universität wien

MASTERARBEIT / MASTER'S THESIS

Titel der Masterarbeit / Title of the Master's Thesis

The Interrelation Between Real Options and Agency Conflicts

verfasst von / submitted by

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angestrebter akademischer Grad / in partial fulfilment of the requirements for the degree of

Master of Science (MSc)

Wien, 2017 / Vienna 2017

Studienkennzahl lt. Studienblatt / degree programme code as it appears on the student record sheet:	A 066 915
Studienrichtung lt. Studienblatt / degree programme as it appears on the student record sheet:	Masterstudium Betriebswirtschaft
Betreut von / Supervisor:	Univ.-Prof. Dr. Thomas Pfeiffer

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1 Introduction

1.1 Motivation

The capability of a firm to develop and exploit new projects is a crucial factor in its success. In many organizations, shareholders delegate the investment decision to managers in order to benefit from their skills and expertise. Therefore, decisions about identifying and initiating new projects are often undertaken by the managers.

In projects without real options, agency conflicts can often be identified as a crucial issue due to the information asymmetry and goal conflict between the principal and the agent. This issue might be enhanced, when real options (e.g. an option to defer, to expand or to abandon) are considered in the context of the project.[1]

Furthermore, capital budgeting is a critical tool to determine how managers of firm should produce and exchange information regarding investment projects. Especially, the timing under which information is shared in a firm, for example between headquarters and divisional managers, is important for a firm's success. The real options literature points out that the budgeting process is flexible and dynamic. It can be stated that real options, especially in the form of abandonment options, are often part of the budgeting process.[2] Therefore, a significant part of this thesis will focus on the influence of an abandonment option on the optimal timing of information.

[1] Krychowski, C., & Quélin, B. V. (2010). Real options and strategic investment decisions: can they be of use to scholars?. The Academy of Management Perspectives, 24(2), 65-78.

[2] Pfeiffer, T., & Schneider, G. (2010). Capital budgeting, information timing, and the value of abandonment options. Management Accounting Research, 21(4), 238-250.

1.2 Objectives

Most literature focuses to the one-sided relationship between real options and agency conflicts. The aim of this thesis is to investigate the interrelation between these two research areas. This is obtained by: (i) showing how a control problem can make a real option valuable, and (ii) focusing on the reverse influence, i.e. revealing how an abandonment option influences the optimal timing of information.

In addition, this thesis provides guidance regarding how to reduce an agency conflict between the headquarters and the divisional manager in the context of a dynamic capital budgeting process.[3]

1.3 Contribution

This thesis contributes to the existing literature in various ways. First, a compact but comprehensive overview of the literature of both the real options approach and the agency theory is provided. This part of the thesis can be seen as a theoretical foundation for the following sections. It is noteworthy that the literature regarding the two underlying research fields remained separate for a long time. Technical difficulties were mainly responsible for this phenomenon. Agency problems have been mostly studied in discrete time, while real options are often explained in a continuous time framework.[4]

Furthermore, in the standard real options approach, usually there are no agency conflicts because it is assumed that the option's owner makes the exercise decision. However, shareholders and owners often delegate the option exercise decision to their managers. Therefore, as

[3] Pfeiffer, T., & Schneider, G. (2010). Capital budgeting, information timing, and the value of abandonment options. Management Accounting Research, 21(4), 238-250.

[4] Philippon, T., & Sannikov, Y. (2007). Real options in a dynamic agency model, with applications to financial development, IPOs, and business risk (No. w13584). National Bureau of Economic Research.

a second contribution, this thesis investigates and analyzes the reciprocal influences of real options and agency conflicts.

1.4 Structure

The present thesis is structured as follows: Section 2 provides a comprehensive overview of the literature on real options and introduces various types of real options. Section 3 deals with the agency theory. An overview about the literature is given and additionally, resource rationing and organizational slack is analyzed based on the model of Antle and Fellingham (1990).

The first part of section 4 reveals how a control problem makes an option to wait valuable by presenting the paper of Arya and Glover (2001). The second part of section 4 focuses on the reverse influence. This means, the influence of a real option (abandonment option) on the timing of information is investigated based on the paper of Pfeiffer and Schneider (2010). Section 5 concludes the thesis with a summary and discusses opportunities for future research.

2 Real Options Theory

2.1 Overview

This section introduces the different types of real options and presents their application. It aims to provide the reader with knowledge about the real options approach in order to understand the following sections in this thesis in which real options will be analyzed in a principal-agent setting.

The term real option was introduced by Stewart Myers in 1977 who conducted numerous studies in this field. According to Myers (1977), real options are decision opportunities for corporations or individuals.[5] Dixit and Pindyck (1994) define real options investments as sequential, irreversible investments made under uncertainty. In addition, they point out that real options are based on an analogy with financial options. For example, if a company has an opportunity to invest, it holds an option similar to a financial option. In other words, the company has the right, but not the obligation to buy an asset for a predetermined price at a specified time in the future. To give an example, consider a company owning a production plant. Depending on demand and competition, the company can choose to construct a plant of larger-capacity in order to generate economies of scale (growth option) or, on the contrary, to temporarily shut down the plant (option to defer). Thus, the company has the right, but not the obligation, to adapt the production capacity.[6]

[5] Myers, S. C. (1977). Determinants of corporate borrowing. Journal of financial economics, 5(2), 147-175.

[6] Dixit, A. K., & Pindyck, R. S. (1994). Investment under uncertainty. Princeton university press.

According to Kogut and Kulatilaka (1994), decision-making based on real options can be seen as an appropriate framework to face an ever changing world.[7]

In the same vein, Adner and Levinthal (2004) also emphasize that companies face uncertain future and suggest that the existing investment opportunities, are, to a significant degree, a function of their prior undertaken investment. The real option approach fits companies' strategic challenges by linking current decision-making to uncertain future.[8,9]

Triantis (2000) defines real options as opportunities to delay and adjust investment decisions over time to face uncertainty. Real options allow companies to postpone a decision until the moment or situation when the uncertainty regarding the opportunity has been reduced.[10]

Bowman and Moskowitz (2001) emphasize that real options models are based on the belief that there is a source of uncertainty, such as the price of an asset or the result of a research project. The outcome of the uncertain opportunity can be observed over time, and the firms are able to adjust their strategy.[11]

To sum up, it can be said that the real options approach can be an appropriate tool to face uncertainty. The real option approach was developed to help companies and their managers in their decision-making process under uncertainty. Based on the information at the moment of

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[7] Kogut, B., & Kulatilaka, N. (1994b). Options thinking and platform investments: Investing in opportunity. California Management Review, 36(2), 52-71.

[8] Adner, R., & Levinthal, D. A. (2004a). What is not a real option: Considering boundaries for the application of real options to business strategy. Academy of management review, 29(1), 74-85.

[9] Adner, R., & Levinthal, D. A. (2004). Real options and real tradeoffs. Academy of Management Review, 29(1), 120-126.

[10] Triantis, A. J. (2000). Real options and corporate risk management. Journal of Applied Corporate Finance, 13(2), 64-73.

[11] Bowman, E. H., & Moskowitz, G. T. (2001). Real options analysis and strategic decision making. Organization Science, 12(6), 772-777.

exercise, it allows managers to deal with uncertainty by generating new revenues and reducing costs.

Various researchers have pointed out that the majority of companies' decisions can be viewed through a strategic options lens (e.g., Bowman and Hurry 1993).[12] Examples of these decisions are: the termination of joint ventures (Kogut 1991), market entries, R&D programs, the management of multinational manufacturing networks (Kogut and Kulatilaka 1994), and capital budgeting decisions (Dixit and Pindyck 1994).[13] In the following, the mentioned decisions will be analyzed in more detail.

In the context of joint ventures a company has to take the decision whether it wants to invest into new markets, which are usually characterized by uncertain demand. Thus, the initial investment of a firm can be seen as buying the right to expand which corresponds to a real option.[14] A further area in which real options are beneficial is related to decisions regarding market entry. The real option approach allows firms that want to enter into a new market, to defer investments until the uncertainty is reduced. It can be determined that the higher the uncertainty, the higher the value of the option to defer.[15]

Additionally, another crucial benefit of the real options approach is that it takes into account that also initial investments, which are not profitable, could be beneficial for firms due to the fact that firms might gain

[12] Bowman, E. H., & Hurry, D. (1993). Strategy through the option lens: An integrated view of resource investments and the incremental-choice process. Academy of management review, 18(4), 760-782.

[13] Bowman, E. H., & Moskowitz, G. T. (2001). Real options analysis and strategic decision making. Organization Science, 12(6), 772-777.

[14] Kogut, B. (1991). Joint ventures and the option to expand and acquire. Management science, 37(1), 19-33.

[15] Krychowski, C., & Quélin, B. V. (2010). Real options and strategic investment decisions: can they be of use to scholars? The Academy of Management Perspectives, 24(2), 65-78.

new capabilities for the future (e.g., knowledge about the new market).[16]

R&D investments fit also with the real options approach. On the one hand, R&D investment decisions are usually taken under high uncertainty. On the other hand, the decisions can be handled flexibly due to the fact that the decision process is often segmented in different phases.[17] By analyzing patents of firms in the pharmaceutical industry McGrath and Nerkar (2004) find out that the investments of the firms are consistent with the real option approach.[18]

It is noteworthy that all the mentioned decisions have one aspect in common; they use a multiple stage process. In the first step, an investment is undertaken. The company purchases the option and gains the right to initiate the project. Later, the company decides whether to undertake further investments in the project or not. Taking into account that investment projects can evolve over time and that this flexibility has a value, is a crucial contribution of the real option approach.[19]

Furthermore, Kahneman et al. (1982) emphasize that due to cognitive biases, managers sometimes undertake an investment although they have received a negative feedback.[20] This behavior arises from the fact that decision-makers tend to accomplish projects in which they already have invested a significant amount. By considering alternative scenari-

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[16] Kogut, B., & Kulatilaka, N. (2004). Real options pricing and organizations: The contingent risks of extended theoretical domains. Academy of Management Review, 29(1), 102-110.

[17] Krychowski, C., & Quélin, B. V. (2010). Real options and strategic investment decisions: can they be of use to scholars?. The Academy of Management Perspectives, 24(2), 65-78.

[18] Gunther McGrath, R., & Nerkar, A. (2004). Real options reasoning and a new look at the R&D investment strategies of pharmaceutical firms. Strategic Management Journal, 25(1), 1-21.

[19] Bowman, E. H., & Moskowitz, G. T. (2001). Real options analysis and strategic decision making. Organization Science, 12(6), 772-777.

[20] Kahneman, D., Slovik, P., & Tversky, A. (1982). Judgment under uncertainty: Heuristics and biases. Cambridge: Cambridge University Press.

os the real options approach can help management to avoid this type of bias.[21]

2.2 Types of Real Options

The literature identifies various types of real options. In this subsection real options will be classified based on their flexibility.[22] The focus is set on the following three types of real options: The option to defer, the option to abandon, and the option to expand.

2.2.1 The Option to Defer

The first option, which will be analyzed, is the option to defer a project. As I will present in more detail later, decision-making about an investment based on the net present value (NPV) approach does only consider the value of the project at the time the calculation was undertaken. However, the value of a project may change over time. Consequently, a project that has a negative NPV today may have a positive NPV in the future. Therefore, the option to defer can be beneficial for decision-maker. Additionally, there are circumstances in which an option to defer can be also beneficial for a project with a positive NPV. This is the case when, for example a company holds a patent for a product. Due to development in connection with the production methods of the product, it can be assumed that the production will be cheaper in the near future. Thus, waiting might provide higher profit for the company.[23]

[21] Krychowski, C., & Quélin, B. V. (2010).
[22] Copeland, T. E., & Antikarov, V. (2001). Real options: a practitioner's guide. New York: Texere.
[23] Copeland, T. E., & Antikarov, V. (2001). Real options: a practitioner's guide. New York: Texere.

2.2.2 The Option to Abandon

The second of the three options is the option to abandon. This type of option is taken if the cash flows of the underlying project do not meet the expectations. An option to abandon can be structured as a put where a firm has the right to exit a project. Then, the exercise price corresponds to the amount required to abandon the project.[24] Later in this thesis, I will analyze the influence of an abandonment option on the optimal timing of information in a principal-agent setting.

2.2.3 The Option to Expand

The last option presented is the option to expand. An example for this type of option is a company that invests in a project with maybe a negative NPV, with the intention, to get an access to other projects with positive NPV's. Options to expand can frequently be observed in the context of market entries. In this context also a project with a negative NPV can enable firms to tap into new markets in order to generate new partnerships and get new customers.

