REAL OPTIONS
AND
THE BIAS
OF
COMMITMENT ESCALATION

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Abstract

Escalation of commitment is a behavioural bias that occurs when a project manager continues a failing course of actions, while it is better to abandon the involved project. In such a case a manager who already invested a lot of effort and resources in a project, may not be able to resist the temptation to continue with their project, and may not understand the logic of sunk costs.

This study investigated whether the use of the real option analysis as a capital budgeting analysis could mitigate this escalation of commitment, in comparison with the use of the traditional net present value method.

An experiment was constructed for 64 university students with a finance background. The treatment group was told to use the real option valuation as capital budgeting analysis, while the control group was told to use the traditional net present value method. Both groups were challenged with the same case. The case was presented as an investment game in which the participants could earn an certain amount of money, depending on their performance. The case simulated an investment opportunity with two sequential time stages. The cash flows and the likelihood of success and failure were given and it was mentioned that the assets could be sold at any moment for a certain percentage of their value (implied option to abandon).

In the first stage the participants had to decide whether to accept the project or not. If invested, they had to decide whether to continue or not in the second stage. In this second stage they were challenged with two different scenarios, both a bad and a good case scenario. The provided numbers in the bad case should evidently lead them to abandon of the project. Nevertheless, when one would continue in this bad case scenario, escalation of commitment is present.

Significant evidence was obtained indicating that students using the net present value method were more prone to escalation of commitment than students using real option analysis. Hence, imbedding real options in a project valuation affects the behaviour of managers, reducing their tendency to escalate their commitment to a failing project.

Furthermore, the occurrence of this escalation seemed to be significantly positively related with the degree of loss aversion of the participants. People with a high loss aversion might find it hard to accept losses when abandoning the project, and rather continue the failing project in order to avoid the threatening losses. Moreover, results did not indicate whether the mitigating effect of the real option valuation differs between men and women.

Table of Contents

1. Introduction and Research Question

In the field of project management behavioural economics plays a major role. When managers have to make decisions about accepting a project or about continuing an existing project, they often fall prey to behavioural biases. These biases cause managers to make incorrect decisions. Managers can be prone to several biases, one of these is *escalation of commitment*.

Project managers might suffer from escalation of commitment when evaluating a project, with the result that their decision whether to continue to invest or not is affected by this bias. This bias occurs when managers, who have already invested a lot of effort and resources in a project, cannot resist the temptation to continue with their project, even when abandoning would be more sensible at that moment of time. In those cases they might want to justify their previous decisions or they might not be willing to kill (in their eyes) their golden goose.

For evaluating projects, several capital budgeting methods are available to measure the value of the project. The most common used technique is called the net present value method. The net present value technique is a method to appraise long-term projects with using the time value of money.
An alternative for this net present value method is the real option analysis. The real option approach incorporates financial future options and places a value on flexibility, whereas the traditional net present value does not take these options into account. The real option approach can cause managers to be more conscious about uncertainties concerning the project, and might lead them to make more rational decisions about continuing or terminating projects. Therefore using the real option analysis when evaluating a project, instead of the more commonly used net present value method, may mitigate the tendency of commitment escalation.

Various authors agree with this theory and in 2011 Karami and Farsani found significant evidence for the mitigating effect of real options on escalation of commitment. On the contrary, among others Adner and Levinthal (2004) are not enchanted by the use of real options and even state that using this technique just increases the probability of commitment escalating. Tiwana et al. (2006) found support for this opposite viewpoint. Hence, an interesting topic to research by phrasing the following research question:

Does the use of a real option approach improve company performances, by mitigating escalation of commitment?

In the next chapter the theory and empirical evidence around real options and existing biases are discussed. The bias of commitment is emphasized in this paper, but other biases that can be solved or aroused by the use of real options are discussed as well. After that, the main hypothesis and two side hypotheses are formulated. Chapter 4 and 5 represent the conducted experiment, with chapter 4 thoroughly describing the design of the experiment and chapter 5 comprehensively revealing the results. An overall conclusion is drawn and recommendations for further research are made in chapter 6.

2. Theory and Empirical Evidence

In this chapter theory and empirical findings about the subject will be discussed. The first section is dedicated to real options in general. After that, biases the real option approach is dealing with will be explained. At last the focus is on escalation of commitment and suggestions to mitigate this.

2.1. Real Options

This section about real options is divided into the following paragraphs. The history and the development of real options are explained first, followed by a description of the different kinds of real options. Subsequently the advantages and some presumed limitations of real option approach are presented.

Brennan and Schwarts (1985) and McDonald en Siegel (1985) were the first economists who came up with the idea to incorporate option valuation techniques when making investment decisions. A few years before that, Myers (1977) had already proposed the concept to see investment opportunities as growth options, and had attached the name real options to it. Since then a lot of studies have been published about real options and their applications in the economy.

In order to define what real options exactly are, we move on to discuss financial options. Essentially financial options provide the basis for real options. Financial options can be basically divided into call and put options. A call option gives its holder the right, but not the obligation, to buy an asset (e.g. a stock) for a predetermined price in a certain period. The opposing party is obligated to deliver the asset against this predetermined price, the exercise price, when the option holder exercises his option. Clearly, the holder should exercise when the stock's share price at maturity[1] exceeds the exercise price. On the contrary, a put option gives a holder the right to sell the asset at a specified moment against a predetermined price. The holder of a put option will do this when the exercise price is above the share price at maturity.[2]
Distinction is made between European and American options. The difference is that the European option can only be exercised at the exact maturity date, whereas American options can be exercised at any time up to the maturity date.

Real options are in fact equivalent to financial options, only then applied to 'real life' decisions. A real option is the right to undertake a certain business-related action; it can be seen as an option on a

[1] Time to maturity is the remaining life of a financial instrument. Price at maturity is the stock's share price at the moment the option expires.

[2] See Smit & Trigeorgis (2004), chapter 3 for more explanation.

strategy. In a real option the required investment costs can be seen as the exercise price of the option and the time till the opportunity disappears can be seen as the time to maturity. Where a financial option uses the current stock price and stock value uncertainty for its calculations, the real option works with the present value of expected cash flows and the project uncertainty. Financial options are traded with low transaction costs. Real options generally have a non-tradable form.[3]

Real options are attractive to a company's management because it copes with future uncertainties and provides them flexibility. A distinction can be made among different types of options. Roughly these types can be divided in options that relate to size, options that relate to the project-life-timing and options that relate to the operating part of a project.

2.1.1. Options to expand or contract

Flexibility with regard to the size of the facility can be desirable when it is not sure that the project will success. An option to expand is to be wished when the demand turns out to be high and functions as a call option, then the company can exercise the option and expand its production. A company could for instance build a capacity in excess of its expected needs, such that it can easily accelerate the production if the demand is rising. The initial costs of a project with such an option to expand will be higher than without because of the establishing costs; however it will be worth it when the arisen advantages in the future are involved.
The opposite option is possible as well: the option to contract. If the market develops less favourably, the company can reduce its scale of operations. It can contract its output if the occasion arises. Of course projects exist where the contrarians are implemented, such that dynamically can be switched between high and low operational productivity.[4]

2.1.2. Option to defer

This timing option provides the management the flexibility to delay the operating activities instead of investing immediately. In this way management can await and see how market develops and then decide whether to exercise its (call) option or not. The option to defer can be seen as a call option to buy a valuable estate or a potential resource; if the market price of the output to be delivered rises and the company should reap the benefits of this estate/resource, exercising the option would be justified.[5]

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[3] These differences are based on the image on page 7 of Villar (2003) and page 12 of Joseph (2007).

[4] McDonald & Siegel (1985) were the first to elaborate comprehensively on the options to expand and contract. After them, the use of these options is widely accepted.

[5] Tourinho (1979) investigated the option to defer by valuing reserves of natural resources and McDonald & Siegel by valuing petroleum lease contracts.

2.1.3. Option to abandon

Just like the previous option, this option is related to the life and timing of the project. In this case the management has the right, not the obligation, to quit a project during its lifetime and liquidate the belonging assets. This might be attractive at a certain moment, when the present value of the remaining cash flows falls below the liquidation value of the project. This variant of flexibility works obviously as a put option, the exercise price is equal to the salvage value.[6] The experiment of this thesis will be focused on this option.

2.1.4. Option to temporarily shut down

This option was also analysed by McDonald and Siegel (1985) and Brennan and Schwartz (1985), the pioneers on the field of real options. This option contains that one could temporarily stop or lower its operational activities when they tend to be not that fruitful, but could start or accelerate these again when opportunities relive. Brennan and Schwartz used the example of a gold mining firm: when the fluctuating spot price comes near to the cost of extracting the commodity, it is attractive to temporarily stop the mining operations.

2.1.5. Proprietary or shared

Options can be proprietary to one party but also to more parties at the same time, which means shared options. For instance a shared real option can be the opportunity to enter a new geographic market or the option to introduce a new product unprotected by potential entries of close substitutes, whereas a proprietary option for instance refers to a purchased licence for a R&D investment or an investment opportunity with very high barriers to entry.

2.1.6. Compound options

The options stated above can all occur as simple options; this means they can be options on their own. However, options can also arise because of another option; an initial investment is necessary to support a follow-on investment. A so called compound option starts to exist from an existing project that has an investment of more than two stages. Each stage is considered an option for the investment of the next stage. One can think of a R&D project for a new medicine, where the costs of R&D in the earlier stage can be considered as an option premium for acquiring the right to invest in a later stage when conditions turn out well. In this way the decision to commit to a pharmaceutical project depends on the expected revenues in the future stages.[7] Compound options are in that way not independent options, but rather links in a chain of interrelated projects. The latter option needs a previous one as

[6] Myers & Majd (1990) were the first who recognized the option to abandon.

[7] Explanation derived from Trigeorgis (1993)

prerequisite. A difference is made between sequential and parallel options. If one option should be exercised to create another one, it is called sequential. Parallel means that the options can exist next to each other, but derive their value from each other.
This sight of view provides an interesting framework for a firm's strategy. For instance the buy-and-build strategy is a widely accepted strategy and is based on this real option framework. Here a platform investment is acquired, from where in later stadia follow-on investments could be done. The platform acquisition can be viewed as a call option that enables sequential options (underlying call options)[8]. There can be thought of the start of a small business as a platform, where expansion into a new geographic market is the follow-on compound option. In fact the platform contains implicitly an option to expand.
Bowman and Hurry already agreed in 1993 that real options are essential for a firm's strategy, in the way of sequential path dependent activities. This is empirically supported by Quigg (1993) who stated that the observed market prices, exceeding the (traditional) model implied prices, could be explained by compound options. In some acquisitions a strategic value is hidden, and the real option framework could clarify this better than old-fashioned gut feel.

2.2. Real Options Valuation Method

When evaluating projects, several capital budgeting methods are available to measure the value of the project. The three most common used techniques are the internal rate of return rule[9], the payback period[10] and the net present value method. The latter is in general the most widely accepted technique. The traditional net present value (NPV) method is simply defined as the present value of the future cash flows minus the purchase price (the invested amount at present). The present value *(PV)* of the future cash flows *(FCF)* is calculated by discounting the cash flows by the rate of return *(i)*:

$$PV\ (i, N) = \frac{FCF\ at\ time\ t}{(1+i)^t}$$

$$NPV\ (i, N) = \ -initial\ investment + \frac{FCF\ at\ time\ t}{(1+i)^t}$$

The traditional net present value analysis makes clear assumptions concerning an expected scenario of cash flows. Therefore it lacks flexibility. It underestimates potential benefits of a project because it ignores the possible flexibility of a management to change settings when new information arises (e.g. information of market development)[11].

[8] Smit & Trigeorgis (2004), chapter 8.3, p. 352-360

[9] Project should be accepted when the average return on the investment (IRR) is higher than the return on alternatives in the market. IRR > cost of capital. Berk & Demarzo (2011), chapter 6.2, p. 160-163

[10] Payback Period = Amount to be invested/Estimated Annual Net Cash Flow. Berk & Demarzo (2011), chapter 6.3, p. 164-165

[11] Explanation derived from Keil & Flatto (1999)

This is where the real option approach comes in. The real option analysis includes next to the static net present value also the value of the real options involved and puts a value on flexibility by doing this. As such, we acquire the extended net present value:

Extended net present value = net present value + value of the real options

This is very broadly how the valuation of real option approach works. However, the real options can be adopted in many ways (e.g. combined with the game theory, see Smit, 2002). In this thesis we will stick with the variant mentioned above.

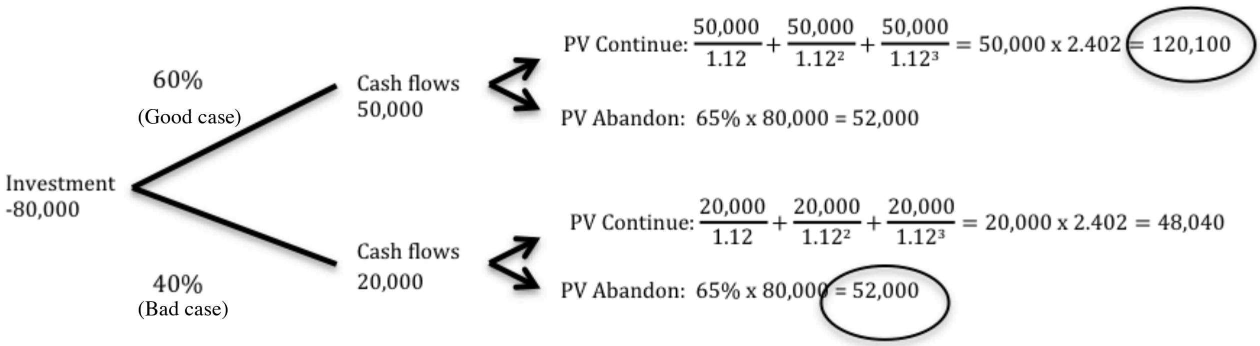
In order to obtain a better view of how real options work, a numerical example is provided.

2.2.1. Numerical example

Imagine a project that requires an initial investment of 80,000 € and has a lifetime of 3 years. After investing this amount, the annual expected cash flows can develop according to two scenarios, either the bad or the good case scenario. The bad case, in which annual cash flows will be 20,000€, occurs with a probability 40%, and with a probability of 60% the good case scenario occurs and the annual cash flows will be 50,000 € during the coming 3 years.

The required rate of return is 12%, which leads to a summed discount factor of 2.402 for 3 years. The manager has an option to abandon at any moment in the first year of the project. If he acts like this way, 65% of the invested capital at that time would be retained.

In the decision tree below, branches for both scenarios with belonging probabilities and cash flows are shown. On the right side of the tree the present values (PV) for continuing and abandoning are computed for both scenarios.



Concluding from the two circled present values, in the good case scenario the company would choose to continue and in the bad case scenario it would choose to abandon, because the choice delivers a higher present value than its equivalent. Now one can calculate the extended present value by multiplying the present values of the best decision's outcomes with the corresponding possibilities, summing those and subtracting the initial investment.

Extended present value of the project: 60% x 120,100 + 40% x 52,000 – 80,000= 12,860 €

Good case scenario Bad case scenario Investment

The value of the project is **positive**; hence the decision should be to **accept** the project, if you want to maximize expected gains.
The difference between the extended present value en the net present value in this case is the value of the real option, in this case the option to abandon. In this example the net present value is computed as follows:

Expected annual cash flow: 40% x 20,000 + 60% x 50,000 = 38,000

Present value of cash flows: $\frac{38,000}{1.12} + \frac{38,000}{1.12^2} + \frac{38,000}{1.12^3}$ = 91,276

Net present value: - 80,000 + 91,276 = 11,276 €

Subsequently, the value of the option to abandon becomes 12,860 – 11,276 = 1,584 €.
The values of options are per definition positive. Like this it can happen that a project will be rejected under the net present value (NPV) conditions, but accepted under real option valuation (ROV) conditions, but not the other way around.
Options can also be computed separately, one way to do this is according to the Black-Scholes Option Pricing Model[12]. However, it is not relevant for our research question to further elaborate on the mathematical details.

