve breach penalties. According to MacLeod and Malcomson (2001, p. 812), if a contract is renegotiated when the original terms make one party prefer either not trading at all or outside option over trade, the joint gain from renegotiation must be shared between the contracting parties. The parties share the surplus as long as neither could do better by choosing the outside option. If investments were general, the marginal return for the contracting parties would be same regardless the partners. However, since the topic of this thesis is procurement contracting for a nuclear power plant, a field with highly specialized design, the focus remains on relationship-specific investments. In this case, the switching costs incurred by breaching the contract erode the marginal return, as the original relationship-specific investment is useless. Relationship-specific investments are valuable for trade only with the chosen partner. The return from this relationship-specific investment is then shared between the contracting parties, contributing to a holdup situation (further discussed in chapter 5 Whenever renegotiation occurs, the parties will not receive full marginal return on investments. Therefore, when both parties commit to a project through relationship-specific investments, an optimal contract is conditioned on sufficient external variables in order to ensure that renegotiation does not occur.

6.2 Incomplete contracts

This section explores *incomplete contracts* and how contractual incompleteness can affect the renegotiation setting in procurement contracting. It is widely agreed that bilateral contracts, especially in complex projects, tend to be incomplete (e.g. Hart & Moore, 1988; Bajari & Tadelis, 2001; Wernerfelt, 2004). Decision-making is a burdensome task, and it might be the easiest to leave trivial decisions out of a contract. Moreover, not all contingencies can be accounted for, and therefore writing a more complete contract incurs an increasing marginal cost tending to infinity. However, the difficulty of formalizing the costs of writing a contingent contract limits the practical applications of research on contractual incompleteness.

This section consists of two subchapters presenting models about contractual incompleteness. The first subchapter presents a model by Crocker and Reynolds (1993). They assess the optimal degree of contractual incompleteness, and state that a contract is the most efficient when intentionally left incomplete. The second subchapter, in turn, discusses contractual incompleteness as a means of signaling. Spier (1993) presents a model where the principal can use contractual incompleteness as a means of capitalizing on his superior information about his type.

6.2.1 Optimal degree of contractual incompleteness

Multiple articles demonstrate that a simple long-term contract can actually induce first-best investments in various contexts, even without achieving completion in describing the possible future contingencies. For example, Crocker and Reynolds (1993, p.128) present a model that defines the degree to which the potential contingencies are optimally covered by the contract. They represent the degree of contractual completeness as the selection of a parameter $p \in [0,1]$ which denotes the probability that a contingency not expressly covered by the agreement may arise during the project. If all contingencies are covered by the contract, then $p = 0$ and there is no room for ex-post bargaining. The other extremity, $p = 1$, places no limitations on the terms under which subsequent trade may be effected. Intermediate degrees of completeness, $0 < p < 1$, specify duties for the more easily anticipated contingencies, leaving the other possibilities to future resolution as events and changing requirements unfold.

According to the model by Crocker and Reynolds (1993), the chosen degree of specificity reflects an efficient tradeoff between the expected costs and benefits of contractual incompleteness. The model reflects the procurement contracting setting of this thesis, assuming a fairly complex contracting environment and a long-term contract, which renders the drafting of a complete contract rather impossible, or at least excessively costly. The model by Crocker and Reynolds follows e.g. Hart and Moore (1988) and Spier (1992) in assuming that contractual incompleteness is mostly due to the excessive cost of both defining all the relevant contingencies and negotiating mutually acceptable responses to all these contingencies. Therefore, if environmental complexity is held constant, which corresponds to the reality, the marginal cost of implementing more precise agreements is increasing in the degree of contractual completeness, $1 - p$, and in the level of environmental and regulatory uncertainty, ω. Crocker and Reynolds (1993) assume that environmental uncertainty is increasing in the duration of a relationship. Therefore contractual completeness should decrease for longer project durations, as defining precise contracts for long-term relationships is costly and inefficient.

According to Crocker and Reynolds (1993, p. 129) a more complete contract reduces a party's ability to engage in effort to effect privately favorable distributions of the ex-post contractual surplus, which speaks on behalf of contractual completeness. On the contrary, a less complete contract creates two possible forms of additional costs. First, incompleteness leads to ex-post renegotiation costs as the contingencies unfold – the repeated bargaining process consumes resources. Second, the possibility of renegotiation raised by contractual incompleteness generates potential inefficiencies by discouraging ex-ante investment. Inefficient ex-ante investment levels and underinvestment are further explored in subsection 5.1 . As the parties are unable to commit to an enforceable division of the contractual surplus in all future states, the investor recognizes that a part of the benefits from his effort may be reaped by the other party as a consequence of future renegotiation. Therefore, the marginal benefit of contractual completeness in this model contributes to a reduction in investment externality, which is positively related to the likelihood of opportunistic behavior *L*. The marginal benefit from contractual completeness is thus a decreasing function of contractual completeness. At the time of the first round of contractual negotiations, the principal and the agent have expectations about ω and *L*; regulatory uncertainty and the likelihood of ex-post opportunism, respectively. The efficient level of contractual incompleteness equates the marginal costs and marginal benefits of contracting (Figure 4: Optimal degree of contractual completeness), depending on both environmental and regulatory uncertainty ω and the likelihood of ex-post opportunism *L*. (Crocker & Reynolds, 1993)