2.3 Real Options vs. Financial Options

Regarding the difference between financial options and real options one main aspect can be identified. Real options are usually non-tradable assets. The price of a financial option is determined by the market, whereas the price of a real option is the cost of acquiring an opportunity. Therefore, usually an acquirer of a real option, in contrast to an acquirer of a financial option, is able to influence the value of the option in the option's maturity, as the value is dependent on good deci-

[24] Copeland, T. E., & Antikarov, V. (2001). Real options: a practitioner's guide. New York: Texere.

sions. Accordingly, managers have a significant impact on the value of the real option.[25]

In the following, I will introduce the characteristics of a financial call option in order to map an investment opportunity into a call option. Two types of options can be determined; European and American options. The option that will be used in the following is an European call, which can be exercised only on their expiration date, whereas, an American option can be exercised at any time up to the date of expiration. The value of a call option on a share of stock is assumed to be by five variables. The variables are stock price (S), exercise price (X), expiration time (T), risk-free rate of return (r_f) and variance of returns on stock (σ^2).[26]

The initial investment, which is required for a project, corresponds to exercising an option (X) on a share of stock. The stock price of a call option (S) is analogous to the present value of the investment of the project. Determining the present value for a real option may represent a challenge, in contrast to financial option where the value is usually provided by financial markets. The option's time to expiration (T) can be compared to the period of time the firm can defer the decision to invest without losing the opportunity to undertake the project. The time to expiration is not always easy to determine. For example, the decision to defer an investment depends often on the behavior of competitors and the development of the macroeconomic environment. A longer period to expiration may provide a higher value of the real option due to

[25] Kodukula, P., & Papudesu, C. (2006). Project valuation using real options: a practitioner's guide. J. Ross Publishing.

[26] Luehrman, T. A. (1998). Investment opportunities as real options: Getting started on the numbers. Harvard business review, 76, 51-66.

the fact that it enables decision-makers to learn more about the uncertainty.[27]

Further, the volatility, measured as the standard deviation of returns on the stock (σ) represents the uncertainty about the future value of the project's cash flows and corresponds to the riskiness of the project. The increase of the volatility affects the value of the option and provides the increase of the latter. Thus, the option value is affected significantly by the volatility. On the other hand, volatility is also the most difficult parameter to estimate. In contrast to financial options, for real options it is not possible to take historical volatilities of stock prices into account.

As has been argued, real options are usually non-tradable assets. Therefore, the price of a real option is not determined by the market. Finding the volatility parameter for real options can be achieved by taking volatility parameters from similar products which are traded on a market. For example, when oil fields are evaluated the historical oil price volatility can be considered as volatility parameter.[28] The risk-free rate of return (r_f) corresponds to the time value of money for both circumstances. This approach allows us to improve our understanding about the value of the project.

Table 1: Comparison of Financial and Real Option[29]

Financial Option	Real Option	Variable
Exercise price	Cost to acquire the asset (initial investment)	X

[27] Luehrman, T. A. (1998). Investment opportunities as real options: Getting started on the numbers. Harvard business review, 76, 51-66.
[28] Lund, M. W. (1999, June). Real options in offshore oil field development projects. In 3rd Annual Real Options Conference, Leiden.
[29] Burger-Helmchen, T. (2007). Justifying the origin of real options and their difficult evaluation in strategic management. Schmalenbach Business Review, 59.

Stock price	Present value of the investment of the project	S
Time to expiration	Time period the option is valid	T
Variance of the stock returns	Riskiness of the project	σ^2
Risk-free rate of return	Risk-free rate of return	r_f

2.4 Real Options vs. NPV

In this section, an investment decision based on the discounted cash flow (DCF) approach is analyzed which means that the NPV of the project will be calculated. The NPV is calculated as follows:

NPV = Present Value of Asset – Capital Expenditure Required

According to the NPV approach, a project should be only undertaken, if its NPV is positive due to the fact that only then the company's value is increased.

However, let us assume a situation, where the NPV and the option value are equal. This is the case when a final decision about a project can no longer be deferred, which corresponds to the point when the firm's option has reached the expiration date. At the expiration date the option value is, either $S - X$ or 0 and corresponds to the NPV (when the NPV is negative, the firm will not invest, thus the NPV is taken to be 0). Both approaches provide the same recommendation (exercise or not).[30]

The results from the NPV approach and option pricing will diverge, when investment decisions are deferred. Deferring an investment deci-

[30] Luehrman, T. A. (1998). Investment opportunities as real options: Getting started on the numbers. Harvard business review, 76, 51-66.

sion provides additional sources of value. First of all, it is generally preferred to rather undertake payments later than sooner (ceteris paribus) due to the fact that one can benefit from the time value of money on the deferred expenditure.[31]

In addition, during the period of waiting, after deferring the investment decision, the circumstances can change. Especially, the value of the underling project (e.g., asset, market entry or joint venture) may change. The situation might develop in two different directions. In the case of an increase of the value, one can benefit from it by exercising the option. However, if the value might go down, the investment decision is rejected. Waiting helps to avoid making poor investments. Therefore, deferring the investment decision might bring a significant advantage.

If we compare the NPV approach with the real option approach it can be stated that the NPV does not take into account the additional value provided by the deferment. The real option approach however, not only considers the possibility to defer but also delivers a method to quantify the value of deferring.

2.5 Black-Scholes Model

In the following I will introduce the famous Black-Scholes model with the aim to give an example of a financial option valuation model.[32] The Black-Scholes formula was introduced in 1973 by Fisher Black and Myron Scholes. The authors find out that by creating a replicating portfolio the option's value could be tracked by a levered position in the traded

[31] Luehrman, T. A. (1998). Investment opportunities as real options: Getting started on the numbers. Harvard business review, 76, 51-66.

[32] Black, F., & Scholes, M. (1973). The pricing of options and corporate liabilities. The journal of political economy, 637-654.

stock.[33] Two major assumptions are made by the formula. First, the stock prices are stochastic and follow a lognormal distribution with a constant level of volatility. Second, no arbitrage opportunities are available in the market.[34]

Black-Scholes formula for a European call option:

$$c = SN(d_1) - Ke^{r_f T}N(d_2),$$

where

$$d_1 = \frac{\ln\left(\frac{S}{X}\right) + (r_f + \frac{\sigma^2}{2})T}{\sigma\sqrt{T}}$$

$$d_2 = d_1 - \sigma\sqrt{T}$$

The call option's price is denoted by c, S corresponds to the stock price, X is the strike price, the risk free interest rate is denoted by r_f, T corresponds to the expiration time, and σ is the volatility of the stock price. In addition, the natural logarithm function is denoted by ln. $N(d_1)$ and $N(d_2)$ correspond to the standard normal cumulative distribution function for d_1 and d_2.[35]

[33] Kogut, B., & Kulatilaka, N. (2001). Capabilities as real options. Organization Science, 12(6), 744-758.

[34] Bowman, E. H., & Moskowitz, G. T. (2001). Real options analysis and strategic decision making. Organization Science, 12(6), 772-777.

[35] Hull, J., Treepongkaruna, S., Colwell, D., Heaney, R., & Pitt, D. (2013). Fundamentals of futures and options markets. Pearson Higher Education AU.

3 Agency Theory

3.1 Overview

This section aims to provide a profound understanding of the agency theory with a comprehensive overview of the relevant literature and analysing the theory's main aspects.

Jensen and Meckling (1976) emphasize that it is not possible for the principal to align the agent's interests to the principal's interests without any costs.[36] This issue, also known as the agency problem, is provided by the conflict of interests in the context of an agency contract, whereby a party (principal) delegates a task to another party (agent) that has to be implemented in the former's interest.

However, according to Jensen and Meckling (1976), it can be assumed that the agent will not always act in the principal's best interest. Various studies in the literature regarding agency theory deal with the relationship between the owners of a company and their managers who run those companies and make decisions.[37] Furthermore, analyses of agency theory have often focused on the mechanism implemented by the owners to align the managers' interests with their own interests.[38]

According to Zeckerhauser and Pratt (1985), managers have control over the company's available resources and have more information about the ongoing activities than the owners, which leads to an information asymmetry.[39] The managers may take an opportunistic ad-

[36] Jensen, M. C., & Meckling, W. H. (1976). Theory of the firm: Managerial behavior, agency costs and ownership structure. Journal of financial economics, 3(4), 305-360.
[37] Fama, E. F., & Jensen, M. C. (1983). Separation of ownership and control. The Journal of Law & Economics, 26(2), 301-325.
[38] Tosi, H. L., & Gomez-Mejia, L. R. (1994). CEO compensation monitoring and firm performance. Academy of Management journal, 37(4), 1002-1016.
[39] Zeckhauser, R. J., & Pratt, J. W. (Eds.). (1985). Principals and agents: The structure of business
(p. 37). Boston: Harvard Business School Press.

vantage of this situation.[40] Due to several reasons, the managers have incentives not to act in the interests of the company that aims to maximize the firm's value. A major reason is that a company has an undetermined life span, whereas a manager usually works only for a temporary period for the company.[41]

Agency theory is typically characterized by three underlying assumptions. First, the principal and the agent are both rational. Second, the agent is averse to effort and risk. Last, information asymmetry can be identified in the context of agency contracts.

In the following, I will introduce the developments of agency theory in the literature. It's evident that agency theory has developed along two different lines.[42] The two lines are positivist and principal-agent.[43] However, both streams have a common unit of analysis: The contract between the principal and the agent. Furthermore, they have similar assumptions about people, organizations, and information. Nevertheless, they differ regarding their mathematical rigor, dependent variables, and style.[44]

Positivist research focuses on situations in which the principal and the agent often have different goals, with the intention to limit the agent's self-serving behaviour.[45] This is explained in detail by two propositions. The first one emphasizes that outcome-based contracts reduce agent opportunism and the second deals with the information system. I will analyse both propositions later in this section.

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[40] Williamson, O. E. (1985). The economic intstitutions of capitalism. Simon and Schuster.
[41] Osakwe, C. (2002). Real option and adverse incentives: determining the incentive compatible cost-of-capital. Working Paper.
[42] Eisenhardt, K. M. (1989). Agency theory: An assessment and review. Academy of management review, 14(1), 57-74.
[43] Jensen, M. (1983) Organization theory and methodology. Accounting Review, 56, 319-338.
[44] Eisenhardt, K. M. (1989).
[45] Eisenhardt, K. M. (1989).

Furthermore, most positivist researches deal with a special case of the principal-agent relationship - the relationship between the owners and the managers of large public corporations.[46]

According to Jensen (1983), positivist agency theory can be seen as an enrichment of economics because it offers a more complex view of organizations.[47] Nevertheless, positivist agency theory is also criticized by organizational theorists as being too minimalist.[48]

In the following, the second line in the literature on agency theory will be presented. The principal-agent research has a strong focus on the general theory of the principal-agent relationship. In contrast to the positivist stream, the underlying theory of the principal-agent approach can be used for various agency relationships (e.g. lawyer-client, buyer-supplier).[49] In addition, comparing the two streams shows that the principal-agent theory is more abstract and mathematical.

However, it should be mentioned that both the positivist and the principal-agent theories are complementary and not competitive. The former identifies contract alternatives, and the latter determines the most efficient contract with regard to varying levels of outcome uncertainty, risk aversion and further variables.[50]

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[46] Berle, A., & Means, G. (1932). The modern corporate and private property. McMillian, New York, NY.

[47] Jensen, M. (1983) Organization theory and methodology. Accounting Review, 56, 319-338.

[48] Hirsch, P., Michaels, S., & Friedman, R. (1987). Dirty hands" versus "clean models. Theory and society, 16(3), 317-336.

[49] Harris, M., & Raviv, A. (1979). Optimal incentive contracts with imperfect information. Journal of economic theory, 20(2), 231-259.

[50] Eisenhardt, K. M. (1989).

The approach of the basic principal-agent model will be presented by using various levels of information and by mapping the associated types of contracts (behaviour-based or outcome-based contract).[51]

First, the case of complete information is assumed. The principal is able to observe the agent's effort. In this situation, a behaviour-based contract is more efficient than an outcome-based contract. The latter would only lead to a transfer of risk to the more risk-averse agent.

In practice, decision-making is usually done under uncertainty and incomplete information. Accordingly, such a circumstance leads to two aspects of agency problems. The first problem is adverse selection. In this case, the principal cannot totally verify if the agent really has the capability to perform like he claims (at the time of hiring or later when the agent is already working). The second problem is moral hazard. In this condition, the principal is uncertain regarding the agent's level of effort.[52]

The principle can overcome the unobservable behaviour provided by moral hazard or adverse selection in two different ways. First, the principal can invest in information systems (e.g. budgeting systems, new reporting approaches, and boards of directors) to receive information about the agent's behaviour. Information systems provide the principal with better information. The higher the principal's information level of the agent's real behaviour, the higher is the probability that the agent will act in the principal's interests. It can be stated that information systems are beneficial in the case of behaviour-based contracts and unnecessary when an outcome-based contract is used.[53]

[51] Demski, J. S., & Feltham, G. A. (1978). Economic incentives in budgetary control systems. Accounting Review, 336-359.
[52] Eisenhardt, K. M. (1989).
[53] Eisenhardt, K. M. (1989).