2.2.2. Advantages

Throughout the years the real option analysis has had either opponents as proponents. The advantage of flexibility is already given: the ROV prompts the decision maker to think about the value of the management's flexibility. Another main benefit of ROV is that it complements the NPV in its limitations. One big lack of NPV is that it may repel worthwhile projects because it does not recognize potential growth options. Because ROV incorporate these options in its valuation, it avoids a premature cancelation. Joseph (2007) revealed a counterargument on this point, alleging that the ROV does not add this difference. Namely, concerning real engineering projects, the decision go/no-go is clear. Just because the uncertainties are high in that business, project values with a doubtful marginal value are not to be wished. Now real option premiums can only add value, it will only bring change to a decision with a NPV value of 0 or lower. In such a case the real option premiums will lift the project value above zero, but they shall not change it to a project with an undoubtful marginal value. Except for real options with a very high option premium (!). This implies that real options do not matter since the real engineering project managers avoid marginal projects.

[12] Berk & Demarzo (2011), chapter 21.2, p. 713-718

2.2.3. Disadvantages

The main shortcomings of the ROV that the opponents argue about are the following. Firstly, the framework does not suitably apply to all kinds of investment decisions. The framework of real options for path-dependent activities is often hard to implement, and is therefore only suitable for well-specified investments (e.g. overseas production facilities and innovation licenses) and not so much for less predictable opportunities, such as high-technological markets, according to Adner and Levinthal (2013).

Secondly, the mathematically complicated method of ROV can cause implementation issues; among others Knaus and Murphy (2008) expressed their doubts about people's ability to apply real option treatment in complex real life situations. Because they are even not able to implement it in a simple, incentivised, structured, demarcated setting. That implementation can indeed be difficult, demonstrated Borison in 2005: he presented different ways in which the ROV can be used and that the output is very dependent among these chosen ways. He showed that the calculated project values differ drastically among the different used methods. Managers employ real option reasoning, without getting all the details correct. Howell and Jägle (1997) empirically supported this vision by showing that more experienced, older managers overestimate real options in compare to younger, less-experienced agents. Next to these bad reviews, Miller and Shapira (2004) pleaded that the ROV or a variant of it is already being used by a lot of managers, without realizing it and not giving it the name "real option technique". Relating to this statement Yavas and Sirmans (2005) conducted an experiment where they served people a crystal clear real option problem. They found that people invested too early and thus did not realize the usefulness of the real option. Concluded, peoples native behaviour is contrary to the ROV suggested manner of acting and hence the use of ROV as guideline could be beneficial to maximize earnings.

2.3. Behavioural Biases

Research in psychology and behavioural economics has identified various behavioural biases that affect business and economic decisions. People act irrationally when they are prone to these judgemental heuristics. A lot is written about real options with regard to behavioural biases. The framework of real options might overcome certain biases, but some state that real option just causes biases. The following section discusses a few biases that have been linked to the real option approach in existing literature.

2.3.1. Overoptimism

The overoptimism bias suggests that people have too rose-coloured expectations of the unknown and overestimate the frequency that positive outcomes will appear. March and Shapira (1987) suggested that managers could be prone to overoptimism when pricing real options, just as when estimating in other risky choice situations. The subjective probabilities necessary for the branches in a real option

decision tree[13] can be overestimated. Uncertainty in extraneous factors or strategic uncertainty is underestimated.
Overoptimism is according to Smith and Moraitis (2004) also reflected in an overestimation of a target's compound options and synergies. Here, optimism can especially be aroused in a serial acquisition by previous successful acquisition actions. By framing acquisition's opportunities as real options, one might recognize real options everywhere and might obtain an overoptimistic view of the acquisition's growth options. On the other hand ROV can perhaps function as a 'devils advocate' mechanism because the real option framework highlights the uncertainties that are on the lookout.
Overall though, overoptimism is a bias that might be agitated when applying real options analysis for valuing projects, one should be careful when applying ROV and should avoid an overoptimistic view.

2.3.2. Loss aversion

Prospect theory, proposed by Kahneman and Tversky (1997), introduced the phenomenon of loss aversion. This occurs when one is more sensitive to a certain loss than to a gain of the same magnitude. The disutility of losing X euro's is higher in absolute terms than the utility of winning that amount X.
When a manager faces the decision of accepting or evaluating a project, he can experience aversion to a certain loss. Like this, a manager with loss aversion finds it hard to abandon a project because that implies he has to accept a certain loss. Prospect theory tells us that people tend to be risk-seeking over losses; which implies that a manager would take a risk of avoiding the present loss, rather than accept the loss and prevent it of getting bigger. For example consider a platform acquisition where the take-over price exceeded its stand-alone value, which means an entry with a loss relative to its reference point. Imagine the take-over has not born fruits yet and does not seem to do either, managers might continue with risky investments trying to gamble their way out, instead of just abandoning the platform at a lower but certain loss.[14]
Staw (1976) predicated that loss aversion leads to escalation of commitment. When a manager is told that the current project is failing, he is confronted with losing both the potential cash flows promised upfront and the previous committed investments. As earlier said, prospect theory tells people are risk-seeking in the domain of losses. This kind of investment feedback frames the decision to be taken in a way. According to loss aversion the manager will experience the decision whether to continue or not as a challenge to avoid the hated loss. In this way loss aversion may lead managers to take unwise decisions over projects and might cause escalation of commitment. Later on, escalation of commitment will be explained comprehensively, and the relation of it with loss aversion will come back in a side hypothesis in chapter 3.

[13] Look back at page 10 to see a decision tree branches with probabilities.

[14] Smit & Moraitis (2010) give a clear example of loss aversion in the acquisition from Vodafone of Mannesmann.

2.3.3. Mental accounting

Mental accounting is the set of cognitive processes used by individuals and households to categorize and evaluate financial activities[15]. The individual classifies its made costs into specific mental accounts. A classic example of this phenomenon is the person who lost a cinema ticket of 10€ and is not willing to buy a new ticket, but if the same person lost 10€ cash out of his pocket before he even bought a ticket he would probably just buy a ticket. In the first situation this individual has specified a certain budget for himself, purposed for theatre and entertainment, and does not want to cross this budget. In the second situation the person lost the same amount of money, but from 'another account', it did not affect the account for theatre and entertainment. Mental accounts can be isolated by content, but also by time differences.

According to Shapira and Miller (2004), mental accounting is present when dealing with the real option analysis. They predicate that mental accounting of project managers seperates the option pricing decision from the subsequent option outcome. In other words, the manager mentally distinguishes the initial option transaction from the subsequent payoff. This is necessary as such, to consider the initial transaction as sunk costs when making later-staged decisions.

2.3.4. Empire building

Empire building is referring to the urge of an executive to expand a firm's size beyond its optimal size. Driven by greed and blindness managers have the tendency to expand (geographical) size of their company, focussing on maximizing both output and revenue, though they forget that it might harm the long-term profit. Empire building preferences will drive managers to spend the available (redundant) cash on investment projects in order to expand.[16]

The system of real option approach might bolster a manager's feeling of empire building, because including an option to expand this valuation-approach might encourage expansion drift. On the other hand one might expect that real option approach brings down the tendency of empire building. ROV prompts the management to consider several options and to handle strictly according to a clear consistent scheme. Therefore the real option analysis might also have a monitoring effect on greedy managers.

2.3.5. Ambiguity aversion

Ambiguity aversion can be defined as a person's attitude of a preference for known risks over unknown risks. Unknown risks are uncertainties; ambiguity aversion can thus also be labelled as uncertainty aversion and is something else than risk aversion. A person with this attitude would prefer an alternative with less uncertain elements in it above an alternative containing more uncertain

[15] Definition of Thaler (1999).

[16] Jensen's free cash flow agency theory (1986).

components. The opposite attitude is ambiguity loving. Ellsberg (1961) demonstrated these attitudes in a thought experiment, also known as the Ellsberg paradox. In this experiment people appeared to prefer a bet on an urn with 50 red balls/50 blue balls over a bet on an urn with 100 balls but with unknown division, which indicated that they were ambiguity averse.

The widely accepted models in finance do not take the ambiguity preferences into consideration, however the different ambiguity attitudes can have quite an impact on the investment decision. The ROV method contributes already a bit to this concept; more than other models real option approach contributes to better planning and evaluating of projects under uncertainty.

Though, the traditional real option techniques assume that the agent has perfect confidence in the perceived probability-measures of the model representing the future uncertainties. In real, other probability measures are possible too and moreover, agents can have different attitudes towards it. Among others, Schröder (2011) and Rouboud, Lapied & Kast (2010) tried to set up a model including this ambiguity and the attitudes towards it. The former established a model where two extreme attitudes were taken into account (the worst and the best cases), the latters incorporated an ambiguity parameter in their model. Both models suggest that the attitude towards ambiguity affects the value of real options and the time of exercising. For instance, an ambiguity averse person will value an option to delay higher than an ambiguity loving person and tends to invest later. On the contrary, the ambiguity-loving type of person will appreciate an option to invest higher and tends to exercise this option earlier than an ambiguity-neutral or -averse person.[17]

Since the real option method addresses uncertainties by structuring these in a model, they could provide investors more confidence in investments in uncertain businesses. And in line with this Schröder (2011) predicated that a higher confidence can offset excessive ambiguity aversion and thus bring down underinvestment in these businesses. As a result, an ambiguity averse investor could be avoided more often from missing potentially profitable opportunities, by using ROV.

2.3.6. Anchoring and adjustment

Anchoring describes the mental process where a person has to make a decision and relies for this too much on a previous experienced bench-mark. The initially perceived information functions as a reference point: once this is set, new judgements are made while adjusting to this initial anchor. This cognitive bias, described by Kahneman and Tversky (1974), suggests that insufficient adjustments are made to this initial anchor when new information arises and new predictions have to be made.

This bias occurs e.g. when consumers in a shop perceive a discounted product as cheaper than a product with the same price but without the notion of the discount.

[17] Rouboud, Lapied & Kast (2010).

According to Smit an Moraitis (2010) the ROV approach can be used as a counteraction for this bias. Because ROV is a forward-looking tool, it does not consider the target as a static scenario but adjust it more accurately and dynamically with regard to uncertain developments.

2.3.7. Self-serving bias

Furthermore ROV is likely to mitigate the self-serving bias, which happens a lot unconsciously among managers. This means that managers only appraise their own decisions when successes are made and due worse results to bad luck. Because the ROV assigns probability distributions and values to particular uncertainties, a quite objective business analysis is obtained (Smith and Moraitis).

2.3.8. Escalation of commitment

The last and most important bias to be discussed is escalation of commitment (EC). It happens when a manager is escalating his commitment to a current course of action despite not achieving the desired result, according to Staw (1976). Project managers can be prone escalation of commitment when making decisions with the evaluation of a project. Managers, who already invested a lot of effort and resources in a project, find it hard to resist the temptation to continue with their project, even while abandoning would be more sensible at that moment of time. Broadly three reasons have been given for escalation of commitment to happen. First of all, managers tend to justify their previous decisions or they are not willing to kill (in their eyes) their golden goose. They are reluctant to acknowledge that their initial choice to invest was a mistake. New additional resources are spend in the hope eventually it will pay out and will justify the made investments, but end up to be futile. This reasoning can be classified under the name of 'self-justification theory'[18].

Another explanation for EC is that managers may not understand the logic of sunk costs. The sunk cost fallacy is described by Arkes and Blumer (1985) and refers to taking into account irreversible investments when making decisions here and now. Rationally one should not consider these costs anymore when deciding. But irrationally, one does not ignore these 'sunk' costs and is not able to recognize feasible alternatives. Projected on the case of EC, managers can be too focussed on the costs of abandoning the project, while they are blind to the opportunity costs of alternative projects (that might be higher). Reasons for sunk cost fallacy can be found in the prospect theory. Quitting a course of actions implies accepting a certain loss and loss-averse people are reluctant to withdraw when sunk costs are high.

A third broadly accepted explanation for EC is the agency theory, suggested by Harrison and Harrel (1993). This theory[19] suggests a lack of goal congruency between the firm and the deciding manager

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[18] Staw (1976).

[19] The theory itself comes from Jensen (1984).

and information asymmetry exists. A manager can commit resources to a failing course of actions in order to serve his own interests. In this way the escalation can be beneficial for the manager, but not for the firm.

Escalation might also be rational, as Desai and Chulkov (2009) wrote, when some escalation is likely to turn out to be in the best interest for both the company and the managers. E.g. when a real option is initially not considered in the project, but actually is embedded and makes its future value positive, despite of a just suffered setback (Tiwana et al., 2006). Another example of rational EC is a situation of learning, and the marginal costs are declining and marginal revenues are increasing throughout the project (Heath, 1995). And as just mentioned, escalation can be rational in the eyes of the agency theory, but only for the manager and not for the firm. From now on this paper will only elaborate on irrational escalation, and irrational escalation of commitment will be meant when talking about EC.

2.4. Mitigating Commitment Escalation

Several solutions have been proposed in literature of how to limit EC in evaluating projects. Like that, Simonson and Staw (1992) suggested a solution could be found in an established external board, which has an objective oversight of the evaluating process and can avoid the decision makers from being prone to loss aversion and blindness to opportunity costs. They can evaluate whether sufficient reasons exist to continue commitment or not.
Another solution proposed by McNamara et al (2002) is to assign the decisions to different entities within the company, as such that the initial decision to accept a project is settled by another individual than the subsequent evaluating-decision is in a later stage. By doing this, the subsequent decision-maker is less emotionally involved in the project and feels less responsibility (the responsibility that agitates loss aversion and lack of recognizing alternative opportunities). However, although these proposed solutions deescalate the 'overcommitment', it is at the same time their pitfall. Because these external evaluators are less committed to the project, adverse effects take place as reduced information processing and reduced dedicated effort. Furthermore, it requires additional time and organizational resources (Molden, 2011).

Beside above studies, several studies investigated whether the kind of valuation method applied can influence the degree of commitment escalation. For example the research of Conlon and Wolf (1980) demonstrated that indeed the type of capital budgeting technique does have an effect, if it goes along with other factors. In this paper, we are interested in whether the application of the real option method does affect the degree of escalation, in compare to the net present value method. Most literature in this field agrees that a relation exists between ROV and EC, though there is no consensus in what direction.

An experimental method of Karami and Farsani (2011) showed that people using the ROV budgeting method are less likely to continue a failing project, than those who adopt the static NPV method. This was explained by the improved access of the possibility of abandoning the project. The ROV puts more emphasis on the abandonment, so that for a manager's sense the sunk cost can be nearly recovered. Tiwana, Keil and Fichman (2006) found quite the opposite, namely that the presence of options in an extended NPV valuation enhances the willingness of a manager to continue with a failing project. But where Karami and Farsani (2011) aimed for a real option to abandon, this study meant that a continuation of a project with an NPV of 0 could be driven by other carried growth options. These separate studies investigated different types of options. The negative finding of Tiwana et al. (2006) might also be explained by the fact that an (in the eyes of the NPV conditions) failing project can 'escalate' because it can be a potential success project in the eyes of the ROV conditions[20]. This means that the occurrences of EC measured by Tiwana et al. also contain rational EC cases. Hence, this result has not to be a bad sign for the ROV. Moreover, this can even be seen as a benefit of ROV. Promising projects with a positive extended NPV but a static NPV below 0 would lead under the NPV conditions to a premature cancelation, while it would lead to continuation (and perhaps a flourish) under the ROV conditions[21].

