Investment and Disinvestment in Irrigation Technology
– An Experimental Analysis of Farmers' Decision Behavior –

Hanna Julia Ihli, Syster Christin Maart, Oliver Musshoff

Georg-August-Universitaet Goettingen
Department of Agricultural Economics and Rural Development
Platz der Goettinger Sieben 5, 37073 Göttingen, Germany
Email: hanna.ihli@agr.uni-goettingen.de (corresponding author)

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Abstract

In agriculture, long-term decisions are usually made in an environment which is almost completely dynamic. For example, uncertainty arises from weather and climatic conditions. (Dis)investment in irrigation technology on farms has become more prominent over the past decade. The use of irrigation has become crucial in many parts of the world as an adaptation strategy to climate change. The purpose of this study is to test whether the Real Options Approach can help to explain why farmers often choose to postpone (dis)investments that appear to be immediately profitable. We combine investment and disinvestment decisions in one experiment using a “within-subject” design and carrying out a comparative analysis between the Net Present Value approach and the Real Options Approach in order to ascertain which of the methods provides a better prediction of the investment and disinvestment behavior of farmers. In our study, we consider a simple optimal stopping (dis)investment problem in which farmers can invest in as well as abandon irrigation technology. Our results show that both theories do not explain the observed (dis)investment behavior exactly. However, some evidence was found that the Real Options Approach provides a better prediction of the (dis)investment behavior of farmers than the Net Present Value approach. Moreover, we find that farmers learn from repeated investment decision-making and consider the value of waiting over time, whereas in disinvestment situations, farmers exaggerate the option to delay. We also find that farmers demonstrate different (dis)investment behavior depending on the order in which they were faced with the investment and disinvestment treatments.

Keywords

Experimental Economics, Investment, Disinvestment, Inertia, Real Options

1. Introduction

Globally, farmers are faced with an ever-changing environment such as changes in the climate, input and output prices, and emergence of new markets, which leads to the need for farmers to implement strategies in order to remain viable. An example of such strategies is the decision by farmers to invest and/or disinvest in agricultural technologies. However, farmers' adaptation to a dynamic environment is often characterized by some kind of inertia in which farmers respond surprisingly slow to changes. Examples of such inertia have been reported in studies focused on the adoption of agricultural technologies (Baerenklau and Knapp 2007, Isik 2004, Purvis et al. 1995, Winter-Nelson and Amegbeto 1998) and specifically on irrigation technologies (Carey and Zilberman 2002, Hafi et al. 2006).

Investment and disinvestment in irrigation technology has become a focus of various government programs as an adaptation strategy to climate change in the agricultural sector (BMU 2009, Ngigi 2009, Smit and Skinner 2002). Water scarcity resulting from changing climate conditions is a growing concern in the agricultural sectors worldwide. Therefore, many nations have tried to reform their water management systems by improving irrigation systems and by promoting investments and disinvestments in irrigation technology. From policy-makers' perspective, it is imperative to understand factors influencing investment and disinvestment decisions of farmers and to predict this behavior. Such understanding is important in order to contribute to an environment in which the adoption of technologies is encouraged.

There are several reasons that have been used to explain farmers' slow response, including economic and sociological factors such as financial constraints and non-monetary goals of the decision-maker (Hill 2008, Musshoff and Hirschauer 2008). The Real Options Approach (ROA) – also called new investment theory - has been discussed as a possible alternative or an additional explanation for economic inertia (Dixit and Pindyck 1994). Apart from sunk costs, investments and disinvestments are characterized by temporal flexibility and often by uncertain returns. The ROA evaluates entrepreneurial flexibility and produces results that can be different from the classical Net Present Value (NPV) approach. In comparison to the NPV, the investment threshold is shifted upwards, while the disinvestment trigger is shifted downwards in case of temporal flexibility. The purpose of this study is to test whether the ROA has an explanatory power why farmers often choose to postpone investments and disinvestments that appear to be immediately profitable.

The study is linked to and inspired by various previous and ongoing research on normative and econometric analyses of investment and disinvestment problems using the ROA, in general (Khanna et al. 2000, Luong and Tauer 2006, Odening et al. 2005, Pietola and Myers 2000, Price and Wetzstein 1999), and in the context of irrigation technology, in particular. The ROA was applied by Seo et al. (2008) to normatively determine trigger values for the decision to invest and disinvest in irrigation technology simultaneously. They showed that the entry threshold is high, whereas the exit threshold is very low over a range of parameter changes including investment cost, exit cost, variable cost, risk-adjusted discount rate, and volatility. This implies that farmers with irrigation systems in placeare unlikely to leave them easily. McClintock (2009) used the ROA to examine the influence of uncertain water prices on the adoption of water saving technologies. The study showed that uncertainty about water prices has an impact on the timing of the investment decision. The water price at which adoption takes place is higher than suggested by the NPV. However, normative applications simply indicate the explanatory potential of the ROA for observed economic inertia. Some studies provide empirical evidence for the validity of the ROA, in general, and in an agricultural context, in particular, using econometrical approaches based on field data (Hinrichs et al. 2008, O'Brien et al. 2003, O'Brien and Folta 2009, Richards and Green 2003). An econometric validation of theoretical models explaining (dis)investment behavior, such as the ROA, is difficult for several reasons including unobservable explanatory variables and heterogeneity. For instance, the results of the ROA usually refer to (dis)investment triggers, which are not directly observable. Furthermore, multiple (dis)investment options may coexist or financial constraints may affect farmers' (dis)investment decisions.

Use of experimental methods in investigating the ROA is nascent and growing. A fundamental difference of experimental approaches to econometric analyses is that researchers can observe the behavior under controlled conditions. The few studies that use experimental approaches on investment and disinvestment behavior come to different conclusions with respect to the explanatory power of the ROA. Yavas and Sirmans (2005) conducted an investment experiment with 114 students and found that participants invested earlier than predicted by the ROA and, thus, failed to recognize the benefit of the option to wait. Maart and Musshoff (2011) carried out an experiment with 106 farmers, which focused on the decision behavior in an agricultural and non-agricultural investment situation. The experimental results showed that the decision behavior is neither exactly predictable with the ROA nor with the NPV. Sandri et al. (2010) experimentally compared the disinvestment behavior of 15 high-tech entrepreneurs and 84 non-entrepreneurs (mainly students) and showed that both groups of decision-makers disinvest significantly later than assumed by the NPV and even later than predicted by the ROA. The task consisted of a problem of optimal stopping stylizing a context-free choice to abandon a project for a termination value. Maart et al. (2011) experimentally analyzed the exit decision of 63 farmers using the ROA. They investigated whether the ROA provides a prediction of the observed disinvestment behavior and revealed that the ROA seems to be more appropriate to account for individuals' behavior than the NPV approach. In accordance with the findings of Sandri et al. (2010), the results of Maart et al. (2011) showed that farmers disinvest even later than predicted by the ROA. The aforementioned studies show that participants often do at least not completely understand the value of waiting in investment decisions, whereas in disinvestment decisions they often exaggerate the option to delay. However, the different results observed in investment and disinvestment experiments might result from the use of different participants, and in particular, as the number of participants is relatively small in the experiments. Therefore, the question arises whether the decision behavior observed in previous experiments can be validated in a "within-subject" design.

In this study, we use a "within-subject" designed experiment to carry out a comparative analysis between the NPV method and the ROA in order to ascertain which of the methods provide a better prediction of the investment and disinvestment behavior of farmers. We also analyze the risk attitudes of participants, which could influence their investment and disinvestment behavior (Knight et al. 2003, Sandri et al. 2010). Closest to our study are two of the aforementioned papers by Sandri et al. (2010) and by Maart and Musshoff (2011) who experimentally analyzed the investment and disinvestment behavior of entrepreneurs and/or non-entrepreneurs. Our paper differs significantly from their studies and contributes to the extant literature by addressing the following two issues: First, we combine investment and disinvestment decisions in one experiment using a "within-subject" design. That means that each participant is exposed to both treatments (investment and disinvestment) in contrast to a between-subject design where each participant is engaged in only one treatment (either investment or disinvestment). Thus, we obtain multiple observations from each participant that enables us to compare an individuals' different behavior in the two treatments and, therefore, leads to a stronger statistical power (Charness et al. 2012, Croson 2002). Second, to the best of our knowledge, this is the first experimental contribution incorporating an optimal stopping framework in the analysis of (dis)investment behavior regarding irrigation technology. Moreover, our paper differs from the papers by Sandri et al. (2010), Yavas and Sirmans (2005), and Oprea et al. (2009) in that farmers are recruited as experimental participants and that their individual risk propensity is measured to determine the normative benchmark for the investment and disinvestment decision.

The paper is structured as follows. In section 2, research hypotheses from the relevant literature are derived. In section 3, the design and the implementation of the experiment is presented, while in section 4 the approach to data analysis is explained. The results of the experiment are presented in section 5. The paper ends with a discussion and a conclusion in section 6.

2. Derivation of Hypotheses

In accordance with the classical investment theory, a decision-maker should realize an investment if the investment costs are covered by the present value of the investment returns. It asserts that an investment should be realized if its NPV is positive (Jorgenson 1963, Tobin 1969). The ROA extends the NPV approach to account for uncertainty, flexibility and irreversibility in (dis)investment decision-making. According to the ROA, the expected investment returns do not only have to cover the investment costs, but also the opportunity costs or the profit that could be realized if the investment is postponed; that is, the investment trigger is shifted upwards (Abel and Eberly 1994, Pindyck 1991, Dixit and Pindyck 1994). With regard to disinvestment, the trigger is shifted downwards. The salvage value does not only have to cover the project's returns, but also the opportunity costs or the profit that could be realized if the disinvestment was postponed.