The second approach to reveal the unobservable behaviour consists of a contract on the outcomes of the agent's behaviour. Jensen and Meckling (1976) argue that due to adverse selection and moral hazard, fixed wage contracts are not always appropriate to reflect the principal-agent relationship. Eisenhardt (1985) emphasizes that fixed wage contracts may reduce the agent's motivation because his reward will be the same independent of his effort.[54] In this case, it might be beneficial to replace fixed wage contracts by compensation based on the company's performance.[55] Accordingly, the agent would thus have an incentive to perform well since his reward depends on it. However, contracting on the outcomes of the agent's behaviour leads to the risk being transferred to the agent. As the agent is presumably more risk averse than the principal, he is not willing to take more risks. Additionally, the performance of a company or a division is not completely dependent on the agent's behaviour. A company's success is also affected by political decisions, the economic environment, competitor behaviour and other factors. It can be stated that the lower the uncertainty about the outcome, the lower is the cost of shifting risk to the agent. Therefore, in this situation, outcome-based contracts are beneficial. When an increase of uncertainty can be observed, then shifting risk to the agent becomes less attractive due to higher costs. Consequently, in this case behaviour-based contracts are more attractive than outcome-based contracts.[56]

Although different variations of the simple agency model are observed in literature, the basis of all these variations is always similar. It consists of the trade-off between (i) the cost related to the measurement of

[54] Eisenhardt, K. M. (1985). Control: Organizational and economic approaches. Management science, 31(2), 134-149.
[55] Alchian, A. A., & Demsetz, H. (1972). Production, information costs, and economic organization. The American economic review, 62(5), 777-795.
[56] Eisenhardt, K. M. (1989).

behaviour and (ii) the cost of measuring outcomes and the transfer of risk to the agent.[57]

To sum up, by changing the assumption about the risk attitudes of the principal and the agent, different recommendations about the appropriate contracts can be determined. The simple agency model assumes a risk-neutral principal and a risk-averse agent; however, research shows that people have different risk attitudes.[58] For a less risk-averse agent, receiving risk from the principal causes no threat, and therefore an outcome-based contract is more attractive in such a case. Transferring risk becomes more costly for the principal when the agent is more risk-averse, and consequently a behaviour-based contract is more attractive in this situation. In the case of a more risk-averse principal, transferring risk to the agent is the preferred strategy and therefore, outcome-based contracts become more attractive again.[59]

Various researchers have adapted the simple agency model by loosening the assumed goal conflict between the principal and the agent. Without any goal conflict, the principal can be sure that the agent will act in his interest. Therefore, the principal does not require monitoring the agent. The utilization of outcome-based contracts due to incentive reasons is not required anymore, and risk-sharing is the only issue that exists between the principal and the agent. In this case, a behaviour-based contract is beneficial (for risk-averse agents).[60]

[57] Eisenhardt, K. M. (1989).
[58] MacCrimmon, K. R., & Wehrung, D. A. (1986). Taking risks: The management of uncertainty, Free Press. New York.
[59] Eisenhardt, K. M. (1989).
[60] Eisenhardt, K. M. (1989).

Additionally, in contrast to the simple model's assumption, outcomes are sometimes not easy to measure. In this case, the attractiveness of an outcome-based contract is reduced. Also, the duration of the principal-agent relationship influences the decision about the type of contract. The longer the relationship lasts, the more the principal learns about the agent's behaviour and the more the attractiveness of a behaviour-based contract increases.[61]

3.2 Rationing and Slack in a Two-Period Model

The following section sets the focus on the paper of Antle and Fellingham (1990) with the aim to introduce rationing and slack based on their model.[62]

The model consists of an owner of an investment project, who only has information about the distribution of possible rates of return and a manager, who was hired by the owner in order to implement the project. The manager has knowledge about the project's rate of return. Since the owner has less information about the project than the manager, an agency problem can be identified. The manager is able to receive economic rents through consumption of organizational slack. By rationing resources, however, the owner will try to reduce the exploitation. Consequently, the owner's lack of information provides inefficiencies in the form of organizational slack and resource rationing. Additionally, the underlying principal-agent model is characterized by the fact that both parties have linear preferences and the same rate of discount for future consumption.[63]

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[61] Lambert, R. A. (1983). Long-term contracts and moral hazard. The Bell Journal of Economics, 441-452.

[62] Antle, R., & Fellingham, J. (1990). Resource rationing and organizational slack in a two-period model. Journal of Accounting Research, 1-24.

[63] Antle, R., & Fellingham, J. (1990). Resource rationing and organizational slack in a two-period model. Journal of Accounting Research, 1-24.

Harris, Kriebel, and Raviv (1982) and Antle and Eppen (1985) also study intrafirm allocation problems.[64,65] However, it is important to take into account that their models are only one-period models. The model of Antle and Fellingham (1990) that will be presented in this section is a two-play extension of the model by Antle and Eppen (1985).[66]

Harris, Kriebel, and Raviv (1982) note that in a situation with asymmetric information and moral hazard, for optimal transfer-pricing schemes, trading off ex-post inefficiencies is the right strategy in order to achieve ex-ante optimality. Antle and Eppen (1985) show how Harris, Kriebel, and Raviv's approach is able to rationalize the existence of organizational slack and capital rationing.[67]

3.2.1 The Model

As already mentioned, the model of Antle and Fellingham (1990) is a two-play extension of the model in Antle and Eppen (1985). The model includes an owner and a manager. The owner of the company is considering two one-period projects. Resources are consumed at the beginning of each period. Additionally, a third period exists in which remaining resources are consumed. Productive activity, however, takes place only in each of the first two periods. The rates of return that can be generated are denoted and labeled as $\rho_1 \leq \rho_2 \leq \ldots \leq \rho_N$. One of the N rates of return can be generated in each period.[68,69]

The information about the real rates of return can be only observed by the manager at the beginning of each period. A nondegenerate probability distribution over $\{\rho_1, \rho_2, \ldots, \rho_N\}$ summarizes the owner's beliefs

[64] Harris, M., Kriebel, C. H., & Raviv, A. (1982). Asymmetric information, incentives and intrafirm resource allocation. Management Science, 28(6), 604-620.
[65] Antle, R., & Eppen, G. D. (1985). Capital rationing and organizational slack in capital budgeting. Management science, 31(2), 163-174.
[66] Antle, R., & Fellingham, J. (1990).
[67] Antle, R., & Fellingham, J. (1990).
[68] The authors assume the cost of resources to be constant and equal to $\rho_0 \leq \rho_1$.
[69] Antle, R., & Fellingham, J. (1990).

about the rates of return. The owner's assessment of the marginal probability that ρ_i is realized in a period is denoted by p_i. Thus, p_{ij} denotes the joint probability of ρ_i in period 1 and ρ_j in period 2. The rate of return of the second period is independent of the rate of return of the first period, thus $p_{ij} = p_i p_j$.[70]

At the beginning of period one, the two parties must determine the amount of resources (y_t) that the manager will receive at the beginning of period t and the amount that the manager has to transfer to the owner (x_t) at the end of period t. This decision is binding for both parties for the entire lifetime of their relationship. The amount of return generated by the project and transferred to the owner is limited by x^{max}.[71]

The actual investment in the project can only be controlled by the manager due to decentralized implementation of the projects. This amount is denoted by z_t. In addition, it is assumed that the manager has no resources; therefore, the invested amount z_t is provided only by the owner, either in the current period or it can be carried over from the first period to the second. After learning the rate of return in period t, the manager provides the owner with a report regarding the applicable rate of return. The manager may consume more resources then invested (organizational slack). If the rate or return are assumed to be ρ_i and the target is x_i, then the amount of resources z_i will correspond to $x_i/(1+\rho_i)$. Let $c_i = 1/(1+\rho_i)$, $i = 0, 1, \ldots, N$ denote the discount factors.[72] Consequently, an allocation of $y_i(y_{ij})$ and a target $x_i(x_{ij})$ provides the manager with the utility $y_i - c_i x_i(y_{ij} - c_j x_{ij})$. The utility is discounted with the factor c_0. Furthermore, it is assumed that manager's preferences are additive over time. By taking into account the con-

[70] Antle, R., & Fellingham, J. (1990).
[71] Antle, R., & Fellingham, J. (1990).
[72] Antle, R., & Fellingham, J. (1990).

straints that will be presented below, the owner determines the resources transferred and the targets that should be maximized. The expected net present value of the investment is:[73]

$$\max[\sum_{i=1}^{N} p_i(c_0 x_i - y_i) + c_0 \sum_{i=1}^{N}\sum_{j=1}^{N} p_i p_j(c_0 x_{ij} - y_{ij})]\,.^{74}$$

The first sum corresponds to the expected net present value provided by the first-period project, and the double sum is the expected net present value provided by the second-period project.[75]

Antle and Fellingham (1990) propose that the owner faces four types of constraints:

(1) **Individual Rationality Constraints (IR):** Given the manager's knowledge regarding the rate of return of the first-period, the contract offered to the manager must be enough attractive, which is the case, if the manager's expected utility equals at least his reservation utility which is denoted by U_{min}:

$$y_i - c_i x_i + c_0[\sum_{j=1}^{N} p_j(y_{ij} - c_j x_{ij})] \geq U_{min}\ i = 1, \ldots, N. \qquad (IR)$$

(2) **Self-Selection Constraints (SS):** The contract must ensure that the manager reports truthfully the rate of return in each period to the owner. Two sets of constraints are supposed. The first set provides that the manager reports truthfully in the second period independently from manager's first-period report. The second set makes sure that the contract induce that the manager reports truthfully in the first period given he will report truthfully in the second period:

[73] The opportunity rate $\rho_0$corresponds to the discount factor.
[74] Antle, R., & Fellingham, J. (1990).
[75] Antle, R., & Fellingham, J. (1990).

$$y_{ij} - c_j x_{ij} - y_{ik} + c_j x_{ik} \geq 0 \quad i,\ j,\ k = 1, \ldots, N. \quad (SS2)$$

$$y_i - c_i x_i - y_i + c_i x_j + c_0 \left[\sum_{k=1}^{N} p_k (y_{ik} - c_k x_{ik} - y_{jk} + c_k x_{jk})\right]$$

$$\geq 0 \; for \; i,\ j = 1, \ldots, N. \quad (SS1)$$

(3) **Resource Feasibility Constraints (RF):** All the resources invested by the manager are provided by the owner. Resources from the first period can be carried over to the following period and grow at the rate c_0.

$$y_i - c_i x_i \geq 0 \quad i = 1, \ldots, N. \quad (RF1)$$

$$y_i - c_i x_i + c_0 \left(y_{ij} - c_j x_{ij}\right) \geq 0 \; i, j = 1, \ldots, N. \quad (RF2)$$

(4) **Output Feasibility Constraints (OF):** These constraints reflect the fact that the amounts transferred to the owner cannot exceed x^{max}. They ensure nonnegative production and enable the existence of an optimum in the presence of the linear production technology. Constraints for the output for each period:

$$0 \leq x_i \leq x^{max} \; i = 1, \ldots, N. \quad (OF1)$$

$$0 \leq x_{ij} \leq x^{max} \; i, j = 1, \ldots, N. \quad (OF2)$$

The owner's problem can be characterized as a linear program and consists of maximizing the expected net present value of his investment (1) subject to the mentioned constraints.[76]

[76] Antle, R., & Fellingham, J. (1990).

3.2.2 Results

First, the solution under full information is analysed, the so called 'first-best' solution to the owner's problem. According to traditional capital-budgeting analysis, if the rate of return is higher than the cost of capital, the production of x^{max} is recommended.[77] This implies that only the amount of resources are provided which is required to enable the production of the target (i.e., $y_i = c_i x^{max}$). Consequently, only the realized rate of return of the period influences the targets and transfers between the owner and manager.[78]

Antle and Fellingham (1990) point out some features of optimal contracts. For example, optimal contracts provide no slack for a manager who gets the lowest rate of return in each period. Additionally, optimal contracts demand x^{max} in any period in which the rate of return is the highest.[79]

The model by Antle and Fellingham (1990) allows that the manager can consume slack in each period. By considering the owner's presumed capacity to commit, the owner has the possibility to rearrange the manager's consumption of slack without any cost.[80] For a contract which enables slack for the manager in the first period, another contract may be determined that provides for the same behaviour from the manager, and which provides the same discounted expected profits for the owner; however, it enables all the slack in the second period for the manager. The aim of this proposition, which is illustrated in Antle and Fellingham's (1990) Lemma 1, is to simplify the owner's problem by

[77] In the underlying model the rate of return is always higher than the cost of capital.
[78] Antle, R., & Fellingham, J. (1990).
[79] Antle, R., & Fellingham, J. (1990).
[80] Antle and Fellingham (1990) assume that the owner can commit to the contracts over both periods.

requiring for all the first-period resource feasibility constraints to hold as equalities.[81]

According to the authors' Lemma 1, for any feasible contract, there is another feasible contract that has the same value regarding the objective function and in which the resource feasibility constraints of the first period $(RF1)$ hold as equalities. Antle and Eppen (1985) suggest how to construct an optimal contract with no commitment. There are two possible setups. First, neither production nor resources are allocated. Second, the owner offers the manager production at x^{max} in connection with the allocation of a sufficient amount of resources to reach the target; however, only if the critical rate of return is achieved. This critical rate of return corresponds to the so-called hurdle rate. The discount factor related to the hurdle rate is denoted c_k and k^* is given by:

$$k^* \underset{k}{\text{maximizes}} \, (c_0 - c_k) \sum_{i=k}^{N} p_i \,.^{82}$$

In addition, Antle and Fellingham (1990) give a definition for the concept of memory. A contract implies memory whenever both production targets and resources transferred in the second period also depend on the first period outcome.[83] Furthermore, a contract can be defined as myopic if the outcome of the first period does not influence the second-period values ($y_{ij} = y_j \; \forall \; i,j \; and \; x_{ij} = x_j \forall \; i,j$).[84]

According to the optimal myopic strategy, x^{max} should be produced if the rate of return reported by the manager is higher than ρ_{k*}. In this situation, the resources transferred to the manager are $c_{k*}x^{max}$. Otherwise, if the reported rate is less than ρ_{k*}, the manager will receive no

[81] Antle, R., & Fellingham, J. (1990).
[82] Antle, R., & Fellingham, J. (1990).
[83] The underlying dependence should not be trivial.
[84] Antle, R., & Fellingham, J. (1990).

resources. Slack can be observed whenever the rate of return is higher than the hurdle rate, and consequently, if the rate of return is less than the hurdle rate, rationing can be identified.[85]

In the following the question how a contract with memory can improve on the myopic solution will be analyzed by revealing how the myopic solution provides truthful reporting. The analysis will focus on three different situations in which true rates of return are (i) less than, (ii) higher than, or (iii) as high as the hurdle rate.[86]

Table 2: Effects of different rate of returns

True Rate of Return	Reported Rate by Manager	Slack Generated
Below the hurdle rate	Manager will report the true rate of return.	No slack can be consumed by the manager under the optimal myopic contract. Reporting a rate of return under the hurdle rate provides that no resources are allocated. Reporting a rate higher than the hurdle rate would mean an unachievable production target.
Rate of return higher than hurdle rate	Optimal myopic contract provides that manager reports truthfully.	Rates higher than hurdle rate provides no additional resources for the manager due to the reason that the owner does not distinguish between rates of return equal to the hurdle rate

[85] Antle, R., & Fellingham, J. (1990).
[86] Antle, R., & Fellingham, J. (1990).

		and rates higher than the hurdle rate. Consequently the manager has no incentive to report a rate higher than the hurdle rate.
Rate of return equal to the hurdle rate	The optimal myopic contract provides that the manager is indifferent in this situation.	Reporting the true rate, which corresponds to the hurdle rate, generates no slack because the owner will transfer only the exact amount of resources required to meet the target.