The mitigating effect of the real option to abandon on EC is called into question by several authors. Adner and Levinthal (2004) agree that in theory the option to abandon could mitigate EC, but that in practice the probability of abandonment just causes EC. Because, the alleged strength of this real option perspective is also its Achilles heel. They presume that abandonment options are often delayed and consequently lead to escalation of commitment. This delay of the abandonment option can be caused by psychological, social factors and justifications. The decision to abandon is a psychologically tough decision; it is difficult for a manager to kill the project they committed to before. Also the combination of options can exacerbate the delay. When e.g. several growth options are imbedded, the *potential* outcome can become very high, and how greater the *potential* outcome, the even more difficult it becomes for a manager to exercise the abandoning option. This with having in mind that this project full with options maybe was not even accepted under normal NPV conditions. Therefore, maybe the NPV method leads to premature cancellation, but it also avoids the above described irrational EC caused by the abandonment option. Delay of abandoning arises when no strict exercise dates are established, therefore Adner and Levinthal doubt the benefits of an option to abandon, except for an option with rigid abandon dates. Zardkoohi (2013) calls this vision suggestive and even considers the abandonment without an explicit expiration date as positive for several reasons. Next he

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[20] Note that the real option value consists of extended NPV = traditional NPV + value of real options, where the values of the real options can only be positive. This means that a project can deliver a traditional NPV of 0, and a positive extended NPV.

[21] This dilemma can be labelled as the escalation of commitment vs. the golden goose. Real options approach can deliver golden opportunities, which would not have been recognized by NPV approach, but can also deliver an escalating project. See Coff and Laverty (2001).

argues that option to abandon does not cause EC, and if so, it is due to wrong application of the technique by the managers. That is, psychological deterrents to abandonment and difficulty of incorporating the logic of sunk costs. As potential solution therefore, he proposes an external audit, which is supported by Janney and Dess (2013). External audits can improve firms in making objective decisions, now they are not initially involved in the project. This fits well with the proposed solution of Simonson and Staw in the begin of this section. In conclusion, according to them and the other findings in mind, a combination of the real option framework and the appointment of an external board would probably mitigate the EC.

2.5. Related experiments

As just discussed, quite a lot theories have been proposed for real options and their arguable effect on EC. However, a bit more scarce are the experiments dealing with real options and EC. Because real options are about projects and cover real life decisions, it is hard to simulate in a lab or experimental set-up. Nevertheless, some similar empirical tests of real options are found which have supported this thesis paper to create a sort of fictive real option scenario.

For example Shapiro and Kent (2003) conducted an experiment about biases affecting real options, where they stated a few hypotheses derived from the prospect theory. This study focussed mainly on the behavioural effects on the real options *pricing*, an aspect what my paper does not cover. However, the way the questionnaire is built up is pretty appropriate for my experiment.

Mittal and He (2007) conducted an experiment where they tested the effects of decision risk and the degree of completion on escalation of commitment. They found that, the closer a project is to the end, the greater the need to finish and the more the decisions are sensitive to EC. Also, the more risky the decision, the less the tendency for EC.

Wang and Bernstein (2013) designed software where the participant had to choose a strategy (high or low production) dependent on the current oil price (which was following a random walk), as such they created a real option scenario. They found learning effect and myopic behaviour. Great inspiration for this paper's experiment, especially their incentivizing system is appropriate for our research. Moreover, they demonstrated why finance students are a fine sample for conducting a real option experiment. Students, generally poor participants, should be more inclined to maximize their (relatively low) payoff, along with this they showed that students perform not less than professional managers and are prone to the same various kinds of biases[22].

Yavas and Sirman (2005) conducted an experimental design of real options and discovered real option

[22] Among others Karami and Farsani (2011) used managers, who have experience in investment project evaluation, and concluded themselves that these obtain similar results as university students.

investors behave differently from normal investors. Also, they explained why experiments are better than case studies, why it is useful to conduct a laboratory experiment. Among others it does limit the confounding effects because the researcher has control over the data, plus it is less costly and it is replicable.

Karami and Farsani (2011), as earlier discussed, showed that people using the ROV budgeting method are less likely to continue a failing project, than those who adopt the static NPV method. Their experiment resembles the most with the experiment in our paper. They conducted an experiment with two sequential periods where the treatment-group had to do real option calculations and had to make recommendations upon those. Subsequently these were compared to a control group calculating with the NPV method. The experiment following in the next chapter of my paper has basically the same design, but differs in a few ways from their experiment. Instead of making recommendations, the participant in this paper has to make the decisions about accept or continue himself. Secondly, the experiment consists of 3 stages, where the participant is firstly presented an initial opportunity to invest, subsequently he is asked to decide whether to continue or not, confronted with *both* a *bad* and a *good* case scenario. Furthermore, the control and treatment group differ in the kind of budgeting method suggested in all the 3 stages, where the groups of Karami and Farsani only differ in this in stage 2. The type of participants is different, and at last but not least an incentive system is added in my paper.

3. Hypothesis development

After taking into account the previous literature and empirical research, one main hypothesis is developed. We expect that including real options in the evaluation method of projects, will lead to better decisions. The framework real options have, will highlight the link between present actions and opportunities in the future. Especially in a high uncertain investment environment, this view seems beneficial. Furthermore it will give a stricter structure for the decision-making process of managers and create awareness among managers about the existence of options. With respect to decreasing the probability of escalation of commitment, *real option approach would stress the opportunity of the option to abandon* when continuing seems not sensible.

Hypothesis 1: Managers are less prone to commitment escalation when the real option approach is used to evaluate the project instead of the net present value method.

Beside the main hypothesis two side hypotheses are stated which are easily to test through a short additional questionnaire without affecting the main test.

When a decision maker receives feedback that his investment is failing, he faces the prospect of losing both the potential rewards the investment originally offered and the resources previously committed to it. Prospect theory tells us that the disutility caused by losses is greater than the utility obtained from equivalent gains. Loss aversion of decision makers impacts the decision about whether to continue with the current course of actions as a decision about whether to accept a loss or to take steps to prevent locking it in. Therefore, a loss averse attitude could lead decision makers to take unwise decisions to avoid losses[23].

Hypothesis 2: Escalation of Commitment has a positive relation with the degree of loss aversion.

Worldwide there has been a lot of discussion about the differences in leadership between men and women. Some empirical evidence suggests that the degree of testosterone increases the sensitivity to empire building and escalation of commitment[24]. I think it is interesting to make this distinction in my experiment, and on top of that it is easy to test additionally.

Hypothesis 3: Female decision makers are less prone to escalation of commitment than male decision makers.

[23] The negative framing of a feedback on an investment already has proven to be an exacerbating factor on EC by Juliusson (2003), this gives indirectly support for the positive relation between loss aversion and EC.

[24] Guiso and Ristichini, 2010

4. Method

4.1. Introduction

The main goal of this experiment is to investigate whether the ROV approach can mitigate escalation of commitment. Thereby a treatment group is distinguished from a control group in the way that they were told to use the ROV method to valuate the served project, instead of the NPV. This chapter will elaborate on the design and the procedure of the experiment.

4.2. Participants

Participants were all recruited from the Erasmus University, and all having finance background. 64 Dutch students between 18 and 25, divided in 19 female students and 45 males, respectively 30-70%. Only students of university level studying in their bachelor 3 or master students were interrogated, within one week in June 2013.

4.3. Design experiment

Participants were split up in two groups, the treatment group and a control group. In both groups the students got the same case in front of them, they had to act as a financial decision maker for a technology company, in two sequential time stages. The difference in treatment between the two groups lies here that the *control group* was told to use the *net present value* analysis as project evaluation method, whereas the *treatment group* was told to use the *real option method*. Instructions were handed out of how to perform the suggested method. The participants were given space to write down the calculations.

The groups were given information about a project involving a new product to launch: a high-tech e-reader of pocket size. The required investment, the cash flows and the probabilities of success and failure were given, and the mention that the technology could be sold any moment for 60% of the investment. The participant had to decide whether to accept or reject the project, after that he had to indicate on a scale of 0 to 100 how sure he was about this decision.

The provided numbers in the **first stage** should in both techniques evidently lead to the decision of accepting the project. However, slight differences can appear in the confidence rates between the two groups.

The **second stage** consisted of two scenarios, 2a and 2b. In the first scenario the groups received a message that due to entrance of competitors on the market the expected cash flows had decreased drastically (bad scenario is happening). The suffered sunk costs, as the grade of completion were mentioned. Also this time the participant had to make a decision whether to continue or not with the project and again a confidence rate was asked. Again the control group was supposed to use the net present value technique, and the treatment group the real option approach.

The provided cash flows and the belonging probability in this second stage should with both used techniques unequivocally lead to abandoning the project. If the students did well, they decided not to continue. For this second stage holds: the higher the number of participants who continue, the higher the average degree of commitment escalation (because the right answer would be: stop with project). According to the expectations, the number of continuers in the second stage of the control group (NPV) should be significantly higher in comparison to the number of continuers of the treatment group (ROV). The students using ROV should be more aware of the option to abandon in compare to those using NPV. If this difference stays off, the confidence rate can be compared; this is expected to be higher in the group with ROV treatment.

After filling in these two decisions, the participant proceeded to the second scenario of stage two (stage 2b), concerning the good case scenario. Here he was asked what to do if the just sketched bad case scenario did not happen, but market flourished instead. Again a confidence rate was asked. This last scenario should obviously be answered with a decision to continue. This last stage is just to complete the overall-picture, it does not deliver additional value for the research, except for the fact that we can see whether participant understood the story of the case.

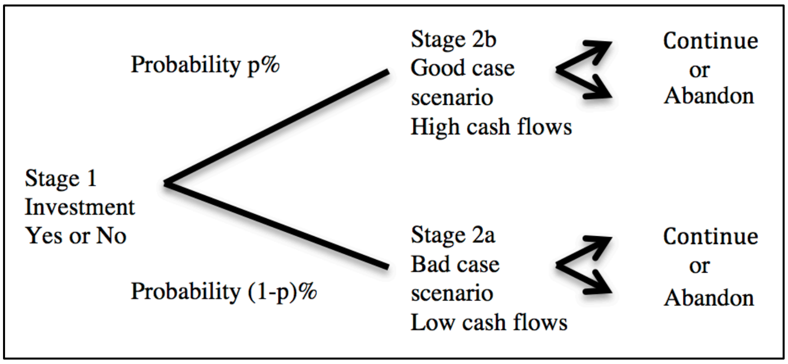

Figure 1: Overview of the two stages, the two scenarios and the available decisions to make.

Afterwards the student had to fill in an additional questionnaire, part 3, not related to the case. Some questions were asked to detect possible disturbances. The student had to point out on a scale of 0 to 100 how well he understood the case and in what way he found the case realistic. Furthermore, questions about financial background and knowledge of real options were asked. At last, in order to test the student's degree of loss aversion, the students had to pick a point in a list of gambles, from where they would accept the gamble[25]. With this information hypothesis two can be tested. Being an additional questionnaire, this third part does not disturb the results of the previous parts for my first hypothesis.

In appendix B the questionnaires for the control group as for the treatment group are presented. The boxes with space are provided with the correct answers, but are of course empty on the participant's questionnaires. During the test, students were allowed to use a provided calculator and could refer to the instructions of the involved method.

[25] This method of measuring is hard to compare to more advanced methods as in Abdellaoui et al. (2007). Basically a relative indifference point is derived by giving 20 choices between 2 alternatives. In this study we just need the relative value of loss aversion towards others. The first choice (0.5,-110€ ; 0.5,100€) serves as a *reference point* for measuring higher degrees of loss aversion.

4.4. Procedure

In order to avoid selection effects, methods of treatment were randomly but equally divided among subjects. In fact the questionnaires were given out alternately, in that way that participant 1 got the control questionnaire, participant 2 the treatment, participant 3 the control and so on; with keeping in mind that among males equal proportions ROV/NPV existed and the same for females.

Students were clearly told that their answers would remain anonymous and they made the questionnaire in private. This was done, in order to control for intrinsic motivations, now participants in public might tend to "be the best". Furthermore, it prevents confounding effects from peer pressure or competition.

Incentivize system

This experiment has a special incentivize system, in order to make sure it is in the participant's interest to respond with truly unbiased answers. Because, caution is needed when imposing kind a heavy workload on students, as the questionnaire requires 10-15 minutes to fill in and requires some calculations from the students.

That is why participants can earn a certain amount of money when they fill in the questionnaire. The questionnaire is presented to the student as an 'investment-game'. In the case each combination of decisions will lead to a certain payout and 10% of the participants will actually be paid out. The participant has to count with large amounts of money, subsequently the actual payout will be obtained from these by a multiplier of 0.0001, such that 10,000 euros stands for 1 euro payout.

The contestant is given an initial credit of 100,000 euros (which represents 10 euros payout) and with this amount he can invest in a suggested project. This amount can either increase or decrease during the exercise, depending on the decisions made and on market development.

The eventual payout consists of the eventual present value of the project and the money that was not invested. In figure 2 below, an overview of the possible payouts is given.

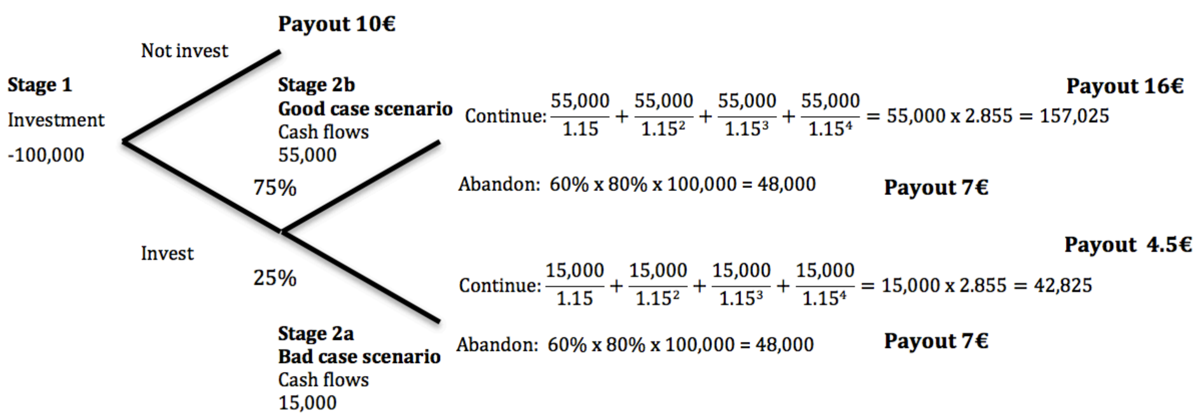

Figure 2: overview of the possible payouts. In the both abandon situations, the participant can abandon the project at a completion rate of 80% by selling the assets against 60% of invested capital by that time. 2 euros is added to the payout, representing the 20.000 euros not invested.

The size of the payout depends on the student's decisions and on market development. Whether the market develops favourably or unfavourably in each case is determined by a roll of a dice (a special dice with twelve sides) done by the researcher, at the end of the experiment.

Cause we deal with students, who are generally known for having limited resources to spend, in this experiment the shown payouts should be sufficient to exceed the mental effort they have to put in to this test. On the other hand, we expect the payouts not to be too high, and it is not too expensive to pay because only 10% of the participants will be paid out. One could argue that the house money effect might backfire the effect of the incentive and could lead to different behaviour, because the participant is given 10 euros as initial credit. However, when the experiment would not obtain the 10 euros, every contestant would invest for sure, because he/she has nothing to lose. The experiment needs a buffer because losses can be made. And it is too dubious to ask the contestant to put in his or her own money with the risk to lose it. Furthermore, the design of the experiment, framed as an 'investment-game' was a pleasant task for the student that they enjoyed, which functions as a incentive of itself. Some doubt might exist about the difficulty of the task. If the task is too difficult, monetary incentives do not work. Therefore a check of understanding is included in part 3 of the questionnaire.