Experimental results of various studies with respect to timing of investment and disinvestment decisions offer mixed evidence for the NPV and the ROA. Yavas and Sirmans (2005) showed that the majority of the participants chose to invest too early than suggested by the ROA and failed to recognize the benefits of delaying the investment. However, the studies by Oprea et al. (2009) and Maart and Musshoff (2011) showed that participants can learn from personal experience to closely approximate the predictions of the ROA reinforcing the predictive power of the ROA. Sandri et al. (2010) and Maart et al. (2011) showed in their experiments that participants postpone irreversible decisions, such as project termination even if the present value of the project cash flow falls below the liquidation value and, therefore, reject the NPV approach. Participants seem to intuitively understand the value of waiting and apply decision rules that result in disinvestment choices somewhat consistent with real options reasoning. This reveals the superiority of the ROA in explaining disinvestment behavior in comparison with the NPV. Figure 1 stylizes investment and disinvestment choices in the aforementioned studies. The above reasoning leads to the following hypotheses:

Hypothesis H1a "ROA superiority to NPV for investment decisions": The ROA provides a better prediction of the investment behavior of farmers than the NPV.

Hypothesis H1b "ROA superiority to NPV for disinvestment decisions": The ROA provides a better prediction of the the disinvestment behavior of farmers than the NPV.

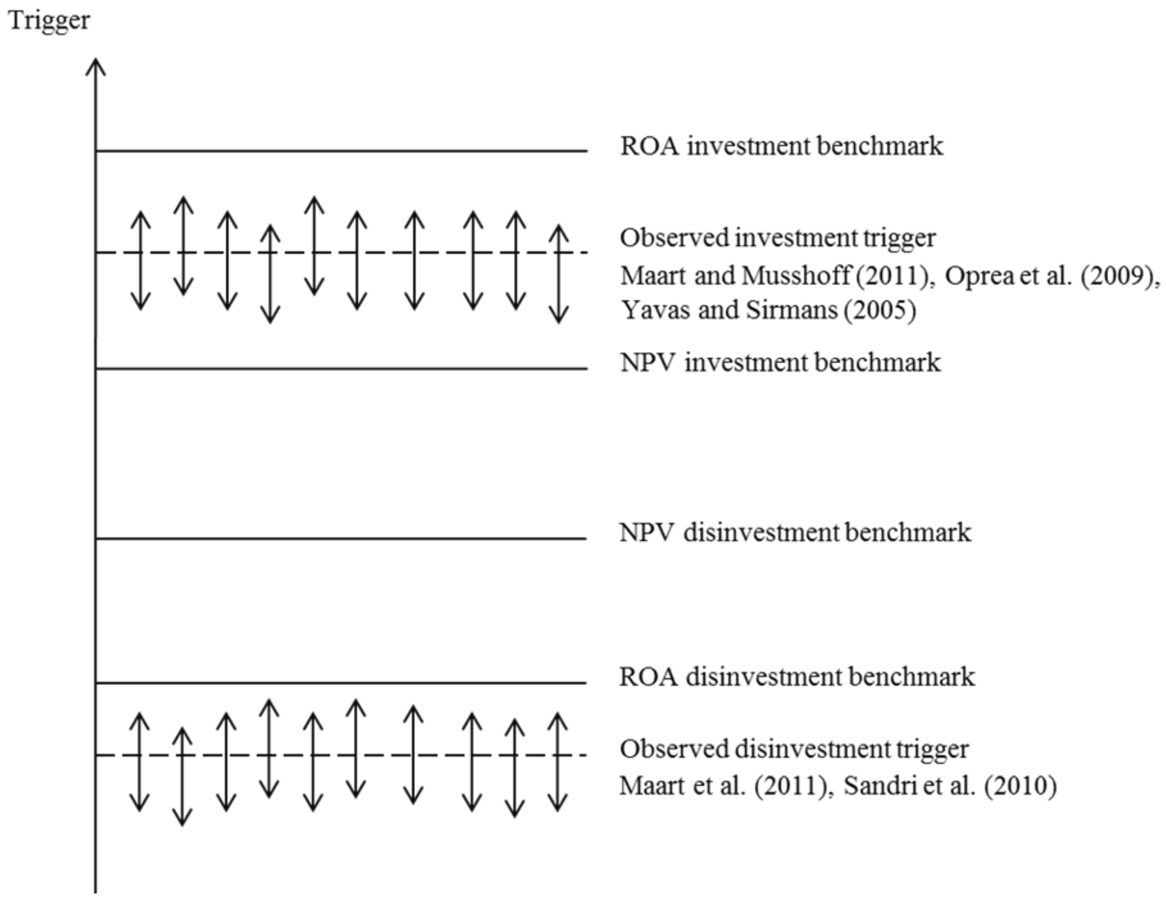

Figure 1: Stylized representation of (dis)investment choices in other experimental (dis)investment studies

In reality, entrepreneurs are constantly faced with decisions which are often characterized in that they are repeated. Decisions from the past can influence the decision-making process and future decisions. That means that the decision behavior is influenced by previous experiences. It stands to reason that a decision-maker tends to avoid repeating past mistakes and in case something positive results from a decision, he/she is more likely to decide in a similar way, given a similar situation. This phenomenon is referred to as "learning effect" and was studied by Brennan (1998), Cason and Friedman (1999) and Oprea et al. (2009) in terms of investment decisions. Against this background, the participants in an experiment are often faced repeatedly with the same treatment in order to examine how participants learn in repetitive situations. With regard to our experiment, we do not expect that participants make optimal decisions due to the complexity of the decision problem. Therefore, participants are faced with repeated choice tasks where they choose when to take an ongoing investment and disinvestment opportunity in one of ten years. The question arises, whether farmers accumulate knowledge through repeated decision-making and approximate optimal exercise of wait options. Thus, we construct the hypotheses that:

Hypothesis H2a "learning effect for investment decisions": With an increasing number of repetitions the investment timing of farmers will approximate to the optimal investment years predicted by the ROA.

Hypothesis H2b "learning effect for disinvestment decisions": With an increasing number of repetitions the disinvestment timing of farmers will approximate to the optimal disinvestment years predicted by the ROA.

In an experiment, the order in which treatments are given may affect participants' behavior. Participants may feel that they have to change their decision when faced with a different treatment, or they have to remain consistent. This phenomenon is referred to as "order effect" and was studied by Croson (2002) and Pereault (1975). Against this background, in an experiment, the order in which participants are faced with different treatments might influence the decision behavior. To counteract this, in our experiment participants are faced with investment and disinvestment treatments in a different order, so that some participants see one treatment first and others first see a different one. This leads us to our last hypotheses:

Hypothesis H3a "order effect for investment decisions": Farmers demonstrate different investment behavior depending on the order how they are faced with the investment and disinvestment treatment.

Hypothesis H3b "order effect for disinvestment decisions": Farmers demonstrate different disinvestment behavior depending on the order how they are faced with the investment and disinvestment treatment.

H3a and H3b *"order effect"* are not defined as alternative hypotheses, i.e. that if one hypothesis is rejected the other could be rejected as well.

3. Experimental Design and Implementation

This study uses an experimental design that is adapted from a study by Sandri et al. (2010) and by Maart and Musshoff (2011) and consists of four parts. The first and second part of the experiment include two randomized treatments. These two treatments stylize the option to invest (treatment A) and disinvest (treatment B) in irrigation technology. In the third part, we use a session of Holt and Laury (2002) Lotteries (HLL) to elicit the risk attitudes of farmers because investment and disinvestment could be influenced by decision-makers' risk attitude. In addition, we gather some socio-demographic and farm-specific information to complement the experimental data in the last part of the experiment. The main variables collected through the survey are age, gender, educational level, economic background in education, household size, farm income type, farm size, farm type, and use of irrigation.

Before the (dis)investment experiment started, participants had to read a set of instructions which were displayed on a computer screen. They were informed about all parameters and assumptions underlying the experimental setting. Participants had to answer some control questions to ensure that they entirely understood the experimental instructions. After completing the control questions, participants also played a trial round to become familiar with the (dis)investment experiment. This trial round only differed from the actual experiment in that participants did not receive any earnings for their decisions. In the Appendix, we present a translated English version of the instructions of the (dis)investment experiment which were submitted to the participants in German.

In treatment A, participants could hypothetically invest in irrigation technology, whereas in treatment B, participants could hypothetically disinvest in the technology. We chose this technology as an exemplary investment and disinvestment object because the use of irrigation in agriculture has become a crucial adaptation strategy to climate change in many parts of the world. Moreover, in this context, it is often challenging to explain the observed decision behavior. The order in which participants were faced with the two treatments was randomly determined. Each participant was faced with ten repetitions of the respective treatment. Within each repetition, participants should decide to realize or to postpone an investment and disinvestment.

Within each repetition of treatment A, participants could decide to take an ongoing investment opportunity in one of ten years. Every participant started the experiment with a deposit of 10,000 € in each repetition. The initial investment outlay also was 10,000 €. For simplicity reasons, the risk-free interest rate was fixed at 10% per year. The gross margin in year 0 always was 1,200 €. According to a discrete approximation of an arithmetic Brownian motion (Dixit and Pindyck 1994, p. 68) the gross margins evolved stochastically with no drift and a standard deviation of 200 € over ten years. That means that the gross margin in year 1 would either increase to 1,400 € with a probability of 50% or decrease to 1,000 € with a probability of 50%. The binomial tree of potential gross margins with their associated probabilities of occurrence was displayed on a screen and accordingly adjusted as shown in Figure 2.