It can be stated that the optimal myopic contract accepts no production at rates of return below the hurdle rate with the aim to enhance truthful reporting of the hurdle rate.[87]

There is another approach that also provides honest reporting of an ‘interior’ hurdle rate but at lower costs. In this context, interior means that there is at least one rate of return that is higher and one rate of return that is lower than the underlying hurdle rate. Due to this interior hurdle rate, the optimal myopic contract contains slack as well as rationing. If the owner is able to commit to contracts that include memory, the slack is provided in such a way that it enables a decrease of rationing in the second period. In the following, this approach will be illustrated on the basis of the optimal myopic contract and by assuming a first-period rate of return that is strictly higher than the myopic hurdle rate, which means that the manager will get slack. Antle and Fellingham (1990) use Lemma 1 to move a part of the slack to the second period with the intention that it can be aligned in such a way that ensures its

[87] Antle, R., & Fellingham, J. (1990).

discounted expected value. Therefore, the needed amount of slack is evenly distributed among the second-period rates of return at least as high as the underlying hurdle rate.[88]

This approach provides a second-period contract, which is similar to a myopic contract. The only difference is that the manager's resources are higher than the hurdle rate. The manager will receive positive slack in excess of the amount, which can be achieved by reporting a lower rate than the hurdle rate, in case the hurdle rate is observed in the second period. Consequently, it is unnecessary to not provide resources for rates or return under the hurdle rate in order to ensure that the manager reports the hurdle rate truthfully. Despite the rate of return being lower than the hurdle rate, production can be achieved without affecting the manager's willingness to report truthfully. In addition, the production is profitable as well because all the rates of return are higher than the cost of capital.[89]

According to Theorem 1 of Antle and Fellingham (1990), it can be identified that if the optimal myopic hurdle rate is interior, then the solution regarding the owner's problem includes memory. In addition, Theorem 1 reveals that by exploiting both the ability to commit and the manager's uncertainty regarding the rate of return of the second period, the owner can reduce the cost for eliciting truthful reports by the manager.[90]

However, Antle and Fellingham (1990) suggest that although the optimal hurdle rate is not interior, nevertheless the owner's problem might include memory. In order to prove this assertion, the authors consider two possible rates of return. Accordingly, with two rates of return, the optimal myopic contract is either a rationing or a slack contract. The first one is applied only if the manager reports a high rate of return and

[88] Antle, R., & Fellingham, J. (1990).
[89] Antle, R., & Fellingham, J. (1990).
[90] Antle, R., & Fellingham, J. (1990).

the latter one provides full production and allocates resources always if low rates of return are reported.

In the underlying situation, four types of contracts could be optimal: (i) myopic slack, (ii) myopic rationing, and (iii) two variations of memory contracts (mem1 and mem2).[91,92] By considering the ratio of the cost of slack and the cost of rationing $R = \frac{p_2\ (c_1 - c_2)}{p_1\ (c_0 - c_1)}$, Antle and Fellingham (1990) provide a solution to the owner's problem.

The authors' Theorem 2 points out the following findings:

(1) The myopic rationing contract is only optimal if $R \geq 2$.

(2) The mem1 contract is optimal only if $2 \geq R \geq 1$.

(3) The mem2 contract is optimal only if $1 \geq R \geq p_1$.

(4) The myopic slack contract is optimal only if $p_1 \geq R$.

To sum up, the paper by Antle and Fellingham (1990) analyses the optimal allocation regarding a multi-period resource allocation problem, in which the members have different information and goals. The paper reveals that gains to long-term contracts can be achieved by increasing the owner's ability to ensure that the manager reports truthfully about his private information. This is achieved by combining the slack in connection with myopic contracts with an interior hurdle rate in order to ensure additional motivation to report favourable rates of return in the second period. Furthermore, the authors' solution to the case of two rates of return points out that it is not always possible to improve the myopic contract.[93]

[91] Antle, R., & Fellingham, J. (1990).
[92] The definitions of the contracts are presented in the appendix.
[93] Antle, R., & Fellingham, J. (1990).

4 Real Options in an Agency Setting

In the standard real options approach, there are no agency conflicts because it is assumed that the option's owner undertakes the decision-making. However, as has been argued above, the owners often delegate the decision regarding the exercise of options to managers.

It can be stated that if real options are involved in the principal-agent setting, the risk of the managers taking advantage from the aforementioned information asymmetry increases due to the fact that they are required to take multiple decisions during one project. Hence, they have more opportunities to benefit from the information asymmetry and to follow their own interest.

4.1 Control Problem and Option to Wait

The following section introduces the paper by Arya and Glover (2001) in order to illustrate how a control problem makes the option to wait valuable. As mentioned, deferring a project can be valuable because it reduces uncertainty. Furthermore, changes and improvements in the environment may also make the option to wait valuable, for example, in consequence to a reduction of interest rates, a project with an initial negative NPV suddenly has a positive NPV. According to Arya and Glover (2001), a control problem can also make an option to wait valuable. It should be mentioned that this option to wait would not have been valuable otherwise.[94]

4.1.1 The Model

The model by Arya and Glover (2001) is based on that of Antle and Eppen (1985) and is a variant of the one by Antle and Fellingham (1990), which was presented above. It consists of a risk-neutral princi-

[94] Arya, A., & Glover, J. (2001). Option value to waiting created by a control problem. Journal of Accounting Research, 405-415.

pal and a risk-neutral agent, who contract for two periods. The underlying control problem deals with the trade-off between production and information rents (slack) in the context of a capital budgeting model. The principal has the chance to invest in a project at the beginning of each period (project 1, project 2). Cash inflow of X is provided by each project at the end of the period and it asks for a cash outflow of cX at the beginning of the period if the project is undertaken (where $c \in \{c_L, c_H\},\ c_L < c_H$). The principal's one-period discount factor is denoted by $c_0, c_H < c_0 < 1$.[95] The common knowledge of marginal probability that a project's cost is c_i $(i = L,\ H)$, is denoted by $p_i,\ p_i > 0$. It can be emphasized that the costs of the two projects are not correlated. Thus, $p_i p_j$ denotes the joint probability that project 1's cost is c_i and that project 2's cost is c_j.[96]

The project's cost within a period is privately learned by the manager at the beginning of the period. The principal seeks a report of the project's cost by the manager so that he can decide about the project's approval. The approval for project 1 and project 2 are made at the beginning of period 1 and period 2 respectively. All resources are provided by the principal.[97]

Let c_k denote the cost of project 1 reported by the agent. The principal can accept the project ($x_k^1 = X$) or reject it ($x_k^1 = 0$). Resources received by the agent from the principal at the beginning of period 1, are denoted by y_k^1. The cash inflow that is transferred from the agent to the principal at the end of period 1 is x_k^1. Furthermore, assuming that the agent reports the project 1 cost of c_k and the project 2 cost of c_m, then the principal will either accept ($x_{km}^2 = X$) or reject ($x_{km}^2 = 0$) the project. At

[95] Even a high cost project has a positive NPV due to the fact that the lower bound on the discount factor implies $c_0 X - c_H X > 0$. In addition, the upper bound on the discount factor denotes that the principal's cost of capital is positive.
[96] Arya, A., & Glover, J. (2001).
[97] Arya, A., & Glover, J. (2001).

the beginning of period 2, the agent receives resources y_{km}^2 from the principal. In return, x_{km}^2 denotes the cash inflow that the principal receives at the end of the period. It is assumed that the agent has the incentive to consume organizational slack.[98]

The utility function of the agent is:

$$y_k^1 - c_i x_k^1 + c_0(y_{km}^2 - c_j x_{km}^2).$$

The true costs are denoted by c_i and c_j. In addition, c_k and c_m are the reported costs. The utility is discounted by the factor c_0. The utility function of the principal is denoted by $c_0 x_k^1 - y_k^1 + c_0(c_0 x_{km}^2 - y_{km}^2)$.[99]

The various phases of projects 1 and 2 (when approval decision is undertaken early) can be illustrated in Figure 1:

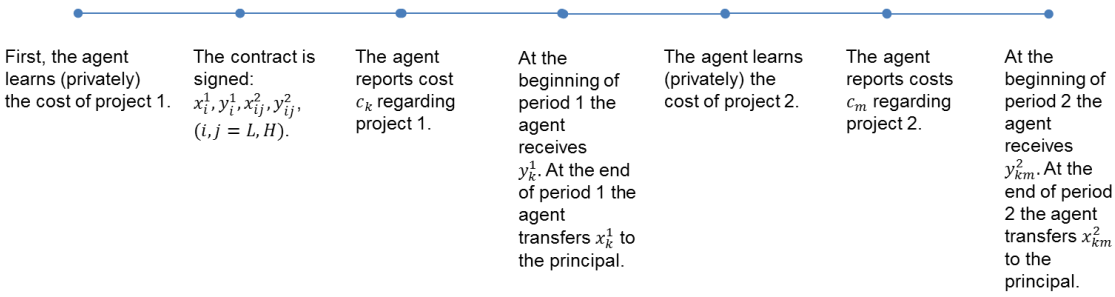

Fig. 1: Early approval decision

The principal's aim is to maximize the expected utility subject to various constraints that will be presented. The constraints are similar to the constraints of Antle and Fellingham (1990) introduced above. The four constraints are: i) individual rationality constraints (IR), ii) self-selection constraints (SS^1 and SS^2), iii) resource feasibility constraints (RF^1 and RF^2), and iv) output feasibility constraints (OF).[100]

[98] Arya, A., & Glover, J. (2001).
[99] Arya, A., & Glover, J. (2001).
[100] Arya, A., & Glover, J. (2001).

The individual rationality constraints (IR) ensure that the contract is attractive enough for the agent. Accordingly, the agent should receive an expected utility at least as high as his reservation utility (U_{min}), regardless of the project's cost. Furthermore, the self-selection constraints (SS^1 and SS^2) provide that the agent is willing to report the cost of the projects truthfully. The resource feasibility constraints (RF^1 and RF^2) ensure that the contract offers the agent a non-negative slack for every period in which he has reported truthfully. In addition, the agent can transfer resources from the first period to the subsequent period. These resources are assumed to grow at the rate of r_0 (where $c_0 = 1/(1 + r_0)$). And finally, the output feasibility constraints provide that the implementation of the projects can either be accepted or rejected.[101]

In the following, the principal's program (P1) is depicted:[102]

$$\underset{xy}{\text{Max}} \sum_{i=L,H} p_i[c_0 x_i^1 - y_i^1] + c_0 \sum_{i=L,H} \sum_{i=L,H} p_i p_j \left[c_0 x_{ij}^2 - y_{ij}^2\right]$$

s.t.

$$y_{ij}^2 - c_j x_{ij}^2 \geq y_{ik}^2 - c_j x_{ik}^2 \qquad \forall i,j,k \quad (SS^2)$$

$$y_i^1 - c_i x_i^1 + c_0 \sum_{j=L,H} p_j \left(y_{ij}^2 - c_j x_{ij}^2\right) \geq y_k^1 - c_i x_k^1 + c_0 \sum_{j=L,H} p_j \left(y_{kj}^2 - c_j x_{kj}^2\right) \qquad \forall i,k \quad (SS^1)$$

$$y_i^1 - c_i x_i^1 \geq 0 \qquad \forall i \quad (RF^1)$$

$$\frac{1}{c_0}(y_i^1 - c_i x_i^1) + y_{ij}^2 - c_j x_{ij}^2 \geq 0 \qquad \forall i,j \quad (RF^2)$$

$$x_i^1, x_{ij}^2 \in \{0, X\} \qquad \forall i,j \quad (OF)$$

[101] Arya, A., & Glover, J. (2001).