With regard to the loss aversion task, no real payout is involved but only questions with hypothetical outcomes are used. Beside the fact that this task is more or less a side test and must not become too complicated, empirical studies showed that for this kind of tasks real incentives are not necessary[26].

4.5. Data and Analysis

In the next chapter the results are discussed and analysed. First the raw data are presented, and then statistical analyses are reported divided into sections related to the three hypotheses.[27] Throughout this chapter several variables or acronyms instead are used; in the list below they are summed. The first two variables, escalation of commitment and the confidence rate, are the dependent variables.

Variable	Description	Values
Escalation of Commitment	Escalation of commitment (EC)	Yes in stage 2a, EC= 1
	Non-escalation of commitment (Non-EC)	No in stage 2a, EC= 0
Confidence Rate	Degree of confidence about a decision (CR)	Rate between 0 to 100
Treatment	Net present value (NPV)	Treatment = 0
	Real options valuation (ROV)	Treatment = 1
Gender	Male	Gender = 0
	Female	Gender = 1
Loss Aversion	Degree of loss aversion (LA)	Score between 0 and 20
Rate of Realism	Degree of experienced realism (RR)	Rate between 0 to 100
Rate of Understanding	Degree of understanding (RU)	Rate between 0 to 100

Table 1: The used variables, with description and the values they can take.

[26] Abdellaoui, Bleichrodt, Paraschiv (2007), page 1664

[27] All statistical methods used in this chapter can be found in Moore et al (2009).

5. Results

5.1. Data

In the first stage more than 95% of the participants chose to accept the project and thus made the initial investment. Still a few persons from the treatment group did not make the initial investment; this might raise concerns about the real options analysis because some people using it fail to recognize a lucrative project. These exceptions consisted of two subjects with a miscalculation and one with a perfect calculation but with a low risk appetite who considered the project not profitable enough in proportion to its risk. However, the latter was found with a very high loss aversion (degree 19 on a scale of 20). Hence from the former two the conclusion could be drawn that the real options valuation might be too complicated and thereby more sensitive to miscalculations.

Figure 3 shows the division of decisions and the average confidence rates (CR) belonging to the first stage. Subjects using the ROV were on average 5% more resolute than the subjects in the control group about their initial decision to invest in the lucrative project. In appendix C14 histograms of the distributions are shown for each category.

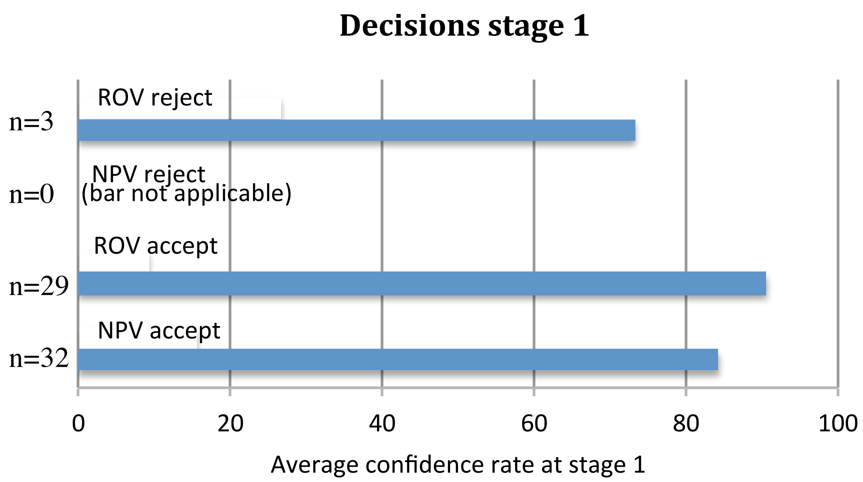

Figure 3: The average confidence rates about the decision to invest in stage 1. The numbers of subjects are given next to the bars. E.g. three subjects in the treatment reject the project with an average CR of 73.

In the second stage *concerning the bad case scenario* (stage 2a) one of the dependent measures was the decision whether to continue or not. A confirming answer would indicate escalation of commitment. In figure 4, a clear overview is shown about the decisions in stage 2a. Half of the subjects using the NPV did not abandon the project in stage 2a and showed escalation of commitment. Visible to the naked eye is that in the treatment group EC occurs considerably less often than in the control group. Not 50%, but 20% of the treatment group seemed to be prone to EC.

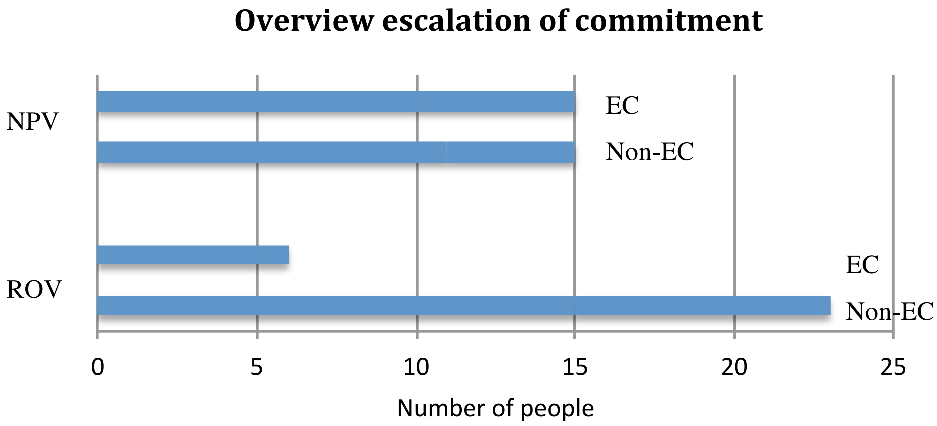

Figure 4: The numbers of cases of EC compared to the abandonments in stage 2a, divided into NPV and ROV treatments.

Figure 5 shows the CR differences between the used methods for the decision in stage 2a. The ROV users were more sure than the NPV users about their correct decision to abandon, as reflected by the first two bars (respectively rates of 86 and 80). However, with figure 1 in mind, the ROV subjects had at stage 1 already a higher CR than the NPV users. Furthermore, the ROV users who chose for project continuation seemed to be more confident about their (wrong) decision as well. So this difference seems to be on each stage and with regard to both rejection and acceptance. Thus, probably using the real option analysis people perceive a higher confidence about their decisions in general, regardless whether those are wrong or correct. But one should be careful with interpreting the results, because the means from figure 5 are distracted from unequal distributions, shown in the graphs of appendix C14. For example the mean of ROV continue (71.67) is acquired from 6 observations with all different answers.

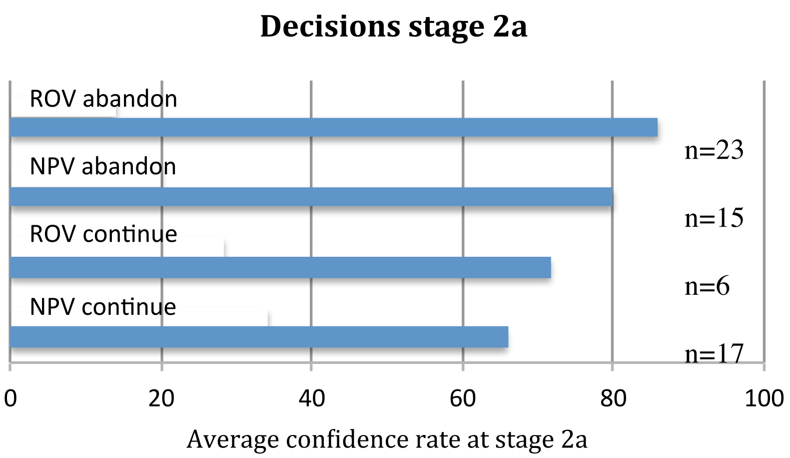

Figure 5: The average confident rates about the decision to continue in stage 2a, concerning the bad case scenario. The n stands for number of subjects found with the choice to continue/abandon in the NPV/ROV group.

In the second stage *concerning the good case scenario* all subjects replied with the decision to continue, except of course for the non-investors in stage 1 because they opt out in the beginning and they did not had to make this last decision. These findings do not provide additional support for the research, but for the experiment as a whole this is a good signal because it shows in a way that the participants have understood the questionnaire. Again a similar difference in CR between the ROV and NPV appeared (respectively 89 and 82), just as in stage 1 and 2a.

Figure 6 contains the average degrees of loss aversion for the different conditions. Logically, loss aversion is personal and should not depend on the method used; this is reflected by the several blue tints that approximately have the same degree. The mean degree of loss aversion of all subjects is approximate 11, with the used yardstick this implicates that one accepts a gamble if it is better than [0.5, - 60€ ; 0.5, 100€]. That is quite loss averse. Apparently loss aversion is positively correlated with escalation of commitment, now the subjects in the EC cases indicate a higher degree of loss aversion than the subjects who were not prone to EC. In a later section statistical evidence is provided.

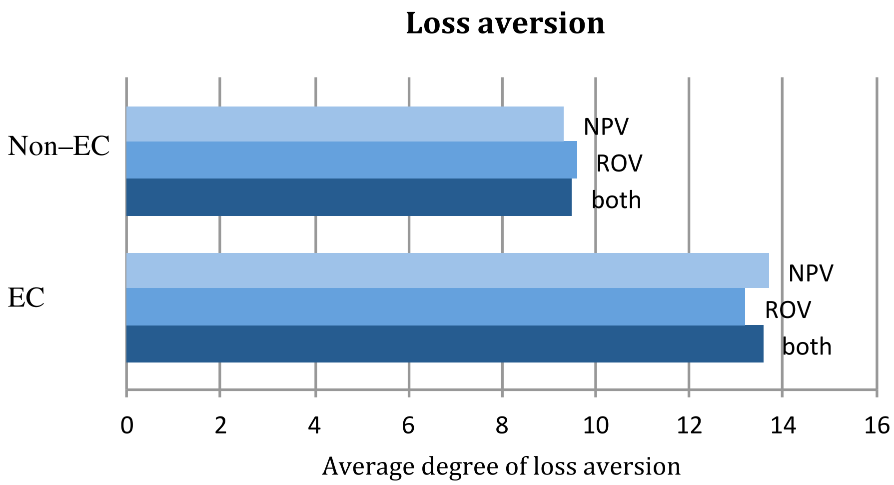

Figure 6: Average degree of loss aversion, sorted into those who showed EC in stage 2 and those who did not.

From figure 7, we can speculate that the real option method has more effect on female subjects, now the difference in proportions -EC/non-EC- from the NPV to ROV is greater for female subjects.

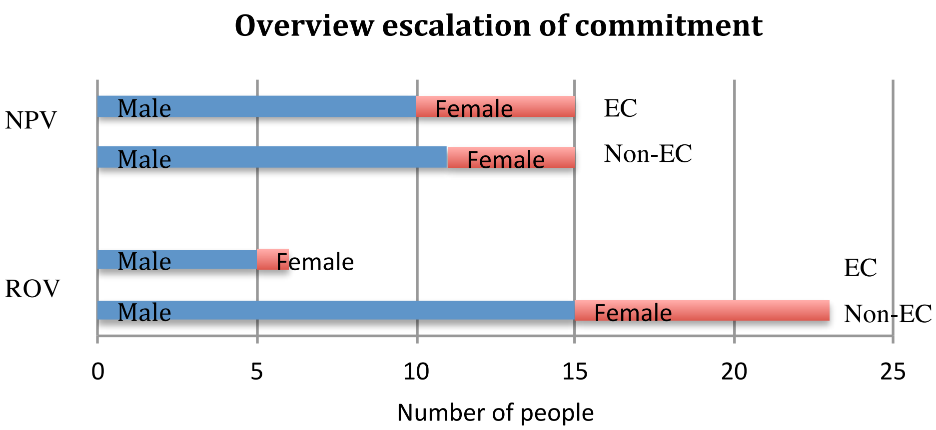

Figure 7: The numbers of cases of EC compared to the abandonments in stage 2a, divided into NPV and ROV treatments and distinction in gender.

Figure 8 represents the relative division of the phenomenon EC per gender. In percentage male subjects have fallen prey to EC slightly more often than female.

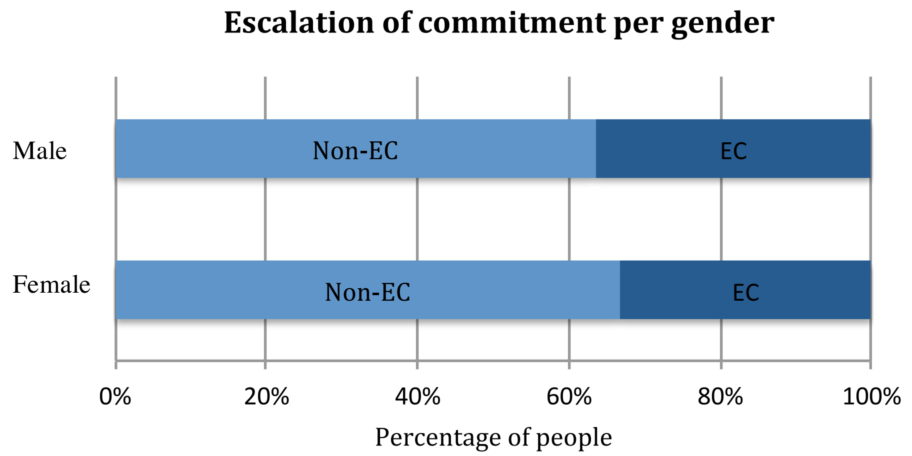

Figure 8: Occurrence of EC per gender expressed in percentages.

5.2. Statistical analyses

5.2.1. Test hypothesis 1

In order to test hypothesis 1, analysis was done on the main dependent variable EC.

This is the decision in stage 2a – whether to continue or not – while being in the bad case scenario. The main question is whether the type of valuation method used affects the frequency of EC. A Chi square test was conducted to compare the means of EC between the NPV and the ROV groups. The participant could only return a yes (1) or a no (0) in part 2a, where the yes stood for continuing and thus indicating EC. The binomial character of the results requires a non-parametric test, because for parametric tests normally distributed data at interval scale is needed. The Chi squared test determines if a significant difference is present between observed outcomes (at nominal scale) in a category and expected outcomes in a category. The critical value with 5% significance level is 3.84 and is taken from a χ^2– distribution[28]. The found χ^2–value for the comparison of the EC frequency between the students with ROV treatment and those without appeared to be 6.81 (p-value = 0.009), as presented in appendix C2. Thereof we can conclude that a significant difference exists and we consequently find support for H1. Hence, the use of the real option analysis as a valuation method mitigates the occurrence of escalation of commitment. One can argue that this result is biased cause of the 3 non-investors with the ROV condition in stage 1. As discussed earlier, the ROV method may be more complicated and may lead to more calculation errors. But these exceptions are negligible; no significant difference exists in rejection in the first stage between the two groups (p=0.238, see appendix C1). Hence, no significant difference appeared between the two valuation groups when they initially had to decide to invest or not. A Fisher's Exact Test was used to check this, now the expected

[28] χ^2– distribution table F from the book of Moore, McCabe, Duckworth, Alwan (2009)

frequency of rejecters in stage 1 is less than 5 (namely 1.5) and a Chi-square test is thus not suitable anymore.