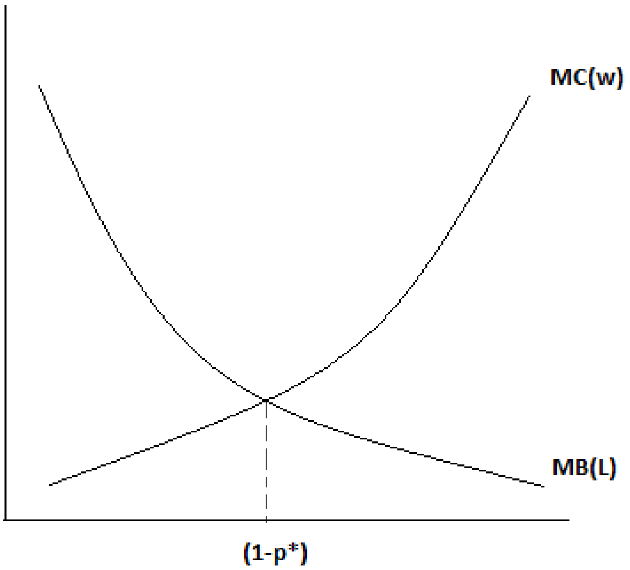

Figure 4: Optimal degree of contractual completeness

The model comprises two opposing forces. First, increasing environmental complexity shifts the marginal cost of contracting upward, resulting in lesser contractual completeness. Second, the increasing likelihood of opportunistic behavior shifts the marginal benefit of contracting upward, which makes increased contractual completeness attractive. Crocker and Reynolds (1993, p. 138–145) test the model with a panel dataset consisting of jet engine procurement contracts. They find the use of less structured contracts, and thus contract renegotiation, to be extensive, particularly when the performance horizon is remote. However, the procurement contracts have become substantially more complete over time – when the technology becomes more familiar, it seems reasonable to assume that a contract can attain a higher level of completeness without demanding any additional effort from the contracting parties. Interestingly, Crocker and Reynolds (1993, p.144), identify a systematic difference in the degree of completeness in contracts with two different contractors. The number of past disputes with the contractors is identified as a significant explanatory variable. It is assumed that the past willingness to engage in litigation reflects some static features of corporate culture and thus correlates with future opportunism. Therefore the number of past disputes can be seen to correlate positively with the marginal benefits of more complete contracts, reflecting higher costs of contracting, thus shifting the MC curve to the left and the equilibrium towards contractual completeness.

The more complete the ex-ante design of a contract is, the lower the likelihood that the parties will need to renegotiate ex-post changes (Bajari and Tadelis, 2001). A more complete ex-ante design imposer higher ex-ante costs on the principal. Thus the chosen degree of contractual completeness is a tradeoff between contracting costs and renegotiation costs. The marginal cost of contractual completeness is increasing, implying that in a complex project even the most comprehensive contract falls short from covering all possible contingencies.

6.2.2 Asymmetric information and incomplete contracts

Spier (1992) identifies three reasons for contractual incompleteness. First, it is commonly agreed that the cost of contracting on an unlikely contingency may easily outweigh the benefits. Second commonly used justification for contractual incompleteness is bounded rationality. This refers to agent's and principal's limited ability to foresee and evaluate elaborate contingencies, i.e. to predict the realization of the random variable affecting the outcome of the bilateral contract. Spier identifies asymmetric information as the third reason for contractual incompleteness. A contracting party might be unwilling to include a particular clause in a contract, which acts as a signal of his type. This implies that when asymmetric information is present, the contract may be incomplete or overly simple. A model by Spier (1992) focuses on asymmetric information as a driver for contractual incompleteness. In particular, contractual incompleteness can act as a sign of agent's type, when transaction costs are present.