[102] It is noteworthy that for simplicity $U_{min} = 0$. Consequently, the individual rationality constraints are dominated by the resource feasibility constraints.

The program (P1) above is related to the situation when the decision for approving project 1 is made in period one. However, Arya and Glover (2001) suggest a solution where the approval decision of project 1 can be deferred to the beginning of period two. Consequently, the principal can condition his approval decision for the two projects on the agent's cost report regarding both projects. For this reason, x_i^1 and y_i^1 develop to x_{ij}^1 and y_{ij}^1.

The various phases of projects 1 and 2 (when approval decision is undertaken late) can be illustrated in Figure 2:

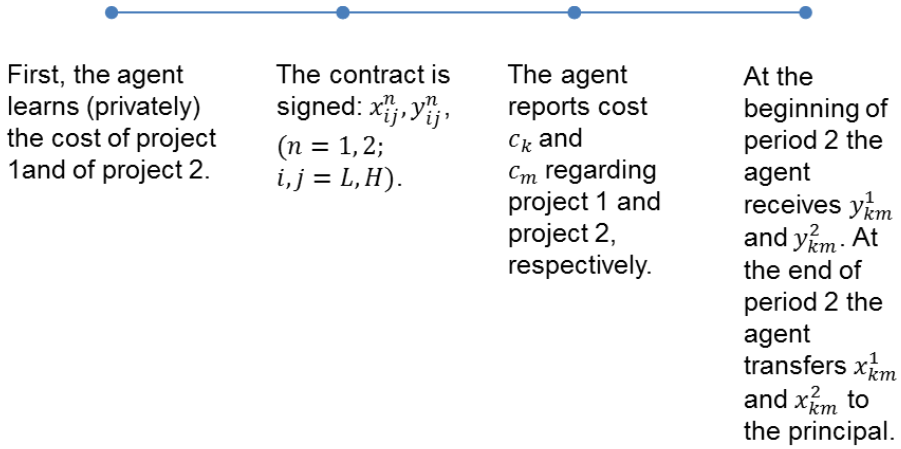

Fig. 2: Late approval decision

By deferring the approval decision, the contracting problem of the principal (given in program [P2]) also changes. The constraints of program (P2) differ from the constraints of program (P1). In program (P1) there are two self-selection constraints (SS^1 and SS^2), whereas in program (P2) is only one self-selection constraint (SS). In (P1), the constraint SS^1 makes the agent to report truthfully on project 1's cost under the assumption that he does not know the cost of project 2. The new constraint (SS) enables honest reporting by the agent assuming that he knows about the costs of both projects when he is reporting. The resource feasibility constraints in program (P2) are equivalent to program (P1). In (P1), it is assumed that the agent can transfer slack from the

first period to the second period. (P2) provides that the agent cannot transfer any slack to the second period. This is because with risk-neutral participants, who have identical discount rates, it does not entail any cost for the principal to transfer slack from the first period to the end of the second period.[103]

$$\underset{x\ y}{\text{Max}}\, c_0 \sum_{i=L,H} \sum_{i=L,H} p_i p_j \left[c_0 x_{ij}^1 - y_{ij}^1 + c_0 x_{ij}^2 - y_{ij}^2\right]$$

s.t.

$$y_{ij}^1 - c_i x_{ij}^1 + y_{ij}^2 - c_j x_{ij}^2 \geq y_{km}^1 - c_i x_{km}^1 + y_{km}^2 - c_j x_{km}^2 \quad \forall i,j,k,m\ (SS)$$

$$y_{ij}^1 - c_i x_{ij}^1 \geq 0 \qquad \forall i,j\ \ (RF^1)$$

$$y_{ij}^2 - c_j x_{ij}^2 \geq 0 \qquad \forall i,j\ \ (RF^2)$$

$$x_{ij}^1, x_{ij}^2 \in \{0, X\} \qquad \forall i,j\ \ (OF)$$

4.1.2 Results

In contrast to Antle and Fellingham (1990), the principal has the opportunity to defer the approval decision for the first project until the second period. This choice has an advantage as well as a disadvantage. The advantage of waiting is provided by the fact that the principal's information is improved and he has the opportunity to base the first project's approval decision on the reported cost of the second project by the agent. Consequently, the principal is able to trade off production and rents better due to a diversification effect. By adding uncorrelated projects, the probability distribution of NPVs becomes less scattered. Consequently, the principal selects a cut-off so that production is lost

[103] Arya, A., & Glover, J. (2001).

only in the lower thin tail of the distribution and the agent receives significant rents only in the upper thin tail of the distribution.[104]

The disadvantage of waiting is due to the fact that the agent knows the second project's NPV when he reports his budget of the first project. Thus, in contrast to the situation in Antle and Fellingham (1990), the principal cannot fine-tune the production-slack trade-off anymore.[105]

By comparison of appropriate contracts for various situations, Arya and Glover (2001) give recommendations in what circumstances waiting may be beneficial. First, as a benchmark, they introduce a case where the principal has all the information about the cost of each project. Consequently, the solution for the underlying case is first-best. The first-best solution includes that all projects are approved. In addition, the agent receives the exact cost of production from the principal. If the principal waits, he would delay receiving the returns from a profitable project. In this first-best case, waiting would only entail costs.[106] Thus, if no control problem is given, the principal will not defer the approval decision for project 1.[107]

In the second situation, the authors introduce a case where the agent privately observes the project cost. They emphasize that the optimal contract in this case consists of a trade-off between rationing projects and limiting the agent's information rents. By considering a one-period and a one-project setting as in Antle and Eppen (1985), either the slack contract or the rationing contract can be identified as the optimal contract. The former contract implies that the project is always approved and that the principal transfers to the agent $c_H X$. Thus, his own payoff is $(c_0 - c_H)X$. Under the latter contract, the project is approved only if

[104] Arya, A., & Glover, J. (2001).
[105] Arya, A., & Glover, J. (2001).
[106] Since $c_0 < 1$, it is strictly costly for the principal to defer the decision.
[107] Arya, A., & Glover, J. (2001).

the costs reported by the agent are c_L. In this case, the agent receives $c_L X$ and the principal's payoff is equal to $p_L(c_0 - c_L)X$. The two contracts presented are the only ones that provide incentives for the agent to report truthfully. According to the revelation principle, either the slack contract or the rationing contract must be optimal. By comparing the two payoffs, it can be stated that the rationing contract is preferred over the slack contract if $R \leq p_L$, where $R := \frac{c_0 - c_H}{c_0 - c_L}$.[108,109]

If the setting of Antle and Eppen (1985) is extended, that is, if a second period and a second project are added, and additionally, a project approval decision is undertaken in each period (as in the setting (P1)), a two-fold replication of the slack or rationing contract would not necessarily be the optimal contract. As has been argued above, the principal may better trade off production and rent by exploiting the agent's uncertainty over the cost of the second period, when he is reporting on the first period's cost. Therefore, it can be stated that the new contract contains memory due to the fact that period two allocations depend on the cost reports of both periods one and two. Under this new setting, the principal offers the slack contract to the agent in period one. The agent is offered the rationing contract in period two if he has reported c_H in period one. However, if the agent reports c_L in period one, the principal will always approve the period 2 project and he will transfer the expected cost of the project to the agent.[110] The authors define this contract as the early approval contract.[111]

Furthermore, if the setting is so adapted that both project approval decisions are made at the same time (as in the setting in (P2)), a two-fold replication of the slack or rationing contract again would not necessarily

[108] Since $0 < c_L < c_H < c_0$, R lies between 0 and 1.
[109] Arya, A., & Glover, J. (2001).
[110] Antle and Fellingham (1990) provide a proof with the Mem2 contract.
[111] Arya, A., & Glover, J. (2001).

be the optimal contract. The agent does not experience uncertainty over the cost of the second period anymore when he is reporting the first period cost, and thus, the principal is not able to exploit any uncertainty. Nevertheless, the principal's information is improved since he can also take into account the agent's project 2 cost report, when he is making the approval decision for project 1. Accordingly, compared to the slack or rationing contract his ability to trade off production and rents is improved.[112]

The solution for (P2) can be determined as follows: Project 1 and project 2 are approved if the agent reports cost of $(c_{L,}\, c_L)$, $(c_{L,}\, c_H)$, or $(c_{H,}\, c_L)$. In this case, the agent is paid $(c_L + c_H)X$. If the reported cost corresponds to $(c_{H,}\, c_H)$, neither project 1 nor project 2 is approved by the principal. The authors define this contract as the late approval contract. Besides the presented solution, a two-fold replication of the slack or rationing contract is the only other existing solution for (P2).[113]

To sum up, it can be stated that there is no advantage in waiting in the first-best setting; however, if a control problem is introduced, it creates value for the option of deferring the approval decision of project 1 until period two.[114]

In order to identify the circumstances under which the late project approval is optimal, Arya and Glover have determined a proposition which states that if a control problem is assumed, the principal strictly prefers:[115]

(1) not to defer the approval decision of project 1 and offers the rationing contract if

[112] Arya, A., & Glover, J. (2001).
[113] Arya, A., & Glover, J. (2001).
[114] Arya, A., & Glover, J. (2001).
[115] Arya, A., & Glover, J. (2001).

$$0 < R < \frac{1-c_0 p_H}{c_0(1+p_{H)}}.$$

(2) to defer the approval decision of project 1 and offers the late approval contract if

$$\frac{1-c_0 p_H}{c_0(1+p_{H)}} < R < \frac{c_0 p_L p_H}{1-c_0 p_L}.$$

(3) not to defer the approval decision of project 1 and offers the early approval contract if

$$\frac{c_0 p_L p_H}{1-c_0 p_L} < R < \frac{p_L}{1-p_L p_H}.$$

(4) not to defer the approval decision of project 1 and offers the slack contract if

$$\frac{p_L}{1-p_L p_H} < R < 1.$$

According to Antle and Fellingham (1990), the solution to (P1) is, as already mentioned, a twofold replication of the slack or the rationing contract, or the early approval contract. Consequently, the principal's expected residual that results from the underlying contracts is $(c_0 - c_H)X + (c_0 - c_H)X$ for the slack contract, $p_L(c_0 - c_L)X + c_0 p_L(c_0 - c_L)X$ for the rationing contract, and $(c_0 - c_H)X + c_0 p_H p_L(c_0 - c_L)X + c_0 p_L(c_0 - p_L c_L - p_H c_H)X$ for the early approval contract.[116]

If the output feasibility constraints in (P2) are replaced with their continuous analogues (i.e., $x_i^1, x_{ij}^2 \in [0, X]$), the integer program is transformed to a linear program. Consequently, it enables the application of standard duality arguments in order to characterize the solution of the revised program. The mentioned standard duality arguments demonstrate that the solution to (P2) is a twofold replication of the slack or the

[116] Arya, A., & Glover, J. (2001).

rationing contract. In addition, a further solution consists of the late approval contract. These contracts provide the following expected residuals for the principal, respectively: $2c_0(c_0 - c_H)X$, $2c_0p_L(c_0 - c_L)X$ and $c_0(p_Lp_L + p_Lp_H + p_Hp_L)(2c_0 - c_L - c_H)X$.[117] It can be stated that if the slack (rationing) contract is optimal in (P2), the better decision for the principal is not to defer the approval decision for project 1. By not deferring the approval decision, and consequently offering the slack (rationing) contract, he can obtain a higher payoff due to the fact that $c_0 < 1$.[118]

Arya and Glover (2001) highlight two circumstances in which it is optimal to defer the approval decision for project 1. First, as mentioned above, the late approval contract is optimal under (P2). Second, if the principal's payoff, which results from the late approval contract, is higher than the optimal contract in (P1), it is also beneficial to defer the approval decision for project 1. The first condition is satisfied when the second condition is fulfilled.[119]

It is noteworthy that the payoff achieved under the early approval decision is not achievable if the project approval is deferred. If the costs are (c_L, c_H), the agent will not report truthfully due to the fact that he knows the cost of project 2 before he reports the cost of project 1. Consequently, he will report (c_H, c_H). This can also be seen by comparing the expected utility of the agent. If the agent reports truthfully, his expected utility is $c_0(c_H - c_L)X - c_0(c_H - p_Lc_L - p_Hc_H)X$. However, he can improve by reporting (c_H, c_H). Then, his expected utility would be $c_0(c_H - c_L)X$. Accordingly, the agent's uncertainty, which is provided by the fact that he does not know the cost of project 2 when he is reporting on the

[117] Arya, A., & Glover, J. (2001).
[118] Arya, A., & Glover, J. (2001).
[119] Arya, A., & Glover, J. (2001).

cost of project 1, is required in order to make the early approval contract allocations incentive beneficial.[120]

In contrast, the allocations determined under the late approval contract are not achievable under the early project approach. This is because the approval decision for project 1, when the cost reported is c_H, is conditioned on the cost report of project 2. Consequently, only project 1 is undertaken, if the cost report of project 2 is c_L. If the cost reported of project 2 is c_H, then project 1 is rejected. However, this type of conditioning is not achievable under the early project approval regime.[121]

To sum up, it can be stated that though waiting generates cost because the principal can no more exploit the agent's uncertainty over the project's future cost, waiting has nevertheless a huge benefit. If the principal delays the approval decision of project 1, it means that the approval decision of project 1 depends on the cost report of project 2, which is a crucial advantage.