Furthermore a test was done to check whether a method in general leads to a wrong decision more often, regardless whether stage 1 or 2 was concerned; in order to make sure the earlier found results are not affected by the three drop outs in first stage. With the 'wrong decision'-variable is meant the decision to not invest in the first stage or a decision to continue in the second stage being in the bad case scenario. Users of the NPV method again delivered significantly more wrong decisions than ROV contestants. (χ^2 –value of 4.146, p-value of 0.042, appendix C3)

The significance of the comparisons of the confidence rates in the different stages between the two groups is given in table 2. The CR's are compared between the two groups, with distinction between accepting and rejecting per stage.

Non-parametric t-tests for two independent samples are used, since the majority of the data appears not to be normally distributed. (Shapiro Wilk tests deliver p-values below 0.05, see appendix C4 for values and C14 for distributions) The non-parametric Mann Whitney U test is suited for these comparisons, because it compares whether two independent samples (NPV and ROV) come from the same population. Its null hypothesis states that the means of the two samples are the same.

Only in the first stage and stage 2b confidence rates appear to differ significantly between the NPV and the ROV subjects (at 10% sign.), so in these stages the subjects using ROV were more sure about their answers than the NPV subjects. It looks quite extraordinary that this difference disappears in stage 2a. This might logically be explained by the fact that the power of the test is bigger in the first stage, now the sample *n* decreases in stage 2a when the group is split up in 'accepters' and 'rejecters'. This explanation is supported by the finding that the overall confidence rate of the ROV subjects is significantly higher again in the second stage in compare to NPV subjects, regardless accepters or rejecters are concerned (t-test of p=0.009, see appendix C4). When assuming such a difference is

	Accept			**Reject**		
	NPV	**ROV**	**Significance**	**NPV**	**ROV**	**Significance**
Stage 1	Mean = 84.38 n=32	Mean= 90.69 n=29	Mann Whitney U p=0.098*	-	Mean= 73.33 n=3	
Stage 2a	Mean= 65.88 n=17	Mean= 71.67 n=6	Mann Whitney U p=0.500	Mean= 80.00 n=15	Mean= 86.09 n=23	Mann Whitney U p=0.202
Stage 2b	Mean= 81.56 n=32	Mean= 87.24 n=29	Mann Whitney U p=0.061*	-	-	

Table 2: Overview of the significance of the differences in average confidence rates, divided in accepters and rejecters.
*** significant at 5% level* **significant at 10% level*

present as well in stage 2a when the size of n increases (and accordingly improvement of the power of the test), this difference appears on each stage and with regard to both rejection and acceptance. Conclusively, using the real option analysis people might perceive higher feelings of confidence about their decisions in general, regardless whether those are wrong or correct.

5.2.2. Test hypothesis 2

Next, hypothesis 2 is tested where we investigate whether a positive correlation exists between escalation of commitment and the degree of loss aversion.

Therefore a test is conducted to obtain the Spearman correlation, since this test is allowed for data at ordinal scale. Indicated is a significant positive correlation of 0.363 (p=0.004). Thus, as expected, people who are more loss averse, tend to be earlier a victim of EC than people who are less loss averse. This can be explained logically, loss averse types would find it hard to accept losses when abandoning the project, and rather continue the (hopeless) project in order to avoid the threatening losses.

Another way to investigate hypothesis 2 is by comparing the mean loss aversion degrees between subjects who were prone to EC and those who were not. A Mann-Whitney U test is used, since the loss aversion data did not seem to be normally distributed (KS p-value=0.015). The test delivered a significant result. Consequently, on average victims of EC point out to have a higher degree of loss aversion (p=0.005, see appendix C5). Hence, a positive correlation exists between EC and LA and evidence for hypothesis 2 is found.

5.2.3. Test hypothesis 3

Hypothesis 3 stated that male decision makers would be more sensitive to EC than female decision makers. A Mann Whitney U test demonstrates that the female participants were more loss averse than male ones (found p-value of 0.002, appendix C6). With the found correlation in the previous section between LA and EC, one may reason that women are more sensitive to EC than men; this is in contrast to hypothesis 3.

In order to compare the observed frequencies between male and female students a Chi square test is performed, just like with hypothesis 1. It delivers a χ^2– value of 0.208, below the critical value of 3.841 (see appendix table C7). Consequently we do not reject the null-hypothesis of equal means. However, the results might be biased, since the distribution of ROV/NPV is not totally equal among the both genders and therefore possible measured effect could appear due to difference in treatment. The female participants are divided 50%-50% among NPV and ROV respectively, while the male participants have a 53-47% division. Most probably this is effect negligible, but is should be mentioned though.

5.2.4. Probit model

In the previous sections the three hypotheses are discussed, including the effect of three different variables on the dependent variable EC. In this section attention is paid to the effects on EC of these factors together and compared to each other. Basically, we want to do a regression analysis of EC on several explaining variables. But as EC is a binomial variable, an ordinary-least-squares regression is not possible to run. Since EC turns out to be exactly 0 or 1, it causes that the explanatory variables and their coefficients together must match zero or one and thus such a formula is not useful. Instead of that a probit binary model is used to estimate the contributions the several explanatory variables are delivering to the binomial EC-variable. Here we introduce a Z-score. The Z-score indicates the probability that EC becomes 1 or reversely 0. With use of the probit model, Z can be defined as an artificial linear regression consisting of the explanatory variables with belonging coefficients βi, given by the following formula:

$$Z = F\,(\text{intercept} + \beta 1 * \text{treatment} + \beta 2 * \text{gender} + \beta 3 * \text{loss aversion})^{29} \qquad (1)$$

The coefficients can be interpreted as the degrees of contribution to the cumulative normal distributed probability Z. For example one unit increase in loss aversion will cause an increase in the z-score. Though the interpretation of coefficient changes is not that straight-forward as in linear OLS functions. The increase in the Z-probability is not only dependent on the one-unit rise in loss aversion, but also depends on the other predictors and the starting value of the concerned predictor. In other words, the marginal effect of the predictors is not constant. For example when loss aversion rises from 10 to 11, keeping other variables constant, it has another effect than when it would have risen from 13 to 14. This has to do with the binomial character of the output, because it depends per unit whether its additional weigh will be that particular weigh that will push the binomial outcome of EC to either 0 or 1. In table 3 the results of a probit regression on EC are shown, with treatment and gender as categorical factors and loss aversion as covariate. Both explanatory variables treatment and loss aversion appear to be significant, and deliver respectively a negative and positive effect on Z. The columns on the right labelled as regression B contain the check on robustness. In order of significance the two significant variables are added to the model, to test whether the variables would keep their

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[29] The F represents the cumulative distribution function $F_X(x) = \frac{1}{\sigma\sqrt{2\pi}} \int_{-\infty}^{x} e^{-\frac{(y-\mu)^2}{2\sigma^2}}\,dy$. Because the Z-score is normal distributed, each Z-score corresponds to a probability, using the cumulative normal table.

power. Apparently the variables treatment and loss aversion are both robust enough, but the coefficient of loss aversion decreased slightly.

Probit Binomial Model, dependent variable: EC				
N=60	**regression A**		**regression B**	
Variable	**Coefficient**	**P-value**	**Coefficient**	**P-value**
Intercept	-1.107	0.022**	-1.005	0.032**
Treatment	-0.853	0.022**	-0.837	0.021**
Gender	-0.710	0.116		
Loss Aversion	0.119	0.003**	0.093	0.008**
McFadden R^2	0.210		0.178	
Likelihood ratio chi-square	16.79	0.001**	14.20	0.001**
Akaike info criterion	1.185		1.195	
Schwarz criterion	1.32		1.30	

** Significant at 5% level.
Table 3: Probit model on EC with 3 explanatory variables. Regression B represents robustness-check.

The found value of treatment can be interpreted as follows; for taking ROV as valuation approach instead of NPV, holding other variables constant at zero, the z-score decreases and lowers the predicted probability of EC. In this case the z-score decreases with 0.853 using the ROV approach, in relation to the NPV approach (NPV is the reference group). In the same way the variable gender should be interpreted *if* it were significant. However, to loss aversion, being a covariate, belongs an other interpretation. Loss aversion causes the z-score to increase with 0.119 for each one unit increase in the degree of loss aversion.

The effect of one unit of ROV can be compared more clearly with regression B, when setting loss aversion constant at its mean (mean LA of all subjects = 11.054, appendix C5).

$$Z = F(-1.005 - 0.837 * 0 + 0.009 * 11.054) = 0.5079 \qquad \text{(when applying NPV)} \qquad (2)$$

$$Z = F(-1.005 - 0.837 * 1 + 0.009 * 11.054) = 0.2069 \qquad \text{(when applying ROV)}^{30} \qquad (3)$$

Thus, according to this model, if a subject is using NPV, its chance to become victim of EC is 50.79%. This probability becomes 20.69% when applying ROV. These outcomes indicate a decrease of 30.11% in predicted probability after switching valuation methods; real options analysis has a mitigating effect. Remember, this is just a predicted probability accounted for the control variables in the model. The probability of the occurrence of EC is still embodied with a lot of uncertainties coming from variables not measured in this model.

[30] Outcomes of formulas 2 and 3 were computed with use of Stata software.

The model as a whole is statistically significant meaning that it predicts the outcomes better than a model without predictors, because the likelihood ratio in table 3 has a chi square of 16.79 with a p-value below the 5%. The Mc Fadden R squared represents the explanatory power of the calculated regression. By omitting gender from the first regression the model has lost some power, namely 3.2% from 21% to 17.8% in the second regression. However, the Mc Fadden R -squared can not be interpreted like the R-squared in a normal OLS regression. Though, the finding is supported by the Akaike info criterion (AIC); this rate increased as well. The AIC should be as low as possible, to avoid loss of information. This counts as well for the Schwarz criterion (SC), this rate takes into account both the statistical goodness of fit and the number of variables that have been estimated for achieving this degree of fit. When comparing the two regressions, one can conclude that a balance must be made between removing variables (and lower the SC, improve goodness of fit) and increasing the explanatory power by adding variables.

Next we check whether the variables may have interaction effects that might explain why in the previous model explanatory power disappeared after omitting gender. We could for example find support that applying the ROV method works better for female than for male individuals. That would explain the loss of power from regression A to B. Or we could find for instance an interaction effect between loss aversion and treatment, such that people with a higher degree of loss aversion are more sensitive for the used type of valuation method.

First a Wald test is conducted to see whether the combination of gender and LA has a significant effect on EC, but a non-significant result is obtained accompanied with a very low Mc Fadden R^2 (p=0.953, see appendix C8). Neither the combination LA and treatment produced a significant result (p=0.607, appendix C9) and neither a significant coherent effect of treatment and gender is found (p=0.431, appendix C10). From the Mc Fadden R^2, the AIC and the SC values as well we can conclude that the regressions in table 3 work as better predictors than these models with interaction effects.

In table 4 regression C shows a model with all the possible predictors + interaction effects. All predictors have become insignificant except for LA and from the Schwarz criterion can be seen that the goodness of fit is very poor. Thereof we find support that LA is the most robust variable. Subsequently, regression D is created by adding the variables one by one ranked by their significance. After LA, the variable treatment*gender is the most significant. But a model including LA as well as the interaction effect treatment*gender and their main effects, does not deliver a better model.

When comparing the Mc Fadden R^2 values of regressions C and D with those of regressions A and B, the latter are a bit lower. Nevertheless, as mentioned earlier: a balance must be made between a model with a high explanatory reach, but on the other side the model should restrict the number of variables. Because the Schwarz criterion of model C and D are quite high, preference goes out to regression B.

Conclusively, if we compare the probit models in this chapter with each other, the most trustworthy model we can derive from these results becomes regression B of table 3.

However, we must not attach too much importance to this probit model. In general a correct estimation of a probit regression requires at least more than 50 observations, because data containing less than 50 barely have enough significant explanatory variables. This research provides 60 observations, but can still be labelled as weak. Furthermore, probit models are very sensitive to small changes, and that is why it is difficult to rely on such a weak model.

In the above stated regressions the possibility of heteroskedasticity is not taken into account. A proper solution for this problem does not exist, because the probit model is that sensitive, any corrections for the phenomenon could ruin the model. Multicollinearity did not occur between the variables, correlations below the 0.5 were found (Appendix C11).

Probit Binomial Model, dependent variable: EC				
N=60	**regression C**		**regression D**	
Variable	**Coefficient**	**P-value**	**Coefficient**	**P-value**
Intercept	-1.210	0.052*	-1.109	0.0163**
Treatment	-0.562	0.556	-0.671	0.120
Gender	-1.015	0.630	-0.465	0.393
Loss Aversion	0.122	0.022**	0.122	0.002**
Treatment*Gender	-0.696	0.504	-0.696	0.423
Treatment*Loss Aversion	-0.011	0.898		
Loss Aversion*Gender	0.037	0.794		
McFadden R^2	0.220		0.218	
Likelihood ratio chi-square	17.54	0.007**	14.20	0.001**
Akaike info criterion	1.272		1.207	
Schwarz criterion	1.517		1.382	

* Significant at 10% level.
** Significant at 5% level.

Table 4: Probit model on EC with explanatory variables including interaction effects. Regression D represents robustness-check, with the most significant variables added in order of significance.

5.3. Extra analysis

In the last part of the questionnaire students had to answer some additional questions, which serve as a manipulation check. Some statistical comparisons are done between the treatment and control group, to mind for confounding factors.

No significant differences were obtained in reported understanding among the participants in the ROV condition and those in the NPV condition (p=0.116, appendix C12). Apparently the case and the way of calculation were understood equally well by students in both groups, regardless the method of treatment. This finding mitigates the concern that had risen after the failure of the students in the first stage, namely that the real option analysis would be too complicated for the students. Overall the rate of understanding was on average 88.75 at a scale from 0 to 100, which shows that the reported effects in this chapter are most probably not due to a lack of understanding.

Neither a significant difference is found in the rate of realism (p=0.798, see appendix C13). The average rate of realism was 72.19, what means the subjects were pretty able to identify the case as if they had to make a real life decision. However, it is difficult to simulate an identical real-life situation in order to receive a subject's unbiasedly true decisions, though the money incentive should remedy this problem a bit.

After all it is worth mentioning that not all answers of participants were mathematically correct, though in vast majority this did not affect the conclusion implemented in the decision.

5. Conclusion

In chapter 1 of this paper the research question was established whether the use of real option analysis mitigates the occurrence of escalation of commitment and thereby improves the decisions of managers.

The literature review of this paper pointed out that real option analysis has earned a major role in the manager's toolbox for evaluating projects. Different authors have discussed whether real option techniques provide a better insight in an uncertain staged investment than other valuation methods. Various economists expect the real option framework, in particular with the option to abandon in mind, to mitigate the escalation of commitment. Admittedly in combination with this real option approach they suggest an external board to evaluate the project in a later stage, a board with people who are not emotionally attached to the project and do not feel the responsibility (responsibility arouses behavioural biases).

In the end of chapter 2 related experiments were presented and with the aid of these previous findings the experiment of my paper was derived. Chapter 4 described comprehensively how my experiment had been set up and carried out. A project with a real option scenario was simulated for participants. Thereby a treatment group was distinguished from a control group in the way that they were told to use the ROV method to valuate the served project, instead of the NPV.

The results in chapter 5 of this study provided significant evidence that the use of the real options in capital budgeting methods reduces the bias of escalation of commitment to a failing course of actions. The experiment did not detect differences in the initial decision-making at the first stage when accepting the project but found managers using ROV to be more accurate in evaluating decisions at a later stage. Hence, the use of real options does not only increase the present value of a project, but it also affects *the behaviour* of the decision-making manager. Most probably the consideration of real options provides the decision makers an imaginary structure, which makes them more aware of the option to abandon. In this way the decision makers will sooner realize when they should leave a sinking ship, compare to decision makers with the net present value as a budgeting approach. Hypothesis 1, as stated in chapter 3, is supported by these findings.