Spier (1992) presents a model with a risk-averse principal and a risk-neutral agent. The principal hires the agent to manage a stochastic technology. The principal is one of two types: good or bad. The good type has higher expected payoff from the technology, and would naturally prefer the agent to carry the risk of production. Therefore the principal would prefer a profit sharing contract, where the agent's wage is higher when the profits are high, and lower when the profits are low. The principal is more likely to offer an incomplete contract when asymmetric information is present. Transaction costs are divided into two classes: drafting costs which are incurred ex ante, and verification costs which are incurred ex post. Asymmetric information reduces the benefits of complete contracts without altering the incurred costs. When transaction costs – ex-ante or ex-post – are negligible, the good type of principal signals his type through a complete contract that gives less insurance, since drafting and verifying a complete contract does not incur significant costs. When transaction costs are large, and drafting and verifying a complete contract would incur greater costs, the principal chooses to signal his type through an incomplete contract. The intuition goes as follows. The agent's payoff is considered to be independent of the principal's type within the class of incomplete contracts. Therefore signaling their concerns make more complete contracts more costly to the good type of principal. Since the good type of principal is unlikely to end up in disputes, the principal is likely to choose the less expensive option and draft an incomplete contract. The reputation of the contracting parties is discussed in subsection 4.2.2 As stated, the one shot nature of the Fennovoima project might render it useless to the company to behave as a principal of the good type, if it is less costly to shirk. The supplier being aware of this, it is of no use to the company to signal its type through the degree of contractual incompleteness.

In the signaling model, Spier (1992) distinguishes three cases. In the first case, the transaction costs are small, and both types of principal offer complete contracts. In the second case, the transaction costs are large, and both types of principal offer incomplete contracts. Finally, there is a signaling equilibrium between these two cases, where the good type of principal offers an incomplete contract and the bad type of principal offers a complete contract. Therefore, the good type of principal may be willing to leave a contract incomplete in order to credibly signal his type to the agent. As a continuation to this, the more complex the contract, the more likely the parties are to end up in costly litigation process about the wage.

Even though Spier (1992) provides valuable insight into the strategic choices of the principal, the model lefts out important considerations about the agent's type. The model suggests that the good type of principal is better off offering an incomplete contract. This model about the effects of informational asymmetry on the contractual completeness focuses on the signaling choice the principal can make. In the Fennovoima project, however, there is hardly any room for strategic speculations. The supplier candidates are aware of the principal's position as a project company, and therefore it might be unnecessary for Fennovoima to enter in signaling games at any cost. Contractual incompleteness might still be efficient, but it has to be justified by other means.

6.3 Topics in renegotiation literature

This section discusses a few articles regarding renegotiation in procurement contracting. The first subsection presents a model that allows for interim renegotiation before the output is realized (Fudenberg & Tirole, 1990). The second subsection, in turn, discusses how renegotiation design can be contracted upon already in the ex-ante contract in order to achieve the pareto-optimal outcome (Hart & Moore, 1988; Aghion et al., 1994) and how ceding decision rights to the other contracting party can lead to efficiency (Wernerfelt, 2004). Finally, the third subsection discusses renegotiation in a complex environment and its effect on the choice of the risk-sharing rate (Bajari & Tadelis, 2001).

6.3.1 Interim renegotiation

The standard moral hazard model (see section 4.1) assumed that the contracting parties commit to a contract, which cannot be renegotiated in later stages. In contrast, e.g. Fudenberg and Tirole (1990) present a model where the principal and the agent are able to renegotiate between the agent's choice of effort level and the observation of the outcome. This is a credible assumption, especially in cases where there are long lags between the agent's choice of effort level and the time the consequences of this choice are revealed. Fudenberg and Tirole (1990) discuss a case where the outcome is only seen five years after the agent has exerted his effort. The standard model then suggests that the agent's compensation should depend on the outcomes that to be observed five years hence. However, as the agent is the only one to know the chosen effort level, for the intervening years he holds private information on the probability distribution of future outcomes. This extended period of informational asymmetry opens a space for voluntary renegotiation. If the principal chooses not to alter the contract during the renegotiation stage, the contract can be called to be renegotiation-proof. If the principal could observe the effort level chosen by the agent, they would renegotiate the initial imperfect insurance contract and change it to a perfect insurance contract. However, if the agent anticipates renegotiation, he would exert less effort, and the outcome would remain inefficient. Therefore the optimal renegotiation-proof contract is such that the agent randomizes over his effort level in order to keep the principal guessing and thus eliminating some gains from renegotiation. As a result, renegotiation yields an undersupply of effort compared to a full-commitment contract.

6.3.2 Contracting for renegotiation

Hart and Moore (1988) assume a model that always allows for renegotiation. They state that it is in the interest of both parties to try to constrain the outcome of the renegotiation process already in the original contract. This implies that a revision game is already designed in the original contract. The analysis provides conditions for a contract mechanism that can be built into the original contract in order to renegotiate the contract, as the parties grow more aware of their benefits and costs. It is shown that the divisions of the ex-post surplus are very sensitive to the communication mechanism and to the potential verifiability of the messages the parties send to each other during the renegotiation stage. Similarly, it is shown that when the parties are risk neutral, efficient investment levels that would ensure a pareto optimal outcome cannot be achieved even through verifiable messaging. However, if the parties are risk neutral and the trade does not involve relationship-specific investments, then it would be possible to achieve a pareto optimal outcome with verifiable messaging. However, messages, in general, are unverifiable by a third party, despite being ex-post observable by the two contracting parties. Since trade is assumed to be voluntary, it takes place at the renegotiation stage only if both parties agree to trade ex-post. Courts cannot observe who did not want to trade in case trade does not take place.