Year 0	Year 1	Year 2	Year 3	Year 4	Year 5	Year 6	Year 7	Year 8	Year 9	Year 10
										3200 0.10%
									3000 0.20%	
								2800 0.39%		**2800** 0.98%
							2600 0.78%		**2600** 1.76%	
						2400 1.56%		**2400** 3.12%		**2400** 4.39%
					2200 3.12%		**2200** 5.47%		**2200** 7.03%	
				2000 6.25%		**2000** 9.38%		**2000** 10.94%		**2000** 11.72%
			1800 12.50%		**1800** 15.62%		**1800** 16.41%		**1800** 16.41%	
		1600 25.00%		**1600** 25.00%		**1600** 23.44%		**1600** 21.88%		**1600** 20.51%
	1400 50.00%		**1400** 37.50%		**1400** 31.25%		**1400** 27.34%		**1400** 24.61%	
1200 100.00%		**1200** 50.00%		**1200** 37.50%		**1200** 31.25%		**1200** 27.34%		**1200** 24.61%
	1000 50.00%		**1000** 37.50%		**1000** 31.25%		**1000** 27.34%		**1000** 24.61%	
		800 25.00%		**800** 25.00%		**800** 23.44%		**800** 21.88%		**800** 20.51%
			600 12.50%		**600** 15.62%		**600** 16.41%		**600** 16.41%	
				400 6.25%		**400** 9.38%		**400** 10.94%		**400** 11.72%
					200 3.12%		**200** 5.47%		**200** 7.03%	
						0 1.56%		**0** 3.12%		**0** 4.39%
							-200 0.78%		**-200** 1.76%	
								-400 0.39%		**-400** 0.98%
									-600 0.20%	
										-800 0.10%

Figure 2: Binominal tree of potential gross margins and associated probabilities of occurrence (treatment A)

The present values of investment returns corresponded to the gross margins, which could be earned in the respective years assuming an infinite useful lifetime of the investment object. Moreover, it was assumed that the gross margin observed at the year after the investment realisation was guaranteed during the entire useful lifetime (Dixit and Pindyck 1994, cf. chapter 2). The risk-free interest rate is the appropriate discount rate for determining the present value of the investment returns if future returns are not uncertain. Therefore, a gross margin of, e.g., 1,400 € per year resulted in a present value of 14,000 €, while a gross margin of, e.g., 1,000 € per year resulted in a present value of 10,000 €.

In treatment A, each participant had three options: First, a participant could invest immediately, i.e. he/she pays the initial outlay of 10,000 € in year 0 and receives 1,400 € (= present value of 14,000 €) or 1,000 € (= present value of 10,000 €) with a probability of 50% in year 1. Second, a participant could decide to postpone the investment decision and could invest in one of the years 1 to 9. In case a participant decided not to invest in year 0, he/she would be faced again with the investment decision in year 1. It was randomly determined if the gross margin in year 1 increased or decreased starting from the value of year 0. On the screen, potential gross margin developments, which were not relevant anymore, were suppressed and the probabilities for future gross margins were updated. Third, a participant could invest in none of the 10 years, i.e. he/she saves the initial outlay of 10,000 €. The deposit and the gross margins less the initial outlay realized before year 10 increased by an interest rate of 10% for every year left in the tree.

Similarly to treatment A, participants could decide to take an ongoing disinvestment opportunity in one of ten years within each repetition of treatment B. The salvage value of the irrigation system was 5,000 €. The risk-free interest rate was also fixed at 10% per year. The binominal tree of potential gross margins always started with 400 € in year 0. The gross margins also evolved stochastically with no drift and a standard deviation of 200 € over ten years. That means that the gross margin in year 1 would either increase to 600 € with a probability of 50% or decrease to 200 € with a probability of 50%. The binomial tree of potential gross margins with their associated probabilities of occurrence was displayed on a screen and adjusted accordingly as shown in Figure 3.

Year 0	Year 1	Year 2	Year 3	Year 4	Year 5	Year 6	Year 7	Year 8	Year 9	Year 10
										2400 0.10%
									2200 0.20%	
								2000 0.39%		**2000** 0.98%
							1800 0.78%		**1800** 1.76%	
						1600 1.56%		**1600** 3.12%		**1600** 4.39%
					1400 3.12%		**1400** 5.47%		**1400** 7.03%	
				1200 6.25%		**1200** 9.38%		**1200** 10.94%		**1200** 11.72%
			1000 12.50%		**1000** 15.62%		**1000** 16.41%		**1000** 16.41%	
		800 25.00%		**800** 25.00%		**800** 23.44%		**800** 21.88%		**800** 20.51%
	600 50.00%		**600** 37.50%		**600** 31.25%		**600** 27.34%		**600** 24.61%	
400 100.00%		**400** 50.00%		**400** 37.50%		**400** 31.25%		**400** 27.34%		**400** 24.61%
	200 50.00%		**200** 37.50%		**200** 31.25%		**200** 27.34%		**200** 24.61%	
		0 25.00%		**0** 25.00%		**0** 23.44%		**0** 21.88%		**0** 20.51%
			-200 12.50%		**-200** 15.62%		**-200** 16.41%		**-200** 16.41%	
				-400 6.25%		**-400** 9.38%		**-400** 10.94%		**-400** 11.72%
					-600 3.12%		**-600** 5.47%		**-600** 7.03%	
						-800 1.56%		**-800** 3.12%		**-800** 4.39%
							-1000 0.78%		**-1000** 1.76%	
								-1200 0.39%		**-1200** 0.98%
									-1400 0.20%	
										-1600 0.10%

Figure 3: Binominal tree of potential gross margins and associated probabilities of occurrence (treatment B)

In treatment B, each participant had three options: First, a participant could disinvest immediately in year 0, i.e. he/she receives the initial gross margin of 400 € and the salvage value of 5,000 €. Second, a participant could decide to postpone the disinvestment decision and could disinvest in one of the years 1 to 9, i.e. he/she receives the gross margins of the respective years until the year he/she decides to disinvest as well as the salvage value in the disinvestment year. In case a participant decided not to disinvest in year 0, he/she would be faced again with the disinvestment decision in year 1. It was randomly determined if the gross margin in year 1 increased or decreased starting from the value of year 0. On the screen, potential gross margin developments, which were not relevant anymore, were suppressed and the probabilities for future gross margins were updated. Third, a participant could disinvest in none of the 10 years, i.e. he/she receives the gross margins of the respective years and the present value of future returns in year 10 assuming an infinite useful lifetime and an interest rate of 10%. The gross margins plus the salvage value increased by an interest rate of 10% for every year left in the tree.

In the third part of the experiment, a session of HLL was carried out in which participants made a series of ten choices between two systematically varied alternatives. Table 1 shows an extract of the choice situations the participants faced in this lottery.

Table 1: Structure of the HLL[a)]

	Alternative 1 ($\mathbf{A_1}$)	Alternative 2 ($\mathbf{A_2}$)	Expected value A_1	Expected value A_2	Critical constant relative risk aversion coefficient[b)]
1	with 10% gain of **600 €** with 90% gain of **480 €**	with 10% gain of **1,155 €** with 90% gain of **30 €**	492 €	142.5 €	-1.71
2	with 20% gain of **600 €** with 80% gain of **480 €**	with 20% gain of **1,155 €** with 80% gain of **30 €**	504 €	255 €	-0.95
…	…	…	…	…	…
9	with 90% gain of **600 €** with 10% gain of **480 €**	with 90% gain of **1,155 €** with 10% gain of **30 €**	588 €	1,042.5 €	1.00
10	with 100% gain of **600 €** with 0% gain of **480 €**	with 100% gain of **1,155 €** with 0% gain of **30 €**	600 €	1,155 €	-

a) The last three columns were not displayed in the experiment.
b) A power risk utility function is assumed.

Participants are faced with different paired lotteries and they had to choose between alternative 1 (the safe alternative) and alternative 2 (the risky alternative). The probabilities varied systematically and therefore created ten possible combinations. In the first row, participants who choose alternative 1 have a 10% chance of winning 600 € and a 90% chance of winning 480 €. Similarly, if they choose alternative 2, there is a 10% chance of winning 1,155 €, and a 90% chance of winning 30 €. In the second row, the probabilities raised to 20% and 80%, and so on. The last row was a test whether the participants understood the experiment. Here obviously alternative 2 dominates over alternative 1 as it yields a secure earning of 1,155 €. The earnings are held constant across the decision rows, whereas the probabilities of the earnings vary in each row. The expected values of the alternatives change as participants move down in the decision rows. Up to the fourth row, the expected value of the safe alternative 1 is higher than the expected value of the risky alternative 2. From the fifth row, the expected value of alternative 2 exceeded the expected value of alternative 1.

Participants were asked to make ten choices of either alternative 1 or alternative 2, one for each row. The switching point from the safe to the risky alternative allows us to determine their individual risk attitude. A risk-seeking participant would switch to alternative 2 in the first three decision rows, while a risk-averse participant would switch to alternative 2 between the decision rows 5 to 9. In turn, a risk-neutral participant would always decide in favor of the alternative with the higher expected value. Therefore, the person would switch from choosing alternative 1 to alternative 2 in row 5. A HLL-value (= number of safe choices) between 0 and 3 expressed risk preference, a HLL-value of 4 implied risk neutrality, and a HLL-value between 5 and 9 expressed risk aversion of the participant.

The computer-based experiment was conducted in November 2011 at the leading agricultural exhibition in Germany. Farmers were recruited during the exhibition by personally asking for their participation in our experiment. All participants received a participation allowance of 10 € after they completed the experiment. In total, we spoke to approximately 500 randomly selected farmers of which 135 participated in our experiment. The overall aim was to recruit around 125 farmers with an acceptable deviation of 10%. On average, the experiment took 45 minutes per individual and choices made by participants were not time constrained. The hypothetical decisions in the investment and disinvestment treatment and in the HLL were related to real earnings to ensure incentive compatibility of the experiment. After the whole experiment was completed, three winners were randomly selected. The earnings of two participants for the investment and the disinvestment experiment were based on their individual scores attained on a randomly chosen repetition of the respective treatment. The winner received 100 € cash for each 2,500 € achieved in the selected repetition. The potential earnings varied between 270 € and 1,900 € for the investment treatment and between 0 € and 1,900 € for the disinvestment treatment. The earning of the participant from the third part of the experiment, i.e. for the HLL, was based on his/her preference expressed between various mutually exclusive alternatives. The potential earning varied between 30 € and 1,155 €.