As expected by hypothesis 2, a significant positive relation between the degree of loss aversion of a decision maker and the presence of escalation of commitment is detected in this study as well. Clearly, managers with a high degree of loss aversion would find it hard to accept losses when abandoning the project, and rather continue the failing project in order to avoid the threatening losses. Hence evidence is found for hypothesis 2.

This study does not give support to the idea that the gender of decision makers as a factor itself matters for the frequency of escalation of commitment, as predicted by hypothesis 3.

A probit model was conducted to analyse the effects of the different variables on EC next to each other. Both factors loss aversion and the used budgeting method seemed to have a significant effect on escalation of commitment. Loss aversion even appeared to be more robust than the used budgeting method and seemed to be a stronger factor. Furthermore a check was done for interaction effects, but no significant effects were found.

However, for deriving a powerful probit model with meaning, a bigger sample is required. Therefore further research could be done with a bigger sample and a greater proportion of female subjects. Also the experiment could be adapted in a few ways, such that wider conclusions could be made about the use of real options in practice and about other options than just the option to abandon.

To conclude, I can answer the research question of this paper with the found support for hypothesis 1. The use of real option analysis indeed mitigates the occurrence of escalation of commitment and thereby improves the decisions of managers. Nevertheless, a few cautionary comments should be made about this conclusion. These comments are discussed in the next chapter.

6. Discussion

Some interesting findings are acquired in this study, nevertheless several comments should be made.

Firstly, this experiment focussed specifically on the option to abandon. We may conclude now that incorporating an option to abandon in the valuation will reduce the frequency of the commitment bias. However it is perhaps too far-reaching to conclude that the addition of all real options to a valuation method does mitigate escalation of commitment, let alone the conclusion that it improves decision making in general. For instance, growth options might just arouse escalation of commitment, because a manager can begin to recognize growth options everywhere and as a result perceiving a too rosily view of the project.

This thesis discussed shortly about the question whether real options improve decision making in general (section 2.2.2. and 2.2.3.), however the experiment was too narrowed to provide an answer for this wide issue. For instance, from this experiment we can not draw sensible conclusions about the initial decision to accept the project, because the underlying case was pretty straight-forward. One of the discussed differentiating advantages ROV has, is that it avoids premature cancelation (a presumed lack of the NPV). But with this straight-forward case, the experiment is not able to test this premature cancelation. To test this, the value of the project should be positive with- and negative without real options.

Furthermore an often proposed argument is that real options would not be suitable to apply to the majority of investments decisions, but just for projects with well specified opportunities where it is possible to build a reliable decision tree and a probability distribution for the future uncertainties. Also this argument was not possible to test with the presented experiment, which just simulated one kind of real option scenario.

The ROV technique would also be too (mathematically) complicated to use in practice according to some literature. Now this experiment used a simple case with not too difficult required calculations, it can also not refute this argument.

A pro of ROV that is given in this thesis is that real option approach provides a structured framework for evaluation of staged projects. It does therefore appear that the method constantly stresses the various alternatives a manager has, for example because the analysis considers the cost and value of delaying the project. However, opportunity costs are not taken into account. Just as the NPV valuation, ROV is designed to evaluate single projects rather that to overlook several projects. Thus, ROV valuation might give the misleading perception that it accounts for opportunity costs, but it does not.

At last, although ROV might give the appearance that it is better in estimating uncertainties, ROV does not do better than NPV in terms of analysis sensitivity. Both methods require perfect accounting analysis. Moreover, within the application of the methods one can still vary a lot. For example, what is the best method for calculating a volatility coefficient in real option analysis? Although the method seems straight-forward, a lot of discussion remains about perceiving the required estimates. Hence, parameters are equally trustful in both valuations, however real option analysis can push managers to appreciate the flexibility in the decision options.

Adjusting the experiments as such that it can address the above discussed issues, might give inspirations for further research.

7. References

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Appendix

Appendix A

Table A1: Code Book

Code	Description	Specification
NPV	Net present value	Treatment = 0
ROV	Real options valuation	Treatment = 1
EC	Irrational escalation of commitment	Yes in stage 2a, EC= 1
Non-EC	Non-escalation of commitment	No in stage 2a, EC= 0
LA	Loss aversion	Score between 0 and 20
CR	Confidence rate	Rate between 0 to 100
RU	Rate of Understanding	Rate between 0 to 100
RR	Rate of Realism	Rate between 0 to 100
G	Gender	Male = 1 Female = 0

Appendix B: Questionnaires

<u>Control group Questionnaire NPV + solutions</u>

Introduction Questionnaire Thesis of Willem Poerink

This experiment is about investment decision making.
You will be given a case in which you will play the role of a decision maker in a company. An investment opportunity is simulated and you will have to decide whether you want to invest in this opportunity or not.
You are supposed to do some calculations and draw conclusions from these.

Possible reward
You can earn a considerable amount of money when you make the correct decisions.
In the case each combination of decisions will lead to a certain payout for the company you're deciding for, and 10% of the participants will **actually be paid out**.
In this case you will count with large amounts of money, your actual payout will be distracted from these by a multiplier of 0.0001, such that 10,000 euros stands for 1 euro payout.

You will be given an initial credit of 100,000 euros (which represents 10 euros payout) and with this amount you can invest in a suggested project.
This amount can either increase or decrease during the exercise, depending on your own decisions and on market development.
The eventual payout consists of the eventual present value of the project and the money you did not invest.
For example you end up with 100,000 euros when you decide to not invest, you can end up with 200,000 euros if you invest successfully or 50,000 if you invest unsuccessfully (respectively equal to a payout of 10, 20 and 5 euros).
Whether the market develops favourably or unfavourably in your case will be determined by a roll of a dice, at the end of the experiment.

Rules
The case consists of two parts, stage 1 and stage 2. Furthermore there is a third part with some additional questions, not related to the case.

- It is important that you **do not read ahead.**
- You may look back to previous answers, but you **cannot change them** once filled in.
- You can first read the instructions about the calculations to freshen up your mind before starting with the case. You **can keep the instructions with you** while answering the case**.**
- You are allowed to use a calculator for the maths.

Good luck and thanks for participating!

Please do not discuss this questionnaire with other participants after finishing it.

Instruction hand-out Net Present Value method

In finance, the net present value method is a standard method to estimate the value of projects. The NPV is simply the present value of the future cash flows minus the initial purchase price of the project. The next steps have to be made in order to calculate a project's NPV.

- Compute net cash flows for each period by calculating the expected cash flows.
- Compute the present value of the cash flow each period. Multiply the cash flows with the discount factor belonging to that period. The discount factor for a period t is $d=\frac{1}{(1+r)^t}$ where r is the required rate of return and t is time in years.
- Define the net present value of the project by summing the present values of all the periods, or multiply the expected constant cash flow with the sum of all the discount factors together.
- Project values with a positive value should be undertaken, now they earn more than the company's required rate of return.

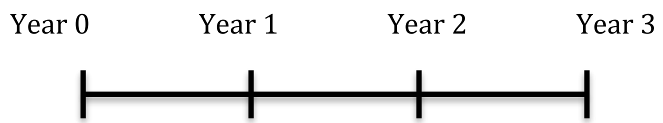
Numerical example:

Imagine a project that requires an initial investment of 80,000 € and has a lifetime of 3 years. After investing this amount, the annual expected cash flows can develop according to two scenarios, either the bad or the good case scenario.
The bad case occurs with a probability of 40% the annual cash flows will be 20,000 €, and with a probability of 60% you will end up in the good case scenario and the annual cash flows will be 50,000 € during the coming 3 years. The required rate of return is 12%, which comes down to a summed discount factor of 2.402 for 3 years.

The calculation:

Expected annual cash flows: 0.40 x 20,000 + 0.60 x 50,000 = 38,000

Define the present value of cash flows:



$$-80,000 \qquad \frac{38,000}{1.12} + \frac{38,000}{1.12^2} + \frac{38,000}{1.12^3}$$

Investment

Present value of cash flows $= 38,000 \text{ x } 2,402 = 91,276$

Net present value $= -80,000 + 91,276 = 11,276$

The net present value of the project is **positive**, hence the decision should be to **accept** the project.

This instruction hand-out is supposed to freshen up your mind and you are allowed to look back at this example when you are doing the calculations that are necessary to fill out the following questionnaire!

Part 1 Questionnaire, the case

Imagine you are the decision maker of a technology company and you are asked to accept or reject the following project. Your company is about to launch a new product, developed by your R & D division. It involves a high-tech e-reader of pocket size.
Launching the product requires a total investment of 100,000 €. The market in which you're investing can either develop itself favourably towards your product, or negatively.
If the market develops favourably, annual cash flows of 55,000 € are expected for the next four years. The probability that this situation will occur is calculated at p=0.75.
However, there is a probability of 1-p=0.25 that the sale won't run that well and that the cash flows will stay at 15,000 €.
During the first year the invested capital can be retained at any moment in time for an amount equal to 60% of the invested capital *by that time*, by selling the factory and the stock supply. The required rate of return of the company is 15% (which comes done to a summed discount factor of 2.855 for four years).

You are supposed to use the Net Present Value method to calculate the value of this project and base your decision whether to accept the project or not on these calculations.

Your decision should not be influenced by the idea of the product, but should only be based on it's profitability.

Space for calculations and explanation:

Expected cash flows per year = 0.75 x 55,000 + 0.25 x 15,000 = 45,000

$$PV = \frac{45{,}000}{1.15} + \frac{45{,}000}{1.15^2} + \frac{45{,}000}{1.15^3} + \frac{45{,}000}{1.15^4} = 128{,}470$$

$$NPV = 128{,}470 - 100{,}000 = 28{,}470$$

NPV is positive so the correct decision is to accept the project.

NPV value: ……………………

☐ Yes, I accept the project ☐ No, I reject the project

How sure are you that you made the right decision on a scale of 0 to 100?
Please circle your rate of determination. (0=totally unsure and 100=totally sure)

0 10 20 30 40 50 60 70 80 90 100

When you have made your decisions you can proceed with part 2a en b.
Made decisions cannot be changed.

Part 2a Questionnaire

Attention: If you *accepted* the project in part 1, you will continue with this part. If you *rejected* the project in part 1, please skip part 2a and b and proceed with part 3.

Exercise 2a: Since your decision to invest in "Project Pocket E-reader" the technology production has begun and by now it has been completed for 80%, you're still in the first year. Unfortunately, this morning some bad news has reached us: our big competitor iPeer just launched a new smartphone, including a screen with e-reader quality. It seems to be that the bad scenario occurred, meaning that the annual cash flows will be 15,000 the coming four years.
At this moment already 80% of the required capital is invested. (Thus, you still have 20,000 to invest)

You are asked to decide if you want to *continue* or not with the project.

Space for calculations and explanation:

$$\text{PV of continuing} = \frac{15{,}000}{1.15} + \frac{15{,}000}{1.15^2} + \frac{15{,}000}{1.15^3} + \frac{15{,}000}{1.15^4} = 42{,}820$$

Abandoning the project = 60% x 80% x 100,000 = 48,000
where the rate of retaining of investments is 60% and the grade of completion 80%.

So abandoning is the most lucrative decision.

☐ Yes, I continue with the project ☐ No, I abandon the project.

How sure are you that you made the right decision on a scale of 0 to 100?
Please circle your rate of determination. (0=totally unsure and 100=totally sure)

0 10 20 30 40 50 60 70 80 90 100

When you have made your decisions you can proceed with part 2b.
Made decisions cannot be changed.

Part 2b Questionnaire

Attention: Only make this part if you accepted the project in part 1.

Exercise 2b: Imagine that the entry of iPeer into the e-reader market *did not happen*. Actually, the business has developed in our favour and the demand is extremely high. The annual cash flows are expected to be 55,000 during the coming four years. Similar to the previous situation the completion of the production technology is 80% at this moment and 80% of the needed capital has already been invested.

You are asked to decide if you want to *continue* or not with the project.

Space for calculations and explanation:

$$\text{PV of continuing} = \frac{55{,}000}{1.15} + \frac{55{,}000}{1.15^2} + \frac{55{,}000}{1.15^3} + \frac{55{,}000}{1.15^4} = 157{,}000$$

Abandoning the project = 60% x 80% x 100,000 = 48,000
where the rate of retaining of investments is 60% and the grade of completion 80%.

So continuing is the most lucrative decision.

☐ Yes, I continue with the project ☐ No, I abandon the project.

How sure are you that you made the right decision on a scale of 0 to 100?
Please circle your rate of determination. (0=totally unsure and 100=totally sure)

0 10 20 30 40 50 60 70 80 90 100

When you have made your decisions you can proceed with the last part.
Made decisions cannot be changed.

Questionnaire Part 3

This part does not influence your payout.

Name: ....

Email address: ....

☐ Male ☐ Female

1. Did you understand the exercise completely? If not, explain what was not clear to you. (0=no understanding at all and 100=totally understand)

0 10 20 30 40 50 60 70 80 90 100

2. Did you find the exercise realistic? (0=very unrealistic and 100=very realistic)

0 10 20 30 40 50 60 70 80 90 100

3. Do you have a financial background? Shortly explain, (study, job, course).

☐ Yes: .... ☐ No

4. If Yes, have you ever applied the Real Option valuation technique in your study or job?

☐ Yes ☐ No

5. Below you see a list with gamble options. For example (0.5, -100 ; 0.5, 100) means probability of losing 100€ is 50 % and probability winning 100€ is 50% as well.
The gambles are ranked in order of attractiveness.
From which point would you accept the gamble?

- o (0.5, -110€ ; 0.5, 100€)
- o (0.5, -105€ ; 0.5, 100€)
- o (0.5, -100€ ; 0.5, 100€)
- o (0.5, -95€ ; 0.5, 100€)
- o (0.5, -90€ ; 0.5, 100€)
- o (0.5, -85€ ; 0.5, 100€)
- o (0.5, -80€ ; 0.5, 100€)
- o (0.5, -75€ ; 0.5, 100€)
- o (0.5, -70€ ; 0.5, 100€)
- o (0.5, -65€ ; 0.5, 100€)
- o (0.5, -60€ ; 0.5, 100€)
- o (0.5, -55€ ; 0.5, 100€)
- o (0.5, -50€ ; 0.5, 100€)
- o (0.5, -45€ ; 0.5, 100€)
- o (0.5, -40€ ; 0.5, 100€)
- o (0.5, -35€ ; 0.5, 100€)
- o (0.5, -30€ ; 0.5, 100€)
- o (0.5, -25€ ; 0.5, 100€)
- o (0.5, -20€ ; 0.5, 100€)
- o (0.5, -15€ ; 0.5, 100€)

THANK YOU FOR PARTICIPATING

The researcher will now roll a dice to determine in which case you belong (75% good case scenario, 25% bad case scenario) to define your payout.

Payout overview
If you did not invest in stage 1 your payout is 10€. (independent of case scenario)

Bad case scenario
If you decided to continue in stage 2 (part 2a) you receive 4.50€.
If you decided to quit in stage 2 (part 2a) you receive 7€.

Good case scenario
If you decided to continue in stage 2 (part 2b) you receive 16 €.
If you decided to quit in stage 2 you (part 2b) you receive 7 €.

When all participants have completed the questionnaire, the winners (10%) will be emailed and money will be transferred to their accounts!

Treatment group Questionnaire ROV + solutions

Introduction Questionnaire Thesis of Willem Poerink

This experiment is about investment decision making, with use of the real option approach. You will be given a case in which you will play the role of a decision maker in a company. An investment opportunity is simulated and you will have to decide about whether you want to invest in this opportunity or not.
You are supposed to do some calculations and draw conclusions from these.