Aghion et al. (1994) develop the ideas of Hart and Moore (1988) further. They argue that unverifiability of renegotiation messages, as described above, is not sufficient to explain underinvestment. However, they demonstrate that the issue of underinvestment can be solved through adequate contractual renegotiation design, which stands in contract with the underinvestment findings of Hart and Moore. Hart and Moore emphasize the unverifiability of messaging, assuming that courts cannot enforce contractually specified levels of trade, so that in the renegotiation phase the only default option is abandoning trade. Aghion et al., instead, attain efficiency at renegotiation phase by assigning all bargaining power to one party. To circumvent the unverifiability problem, the parties can include a revelation mechanism in the initial contract. This is possible since the model assumes that the court is able to verify that each party did their part of the trade. If the revelation mechanism is adequate, it can induce the contracting parties to choose first-best investments leading to a pareto-efficient outcome.

Wernerfelt (2004), in turn, presents a renegotiation mechanism that leads to choosing the investment alternative that would have been picked by a joint decision making process. If a unilaterally made decision is renegotiated before implementation, the initially uninvolved party incurs the decision-making cost. Renegotiation pays off depending on this cost and the additional surplus incurred by renegotiation. Consequently, the informed party, i.e. the original decision maker, can prevent renegotiation by rendering the joint decision just costly enough for the other party to leave it. Thus the threat of costly renegotiation allows for unilateral decisions reducing the cost of contractual incompleteness. As long as decision-making costs are worth saving, all renegotiation can be avoided, even with very incomplete contracts.

Wernerfelt (2004) proves that when renegotiation is impossible, the contracting parties are more likely to cede decision power to each other. However, this requires that the relative importance is low, the initial level of information is low, decision-making is costly and there is little difference of opinion about the decision. Thus the parties are likely to gain decision rights if they have better information about it. The cost of incompleteness, when renegotiation is impossible, is that the preferences of the uninvolved party are ignored. If the parties are able to make less selfish decision, i.e. to agree on a shared goal, the outcome becomes pareto-optimal. As the can be seen in Wernerfelt's model, aligning the parties' goals can allow for an improved outcome. The implications of the findings to the Fennovoima case are straightforward and rather intuitive: if the goals of the two contracting parties are aligned, the parties can bear with less decision rights over the contracted items. More incompleteness can be allowed, thus incurring savings on contracting and renegotiation costs.

When renegotiation is possible, which is likely in a complex project, it is considered to be costless for the party who makes the decisions (Wernerfelt, 2004). It is shown that when renegotiation is possible, the contracting parties are likely to cede decision rights if the difference between renegotiation costs and decision costs is low enough. If renegotiation is as cheap as decision-making, the threat of renegotiation allows for maximally incomplete contracts. However, the implications to the Fennovoima case are not quite clear. With an increasing project complexity, the cost of renegotiation is likely to be high. It seems intuitive, that only perfectly aligned goals could allow for a maximally incomplete contract and thus contribute to a reduction in the cost of contracting.

6.3.3 Renegotiation and risk-sharing

On the risk sharing scale, renegotiation is associated only with fixed-price contracts (Bajari and Tadelis, 2001). The right to renegotiate is not part of a cost-plus contract – instead, a cost-plus contract offers the agent initial flexibility by always guaranteeing the outside option of zero value. Hence this section explores only renegotiation of cost-plus contracts. The binary choice between a fixed-price contract and a cost-plus contract is, of course, an extreme occurrence of risk sharing. However, as Bajari and Tadelis (2001) argue, these extreme cases do provide sufficient insight into the renegotiation game. According to the model, the complexity of a project has actually an ambiguous effect on the likelihood of renegotiation. First, if a product is less complete by design, the contract is likely to be of a cost-plus form, in which case renegotiation does not occur. In contrast, if the complexity of the project has not been taken into account in the contracting phase, a more complex project is likely to incur renegotiations as the product design shows insufficient. This tradeoff could be dissipated through a more complete design. However, this comes at an increasing marginal cost implying that the more complete the contract is, the more costly it becomes to further specify the design. Following this logic, choosing a fixed-price contract as presented by Bajari and Tadelis (2001) brings about a tradeoff between specifying the design at an increasing cost and facing costly renegotiations.

Bajari and Tadelis (2001) suggest that with a fixed-price contract it is beneficial to specify the design further if friction increases. This may render renegotiation unnecessary and mitigate ex-post cost from renegotiating the contract. Consequently, with a cost-plus contract the optimal action is to hold on to a cost-plus contract. However, sufficient friction may cause the contracting parties to shift from a fixed-price contract to a cost-plus contract, since a cost-plus contract does not necessarily even require any renegotiation in order to be modified. If renegotiation is anticipated, and the contracting environment is complex enough, a cost-plus contract might thus turn out to be the most cost-efficient form of contracting.