4.2 Influence of Real Option on the Agency Conflict

The last section shows how a control problem makes an option to wait valuable. One question that might be interesting to focus on and which arises now is: How do real options influence the agency conflict? To be more precise, this section analyzes the impact of an option to abandon on the optimal timing of information. By introducing the paper of Pfeiffer and Schneider (2010), this influence will be revealed.[122]

In their paper, the authors analyze the influence of an abandonment option on the timing of information in a sequential adverse selection capital budgeting model.[123] Similar to Antle and Fellingham (1990) and

[120] Arya, A., & Glover, J. (2001).
[121] Arya, A., & Glover, J. (2001).
[122] Pfeiffer, T., & Schneider, G. (2010).
[123] Pfeiffer, T., & Schneider, G. (2010).

Arya and Glover (2001), the model of Pfeiffer and Schneider (2010) is also a variant of Antle and Eppen (1985).

The model of Pfeiffer and Schneider (2010) takes into account a headquarters and a divisional manager. Both parties are risk-neutral. The manager has pre-contract information about the profitability of the underlying investment project. The headquarters can provide the divisional manager with additional information which only the manager as an expert can benefit from.[124]

Regarding the analysis of the optimal timing of information, the authors distinguish two different temporal circumstances:[125]

- ***Timely information:*** The headquarters provides the manager with additional information before signing the contract. Accordingly, both the initial investment and abandonment decisions can be undertaken under perfect information regarding the project's profitability. However, this requires that the manager truthfully reports his private information.

- ***Delayed information:*** The headquarters provides the manager with additional information regarding the project's profitability after signing the contract and after the initial investment decision has been made. However, the manager receives the information before the abandonment decision can be undertaken. As a result, the decision about the initial investment is made under imperfect information regarding the project's profitability.

4.2.1 The Model

The model by Pfeiffer and Schneider (2010) consists of a single investment project with two investment stages. First, at t = 0, headquar-

[124] Pfeiffer, T., & Schneider, G. (2010).
[125] Pfeiffer, T., & Schneider, G. (2010).

ters has the opportunity to undertake an investment project that needs a cash outlay of c. The variable k_0 denotes the initial financing decision ($k_0 \in \{0, 1\}$). Therefore, if headquarters undertakes the investment project $k_0 = 1$; otherwise $k_0 = 0$. Second, at t = 1, headquarters has to decide if it wants either to continue or abandon the investment project.[126] Accordingly, the indicator variable is $k_1 = 1$ if headquarters continues with the project and k_1 equals 0 if the option to abandon is exercised. Third, at date t = 2, the manager delivers effort e (e lies in the interval $[0, \bar{e}]$). The effort of the manager cannot be observed. Finally, at t = 3, the cash flow of the firm, which consist of cash flows of the investments and of the operations is realized:[127]

$$C(\cdot) := (\theta + \alpha)k_1k_0 + e = sk_1k_0 + e.$$

In this circumstance θ and α are the productivity parameter. The higher the value of both parameters, the more favorable the investment environment. The total productivity of the project (θ + α) is denoted by s. The probability distributions $F(\theta)$ on the interval $[0, \bar{\theta}]$ and $G(\alpha)$ on $[0, \bar{\alpha}]$ reflect the beliefs regarding the productivity parameters. The probability distributions are assumed to be independently distributed. In addition, the productivity parameters are supposed to be uniformly distributed on $[0, 1]$. Accordingly, the probability distribution, which is denoted by $H(s)$, of the overall productivity $s = \theta + \alpha$ is a triangle distribution on $[0, \bar{s}]$, $\bar{s} = \bar{\theta} + \bar{\alpha}$. The density functions are $f(\theta), g(\alpha), h(s)$, respectively.[128,129]

The utility of the manager $\mathrm{U}(\cdot)$ can be divided in reward $\mathrm{S}(\cdot)$ and cost of effort e with a disutility parameter, which is denoted by v ($\mathrm{v} = \frac{1}{2}$),

$$U(S(\cdot), e) := S(\cdot) - ve.$$

[126] Pfeiffer, T., & Schneider, G. (2010).
[127] Pfeiffer, T., & Schneider, G. (2010).
[128] The authors assume that the interest rate equals to zero.
[129] Pfeiffer, T., & Schneider, G. (2010).

As already mentioned, the manager owns private pre-contract information regarding the parameter θ. The headquarters has to decide when the manager should receive additional information about the project so that he can learn about the second productivity parameter α. If the headquarters chooses delayed information, the manager receives the information about the parameter α after contracting at t=1. Otherwise (timely information), the manager obtains all information before contracting. It is worth to mention that the productivity parameter α cannot be observed by headquarters due to the fact that only the manager as an expert is able to interpret the information.[130]

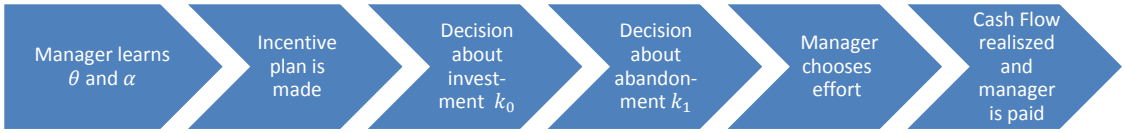

Fig. 3: Timely information regime.[131]

The timeline of events regarding the timely information regime can be observed in Fig. 1. First, the manager learns both productivity parameters. After that, the headquarters and the manager have to find an agreement about the incentive plan. It is required that the incentive plan provides the manager with at least the reservation utility. Next, the manager has to wait for the decision of the headquarters whether the investment is undertaken or not. In the case the headquarters wants to initiate the investment project, a cash outlay of c is required. The headquarters has to take a further decision at t=1. It has to choose if it wants to go on with the investment project or to abandon it. Then, at t=2, the manager sets his effort level e. As a last step, at date t=3, the investment project's cash flow is realized and the manager gets paid.[132]

[130] Pfeiffer, T., & Schneider, G. (2010).
[131] Pfeiffer, T., & Schneider, G. (2010).
[132] Pfeiffer, T., & Schneider, G. (2010).

Fig. 4: Delayed information regime.[133]

The timeline of the delayed information regime is depicted in Fig. 2. As has been argued above, at t=0, the manager has only pre-contract information about the productivity parameter θ. Similar to the timely information regime the two parties have to determine the incentive plan. After that, the headquarters has to decide whether to undertake the investment project or not. If the investment project is initiated, the manager is provided with information about the second productivity parameter α at t=1. Next, the headquarters has to take the decision whether to abandon the project or not. The manager determines his level of effort at t=2. As a last step, the cash flow is realized and the headquarters transfers the reward to the manager.[134]

In order to analyze the influence of an abandonment option on the optimal timing of information, Pfeiffer and Schneider (2010) determine the optimal timing of information without the real option as a benchmark for both, the timely information regime and the delayed information regime.

4.2.2 Results

Benchmark Case: Timely information regime without Real Option

If no real option is considered, the manager has perfect information about the project's productivity under the timely information regime at t=0. According to Pfeiffer and Schneider (2010), the incentive plan is composed of the manager's compensation $S(m)$, the required performance $C^{req}(m)$, which is measured by the cash flow, and both the in-

[133] Pfeiffer, T., & Schneider, G. (2010).
[134] Pfeiffer, T., & Schneider, G. (2010).

vestment $k_0(m)$ and abandonment decision $k_1(m)$. The mentioned components of the incentive plan are all functions of the report m made by the manager. The pre-specified divisional cash flow that has to be reached by the manager, and which can be enforced by headquarters with penalties, is then

$$C^{req}(m) = sk_1(m)k_0(m) + e(m,s)$$

$$\rightarrow e(m,s) = C^{req}(m) - sk_1(m)k_0(m).$$

To be consistent with his report, the manager has to apply the effort level $e(m,s)$.[135] The pre-specified required cash flow identified by the headquarters is

$$C^{req}(m) = mk_1(m)k_0(m) + \bar{e}.$$

The manager's preferences can be described as follows:

$$U(m,s) := S(m) - ve(m,s) = S(m) - v\big(\bar{e} - (s-m)k_1(m)k_0(m)\big).$$

According to Pfeiffer and Schneider (2010), this utility function implies that the manager has the incentive not to reach the total productivity s with the aim to apply a lower effort than required.

In addition, the profit of the firm can be determined as the cash flow less both the undertaken investment and compensation cost:

$$(sk_1k_0 + e) - ck_0 - S.$$

Consequently, it can be said that the aim of the headquarters is to set up an incentive plan which maximizes expected profit under consideration of the following constraints:

[135] The authors assume that the maximum effort level $\bar{e}$ is sufficiently high and consequently, it is always optimal to induce it.

$$(P_{TA})\colon \prod_{TA}^{max} = max \int_0^{\bar{s}} \big((sk_1(s) - c)k_0(s) + e(s,s) - S(s)\big)dH(s)$$

$$(IC)\colon U(s,s) \geq U(m,s)\ for\ all\ (m,s)$$

$$(PC)\colon U(s,s) \geq 0\ for\ all\ s$$

$$(AR)\colon k_1(s) = 1\ for\ all\ s.$$

The incentive compatibility constraints (IC), which provide that the manager is motivated to truthfully report his private information related to the total productivity s, are similar to the self-selection constraints in Antle and Fellingham (1990) and Arya and Glover (2001). The participation constraints (PC) can be compared to the individual rationality constraints in Antle and Fellingham (1990) and ensure that the manager receives at least his reservation utility (assumed to be zero). The last constraints (AR) take into account the fact that the abandonment option is not considered in this scenario.[136] Pfeiffer and Schneider (2010) rewrite (P_{TA}) in order to receive the unconstrained optimization problem:

$$(P_{TA})\colon\ max \int_0^{\bar{s}} (s - v\frac{1 - H(s)}{h(s)} - c)k_0(s)dH(s) + (1 - v)\bar{e}.$$

By compensating the manager for his disutility $v\bar{e}$, headquarters tries to satisfy the incentive and participation constraints. The manager also receives a further compensation from the headquarters in form of virtual costs $((1 - H(s))/h(s))k_0(s)$, due to the fact that headquarters has to pay information rents for manager's private information regarding the total productivity s of the project. The mentioned virtual costs are composed of the marginal disutility of the manager v multiplied with the hazard rate of the overall productivity $((1 - H(s))/h(s))k_0(s)$. In case the investment project is not initiated by the headquarters, the cash flow $C(\cdot) = sk_0 + e$, which can be observed, only consists of the effort

[136] The index TA denotes the timely information regime without a Real Option.

of the manager. Subsequently, this means first, that the level of effort is observable and second, that headquarters does not need to pay the information rents in the form of virtual costs.[137]

By undertaking pointwise optimization of (P_{TA}) Pfeiffer and Schneider (2010) find out that the investment project is implemented only in the case that the total profitability of the project exceeds both, the investment and the virtual costs

$$k_0(s) = 1 \; only \; if \; s \geq c + v\frac{1 - H(s)}{h(s)}.$$

Consequently, the firm's maximum expected profit from the investment project is as follows

$$\prod_{TA}^{Inv}(c) = \prod_{TA}^{max}(c) - (1 - v)\bar{e}$$

$$\prod_{TA}^{Inv}(c) = \begin{cases} \dfrac{75 + 10\sqrt{10 + 4c^2} + 4c(2c^2 + \left(2c\sqrt{10 + 4c^2}\right) - 30}{150} & 0 \leq c \leq \dfrac{3}{4} \\ \dfrac{8(2 - c)^3}{75} & for \; \dfrac{3}{4} \leq c \leq 2 \\ 0 & c \geq 2. \end{cases}$$

To sum up, it can be stated that headquarters has to pay additional information rents, depending on the information regime. For example, under timely information, virtual costs for the profitability have to be paid by the headquarters.[138]

Benchmark Case: Delayed information regime without Real Option

In the following the case of the delayed information will be introduced. Now, the manager has pre-contract information about θ and post-contract information about α. At t=0, the headquarters and the manager have to find an agreement regarding the incentive plan. The incen-

[137] Pfeiffer, T., & Schneider, G. (2010).
[138] Pfeiffer, T., & Schneider, G. (2010).

tive plan includes the manager's compensation $S(m,n)$, the cash flow which is required $C^{req}(m,n)$ and both the investment $k_0(m)$ and abandonment decision $k_1(m,n)$. It is worth to mention that the initial investment decision $k_0(m)$ depends only on the report m due to the fact that the second parameter α is learned by the manager at t=1. The manager's utility is similar to the timely information regime:

$$U(m,n,\theta,\alpha) = S(m,n) - v\big(\bar{e} - (\theta + \alpha - m - n)k_1(m,n)\big)k_0(m).^{139}$$

It is noteworthy that in this circumstance the manager has an incentive to understate both productivities due to the fact that he wants to reduce his effort.[140]