Possible reward

You can earn a considerable amount of money when you make the correct decisions.
In the case each combination of decisions will lead to a certain payout for the company you're deciding for, and 10% of the participants will **actually be paid out**.
In this case you will count with large amounts of money, your actual payout will be distracted from these by a multiplier of 0.0001, such that 10,000 euros stands for 1 euro payout.

You will be given an initial credit of 100,000 euros (which represents 10 euros payout) and with this amount you can invest in a suggested project.
This amount can either increase or decrease during the exercise, depending on your own decisions and on market development.
The eventual payout consists of the eventual present value of the project and the money you did not invest.
For example you end up with 100,000 euros when you decide to not invest, you end up with 200,000 euros if you invest successfully or 50,000 if you invest unsuccessfully (respectively equal to a payout of 10, 20 and 5 euros).
Whether the market develops favourably or unfavourably in your case will be determined by a roll of a dice, at the end of the experiment.

Rules

The case consists of two parts, stage 1 and stage 2. Furthermore there is a third part with some additional questions, not related to the case.

- It is important that you **do not read ahead.**
- You may look back to previous answers, but you **cannot change them** once filled in.
- You can first read the instructions about real option calculations to freshen up your mind before starting with the case. You **can keep the instructions with you** while answering the case.
- You are allowed to use a calculator for the maths.

Good luck and thanks for participating!

Please do not discuss this questionnaire with other participants after finishing it.

Instruction hand-out Real Option Method

(this instruction is just to freshen up your mind, you don't have to read it entirely)

Real options approach is a valuation method that applies option valuation techniques when valuing a capital investment.
In compare to the more frequently used *net present value method*, the real option approach incorporates the value of certain real options, additionally to the value of the discounted cash flows.

Different real options exist; one of them is the option to abandon. This is the right, not the obligation, to quit a project during its lifetime and liquidate the belonging assets. This might be attractive at a certain moment, when the present value of the remaining cash flows falls below the liquidation value of the project.

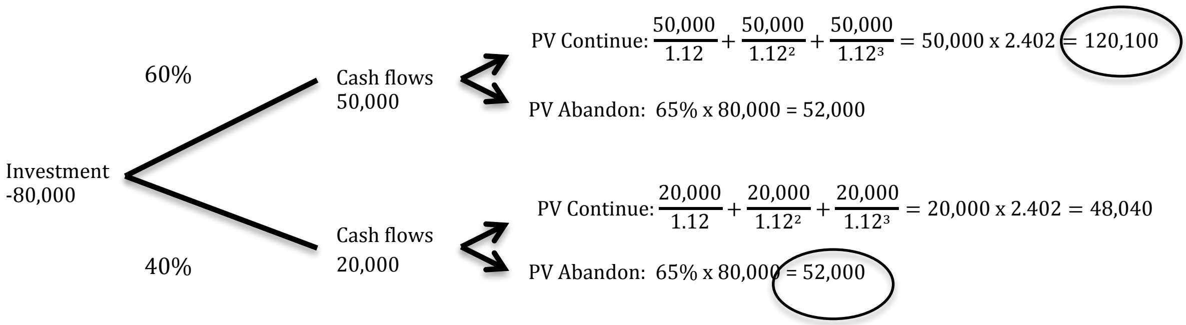
In order to calculate a project's value according to the real option method, the steps below have to be followed:

- Determine the choices available to the firm and their different possible outcomes. A decision tree can be used to get a clear overview.
  For example, the choice between abandoning or continuing with the project.
- For each possible scenario you have to compute the present value of the future cash flows, multiply the cash flows with the discount factor appropriate for that period.
  The discount factor for a period t is d=$\frac{1}{(1+r)^t}$ in which r is the required rate of return and t the time in years. Or you can just multiply the constant cash flow with the sum of discount factors of all periods.
- Compute which of the available choices yields the highest present value and decide which decision the company should make in each branch.
- Compute the value of the project by multiplying the present value of the outcomes from the best decisions with the corresponding possibilities, sum them and subtract the investment.
- Project values with a positive value should be undertaken to maximize expected gains, now they earn more than the company's required rate of return.

To explain this more clearly, a numerical example is given on the next page.

Numerical example:

Imagine a project that requires an initial investment of 80,000 € and has a lifetime of 3 years. After investing this amount, the annual expected cash flows can develop according to two scenarios, either the bad or the good case scenario.
The bad case occurs with a probability of 40% the annual cash flows will be 20,000 €, and with a probability of 60% you will end up in the good case scenario and the annual cash flows will be 50,000 € during the coming 3 years.
The required rate of return is 12%, which comes down to a summed discount factor of 2.402 for 3 years. You have an option to abandon at any moment in the first year of the project, if you would do that 65% of the invested capital at that time would be retained.



So in the good case scenario the company would choose to continue and in the bad case scenario it would choose to abandon, because the choice delivers a higher PV than it's equivalent.

Value of the project: 60% x 120,100 + 40% x 52,000 – 80,000= 12,860 €

Good case scenario   Bad case scenario   Investment

The value of the project is **positive**; hence the decision should be to **accept** the project, if you want to maximize expected gains.

This instruction hand-out is supposed to freshen up your mind and you are allowed to look back at this example when you are doing the calculations that are necessary to fill out the following questionnaire!

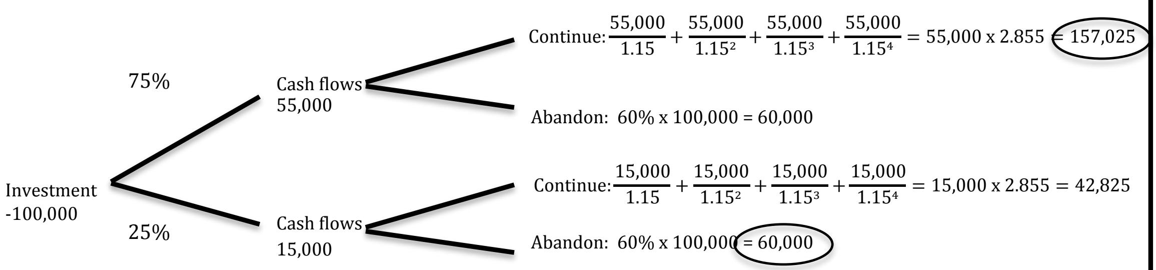
Part 1 Questionnaire, the case

Imagine you are the decision maker of a technology company and you are asked to accept or reject the following project. Your company is about to launch a new product, developed by your R & D division. It involves a high-tech e-reader of pocket size.
Launching the product requires a total investment of 100,000 €. The market in which you're investing can either develop itself favourably towards your product, or negatively.
If the market develops favourably, annual cash flows of 55,000 € are expected for the next four years. The probability that this situation will occur is calculated at p=0.75.
However, there is a probability of 1-p=0.25 that the sale won't run that well and that the cash flows will stay at 15,000 €.
During the first year the invested capital can be retained at any moment in time for an amount equal to 60% of the invested capital *by that time*, by selling the factory and the stock supply. The required rate of return of the company is 15% (which comes done to a summed discount factor of 2.855 for four years).

You are supposed to use the Real Option Valuation method to calculate the value of this project and base your decision whether to accept the project or not on these calculations.

Your decision should not be influenced by the idea of the product, but should only be based on it's profitability.

Space for calculations and explanation:



Value of the project : 75% x 157,025 + 25% x 60,000 – 100,000 = 32,769
Positive project value, so project should be undertaken.

☐ Yes, I accept the project ☐ No, I reject the project

How sure are you that you made the right decision on a scale of 0 to 100?
Please circle your rate of determination. (0=totally unsure and 100=totally sure)

0 10 20 30 40 50 60 70 80 90 100

When you have made your decisions you can proceed with part 2a en b.
Made decisions cannot be changed.

Part 2a Questionnaire

Attention: If you *accepted* the project in part 1, you will continue with this part. If you *rejected* the project in part 1, please skip part 2a and b and proceed with part 3.

Exercise 2a: Since your decision to invest in "Project Pocket E-reader" the technology production has begun and by now it has been completed for 80%, you're still in the first year. Unfortunately, this morning some bad news has reached us: our big competitor iPeer just launched a new smartphone, including a screen with e-reader quality. It seems to be that the bad scenario occurred, meaning that annual cash flows will be 15,000 the coming four years.
At this moment already 80% of the required capital is invested. (Thus, you still have 20,000 to invest)

You are asked to decide if you want to *continue* or not with the project.

Space for calculations and explanation:

$$\text{PV of continuing} = \frac{15{,}000}{1.15} + \frac{15{,}000}{1.15^2} + \frac{15{,}000}{1.15^3} + \frac{15{,}000}{1.15^4} = 42{,}820$$

Abandoning the project = 60% x 80% x 100,000 = 48,000
where the rate of retaining of investments is 60% and the grade of completion 80%.

So abandoning is the most lucrative decision. This is the same calculation for both methods, NPV and the Real options method.

☐ Yes, I continue with the project ☐ No, I abandon the project.

How sure are you that you made the right decision on a scale of 0 to 100?
Please circle your rate of determination. (0=totally unsure and 100=totally sure)

0 10 20 30 40 50 60 70 80 90 100

When you have made your decisions you can proceed with part 2b.
Made decisions cannot be changed.

Part 2b Questionnaire

Attention: Only make this part if you accepted the project in part 1.

Exercise 2b: Imagine that the entry of iPeer into the e-reader market *did not happen*.
Actually, the business has developed in our favour and the demand is extremely high.
The annual cash flows are expected to be 55,000 during the coming four years.
Similar to the previous situation the completion of the production technology is 80% at this moment and 80% of the needed capital has already been invested.

You are asked to decide if you want to *continue* or not with the project.

Space for calculations and explanation:

$$\text{PV of continuing} = \frac{55{,}000}{1.15} + \frac{55{,}000}{1.15^2} + \frac{55{,}000}{1.15^3} + \frac{55{,}000}{1.15^4} = 157{,}000$$

Abandoning the project = 60% x 80% x 100,000 = 48,000
where the rate of retaining of investments is 60% and the grade of completion 80%.

So continuing is the most lucrative decision. This is the same calculation for both methods, NPV and the Real options method.

☐ Yes, I continue with the project

☐ No, I abandon the project.

How sure are you that you made the right decision on a scale of 0 to 100?
Please circle your rate of determination. (0=totally unsure and 100=totally sure)

0 10 20 30 40 50 60 70 80 90 100

When you have made your decisions you can proceed with the last part.
Made decisions cannot be changed.

Questionnaire Part 3

This part does not influence your payout.

Name: …………………………………………………….

Email address: ………………………………………………….

☐ Male ☐ Female

1. Did you understand the exercise completely? If not, explain what was not clear to you. (0=no understanding at all and 100=totally understand)

0 10 20 30 40 50 60 70 80 90 100

2. Did you find the exercise realistic? (0=very unrealistic and 100=very realistic)

0 10 20 30 40 50 60 70 80 90 100

3. Do you have a financial background? Shortly explain, (study, job, course).

☐ Yes: ………………………………………………………………………. ☐ No

4. If Yes, have you ever applied the Real Option valuation technique in your study or job?

☐ Yes ☐ No

5. Below you see a list with gamble options. For example (0.5, -100 ; 0.5, 100) means probability of losing 100€ is 50 % and probability winning 100€ is 50% as well.
The gambles are ranked in order of attractiveness.
From which point would you accept the gamble?

- ○ (0.5, -110€ ; 0.5, 100€)
- ○ (0.5, -105€ ; 0.5, 100€)
- ○ (0.5, -100€ ; 0.5, 100€)
- ○ (0.5, -95€ ; 0.5, 100€)
- ○ (0.5, -90€ ; 0.5, 100€)
- ○ (0.5, -85€ ; 0.5, 100€)
- ○ (0.5, -80€ ; 0.5, 100€)
- ○ (0.5, -75€ ; 0.5, 100€)
- ○ (0.5, -70€ ; 0.5, 100€)
- ○ (0.5, -65€ ; 0.5, 100€)
- ○ (0.5, -60€ ; 0.5, 100€)
- ○ (0.5, -55€ ; 0.5, 100€)
- ○ (0.5, -50€ ; 0.5, 100€)
- ○ (0.5, -45€ ; 0.5, 100€)
- ○ (0.5, -40€ ; 0.5, 100€)
- ○ (0.5, -35€ ; 0.5, 100€)
- ○ (0.5, -30€ ; 0.5, 100€)
- ○ (0.5, -25€ ; 0.5, 100€)
- ○ (0.5, -20€ ; 0.5, 100€)
- ○ (0.5, -15€ ; 0.5, 100€)

THANK YOU FOR PARTICIPATING

The researcher will now roll a dice to determine in which case you belong (75% good case scenario, 25% bad case scenario) to define your payout.

Payout overview
If you did not invest in stage 1 your payout is 10€. (independent of case scenario)

Bad case scenario
If you decided to continue in stage 2 (part 2a) you receive 4.50€.
If you decided to quit in stage 2 (part 2a) you receive 7€.

Good case scenario
If you decided to continue in stage 2 (part 2b) you receive 16 €.
If you decided to quit in stage 2 you (part 2b) you receive 7 €.

When all participants have completed the questionnaire, the winners (10%) will be emailed and money will be transferred to their accounts!

Appendix C

Table C1: 2x2 table decisions stage 1.

		Accept	Reject	Significance	
Stage 1	**NPV**	32	0	Fisher's Exact Test p = 0.238	
	ROV	29	3		

Table C2: Decisions stage 2, escalation of commitment or not.

Observations in stage 2 = 61

Critical Value = 3.84

P – value = 0.009**

Degrees of Freedom = 1

	NPV		ROV	
	Observed	Expected	Observed	Expected
Non-EC	15	19.93	23	18.07
EC	17	12.07	6	10.93
	Estimated value: $\sum_i^k \frac{(Oi-Ei)^2}{Ei}$ = 1.22+2.02+1.35+2.23 = 6.81 6.81 > 3.84, H_0 rejected at 5% significance			

Table C3: Wrong/right decisions stage 1 and 2

Observations = 64

Critical Value = 3.84

P – value = 0.042**

Degrees of Freedom = 1

	NPV		ROV	
	Observed	Expected	Observed	Expected
Investment stage 1, Non-EC	15	19.93	23	18.07
No investment stage 1 or EC	17	12.07	9	10.93
	Estimated value: $\sum_i^k \frac{(Oi-Ei)^2}{Ei}$ = 1.23+0.84+1.23+0.84 = 4.146 4.146 > 3.84, H_0 rejected at 5% significance			

Table C4: Confidence rates

<table>
<tr><th rowspan="2"></th><th colspan="2">Accept</th><th colspan="2">Reject</th></tr>
<tr><th>NPV</th><th>ROV</th><th>NPV</th><th>ROV</th></tr>
<tr><td rowspan="2">Stage 1</td><td>Mean = 84.38
n = 32
Shapiro Wilk
p = 0.001**</td><td>Mean = 90.69
n = 29
Shapiro Wilk
p = 0.000**</td><td rowspan="2">-</td><td rowspan="2">Mean = 73.33
n = 3</td></tr>
<tr><td colspan="2">2-sample test
Mann-Whitney U test p = 0.098*,
H0 accepted at 5%, rejected at 10% level.</td></tr>
<tr><td rowspan="2">Stage 2a</td><td>Mean = 65.88
n = 17
Shapiro Wilk
p = 0.569</td><td>Mean = 71.67
n = 6
Shapiro Wilk
p = 0.801</td><td>Mean = 80.00
n = 15
Shapiro Wilk
p = 0.103</td><td>Mean = 86.09
n = 23
Shapiro Wilk
p = 0.005**</td></tr>
<tr><td colspan="2">2-sample test
Mann-Whitney U test p = 0.500,
Allowed parametric t-test:
(Levene's test p=0.249
2 samples t-test gives p=0.509, H0 accepted</td><td colspan="2">2-sample test
Mann-Whitney U test p = 0.202,
H0 accepted</td></tr>
<tr><td>Stage 2a</td><td colspan="4">Test for the overall confidence rate, regardless acceptance or rejection
NPV ROV
Mean = 72.50 Mean=83.10
n = 32 n = 29
Shapiro Wilk Shapiro Wilk
p = 0.128 p=0.003**
2-sample test
Mann-Whitney U test p = 0.009**, H0 rejected</td></tr>
<tr><td rowspan="2">Stage 2b</td><td>Mean = 81.56
n = 32
Shapiro Wilk
p = 0.024**</td><td>Mean = 87.24
n = 29
Shapiro Wilk
p = 0.000**</td><td rowspan="2">-</td><td rowspan="2">-</td></tr>
<tr><td colspan="2">2-sample test
Mann-Whitney U test p = 0.061*,
H0 accepted at 5% level
rejected at 10% level</td></tr>
</table>

**significant at 5% level
* significant at 10% level

Table C5: Correlation EC + Loss Aversion

	N	**Mean LA**	**Mean rank**
Non-EC	37	9.49	25.55
EC	23	13.57	38.46
Mann-Whitney U 2-tailed p = 0.005, H0 rejected. Spearman Correlation: coefficient = 0.364 p = 0.004			

Table C6: Loss aversion among different genders

	N	**Mean LA**	**Mean rank**
Male	45	9.69	27.49
Female	18	14.22	43.28
Mann-Whitney U 2-tailed p = 0.002, H0 rejected.			