6.4 General remarks about renegotiation

Renegotiation is likely to occur at some point of a risky long-term project. The contracting environment, or the design, can evolve over time such that a better outcome can be obtained if the original contract is revised. The renegotiation can be facilitated with an appropriate choice of contract structure: a simple cost-plus contract is fully flexible. In contrast, if the original contract is complex and of fixed-price form, the renegotiation costs are likely to be high. Revising the contract can be fully avoided only if the renegotiation costs are sufficiently high.

Theoretically, the outcome from a renegotiated contract can approach the equilibrium if the ex-post surplus is divided between the contracting parties in relation to their negotiation power. However, as seen in the previous chapter, this approach leads to underinvestment, when the investments are project-specific.

Another issue discussed in this chapter is contractual incompleteness. Since writing a fully contingent contract is extremely costly, incompleteness might actually be intentional. However, a complete contract would render renegotiation unnecessary. If contracting is sequential, then it is possible for the contracting parties to begin with incomplete contracts, and then gradually move towards a more complete form if friction arises. The contractual incompleteness, delayed benefits from the project and the lack of outside options create a holdup situation, which is likely to lead to the renegotiation of the contract.

In all, renegotiation literature is rather descriptive: the focus lies on the characteristics of the contracting parties or on how renegotiation can be avoided altogether. Since it is impossible to rule out renegotiation altogether, it might be worthwhile to limit the outcome from renegotiation already in the original contract. The contract design can also be used as a tool of mitigating friction in the renegotiation process, assuming that both parties have agreed to predetermine the renegotiation process.

7 Conclusions and practical implications

Customarily, the contracting for major procurement projects has been seen mainly as a juridical, financial and managerial issue. Economic insight has not been applied to greater extent. Whereas economics as a science tends towards theoretical simplifications, the Fennovoima procurement project involves major complexities and uncertainties. In this thesis, these simplifications are used as a tool to dissect the complex procurement problem and to provide practical insight into overcoming some of the related risks. These risks have been gathered under the topics of bidding, contracting, holdup situations and renegotiation. Each chapter is started with the description of a relevant model.

Even though contract theory falls short of providing precise recommendations for the formulation of a complex long-term contract, it does provide insight into a variety of features that should be accounted for, and optimal solutions, if these features would not appear simultaneously in a complex interplay. The contracting guidelines presented in this chapter are based on this insight.

The first section of this chapter presents a research summary to remind the reader about the objectives and methods of this study. The second section concludes the managerial implications of the theoretical findings phase by phase. The bidding phase focuses on mitigating adverse selection through the supplier selection mechanism. As for contracting phase, the focus lies on the risk-sharing and on mitigating moral hazard through ex-ante and ex-post incentives. Holdups and renegotiation phase, in turn, are best governed through ex-post incentives. The chapter is summed up in the third section by a discussion on the limitations of the study and a presentation of potential topics for further research.

7.1 Research summary

The aim of the thesis was to provide insight into procurement contracting with asymmetric information. The procurement process was divided into four subsequent phases – bidding, contracting, holdups and renegotiation. Each of these phases was characterized by a simple model and the main threats for each phased were recognized. The literature was used to provide practical insight into the mitigation of these threats. As an outcome, recommendations for the organization of a contracting process are presented in section 7.2

Procurement contracting has been subject to rather little research. However, the recent shortcomings of contractual arrangements in the context of nuclear power plant industry have created demand for economic insight about long-term procurement contracts. Furthermore, the one-shot nature of the Fennovoima project does not allow for repeating the mistakes made in previous projects. In a wider context, studying procurement contracting is important not only for industry purposes but also for pointing out gaps in the previous research. When dynamics are introduced into contract theory, there is still little consensus about both what the main issues are and of their formulation.

7.2 Findings and managerial implications

The figure below (Figure 5: Solutions to contractual issues) presents the findings with regards to the theoretical framework presented in section 1.2 Adverse selection, taking place in the bidding phase, is theoretically best mitigated through screening or signaling. Moreover, the use of these tools is enabled by sufficient competition. Moral hazard, in turn, is best mitigated through an appropriate risk-sharing structure or ex-post incentives. The bidding and contracting phases form the static part of the theory, and the theory offers tools for achieving an ex-ante efficient outcome. However, introducing dynamics into the setting gives rise to holdups and renegotiation. Theoretically, the same solutions (risk sharing, ex-post incentives) can be used to achieve an ex-post efficient outcome.