4. Data Analysis

Normative benchmarks

For the evaluation of the observed (dis)investment behavior in the experiment we have to derive normative benchmarks which reflect the NPV and the ROA, respectively. We calculate the (dis)investment trigger of the NPV and the ROA, which mark the threshold level on which it becomes optimal to (dis)invest. The (dis)investment trigger following the NPV can be directly determined via annualizing the investment costs and the salvage value, respectively. In contrast to that, the (dis)investment trigger of the ROA has to be calculated by dynamic stochastic programming (Trigeorgis 1996, p. 312). Figure 4 illustrates the normative benchmarks of the investment and disinvestment according to the NPV and the ROA for a risk-neutral decision-maker.

a) Treatment A (investment) **b) Treatment B (disinvestment)**

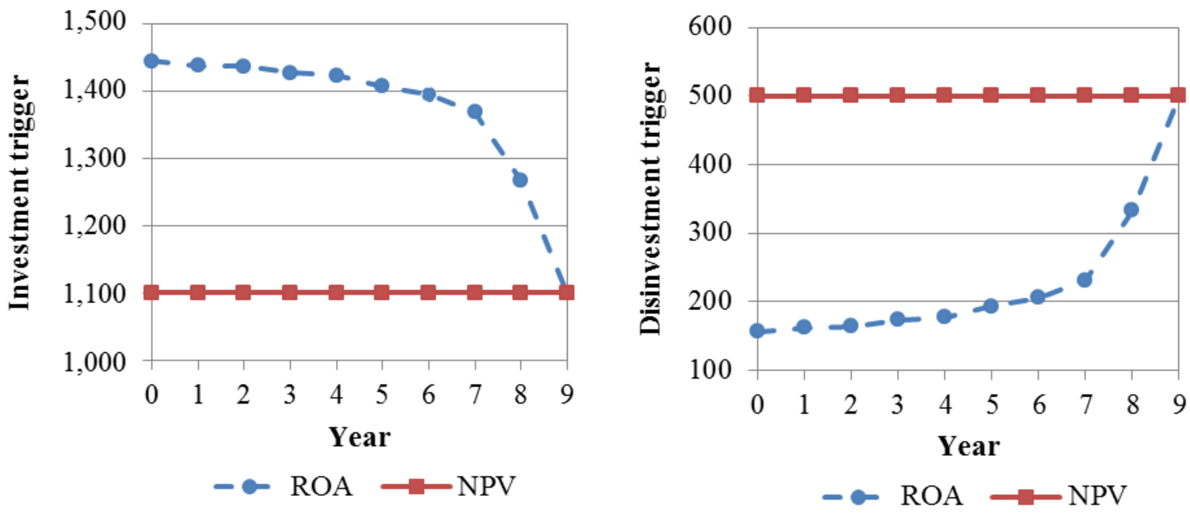

Figure 4: (Dis)investment trigger for a risk-neutral decision-maker

The investment triggers of the ROA decrease exponentially reflecting the diminishing time value of the investment option. In turn, the disinvestment triggers of the ROA increase exponentially reflecting the diminishing time value of the disinvestment option. The trigger values start in year 0 at 1,444 and 166 for the investment and the disinvestment treatment, respectively. The curves coincide with the NPV at 1,100 and 500 at year 9, respectively. That means that the investment and disinvestment option expired in year 9 and, thus, there was no more time to postpone the decision.

Moreover, we determine the normative benchmark for the (dis)investment decisions while considering the individual risk propensity participants show in the HLL, i.e. using risk-adjusted discount rates. According to Holt and Laury (2002), a power risk utility function is assumed, which implies decreasing absolute risk aversion and constant relative risk aversion:

$$U(V) = V^{1-\theta}, \quad (1)$$

where U donates utility, V describes the (dis)investment returns, and θ is the relative risk aversion coefficient. Based on equation (1) we can derive θ for each farmer and his/her choices in the HLL. Thus, the certainty equivalent CE of a risky prospect can be formulated as:

$$CE = V\left(E\big(U(V)\big)\right) = E\big(U(V)\big)^{\frac{1}{1-\theta}} = E(V) - RP \quad (2)$$

where $E(V)$ is the expected value of the (dis)investment returns and RP is a risk premium. The present value of the certainty equivalent CE_0 of an uncertain payment V_t at time T can be defined as follows:

$$CE_0 = CE_T \cdot (1+r)^{-T} = (E(V_T) - RP_T) \cdot (1+r)^{-T} \quad (3)$$

where r is the risk-free interest rate. An equivalent risk-adjusted discount rate $r^* = r + v$ can be derived from equation (3) using the following equation:

$$(E(V_T) - RP_T) \cdot (1+r)^{-T} = E(V_T) \cdot (1+r+v)^{-T} \quad (4)$$

$$\rightarrow v = (1+r) \cdot \left(\left(\frac{E(V_T)}{E(V_T) - RP_T}\right)^{1/T} - 1\right)$$

The risk loading v and, thus, the risk-adjusted discount rate $r + v$ depend on the risk premium RP as well as on the length of the discounting period T.

Applying dynamic programming to the binominal tree displayed in figure 2 and 3 using the risk-adjusted discount rates from equation (4) is problematic due to the fact that the number of potential states increases exponentially with the number of years. This would lead to a non-recombining binomial tree for the stochastic variable (Longstaff and Schwartz 2001). Therefore, we first fix the level of the returns for the (dis)investment at its initial value when determining the risk-adjusted discount rate by equation (4). Second, we fix T at one period in equation (4). Finally, we derive nine discount rates representing different risk attitudes for each treatment. The risk-adjusted discount rates vary in the range from 7.72% (HLL-value = 0-1) to 13.14% (HLL-value = 9-10) in the investment treatment and between 6.69% and 16.51% in the disinvestment treatment. The curve shapes of the ROA and the NPV would change slightly when taking into account the different risk attitudes of the participants.

Kaplan-Meier Survival Estimator

In the (dis)investment experiment, participants were given the opportunity to (dis)invest in one of ten years or to reject the offer to (dis)invest within the same time frame. Thus, in some of the total 2,700 investment and disinvestment decisions, a defined year of (dis)investment was not observed. That means that the opportunity to (dis)invest expired before participants' decision-making. In this case, data is right-censored as durations end after the time frame of observation. In order to test the hypotheses H1a and H1b, we use the product limit (PL) estimator, also referred to as the Kaplan-Meier survival estimator (Kaplan and Meier 1958). It produces an estimate of the distribution function that considers information contained in censored observations to correct censoring bias. The PL estimator is mainly used in survival studies in the field of medical research to estimate the survival function from life-time data. That means, it estimates the distribution functions of subjects' time-until-death when many subjects exit the study before dying. The PL estimator takes into account censored data, e.g. if a subject is lost from the sample before the final outcome is observed. In our study, we adapt the method to compare the actual investment and disinvestment decisions of farmers according to the NPV and the ROA. A non-parametric log-rank test is used to compare the survival functions of the observed and optimal investment and disinvestment decisions according to the NPV and the ROA.

Tobit Model

A tobit model (Tobin 1958) is used to test the hypotheses H2a, H2b, H3a and H3b. While doing this, socio-demographic and farm-specific variables are taken into account to analyze their impact on the (dis)investment behavior of farmers. These variables are age, gender, educational level, economic background in education, household size, farm income type, farm size, farm type, and use of irrigation. The tobit model is used to estimate linear relationships between variables when the dependent variable is either left- or right-censored. Right-censoring can be observed when cases with a value at or above some threshold take on the value of that same threshold. However, the true value might be equal or higher to the threshold. In case of left-censoring, values that fall below some threshold and take on the value of that same threshold are censored. In our case, the dependent variable representing the farmer's time of (dis)investment, is censored. The time of (dis)investment could only be observed when it falls between zero and nine. Let Y_i denote the time of (dis)investment of a farmer,

$$Y_i = \beta X_i + u_i, \text{ with } i = 1,2,\dots,N. \quad (5)$$

where N is the number of observations, Y_i is the dependent variable, X_i is a vector of independent variables, β is a vector of unknown regression parameters to be estimated, and u_i is a normal random variate with a mean of 0 and a variance of σ^2. The model for the dependent variable Y_i under interval censoring can be described as follows:

$$Y_i = \begin{Bmatrix} 0, if\ \beta X_i + u_i < 0 \\ 9, if\ \beta X_i + u_i > 9 \\ \beta X_i + u_i,\ otherwise \end{Bmatrix} \quad (6)$$

Here, 0 and 9 are the censoring interval endpoints. Equation (6) describes a tobit model with double censoring (Maddala 1983).

5. Experimental Results

Table 2 shows some descriptive statistics of the participants as well as some facts of the normatively expected and the observed decision behavior exhibited during the experiment.

Table 2: Descriptive statistics

Parameter	Treatment A (investment) with 1,350 decisions	Treatment B (disinvestment) with 1,350 decisions
Average farm size	228.9 ha (452.4 ha)	
Crop producers	77.0%	
Average age of farmers	32.1 years (11.9 years)	
Female farmers	22.2%	
Farmers with higher education	51.1%	
Farmers with economic background in education	39.3%	
Principal income farmers	65.9%	
Average risk attitude of a farmer (HLL-value)[a)]	5.21 (2.04)	
Average year of (dis)investment of farmers without non-(dis)investment years	2.0 (2.8)	4.0 (2.9)
Percentage of non-(dis)investment of farmers	20.2%	25.3%
Average year of (dis)investment according to NPV without non-(dis)investment years	0.0 (0.0)	0.2 (0.8)
Normative percentage of non-(dis)investment following NPV	0.0%	0.0%
Average year of (dis)investment according to ROA without non-(dis)investment years	4.3 (2.4)	3.2 (2.6)
Percentage of non-(dis)investment according to ROA	37.7%	28.2%

Note: Standard deviations are indicated in parentheses
[a)] A HLL-value between 0 and 3 expresses risk preference, a HLL-value of 4 implies risk neutrality, and a HLL-value between 5 and 9 expresses risk aversion of the participant.