By considering the following constraints, headquarters determines the incentive plan with the aim to maximize the expected profit

$$(P_{DA}): \prod\nolimits_{DA}^{max} = max \int_0^{\bar{\theta}} \int_0^{\bar{\alpha}} \Big(\big((\theta+\alpha)k_1(\theta,\alpha) - c\big)k_0(\theta) + e(\theta,\alpha,\theta,\alpha) - S(\theta,\alpha)\Big)\, dG(\alpha)dF(\theta)$$

$$(IC_1): U(m,\alpha,\theta,\alpha) \geq U(m,n,\theta,\alpha)\ for\ all\ (m,n,\theta,\alpha)$$

$$(IC_0): E_\alpha[U(\theta,\alpha,\theta,\alpha)] \geq E_\alpha[U(m,\alpha,\theta,\alpha)]\ for\ all\ (m,\theta)$$

$$(PC): E_\alpha[U(\theta,\alpha,\theta,\alpha)] \geq 0\ for\ all\ \theta$$

$$(AR): k_1(s) = 1\ for\ all\ s.^{141}$$

The headquarters has the task to provide that the manager transfers his private information sequentially and truthfully. Consequently, the constraints (IC_1) ensure that the manager reports the parameter α truthfully without considering the report m, which had already been made by the manager before. (IC_0) provides that the manager truthfully

[139] Pfeiffer, T., & Schneider, G. (2010).
[140] Pfeiffer, T., & Schneider, G. (2010).
[141] Pfeiffer, T., & Schneider, G. (2010).

reports the parameter θ by assuming that the manager will truthfully report the second parameter α. Furthermore, (PC) is required in order to provide the manager with his reservation utility of 0. (AR) denotes the fact that real options are not considered.[142] Pfeiffer and Schneider (2010) rewrite the optimization problem (P_{DA}) as an unconstrained optimization problem:

$$(P_{DA}): max \int_0^{\bar{\theta}} (\theta + E[\alpha] - v\frac{1-F(\theta)}{f(\theta)} - c)k_0(\theta)dF(\theta) + (1-v)\bar{e}.$$

The aim of the headquarters is to maximize the expected profit of the company, which is composed by the expected cash flow reduced by the investment costs

$$E_\alpha[s]k_0 + \bar{e} - ck_0 = (\theta + E[\alpha])k_0 + \bar{e} - ck_0.$$

As already mentioned above, under the delayed information regime, the headquarters does not have all information about the second parameter α. Thus, the manager receives from the headquarters his effort costs $v\bar{e}$ and information rents regarding the pre-contract information θ. However, he does not receive any information rents for the post-contract information α. By undertaking a pointwise optimization of the unconstrained (P_{DA}), it can be identified that headquarters only invest if

$$k_0(s) = 1 \; only \; if \; \theta + E[\alpha] \geq c + v\frac{1-F(\theta)}{f(\theta)}.$$ [143]

The expected profitability has to be higher than the investment and virtual costs under consideration of the pre-contract information θ. Thus, the expected profit of the firm, which results from the investments, is as follows:

[142] The index "DA" denotes the delayed information regime without Real Option.
[143] Pfeiffer, T., & Schneider, G. (2010).

$$\prod_{DA}^{Inv}(c) = \prod_{DA}^{max}(c) - (1 - v)\bar{e}$$

$$\prod_{DA}^{Inv}(c) = \begin{cases} \frac{(3-2c)^2}{12} & for\ c \leq \frac{3}{2} \\ 0 & c \geq \frac{3}{2}. \end{cases}$$ [144]

In the following the timely and the delayed information regime will be compared. First, it can be identified that delaying information provides a reduction of the expected information rents of the manager. However, headquarters is forced to undertake the initial investment decision without complete information. Consequently, high investments costs favor the timely information regime due to the requirement of more detailed information. Low investment costs however, more often provide investments in the project, which requires a better management of the adverse selection problem. Thus, the delayed information regime has more advantages in this circumstance. These findings are also confirmed by Pfeiffer and Schneider (2010) in Fig. 3, which compares the expected profit of the firm under the timely information regime and under the delayed information regime ($\prod_{DA}^{max}(c) - \prod_{DA}^{max}(c)$).[145]

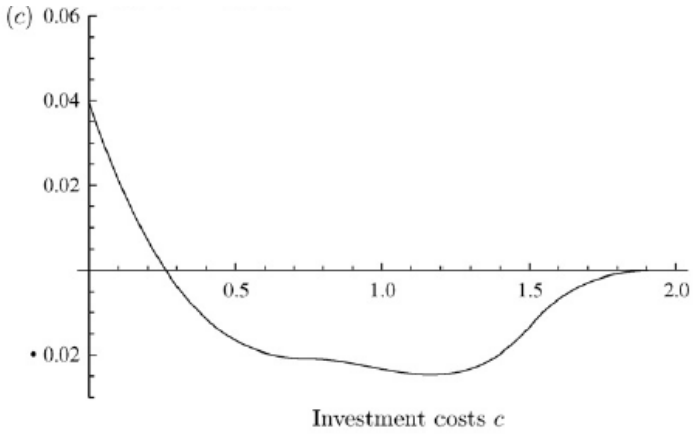

Fig. 5: Comparison of firm's expected profit under both regimes[146]

[144] Pfeiffer, T., & Schneider, G. (2010).

[145] Pfeiffer, T., & Schneider, G. (2010).
[146] Pfeiffer, T., & Schneider, G. (2010).

According to Pfeiffer and Schneider (2010), a cut-off value $\hat{c}$ can be identified, whereas under this value $c \in [0,\ \hat{c})$ delayed information is favorable. For all $c \in (\hat{c},\ 2]$ timely information is better. Finally, for $c = \hat{c}$ and $c \in [2,\ \infty]$ the expected profits of both information regimes are the same.[147]

Timely information regime with Real Option

In the following section the timely information regime under consideration of a real option will be introduced. Similar to the timely information regime without real option the headquarters maximizes the expected profit as follows:

$$(P_{TP}): \prod_{TP}^{max} = max \int_0^{\bar{s}} \big((sk_1(s) - c)k_0(s) + e(s,s) - S(s)\big) dH(s)$$

$$(IC): U(s,s) \geq U(m,s)\ for\ all\ (m,s)$$

$$(PC): U(s,s) \geq 0\ for\ all\ s.$$ [148]

It can be observed that the only difference to the case without real option consists of the missing constraints (AR). These do not have to be considered anymore because of the possibility to abandon the project.[149] Again, Pfeiffer and Schneider (2010) rewrite (P_{TP}) in order to receive the unconstrained optimization problem

$$(P_{TP}): max \int_0^{\bar{s}} ((s - v\frac{1-H(s)}{h(s)})k_1(s) - c)k_0(s) dH(s) + (1-v)\overline{e}.$$ [150]

This equation is also similar to the equation under the timely information regime without the real option. The only exception is that headquarters can save information rents through abandoning the project

[147] Pfeiffer, T., & Schneider, G. (2010).
[148] Pfeiffer, T., & Schneider, G. (2010).
[149] The index "TP" denotes the timely information in the presence of a Real Option.
[150] Pfeiffer, T., & Schneider, G. (2010).

due to the fact that the cash flow $C(\cdot) = Sk_0k_1 + e$, which is observable, consists of the effort of the manager. Thus, after backward induction and pointwise optimization, Pfeiffer and Schneider (2010) determine both, the optimal investment and the abandonment strategy. Only if the total profitability of the project is higher than the virtual costs, headquarters will proceed with the project

$$k_1(s) = 1 \; only \; if \; s \geq v\frac{1 - H(s)}{h(s)}.$$ [151]

The abandonment option can be seen as an additional control instrument for headquarters in order to better elicit the expected information rents of the manager (in the form of the virtual costs). Furthermore, it is worth to mention that without virtual costs (i.e. without an agency conflict) the real option has no value due to the fact that the total profitability s is never negative.[152]

As already mentioned, under the timely information regime without real option headquarters undertakes the project only if the total profitability of the project is higher than the investment and the virtual costs

$$k_0(s) = 1 \; only \; if \; s \geq c + v\frac{1 - H(s)}{h(s)}.$$ [153]

Consequently, by comparing the timely regime with real option to the timely regime without real option, it can be identified that it is always beneficial to continue with the project once it has been initiated. Furthermore, since headquarters has ex-ante perfect information regarding the project and consequently, there is no need to re-think the initial investment decision, the abandonment option can be seen as worthless. Thus, the findings from the timely regime without real option,

[151] Pfeiffer, T., & Schneider, G. (2010).
[152] Pfeiffer, T., & Schneider, G. (2010).
[153] Pfeiffer, T., & Schneider, G. (2010).

which state that the investment project is implemented only in the case that the total profitability of the project exceeds both, the investment and the virtual costs, are confirmed.[154] To sum up, headquarters never takes the abandonment option ($k_1(s) = 1\ for\ all\ s$) and therefore, the firm's expected profit from the investment with the real option equals the expected profit from the investment without the real option ($\prod_{TP}^{Inv}(c) = \prod_{TA}^{Inv}(c)$).[155]

Delayed information regime with Real Option

In the following section the delayed information regime with a real option will be analyzed. As in the delayed information regime without the real option, headquarters tries to maximize its expected profit subject as follows:

$$(P_{DP}): \prod_{DP}^{max} = max \int_0^{\overline{\theta}} \int_0^{\overline{\alpha}} \Big(\big((\theta + \alpha)k_1(\theta, \alpha) - c\big)k_0(\theta) + e(\theta, \alpha, \theta, \alpha) - S(\theta, \alpha) \Big) dG(\alpha) dF(\theta)$$

$$(IC_1): U(m, \alpha, \theta, \alpha) \geq U(m, n, \theta, \alpha)\ for\ all\ (m, n, \theta, \alpha)$$

$$(IC_0): E_\alpha[U(\theta, \alpha, \theta, \alpha)] \geq E_\alpha[U(m, \alpha, \theta, \alpha)]\ for\ all\ (m, \theta)$$

$$(PC): E_\alpha[U(\theta, \alpha, \theta, \alpha)] \geq 0\ for\ all\ \theta.$$[156]

Since the real option is considered in this case, the (AR) constraints is not necessary anymore. Further, the index "DP" depicts the delayed information regime with the real option. Once again, Pfeiffer and Schneider (2010) rewrite the optimization problem as an unconstrained problem

$$(P_{DP}): max \int_0^{\bar{s}} \left(\left(s - v\frac{1 - H(s)}{h(s)}\right)k_1(s) - c \right)k_0(s) dH(s) + (1 - v)\overline{e}.$$

[154] Pfeiffer, T., & Schneider, G. (2010).
[155] Pfeiffer, T., & Schneider, G. (2010).
[156] Pfeiffer, T., & Schneider, G. (2010).

As already mentioned, the profit of the firm can be determined as the cash flow minus the investment costs $(\theta + \alpha)k_1k_0 + \bar{e} - ck_0$. The manager receives his effort costs $v\bar{e}$ from headquarters and, also additional information rents $v(1 - F(\theta))/f(\theta)k_1k_0$ only if headquarters continues with the investment project. In the case headquarters does not continue with the project, then the cash flow corresponds to the manager's effort and consequently, the manager would not get any information rents. It is worth to mention that the abandonment option can be seen as a further instrument for control in order to elicit the information rents of the manager in a better way.[157]

By undertaking pointwise optimization Pfeiffer and Schneider (2010) find out that headquarters goes on with the investment project only if total profitability of the project is higher than the virtual costs

$$k_1(\theta, \alpha) = 1 \; only \; if \; \theta + \alpha \geq v\frac{1 - F(\theta)}{f(\theta)}.$$ [158]

It is not necessary to consider the investment costs of c due to the fact that they are sunk. The optimal abandonment decision provides that for headquarters it is optimal to undertake the investment project only if the expected value of the total profitability of the project minus the virtual costs is higher than the investment costs

$$k(\theta, \alpha) = 1 \; only \; if \; \int_0^{\overline{\alpha}} \max\left\{\theta + \alpha - v\frac{1 - F(\theta)}{f(\theta)}, 0\right\} dG(\alpha) \geq c.$$ [159]

Consequently, the expected profit from investments for the firm is

[157] Pfeiffer, T., & Schneider, G. (2010).
[158] Pfeiffer, T., & Schneider, G. (2010).
[159] Pfeiffer, T., & Schneider, G. (2010).

$$\prod_{DP}^{Inv}(c)\begin{cases}\frac{55}{72}-c & 0\leq c\leq\frac{1}{8}\\ \frac{7-12c+4\sqrt{2}c^{\frac{3}{2}}}{9} & \frac{1}{8}\leq c\,\frac{1}{2}\\ \frac{(3-2c)^2}{12} & \frac{1}{2}\leq c\leq\frac{3}{2}.\end{cases}$$ [160]

For $c \geq \frac{3}{2}$ the expected profit is equal to 0. Further, the real option's value is

$$V_D(c)=\begin{cases}\frac{1-24c^2}{72} & for\ 0\leq c\leq\frac{1}{8}\\ \frac{1}{3}\left(\frac{\sqrt{2}}{6}+\sqrt{c}\right)\left(\frac{\sqrt{2}}{2}-\sqrt{c}\right)^3 & \frac{1}{8}\leq c\leq\frac{1}{2}.\end{cases}$$ [161]

The following subsection will analyze whether headquarters should provide the manager with timely information or with delayed information. As already determined above, in the case without a real option, the delayed information regime is the better strategy for low costs $c \in [0, \hat{c}]$. If the abandonment option is taken into account, the maximum expected profit for headquarters is as high as the maximum expected profit when the option is not considered plus the option's value, independently from the information regimes

$$\prod_{TP}^{max}(c)=\prod_{TA}^{max}(c)+V_T(c) \text{ and}$$

$$\prod_{DP}^{max}(c)=\prod_{DA}^{max}(c)+V_D(c).$$ [162]

As already mentioned above, the value of the abandonment option is higher than 0 under the delayed information regime, in contrast to under timely information. In more detail, under the delayed regime the value is strictly positive for low investment costs. Accordingly, the delayed information regime is beneficial if a real option is available

[160] Pfeiffer, T., & Schneider, G. (2010).
[161] Pfeiffer, T., & Schneider, G. (2010).
[162] Pfeiffer, T., & Schneider, G. (2010).

$$\prod_{DP}^{max}(\hat{c}) - \prod_{TP}^{max}(\hat{c}) = \prod_{DA}^{max}(\hat{c}) + V_D(\hat{c}) - \prod_{TA}^{max}(\hat{c})$$

$$> \prod_{DA}^{max}(\hat{c}) - \prod_{TA}^{max}(\hat{c}), \text{ (with } \hat{c} < \tfrac{1}{2}).^{163}$$

Pfeiffer and Schneider (2010) prove that there exists a unique value $\hat{\hat{c}}$ such that delayed information is advantageous over timely information if $c \in [0, \hat{\hat{c}})$.[164] If $c \in [\hat{\hat{c}}, 2)$ timely information is more beneficial. In addition, if $c = \hat{\hat{c}}$ or $c \in [2, \infty]$ headquarters should be indifferent regarding the two information regimes.