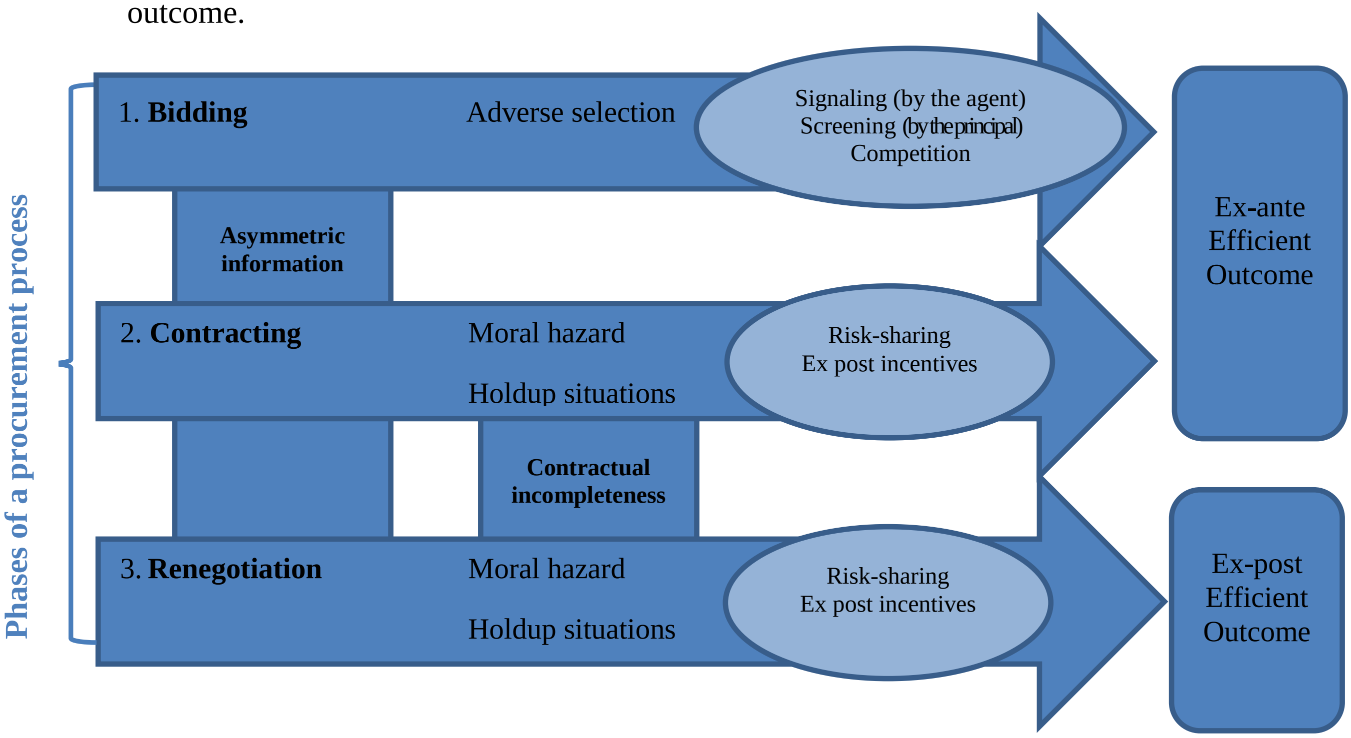

Figure 5: Solutions to contractual issues

In the bidding phase, Fennovoima is negotiating in parallel with two potential suppliers. The main concern of the company is to select a supplier who is capable of delivering a licensable product: if both suppliers are capable, then the task boils down to selecting the one who performs at a lower cost. Ideally, both bidders would qualify so that competition between the bidders could be maintained until final closure.

Two features stand out when the competing bidders are assessed against the literature. First, the French Areva has lately been involved in two largely overdue nuclear reactor projects, and has entered in a costly litigation process with another Finnish power company. This can be interpreted as a sign of the supplier’s type. Second, the Japanese supplier candidate Toshiba is likely to hold inferior information about the country-specific circumstances, which can both enhance the negotiation position of Fennovoima vis-à-vis Toshiba or induce a higher bid due to greater uncertainty faced by the supplier.

Whereas the precontractual phase is commonly characterized by private information about the supplier’s type leading to adverse selection, it may not the case in nuclear industry. Instead, adverse selection can be induced by the bidder's impropriety for the particular project and not necessarily a sign of inaptitude or unwillingness to perform. Theoretically, adverse selection can be mitigated in two ways. The first solution is signaling. In a signaling model, the supplier holds superior information about his type. The second solution, screening, is conducted by the uninformed buyer. Screening is executed through a menu of contracts, from which the informed supplier chooses the one that yields the best payoff, considering his ability. The supplier’s type is revealed through his selection of compensation scheme, and the informational asymmetry no longer exists. Signaling is of little significance in the setting of this thesis, since the uncertainty about the contingencies and the functionality of the design is likely to be bilateral: the supplier is as ignorant about the future outcome as the buyer is. Screening, instead, can in practice be executed through the selection of a suitable bidding mechanism.