Participants' average farm size was 228.9 ha. The farm sizes ranged between 0.13 ha and 3,600 ha. About 77.0% of the farmers are engaged in crop production. Participants' average age was 32.1 years. The youngest participant was 19 years old and the oldest participant was 61 years old. About 22.2% of the participants were female, 51.1% had a higher education and 39.3% had an economic background in education. The proportion of farmers that indicated farming as their main income source was 65.9%. On average, participants were slightly risk-averse. The observed investment time (treatment A) was year 3.0, while the observed disinvestment time (treatment B) was year 4.0. It should be noted that these figures do not take into account non-(dis)investment of farmers. About 20.2% of the participants choose not to invest in treatment A, whereas 25.3% chose not to disinvest in treatment B. Normative benchmarks derived for the NPV and the ROA were applied to 1,350 (treatment A) and 1,350 (treatment B) random realizations of the discrete approximation of an arithmetic Brownian motion generated during the experiment. As it can be seen in table 2, the average years of (dis)investment according to the ROA benchmark are considerably later than suggested by the NPV benchmark. In addition, the ROA benchmark has a higher percentage of non-(dis)investment decisions than the NPV benchmark. Regarding treatment A, farmers invest later than suggested by the NPV and earlier than suggested by the ROA. In treatment B, farmers disinvest later than suggested by the NPV and by the ROA.

In the following, we test our hypotheses.

Test of hypotheses H1a and H1b "ROA superiority to NPV"

In order to test H1a and H1b, we compare the investment and disinvestment behavior of farmers with the benchmark prediction according to the NPV and the ROA. Table 3 shows the hit ratio of the observed behavior and the investment and disinvestment benchmarks. In treatment A, in about 25% of the cases participants invested as predicted by the NPV, whereas in 75% of the cases, participants invested later than predicted by the NPV. Regarding the ROA, in about 16.2% of the cases, participants had an optimal investment timing as predicted by the ROA, while in 58.6% of the cases they invested earlier and in 25.2% of the cases later than predicted by the ROA. In treatment B, in about 12.4% of the cases, participants decided in accordance with the NPV. However, in about 86.1% of the cases, participants disinvested later than predicted by the NPV benchmark. Regarding the ROA, in about 15.8% of the cases, participants disinvested as predicted by the ROA, while in 37.9% of the cases, they disinvested earlier and in 46.3% of the cases later than predicted by the ROA. In most cases, farmers invested and disinvested later than predicted by the NPV. A more balanced ratio regarding the ROA is observed in treatment A (investment) and B (disinvestment) compared to the NPV. This already is a first indication for the validity of H1a and H1b.

Table 3: Hit ratio of the observed behavior and investment and disinvestment benchmarks

Parameter	Treatment A (investment) with 1,350 decisions	Treatment B (disinvestment) with 1,350 decisions
Earlier (dis)investment than predicted by the NPV	0.0%	1.5%
Optimal (dis)investment as predicted by the NPV	25.0%	12.4%
Later (dis)investment than predicted by the NPV	75.0%	86.1%
Earlier (dis)investment than predicted by the ROA	58.6%	37.9%
Optimal (dis)investment as predicted by the ROA	16.2%	15.8%
Later (dis)investment than predicted by the ROA	25.2%	46.3%

Figure 5 shows the survival functions of the Kaplan-Meier estimation of the observed and the optimal a) investment and b) disinvestment decision-making according to the NPV and the ROA. The horizontal axis shows the time to event that is the year of (dis)investment, while the vertical axis shows the probability of survival. The staircase-shaped curves illustrate the cumulative option exercise over the years. It indicates the percentage of (dis)investments realized per year. Drops in the survival curve occur whenever participants decide to (dis)invest. A log-rank test of the equality of the survival functions shows that there is a statistically significant difference between the observed investment and disinvestment decisions and the normative benchmarks according to the NPV and the ROA (p-value < 0.001, log-rank test). Based on this finding, we conclude that neither the NPV nor the ROA provides an accurate prediction of the actual (experimentally observed) investment and disinvestment behavior of farmers.

In graph a), the curve of the decision behavior observed is below that of the optimal decision behavior according to the ROA and above the curve of the optimal decision behavior according to the NPV throughout the time. That means that farmers invest later than predicted by the NPV, but earlier as suggested by the ROA. In graph b), the curve of the decision behavior observed is above the curve of the optimal decision behavior according to the ROA and the NPV during most of the time. It means that farmers disinvest later than predicted by the NPV and the ROA. In both graphs, the curve of the observed decision behavior is closer to the optimal decision behavior according to the ROA then to the NPV meaning that farmers (dis)invest more in accordance with the ROA. Against this background, we fail to reject *H1a and H1b "ROA superiority to NPV"*. Our results show that the ROA is able to predict actual (dis)investment decisions better than the NPV. Nevertheless, the observed disinvestment reluctance is even more pronounced as predicted by the ROA. These findings are consistent with previous investigations (Maart et al. 2011, Maart and Musshoff 2011, Oprea et al. 2009, Sandri et al. 2010). Moreover, it can be observed that the curve of the decision behavior observed in treatment B is closer to the optimal decision behavior according to the ROA than it is in treatment A. This indicates that the ROA may provide a better prediction of the disinvestment behavior than of the investment behavior.

a) Treatment A (investment) **b) Treatment B (disinvestment)**

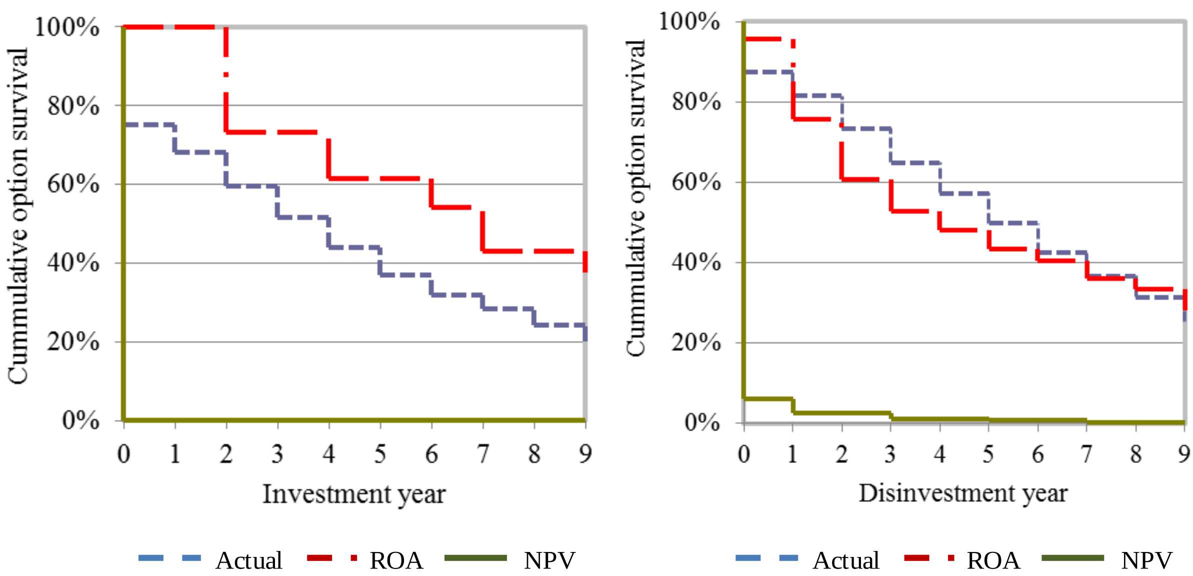

Figure 5: Survival functions of observed and optimal investment and disinvestment decision-making according to the NPV and the ROA

Test of hypotheses H2a and H2b "learning effect" and H3a and H3b "order effect"

To test hypotheses H2a, H2b, H3a and H3b, we run two tobit models. The results of the tobit regression of treatment A and B are presented in Table 4. We found that, on average, the ROA does not provide an accurate prediction of the decision behavior of farmers when considering all repetitions. That means that farmers invest earlier and disinvest later than predicted by the ROA. In our experiment, farmers were faced with repeating (dis)investment opportunities. Each farmer repeated treatment A (investment) and treatment B (disinvestment) ten times, so that in each case they had ten times the option to (dis)invest. We investigated the presence of a "learning effect" in the (dis)investment behavior of farmers meaning that we tested whether farmers approximate to the optimal (dis)investment years predicted by the ROA with increasing number of repetitions. In treatment A, the estimated coefficient of the variable "repetition" is significant and has a positive sign (p-value = 0.001). That means that with each repetition of the investment treatment, farmers invested 0.173 years later. They learn from their experiences of previous investment decisions. This result confirms previous findings of Oprea et al. (2009) stating that participants consider the value of waiting in investment decisions over time if they are given a chance to learn from personal experience. The estimated coefficient of the variable "repetition" in treatment B (disinvestment) is not significant (p-value = 0.068). Therefore, we fail to reject H2a "learning effect for investment decisions" and reject H2b "learning effect for disinvestment decisions".

Table 4: Tobit regression of the individual (dis)investment year of farmers (N=2,700)

	Treatment A (investment)			Treatment B (disinvestment)		
Parameter	Coefficient	p-value		Coefficient	p-value	
Constant	7.922	<0.001	**	7.643	<0.001	**
Repetition (1 to 10 repetitions)	0.173	0.001	**	0.081	0.068	
Order (1: first A or B, 0: second A[1] or B[2])	-1.638[1]	<0.001	**	0.698[2]	0.008	**
Risk attitude (HLL-value between 0 to 10)	-0.163	0.010	**	-0.215	0.001	**
Age	-0.051	0.001	**	-0.036	0.003	**
Gender (1: male, 0: female)	-0.099	0.756		-0.884	0.007	**
Higher education (1: with, 0: without)	0.188	0.496		0.298	0.293	
Economic background in education (1: yes, 0: no)	0.656	0.016	*	0.740	0.008	**
Household size	-0.311	0.001	**	-0.0614	0.396	
Farm income type (1: principal income, 0: sideline)	-0.074	0.806		0.308	0.310	
Farm size	0.001	0.001	**	0.001	0.001	**
Farm type (1: crop production, 0: other)	-0.298	0.263		0.106	0.697	
Use of irrigation (1: with, 0: without)	0.221	0.534		-0.231	0.525	
Log Likelihood	-3271			-3148		
Chi^2	127			75		

Note: Asterisk (*), double asterisk (**) denote variables significant at 5% and 1%, respectively.