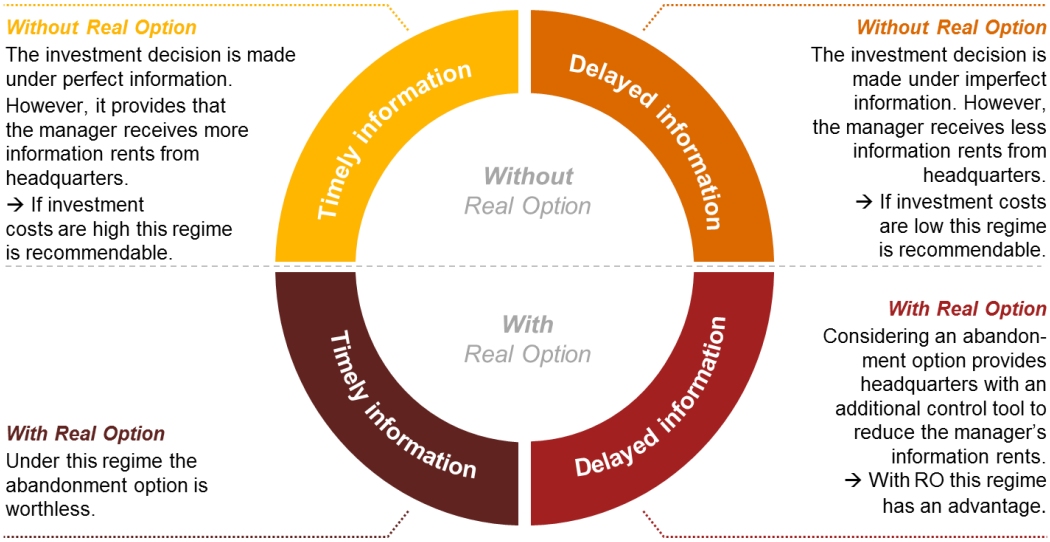

Fig. 6: Overview of the findings

Pfeiffer and Schneider's paper (2010) reveals the interdependency between the information timing and the real option's value as a tool to decrease the agency conflict which exists between the manager and the headquarters.

To sum up, it can be stated that Pfeiffer and Schneider's paper (2010) provides the answer to Arya and Glover's question: How do real options influence the agency conflict? According to Pfeiffer and Schneider's paper (2010) the abandonment option makes the timing when the manager receives the information about the productivity parameter α

[163] Pfeiffer, T., & Schneider, G. (2010).

relevant. Due to the opportunity to stop the project by the abandonment option an additional agency conflict arises. Without an abandonment option it would not matter that the manager would receive the information regarding α ex-post (delayed information). The manager would only receive the information premium for θ. However, with the abandonment option the manager could benefit from the information asymmetry through α (from headquarters).

5 Conclusion

This thesis aims to analyze the interrelation between real options and agency conflicts. First, the focus is set on how a control problem can make a real option valuable. Second, the reverse dependence is taken into consideration, which means that it is identified how an abandonment option creates an agency conflict.

A brief overview of the literature regarding real options and agency theory creates a basis for the analysis of this interrelation and provides the theoretical foundation.

Subsequently, by introducing the paper of Arya and Glover (2001) it is pointed out how a control problem makes an option to wait valuable. The main results are that despite waiting generates cost due to the fact that the principal cannot benefit anymore from the uncertainty of the agent about future cost of the project, waiting has nevertheless a huge advantage. If the principal delays the approval decision of project 1 it provides that the approval decision of project 1 depends on the cost report of project 2, which is a crucial advantage.[165]

To understand the other side of the interrelation, namely the influence of real options on agency conflicts, the paper of Pfeiffer and Schneider (2010) is introduced. To be more precise, it is analyzed how an abandonment option influences the optimal timing of information.

The major finding is that the abandonment option makes the timing when the manager receives the information about the productivity parameter α relevant. Due to the opportunity to stop the project by the abandonment option an additional agency conflict arises. Without an abandonment option it would not matter that the manager would receive the information regarding α ex-post (delayed information). The

[165] Arya, A., & Glover, J. (2001).

manager would only receive the information premium for θ. However, with the abandonment option the manager could benefit from the information asymmetry through α (from headquarters).

Furthermore, the real option has no influence in the timely information case. However, in the delayed information case the option of abandonment provides headquarters with a further control tool to reveal the information rent of the manager.[166] Accordingly, the real option (in form of an abandonment option) makes the delayed information case more beneficial and therefore acts as an influence on the agency conflict.

As mentioned in the beginning, this thesis tried to reveal the interrelation by focusing on two aspects: (i) how a control problem can make a real option valuable, and (ii) how an abandonment option influences the optimal timing of information. However, these are only two possible aspects to identify interrelation. To receive a comprehensive overview about the interrelation between real options and agency conflicts further research is required. For example, one could replace the abandonment option by another type of option and analyze the impact of the change on the interrelation.

[166] Pfeiffer, T., & Schneider, G. (2010).

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Appendices

Appendix A – Definition of Contracts[167]

In the following the various contracts which can be optimal in a two-period setting according to the paper of Antle and Fellingham (1990) will be presented:

Contract	Definition	Advantage	Disadvantage
Myopic Rationing	Extension of the one-period rationing contract.	Avoids generation & consumption of slack by the manager by renounce production if the manager reports ρ_1(even if $\rho_1 > \rho_0$).	
Mem1	The owner transfer resources to the manager if latter reports ρ_1 in the first period until to the point where the manager's gain to lying in the first period when ρ_2 is the true rate of return is just offset by the manager's discounted expected second-period gains to truthfully reporting ρ_2 in the first period.	Benefits compared to myopic rationing: (1) Cost of rationing in the second period is not taken if rate of return is ρ_1 in the first period (2) Additional production from the first period is available the manager reports ρ_1. Mem1 has an higher expected net present value compared to the myopic rationing contract if the expected cost of slack is less than two times the expected cost of rationing.	Higher cost than myopic rationing due to mem1 causes slack in the second period if ρ_2 is achieved in the first period.
Mem2	The mem2 contract avoids the first-period rationing of a mem1 contract by alter-	Compared to mem1 the benefit of mem2 is that no production is lost and no slack is incurred in	Compared to mem1 additional expected slack is incurred in the second

[167] Antle, R., & Fellingham, J. (1990). Resource rationing and organizational slack in a two-period model. Journal of Accounting Research, 1-24.

	ing the contract to ensure additional slack in the second period if the high rate of return ρ_1 is reported in the first period by the manager. A mem2 contract dominates a mem1 contract if the cost of slack is small enough.	the first period.	period when ρ_2 is reported in the first period by the manager.
Myopic Slack	The myopic slack contract is a straightforward extension of the one-period slack contract.	Compared to the mem2 the benefit is that the expected cost of rationing in the second period if ρ_1 is reported in the first period is not incurred.	Compared to the mem2 the disadvantage is that the expected cost of slack in the first period is not avoided.

Appendix B – Summary in German

Die vorliegende Masterarbeit beschäftigt sich mit den wechselseitigen Beziehungen zwischen Realoptionen und Prinzipal-Agenten Konflikten. Zunächst wird festgestellt, wie eine Realoption durch ein Kontrollproblem an Wert gewinnt. Des Weiteren wird der wechselseitige Einfluss betrachtet. In diesem Zusammenhang wird der Einfluss einer Abbruchsoption auf den optimalen Informationszeitpunkt in einem Prinzipal-Agenten Modell aufgezeigt.

Um eine theoretische Grundlage für die Analyse der genannten Wechselbeziehung zu schaffen, wird ein kurzer Überblick über die Literatur hinsichtlich Realoptionen und Agency-Theorie gegeben.

Anschließend wird durch die Publikation von Arya und Glover (2001) aufgezeigt, wie ein Steuerungs- bzw. Kontrollproblem eine Option zu warten wertvoll macht. Die wichtigsten Ergebnisse sind, dass trotz der Kosten, die sich durch das Warten ergeben, aufgrund der Tatsache, dass der Prinzipal nicht mehr die Unsicherheit des Agenten über die zukünftigen Kosten des Projektes zu seine Gunsten nutzen kann, die Option zu warten nichtsdestotrotz von Vorteil sein kann. Wenn der Prinzipal die Entscheidung über die Genehmigungszusage des Projektes 1 verschiebt, dann hängt diese von dem Kostenbericht von Projekt 2 ab, der durch den Agenten abgegeben wird. Hierdurch gewinnt die Option zu warten an Wert.[168]

Um die andere Seite der Wechselbeziehung, nämlich den Einfluss einer Realoption auf einen Agency-Konflikt aufzuzeigen wird im nächsten Schritt die Publikation von Pfeiffer und Schneider (2010) herangezogen. Insbesondere wird untersucht, wie eine Abbruchsoption den optimalen Informationszeitpunkt beeinflusst. Es wurde festgestellt, dass bei einer frühen Entscheidungssituation die Realoption keinen Einfluss

[168] Arya, A., & Glover, J. (2001).

ausübt. Jedoch wenn man die späte Entscheidungssituation betrachtet, kann ein Einfluss der Abbruchsoption identifiziert werden. Durch die Abbruchsoption erhält die Zentrale ein zusätzliches Instrument, um den Informationsvorteil des Managers aufzudecken und zu minimieren.[169]

Zusammenfassend wird durch die Realoption - in Form einer Abbruchsoption - der optimale Informationszeitpunkt (späte Entscheidungssituation ist durch die Realoption vorteilhafter) und damit der Agency-Konflikt beeinflusst.

Wie bereits erwähnt liegt der Fokus der vorliegenden These auf das Aufzeigen von wechselseitigen zwischen Realoptionen und Agency-Konflikten. Dabei liegt der Fokus darauf einerseits, wie eine Realoption durch ein Kontrollproblem an Wert gewinnt und andererseits, wie der Einfluss einer Abbruchsoption auf den optimalen Informationszeitpunkt in einem Prinzipal-Agenten Modell sich verhält. Dies sind jedoch nur zwei Aspekte, wie die wechselseitige Beziehung identifiziert werden kann. Um einen umfassenden Überblick über diese Wechselbeziehungen zwischen Realoptionen und Agency-Konflikten zu erhalten sind weitere zukünftige Forschungsaktivitäten erforderlich. Eine mögliche Adaption wäre die Abbruchsoption durch eine andere Option zu ersetzen, um die Auswirkungen der Änderung zu untersuchen.

[169] Pfeiffer, T., & Schneider, G. (2010).

Appendix C – Curriculum Vitae

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02/2015 – 07/2015 — **Praktikant im Advisory bei PwC in Wien** Consulting & Risk Services, Strategy & Operations
Aufgaben: Unterstützung bei der Erstellung einer Studie zum Thema Industrie 4.0, Erstellung von Kundenpräsentationen und Durchführung von Recherchen

08/2012 – 09/2012	**Werkstudent im Vertriebscontrolling bei der Daimler AG** Ergebnis- & Erlöscontrolling für das Mercedes-Benz Großkunden-Flottengeschäft, Autovermietergeschäft und für smart Deutschland
02/2012 – 07/2012	**Praktikant im Vertriebscontrolling bei der Daimler AG** Ergebnis- & Erlöscontrolling für das Mercedes-Benz Großkunden-Flottengeschäft, Autovermietergeschäft und für smart Deutschland Aufgaben: Erstellung von Wirtschaftlichkeitsanalysen und Geschäftsentscheidungsunterlagen für das mittlere Management

Besondere Kenntnisse

Sprachen	Deutsch:	Muttersprache
	Englisch:	Verhandlungssicher
	Italienisch:	Verhandlungssicher
	Französisch:	Fließend
	Spanisch:	Fließend
EDV-Kenntnisse	Sehr gute Kenntnisse in allen MS-Office-Anwendungen, Grundkenntnisse in SAP und SQL	

Wien, Juli 2017