Theoretically, a scoring auction between multiple supplier candidates allows for a close-to-optimal solution. However, the market features and the industry practices render an extensive auction impossible. Due to the thinness of the market and the high cost of negotiations, the number of potential suppliers has been limited to two in an early stage. Furthermore, the complexity of the product design deters the buyer from arranging a perfect scoring auction, accounting for all the required features and also the related risk-sharing structure in case of later modifications. Sequential bargaining, instead, allows for greater flexibility in terms of joint design development and bilateral reputation building. This phase is especially crucial for Fennovoima to establish a reputation as a credible buyer with full capability to execute and complete the project, since there exists no previous track record about the company.

To sum up, it is optimal for the buyer to weight the costs of double negotiations against the possible cost-savings from enhanced competition between the two suppliers – this should in part determine the duration of the parallel negotiations. Moreover, if the two supplier candidates seem to be equally qualified, it might be optimal to opt for the over which Fennovoima has an informational advantage.

7.2.2 Arrangements for contracting

In the contracting phase, Fennovoima's main concern is to induce the supplier to provide a sufficient level of quality at the lowest possible cost. Here it is important to notice, that the plant cannot be licensed if the basic product requirements are not fulfilled. Providing an insufficient level of quality is hence equal to non-delivery. Therefore *quality*, interpreted as the product features, is an exogenous factor. In contrast, *quality* in the context of this procurement project, should be interpreted as the timeliness of the delivery: the faster the delivery of the licensable plant, the higher the buyer's valuation.

The long delays in the current nuclear power plant projects require careful consideration – the selected supplier must be both capable and willing of timely delivery. Once the more suitable supplier has been selected, the contract must be structured so as to induce the supplier to exert optimal effort, i.e. the marginal cost of effort must equal the marginal benefit from effort. Theoretically, monitoring enables compensating the supplier for his effort. However, this compensation can only be determined once the project is completed and the payoff is known to the buyer. If performance-related incentives are sufficient, i.e. the supplier agrees to being compensated according to his observed effort level once the project is complete, the informational asymmetry is eliminated and no further compensation scheme need to be considered. However, the supplier is likely to require compensation for the risk he bears already during the project execution. Therefore the contracting parties must agree on an ex-ante compensation scheme, which includes a definition of the risk-sharing structure.

The risk-sharing literature examines a variety of features affecting the optimal choice. Table 1 sums up these features. As can be seen, the characteristics of the Fennovoima project involve an ambiguous effect on the optimal risk-sharing structure. First, if the supplier's reputation is good, or probability of repeated contracting is high, then a cost-plus contract would allow for greater flexibility and thus better quality. Moreover, the high complexity of the project and the high probability of changes in the design render renegotiation highly likely, which in turn make a cost-plus contract more desirable. However, cost reductions are best achieved through a fixed-price contract, whereas quality can be more easily mandated through a cost-plus contract. It might therefore be optimal for the supplier to divide the procurement contract into more refined subprojects, each of which can then be separately contracted.

Table 1: Considerations for risk-sharing

	Fixed Price	Cost Plus
Reputation	↓	↑
Chance of repeated contracting	↓	↑
Project complexity	↓	↑
Likelihood of changes in design	↓	↑
Importance of cost reductions	↑	↓
Importance of high quality	↓	↑

Whereas the supplier's ex-ante incentives can be defined through the risk-sharing structure, the ex-post incentives require further consideration. To fully align the incentives of the contracting parties, the supplier's payoff must be contingent on the buyer's payoff. Therefore the optimal contract includes ex-post incentives, which ensure that the low cost and timely delivery are in the best interest of the supplier, regardless the risk-sharing structure defined in the initial contract.

To sum up, it is optimal for Fennovoima as the buyer to consider both ex-ante and ex-post incentives. Ex-ante incentives are given significant weight due to the long duration and the high riskiness of the project. Ex-post incentives, in turn, contribute to aligning the goals of the contracting parties beyond covering the related risks. These incentives involve sharing ex-post surplus, i.e. a part of the buyer's payoff to be traded for the supplier's enhanced effort.

7.2.3 Holdups

Holdups and underinvestment are a relevant threat since the Fennovoima project requires project-specific investments from the contracting parties. With regards to holdups, Fennovoima's main concern is to incentivize an optimal investment level, i.e. equate the marginal cost of total investment with its marginal benefit. Holdups occur when the investing party is unlikely to receive full compensation for its investment. In the Fennovoima project a holdup can occur if the supplier sees that a significant proportion of the increase in the value of the project, induced by his additional investment, would accrue to Fennovoima, and that his additional compensation does not cover the additional expenses.

Whereas competition mitigates opportunism is the bidding phase, fair division of ex-post surplus mitigates opportunism in the contracting phase. Contractually, the parties need to ensure that a sufficient proportion of the additional payoff is given to the supplier so as to fully compensate for his investment.

Different forms of option contracts are considered as a theoretical solution to the underinvestment problem. However, a sequential ownership option, where the supplier would sell the project to Fennovoima. once the investments are made, is out of question due to the industry regulation. Another way of utilizing an option contract would be to give the supplier a buy option on a share of the utility once the project is completed. This scheme involves risk-sharing considerations with regards industry risks and e.g. electricity market, and merits further study on its own.