In the experiment, farmers were faced with both treatments in a different order (treatment A and treatment B or treatment B and treatment A), so that some were at first faced with the investment treatment and then with the disinvestment treatment or with both treatments in a reverse order. We examined the presence of an "order effect" in the (dis)investment behavior of farmers meaning that we tested whether farmers show different (dis)investment behavior when they were faced with the treatments in a different order. The estimated coefficient of the variable “order” is highly significant in both treatments. Regarding treatment A (investment), farmers who are first faced with the investment treatment, invest 1.638 years earlier than farmers who are second faced with treatment A. Regarding treatment B, farmers who are first faced with the disinvestment treatment, disinvest 0.698 years later than farmers who are second faced with treatment B. Therefore, we fail to reject *H3a “order effect for investment decisions” and H3b “order effect for disinvestment decisions”*. That means that farmers demonstrate different investment and disinvestment behavior dependent on the order in which they are faced with the two treatments. However, it could also indicate a *“learning effect*” meaning that farmers acquire routines for repetitive decisions at the beginning of the experiment and apply them to later decisions even if they are related to another treatment. These findings indicate that decisions in both treatments approximate the ROA benchmark.

Socio-demographic and farm-specific variables might also have an influence on the (dis)investment year. Therefore, we selected specific variables from the literature for further consideration in our analysis. Viscusi et al. (2011) point out that risk-averse people are less willing to accept investments. Sandri et al. (2010) state that the more risk-averse the individual, the higher his/her disinvestment trigger and the earlier the disinvestment. In our experiment, we expect that risk-averse participants are more reluctant to make investments and, thus, invest later, whereas they disinvest earlier. The HLL-value in table 4 is significant and has a negative sign in both treatments. It implies that risk-averse farmers invest and disinvest earlier. This result does not meet our expectations regarding the investment, whereas it is in line with our expectations regarding the disinvestment. The starting value might be one explanation for this observation. The gross margin in year 0 was 1,200 € (= present value of 12,000 €) and, thus, the NPV is always greater than 0. From Gardebroek and Oude Lansink (2004) we can derive that age reduces the willingness of farmers to invest. Pushkarskaya and Vedenov (2009) argue that older farmers are more likely to exit a business. We find that older farmers invest and disinvest earlier than younger farmers. In contrast to the finding of Jianakoplos and Bernasek (1998) that women make more conservative investment decisions, we do not find a significant effect on the variable “gender” in treatment A. Justo and DeTiennne (2008) explore the impact of gender on entrepreneurial exit and find that females are more likely than males to voluntarily exit a business. In treatment B, the variable “gender” is significant and has a negative sign implying that male farmers disinvest earlier than female farmers. Lewellen et al. (1977) state that investors who have a large household size invest more conservative, while Justo and DeTienne (2008) find that parenting entrepreneurs are more likely to voluntarily exit the business. The variable “household size” is significant and has a negative value in treatment A. That means that the larger the household size, the earlier he/she invests. There is no significant effect of the variable in treatment B. Gardebroek and Oude Lansink (2004) find that higher education reduces the investment thresholds, while Pushkarskaya and Vedenov (2000) show that education has a positive and significant effect on the probability of exit. DeTienne and Cardon (2005) find that the area of educational study also relates to the specific exit strategy chosen. There is no significant effect on the variable “higher education”, whereas the variable “economic background in education” is significant and has a positive sign. Farmers with an economic background in education (dis)invest later.

Daberkow and McBride (2003) state that the adoption of an innovation will tend to take place earlier on larger farms than on smaller farms. Foltz (2004) argues that smaller farms are more likely to exit a business than larger farms. We find a positive significant effect of the variable “farm size” in both treatments meaning that farmers (dis)invest later when they have a larger size of farm land. Furthermore, we derive from Adesina et al. (2000) that farmers with a principal income from farming will invest later. O’Brien et al. (2003) argue that the entry into some target industries requires more irreversible investments compared to other industries. We consider that crop producing farms own less assets with irreversible costs than other types of farms. Therefore, we expect that crop producing farms will invest earlier than farms that do not produce crops. We find that the variables “farm income type” and “farm type” are not significant and do not affect farmers’ investment decision-making significantly. There is also no significant effect of these variables in treatment B. The variable “use of irrigation” also does not have a significant effect on the (dis)investment decisions of farmers. The non-significance of the variable “use of irrigation” could be a hint that our results are not considerably influenced by the framing of our experiment.

Table 5 summarizes the results with regard to the validity of our hypotheses.

Table 5: Validity of hypotheses on (dis)investment behavior of farmers

Hypotheses		Validity
H1a "ROA superiority to NPV for investment decisions"	The ROA provides a better prediction of the investment behavior of farmers than the NPV.	Fail to reject
H1b "ROA superiority to NPV for disinvestment decisions"	The ROA provides a better prediction of the disinvestment behavior of farmers than the NPV.	Fail to reject
H2a "learning effect for investment decisions"	With an increasing number of repetitions the investment timing of farmers will approximate to the optimal investment years predicted by the ROA.	Fail to reject
H2b "learning effect for disinvestment decisions"	With an increasing number of repetitions the disinvestment timing of farmers will approximate to the optimal disinvestment years predicted by the ROA.	Reject
H3a "order effect for investment decisions"	Farmers demonstrate different investment behavior depending on the order how they are faced with the investment and disinvestment treatment.	Fail to reject
H3b "order effect for disinvestment decisions"	Farmers demonstrate different disinvestment behavior depending on the order how they are faced with the investment and disinvestment treatment.	Fail to reject

6. Discussion and Conclusions

(Dis)investment in irrigation technology has become more prominent over the past decade due to changing climate conditions. Water is becoming an increasingly scarce resource for the agricultural sector in many countries around the world and the use of irrigation technologies is seen as one possible adaptation strategy to climate change. Understanding farmers' decision behavior in (dis)investment situations is crucial to gain an insight into the dynamics of the adoption and abandonment of specific technologies and to contribute to an environment in which the adoption of new technologies is encouraged. However, extensive research that experimentally analyzes (dis)investment decisions under conditions of uncertainty has not been carried out, yet. The ROA provides the scope to examine the effect of uncertainty on (dis)investment decisions and further extends the classical NPV to account for flexibility and irreversibility. Experimental results of various studies offer mixed evidence for the NPV and the ROA. They find that the value of waiting in investment decisions often is not completely understood by the participants, whereas in disinvestment decisions, they often exaggerate the option to delay. In our study, we examined investment and disinvestment behavior in one experiment using a "within-subject" design. We tested whether the NPV or the ROA provides a better prediction of the observed (dis)investment decision behavior of farmers and whether the decision behavior observed in previous experiments can be validated. In order to do so, the observed (dis)investment decisions were contrasted with theoretical benchmarks, which were derived from the NPV and the ROA. The experiment considered an optimal stopping (dis)investment problem in which farmers could invest in as well as abandon irrigation technology.

The findings indicate that neither the NPV nor the ROA provides an exact prediction of farmers' (dis)investment behavior observed in the experiment. Farmers invest later than predicted by the NPV, but earlier as suggested by the ROA. Regarding the disinvestment situation, farmers disinvest later than predicted by the NPV and even later than suggested by the ROA. That means that the decision behavior observed in previous experiments can be validated in a "within-subject" design. The results suggest that the ROA provides a better prediction of the (dis)investment behavior of farmers than the NPV. In addition, we found that farmers accumulate knowledge through repeated decision-making in investment situations and hence, approximate to the predictions of the ROA. That means that participants learn from their experience, whereas farmers exaggerate the option to delay in disinvestment situations. The analysis also showed that farmers demonstrate different (dis)investment behavior depending on the order how they were faced with the investment and disinvestment treatment.

Further research in the vein of this study is needed to investigate why (i) the ROA provides a better prediction of the observed investment and disinvestment behavior of farmers than the NPV and (ii) the ROA provided a better prediction of the observed disinvestment behavior than the investment behavior of farmers. It is possible that potential drivers of psychological inertia also play a role when explaining (dis)investment behavior. A behavioral phenomenon that might influence the intuitive choice of (dis)investment trigger towards postponement of this decision is the escalation-of-commitment-effect (Denison 2009, Staw 1981). This effect describes the phenomenon that it is difficult to dissuade somebody from a course that the person once adopted. That would mean that decision-makers have the tendency to persist on a failing course of action. With regard to our (dis)investment experiment, participants are faced with repeated decision situations in which object returns may fall x-times in a row. Then, participants have the choice either to continue waiting in the hopes that returns increase or to (dis)invest. Here, the question arises, whether participants follow specific rules of thumb in their decision-making. It would be interesting to reveal the heuristics, which participants apply to make (dis)investment decisions. Another interesting path to be taken would be to test whether farmers in developing countries show a similar (dis)investment behavior as farmers in developed countries. To the best of our knowledge, there are no experimental studies that consider farmers' behavior under uncertainty with regard to long-term (dis)investment decisions in developing countries: How do farmers in developing countries make (dis)investment decisions under uncertainty? The experimental investigation of real options settings is still in its early stages, so that in this regard further work is needed to better understand what exactly drives individuals' decision-making in investment and disinvestment situations.

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Appendix: Experimental Instructions

Translation from German;

Instructions for investment and disinvestment in irrigation technology

General Information

[…] The game consists of four parts and would require approximately 45 minutes of your time. Please read the following instructions carefully as your earnings in the experiment will depend on your decisions. Of course, your data will be treated as confidential and will be analyzed anonymously. […]

In each game, you should try to collect as many Euros € as possible because your potential earnings are proportional to the number of Euros € you collect during the game.

Beside an expense allowance of 10 € each participant has three times the chance to receive a bonus if he/she completes the entire game.

In the first and second part of the game, one player is randomly selected and is given 100 € cash per 2,500 € achieved in a randomly selected round. The selected players for both parts will therefore receive between 270 € and 1,900 € as well as between 0 € and 1,900 € respectively. In the third part of the game, again one player is randomly selected and is given a cash bonus of between 30 € and 1,155 €.

In total, around 125 farmers can participate in the game. They will be informed via e-mail by 10th of December 2011 if they receive one of the three cash bonuses in addition to the expense allowance. The earnings can be paid out or transferred to an account specified by the player selected.

Good luck!

Please note that submitted decisions during the game cannot be changed.