Table C7: Compare means EC for different genders

Observations in stage = 61

Critical Value = 3.84

P-value = 0.649

Degrees of Freedom = 1

	Male		**Female**	
	Observed	Expected	Observed	Expected
Non-EC	26	26.79	12	11.21
EC	17	16.21	6	6.79
	Estimated value: $\sum_i^k \frac{(Oi-Ei)^2}{Ei}$ = 0.02+0.04+0.06+0.09= 0.208 0.208 < 3.84, H_0 accepted at 5% significance			

Table C8: Check for interaction effects loss aversion * gender.

Probit Binomial Model, dependent variable: EC **N=60**		
Variable	**Coefficient**	**p-value**
Intercept	-1.5040	0.0017**
Loss Aversion	0.1216	0.0034**
Gender	-0.5887	0.7066
Loss Aversion * Gender	-0.0061	0.9533
McFadden R^2	0.1414	
Akaike info criterion	1.27	
Schwarz criterion	1.42	

Table C9: Check for interaction effects treatment*loss aversion

Probit Binomial Model, dependent variable: EC **N=60**		
Variable	**Coefficient**	**p-value**
Intercept	-1.1892	0.0467*
Treatment	-0.4149	0.6424
Loss aversion	0.1084	0.0198**
Treatment*Loss aversion	-0.0349	0.6072
McFadden R^2	0.1811	
Akaike info criterion	1.223	
Schwarz criterion	1.363	

Table C10: Check for interaction effects gender*treatment

Probit Binomial Model, dependent variable: EC **N=60**		
Variable	**Coefficient**	**p-value**
Intercept	0.0545	0.8348
Treatment	-0.7290	0.0694*
Gender	0.0852	0.8631
Treatment*Gender	-0.6313	0.4311
McFadden R^2	0.0972	
Akaike info criterion	1.32	
Schwarz criterion	1.46	

Table C11: Correlations of parameters in probit model

Correlations of parameters in probit model			
Variable	Gender	Treatment	Loss Aversion
Gender	-	0.068	0.451
Treatment	0.068	-	0.049
Loss Aversion	0.451	0.049	-

> 0.5 indicates multicollinearity

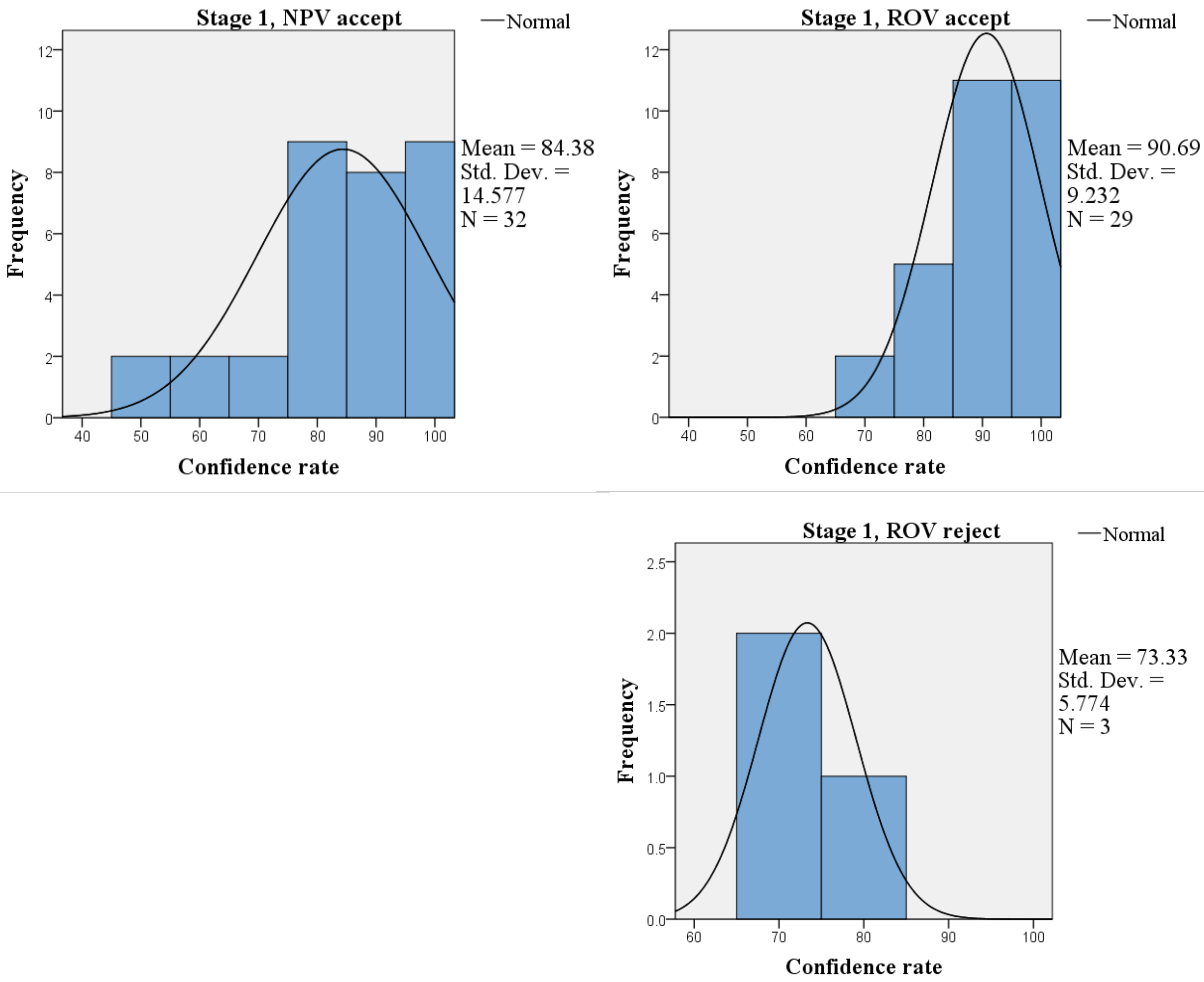
Table C12: Rate of understanding among different treatments

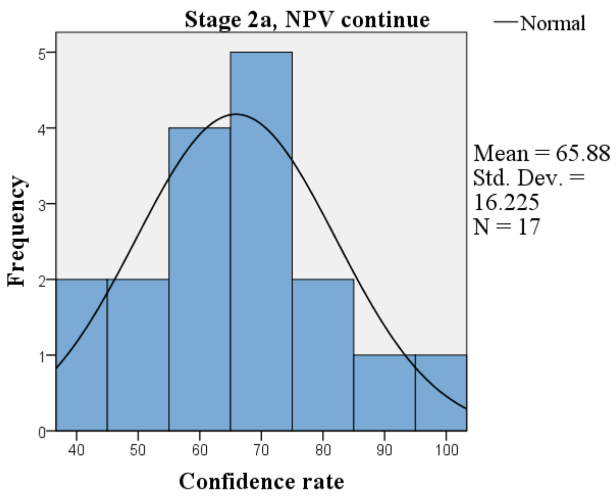
	N	**Mean RU**	**Mean rank**
NPV	32	87.50	29.17
ROV	32	90.00	35.83
Mann-Whitney U 2-tailed p = 0.116, H0 accepted.			

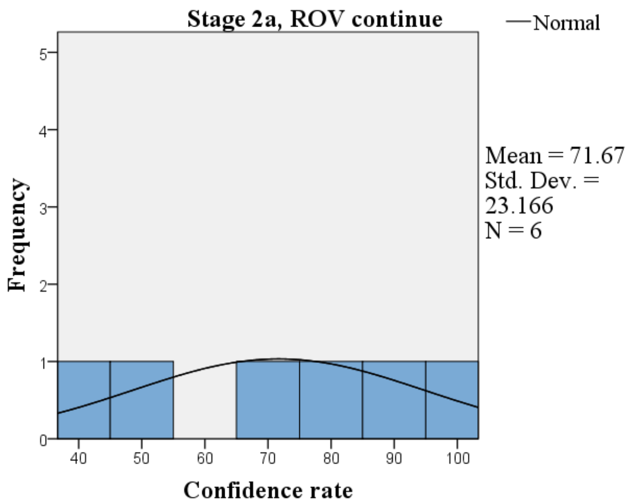
Table C13: Rate of realism among different treatments

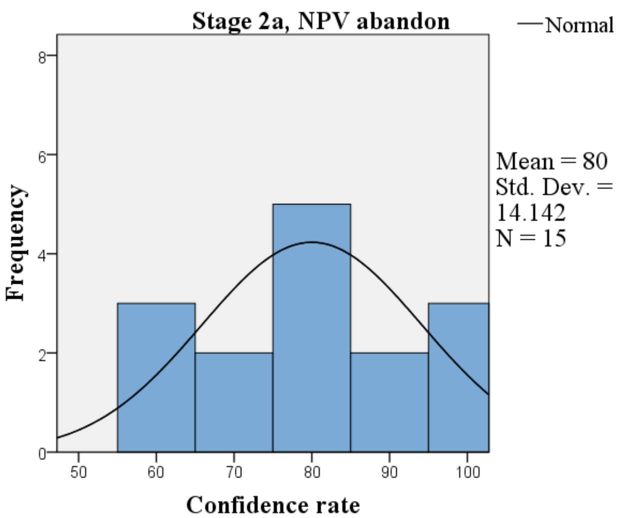
	N	**Mean RR**	**Mean rank**
NPV	32	74.69	1058.50
ROV	32	69.69	1021.50
Mann-Whitney U 2-tailed p = 0.798, H0 accepted.			

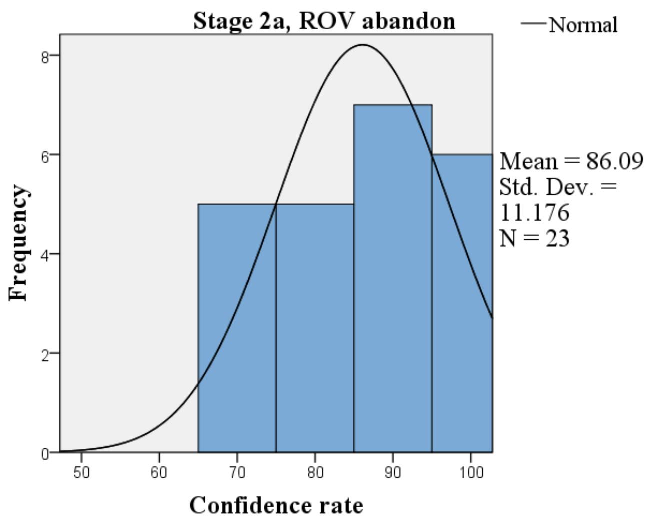
Table C14: Confidence rates histograms

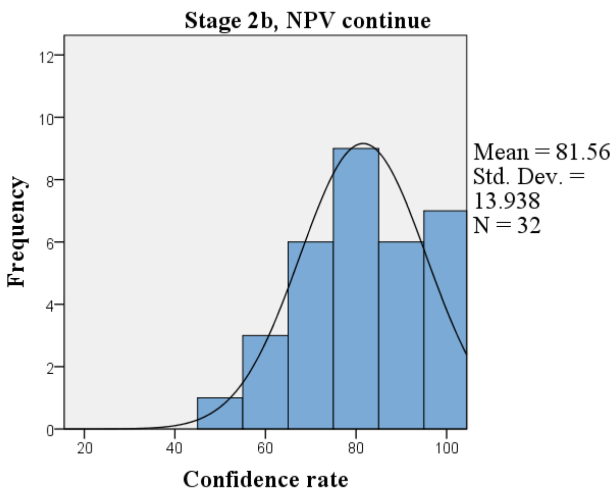


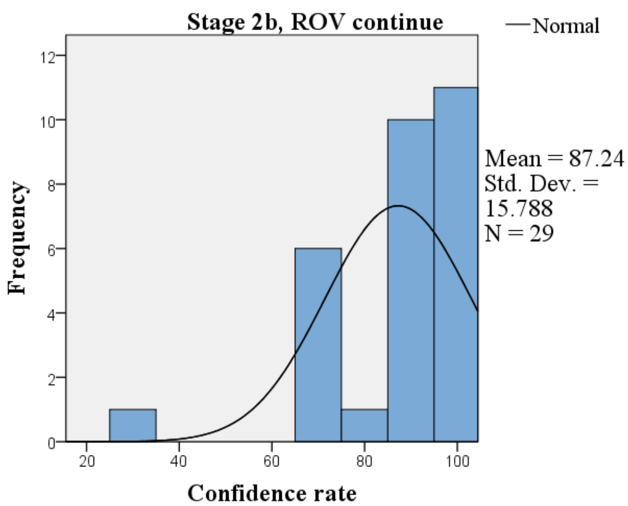

Stage 2a, NPV continue
Normal
Mean = 65.88
Std. Dev. =
16.225
N = 17
Frequency
Confidence rate
0
1
2
3
4
5
40
50
60
70
80
90
100


Stage 2a, ROV continue
Normal
Mean = 71.67
Std. Dev. =
23.166
N = 6
Frequency
Confidence rate
0
1
2
3
4
5
40
50
60
70
80
90
100


Stage 2a, NPV abandon
Normal
Mean = 80
Std. Dev. =
14.142
N = 15
Frequency
Confidence rate
0
2
4
6
8
50
60
70
80
90
100


Stage 2a, ROV abandon
Normal
Mean = 86.09
Std. Dev. =
11.176
N = 23
Frequency
Confidence rate
0
2
4
6
8
50
60
70
80
90
100


Stage 2b, NPV continue
Mean = 81.56
Std. Dev. =
13.938
N = 32
Frequency
Confidence rate
0
2
4
6
8
10
12
20
40
60
80
100


Stage 2b, ROV continue
Normal
Mean = 87.24
Std. Dev. =
15.788
N = 29
Frequency
Confidence rate
0
2
4
6
8
10
12
20
40
60
80
100