To sum up, holdup situation are best mitigated through adequate ex-post incentives, which coincides with the general findings about the contracting phase. When designing the incentive structure, the contracting parties must ensure that both parties are sufficiently compensated for their additional investments. In practice, the strongest ex-post incentives take the form of a joint venture. Weaker forms of ex-post incentives, in contrast, can be induced through schedule-related division of ex-post surplus. For instance, conditioning a part of the supplier’s compensation on the ex-post surplus generated within the target schedule would greatly contribute to the elimination of schedule-related risks.

7.2.4 Renegotiation

Due to the project complexity, Fennovoima is highly likely to enter into renegotiation with the selected supplier at some point of the project. The long duration of the project, volatility of the regulatory environment and potential incompleteness of the design all contribute to a high probability of renegotiations. The initial contracting principles apply at this stage, as well: both ex-ante and ex-post incentives need to be accounted for. The later in the project renegotiation takes place, the more weight can be allotted to the ex-post incentives. This means that as the project nears completion, the risk-sharing structure of the contract loses relevance, and a better outcome can be attained by focusing on the ex-post division of surplus. Moreover, closer the project is to completion, the more complete the renegotiated contract is likely to be. Consequently, renegotiations are most probable to take place in the earlier stages of the project.

If renegotiations are foreseen to incur high costs, it is recommendable to use a cost-plus contract. The buyer needs to consider whether the cost of renegotiation would exceed to cost increase due to the weaker cost reduction incentives a cost-plus contract offers. If, instead, a flexible renegotiation mechanism can be agreed upon in the initial contract and the contracting parties can commit not to deviate from it, a fixed-price contract can outperform the cost-plus form.

To sum up, renegotiations can be seen as a normal phase of a long-term procurement project. In case the supplier’s reputation is low, which can be signaled by e.g. a high number of past lawsuits and litigation processes, the renegotiation can be anticipated to incur high costs. In this case, it might be worthwhile for Fennovoima to invest in a more complete contract so as to minimize the likelihood or renegotiations. If, however, the contract is written so as to leave room for renegotiations, i.e. it is left incomplete, it is advisable to include a renegotiation mechanism in the original contract design, and to apply the same incentive principles that in the contracting phase.

7.3 Limitations of the study and topics for further research

The extent of the Fennovoima project sets a limitation to the depth of the analysis of this thesis. Rather than giving exact guidelines, this thesis aims at pointing out considerations that need to be accounted for in different phases of the procurement project. This is due to the fact that despite the extensive research on asymmetric information, there exists little literature about long-term procurement projects. As the purpose of this thesis was to give an overview on contract theory in procurement contracting, the four topics (bidding, contracting, holdups and renegotiation) have each received only relatively little attention. In particular, the theory on dynamic long-term contracts has not yet been canonized, and the presentation varies greatly between articles.

The imbalance between the main topics of this thesis is acknowledged. The risk-sharing rate has been analyzed in detail; however, research on the option contracts and the division of ex-post surplus is scarce. An optimal solution for a static contract can be achieved through careful mechanism design. However, as soon as the setting turns into a dynamic one, i.e. uncertainty, contractual incompleteness and therefore need for renegotiation is introduced into the scheme, the optimal allocating is no longer necessarily attainable through a simple contract. The challenges of defining an optimal contract for a complex dynamic setting also stem from the scarcity of the literature. Whereas static contracts and the related theory are well established, the literature about the dynamic setting is still to boom. Perhaps the need for theory is also growing stronger, as the complexity of contracting environment increases. The globalized markets, accelerating pace of R&D and evolving information technology, for instance, support the need for further research about complex dynamic contracts. It is no longer customary to automatically rely on repeated contracting in extensive projects – the trading culture has evolved towards global competition, instead of local good-will based stable networks.

This imbalance indicates an opening for further research: the ex-post incentives in the context of long-term contracting cannot be duly addressed in this thesis and deserve further attention. Combining these two topics – examining the optimal ex-post risk-sharing rate – would offer valuable insight into the formulation of an incentive-aligning long-term contract.

Another source of imbalance in the thesis stems from the lack of canonical understanding on the dynamic contracting setting. Whereas there exists a consensus on the presentation of the stable models, the relative youth of the theory on dynamic contracting challenges the elegant presentation of the holdup problem as well as formulating the renegotiation. Quite clearly, this shortcoming resonates with the lack of research on long-term contracts, and will hopefully be shortly addressed.

A cautionary word about the practical implications was given in section 7.2 . The theoretical overview on contracting is based on simplifying models, and reducing an extremely complex procurement situation into a descriptive study will fall short of providing a perfect framework for a real life procurement project. Therefore the findings of this thesis tend to be suggestive rather than positivistic.

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