First Part *(Instructions: treatment A (investment))*

The game consists of various repetitions of one game with an equal basic structure.

Imagine that you as a farmer have liquid assets of 10,000 € at your disposal. Due to the ongoing phenomenon of global warming, the climate changes, which has an increasingly noticeable impact on agricultural production. Therefore, you are considering purchasing an irrigation system. In the time frame between 0 and 9 years, you can invest in an irrigation system only once. You can decide within the next 10 years:

- to immediately invest in an irrigation system
- to wait and see the development of the gross margins that can potentially be achieved (up to 10 years) and to invest in an irrigation system later
- or not to invest in an irrigation system.

The liquid assets you dispose of in your account in a given year will yield an interest rate of 10% meaning that they will increase by a tenth of their value. For example, if you do not decide to invest in an irrigation system within the 10 years (between year 0 and year 9), your chance to invest expires and you will leave the game with your starting credit of 10,000 € that has increased to 25,937 € over the 10 years.

In case this game would be randomly selected for the cash premium, you would receive 1,038 € (= 25,937 € : 2,500 € · 100 €).

If you decide to invest in an irrigation system you have to pay 10,000 €. It is assumed that the gross margin observed at the time of investment is guaranteed by an infinite useful lifetime of the investment object.

The gross margin corresponds to the present value of investment returns, which can be achieved at the respective time of investment assuming an infinite useful lifetime of the investment object. A gross margin of 1,200 € and year would then result in a present value of 12,000 € (= 1,200 € · 10), while a gross margin of 1,400 € and year would result in a present value of 14,000 € (= 1,400 € · 10) etc.

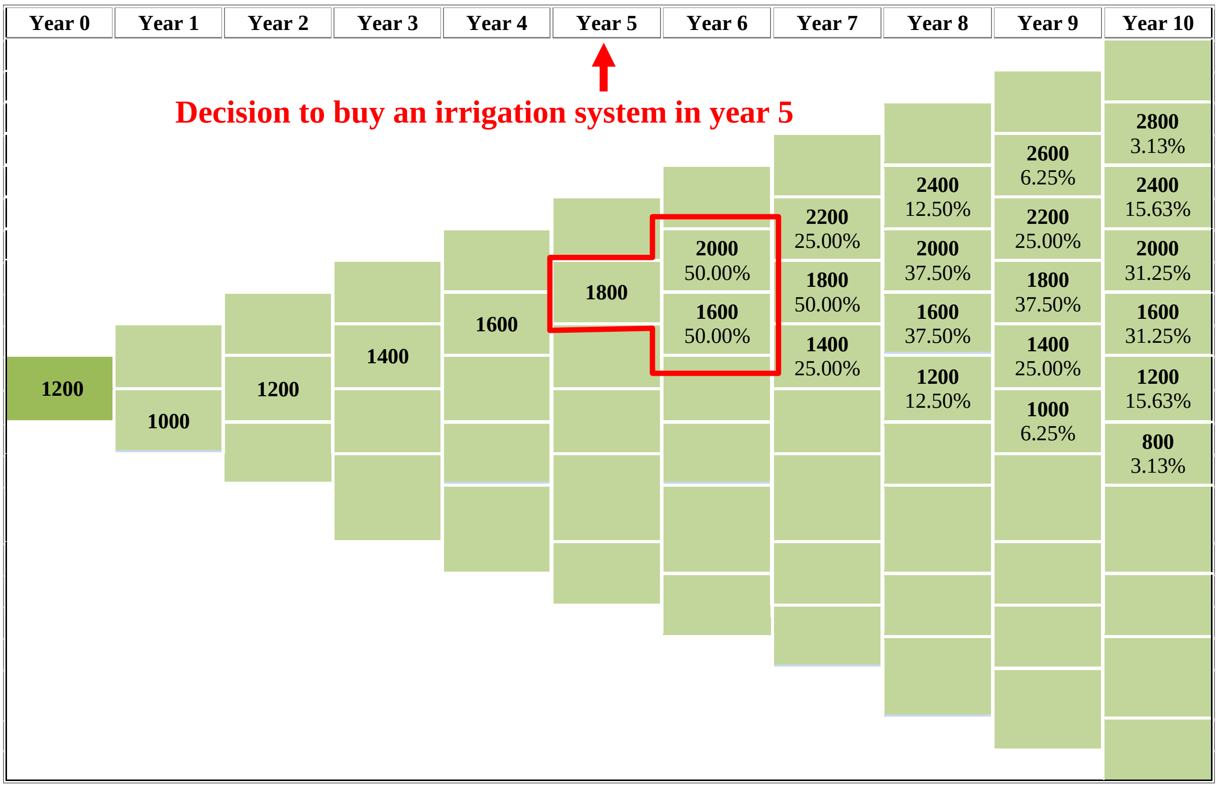
The tree chart below shows the possible gross margins of the investment, which you can earn in the respective years when investing in an irrigation system. The tree chart starts with a gross margin of 1,200 € in year 0. Starting from this initial value, the gross margin of the following years increases or decreases by 200 €. The probability of the occurrence of the gross margin in each year is indicated under the gross margin.

Year 0	Year 1	Year 2	Year 3	Year 4	Year 5	Year 6	Year 7	Year 8	Year 9	Year 10
										3200 0.10%
									3000 0.20%	
								2800 0.39%		**2800** 0.98%
							2600 0.78%		**2600** 1.76%	
						2400 1.56%		**2400** 3.12%		**2400** 4.39%
					2200 3.12%		**2200** 5.47%		**2200** 7.03%	
				2000 6.25%		**2000** 9.38%		**2000** 10.94%		**2000** 11.72%
			1800 12.50%		**1800** 15.62%		**1800** 16.41%		**1800** 16.41%	
		1600 25.00%		**1600** 25.00%		**1600** 23.44%		**1600** 21.88%		**1600** 20.51%
	1400 50.00%		**1400** 37.50%		**1400** 31.25%		**1400** 27.34%		**1400** 24.61%	
1200 100.00%		**1200** 50.00%		**1200** 37.50%		**1200** 31.25%		**1200** 27.34%		**1200** 24.61%
	1000 50.00%		**1000** 37.50%		**1000** 31.25%		**1000** 27.34%		**1000** 24.61%	
		800 25.00%		**800** 25.00%		**800** 23.44%		**800** 21.88%		**800** 20.51%
			600 12.50%		**600** 15.62%		**600** 16.41%		**600** 16.41%	
				400 6.25%		**400** 9.38%		**400** 10.94%		**400** 11.72%
					200 3.12%		**200** 5.47%		**200** 7.03%	
						0 1.56%		**0** 3.12%		**0** 4.39%
							-200 0.78%		**-200** 1.76%	
								-400 0.39%		**-400** 0.98%
									-600 0.20%	
										-800 0.10%

An Investment Decision Example

Imagine you decide to invest in an irrigation system in year 5. The gross margin has developed randomly as shown below and currently amounts to 1,800 €. What exactly you will earn from the investment in an irrigation system depends on the gross margin development in the next year (year 6):

- you will either earn 2,000 € with a probability of 50%
- or you will earn 1,600 € with a probability of again 50%



Example for the Calculation of your Final Account Balance in Case of an Investment in Year 10

Imagine the situation of the aforementioned example. In year 5, you decided to invest given a gross margin of 1,800 €. We assume a negative development of the gross margin from year 5 to year 6 resulting in a decrease of 200 €. With this investment, you would therefore earn 1,600 €. In this case, your total balance of year 10 would be calculated as follows:

- Your starting credit of 10,000 € increases by 10% up to year 5 to 10,000 € $\cdot$ 1.1^5 = 16,105 €.
- In year 5, your account balance is therefore 16,105 €.
- You will invest 10,000 € of these 16,105 € to purchase an irrigation system.
- The residual amount of 6,105 € yields 10% interest by year 10 (another 5 years) meaning that it increases as follows: 6,105 € $\cdot$ 1.1^5 = 9,832 €.
- In year 6, you receive a gross margin from the investment in an irrigation system of 1,600 €. Given that we assume an infinite useful lifetime, the investment will earn 16,000 €, which also will yield 10% interest by year 10 (another 5 years). 16,000 € $\cdot$ 1.1^5 = 25,768 €.

In this example, your total balance in year 10 will correspond to the following:

9,832 € + 25,768 € = 35,600 €.

In this example, your account balance would be 35,600 € in year 10. If this game was randomly selected for determining the cash premium, you would receive 1,424 € (= 35,600 € : 2,500 € · 100 €).

Before the game starts, we would like to ask you to answer some control questions. This is to ensure that you understand all instructions.

If the gross margin of the investment in an irrigation system is 2,200 € in one year, which two gross margins can occur in the next year?
Please indicate the two gross margins here:

____ €

____ €

What is the probability (in %) that the gross margin in the tree chart increases by 200 € from one year to another?
Please indicate your answer here: ____ %

What is the probability (in %) that the gross margin in the tree chart decreases by 200 € from one year to another?
Please indicate your answer here: ____ %

How much interest (in %) do your liquid assets in your account yield per year?
Please indicate your answer here: ____ %

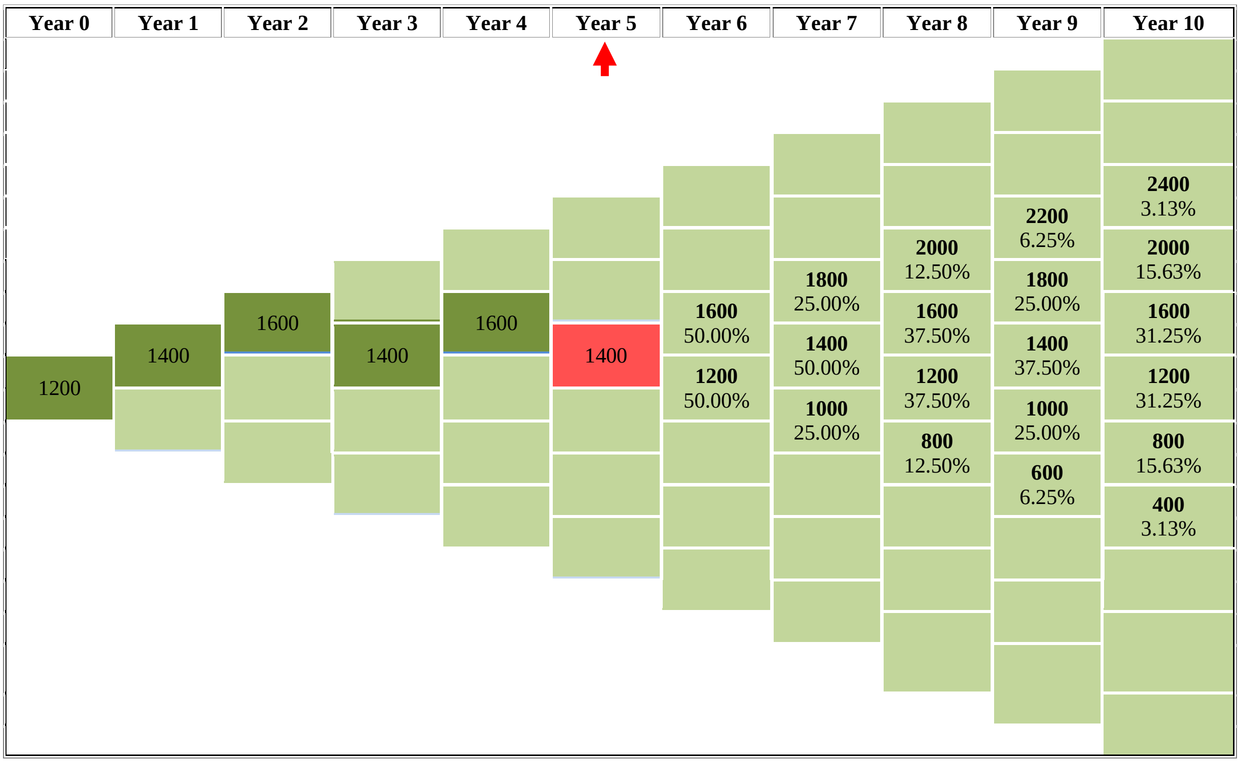
What are the costs of the investment in an irrigation system?

____ €

How much does the investment earn if the gross margin is 1,400 € per year assuming an infinite useful lifetime of the investment object?

____ €

In the observed year 5, the gross margin in the tree chart is 1,400 €. The possible gross margins which can be realized in the next years are indicated in bold.



Which of the two gross margins can potentially be realized in the coming year (year 6)? Please indicate the two gross margins here:

____ €

____ €

You answered all control questions correctly!

Please click “continue” to start the game.

- Here, the experiment starts –

Second Part *(Instructions: treatment B (disinvestment))*

The game consists of various repetitions of one game with an equal basic structure.

Imagine you as a farmer have an irrigation system. Due to changes in the water guidelines you are considering selling your irrigation system. In the time frame between 0 and 9 years, you can sell the irrigation system only once and receive a sales revenue of 5,000 €. You can decide within the next 10 years:

- to immediately sell the irrigation system
- wait and see the development of the gross margins that can potentially be achieved (up to 10 years) when continuing using the irrigation system and to sell the irrigation system later
- or not to sell the irrigation system.

The money, you have at your disposal in each year will yield an interest rate of 10% meaning that it increases by a tenth of its value. For example, if you decide to sell the irrigation system immediately you will leave the game with a sales revenue of 5,000 € that has increased to 12,969 € over the 10 years and a gross margin of 400 € in year 0, which amounts to 13,369 €.

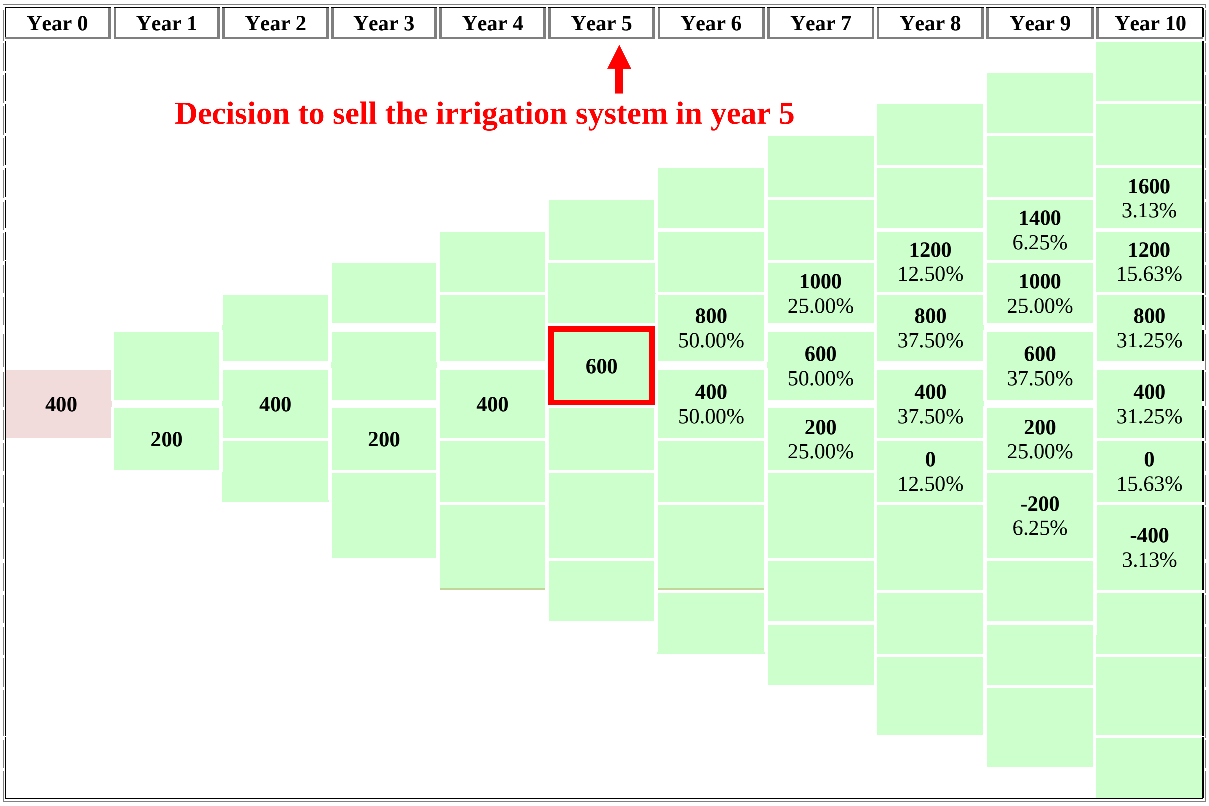
In case this game would be randomly selected for the cash premium, you would receive 535 € (= 13,369 € : 2,500 € · 100 €).

The tree chart below shows the possible gross margins, which you can earn in the respective years if you continue to use the irrigation system. The tree chart starts with a gross margin of 400 € in year 0. Starting from this initial value, the gross margin of the following years increases or decreases by 200 €. The probability of the occurrence of the gross margin in each year is indicated under the gross margin.

Year 0	Year 1	Year 2	Year 3	Year 4	Year 5	Year 6	Year 7	Year 8	Year 9	Year 10
										2400 0.10%
									2200 0.20%	
								2000 0.39%		**2000** 0.98%
							1800 0.78%		**1800** 1.76%	
						1600 1.56%		**1600** 3.12%		**1600** 4.39%
					1400 3.12%		**1400** 5.47%		**1400** 7.03%	
				1200 6.25%		**1200** 9.38%		**1200** 10.94%		**1200** 11.72%
			1000 12.50%		**1000** 15.62%		**1000** 16.41%		**1000** 16.41%	
		800 25.00%		**800** 25.00%		**800** 23.44%		**800** 21.88%		**800** 20.51%
	600 50.00%		**600** 37.50%		**600** 31.25%		**600** 27.34%		**600** 24.61%	
400 100.00%		**400** 50.00%		**400** 37.50%		**400** 31.25%		**400** 27.34%		**400** 24.61%
	200 50.00%		**200** 37.50%		**200** 31.25%		**200** 27.34%		**200** 24.61%	
		0 25.00%		**0** 25.00%		**0** 23.44%		**0** 21.88%		**0** 20.51%
			-200 12.50%		**-200** 15.62%		**-200** 16.41%		**-200** 16.41%	
				-400 6.25%		**-400** 9.38%		**-400** 10.94%		**-400** 11.72%
					-600 3.12%		**-600** 5.47%		**-600** 7.03%	
						-800 1.56%		**-800** 3.12%		**-800** 4.39%
							-1000 0.78%		**-1000** 1.76%	
								-1200 0.39%		**-1200** 0.98%
									-1400 0.20%	
										-1600 0.10%

A Selling Decision Example

Imagine you decide to sell the irrigation system in year 5 and receive the sales revenue of 5,000 €. The gross margin has developed randomly as shown below and currently amounts to 600 €.



In this case, your total balance of year 10 would be calculated as follows:

- The gross margin of 400 € of year 0 increases by 10% for each of the remaining years up to year 10, i.e. 400 € · 1.1^{10} = 1,037 €
- The gross margin of 200 € of year 1 increases by 10% for each of the remaining years up to year 10, i.e. 200 € · 1.1^{9} = 472 €
- The gross margin of 400 € of year 2 increases by 10% for each of the remaining years up to year 10, i.e. 400 € · 1.1^{8} = 857 €
- The gross margin of 200 € of year 3 increases by 10% for each of the remaining years up to year 10, i.e. 200 € · 1.1^{7} = 390 €
- The gross margin of 400 € of year 4 increases by 10% for each of the remaining years up to year 10, i.e. 400 € · 1.1^{6} = 709 €
- The gross margin of 600 € of year 5 increases by 10% for each of the remaining years up to year 10, i.e. 600 € · 1.1^{5} = 966 €
- The sales revenue of 5000 € that you receive in year 5 (because you decided to sell the irrigation system), also increases by 10% for each of the remaining years up to year 10, i.e. 5000 € · 1.1^{5} = 8,053 €.

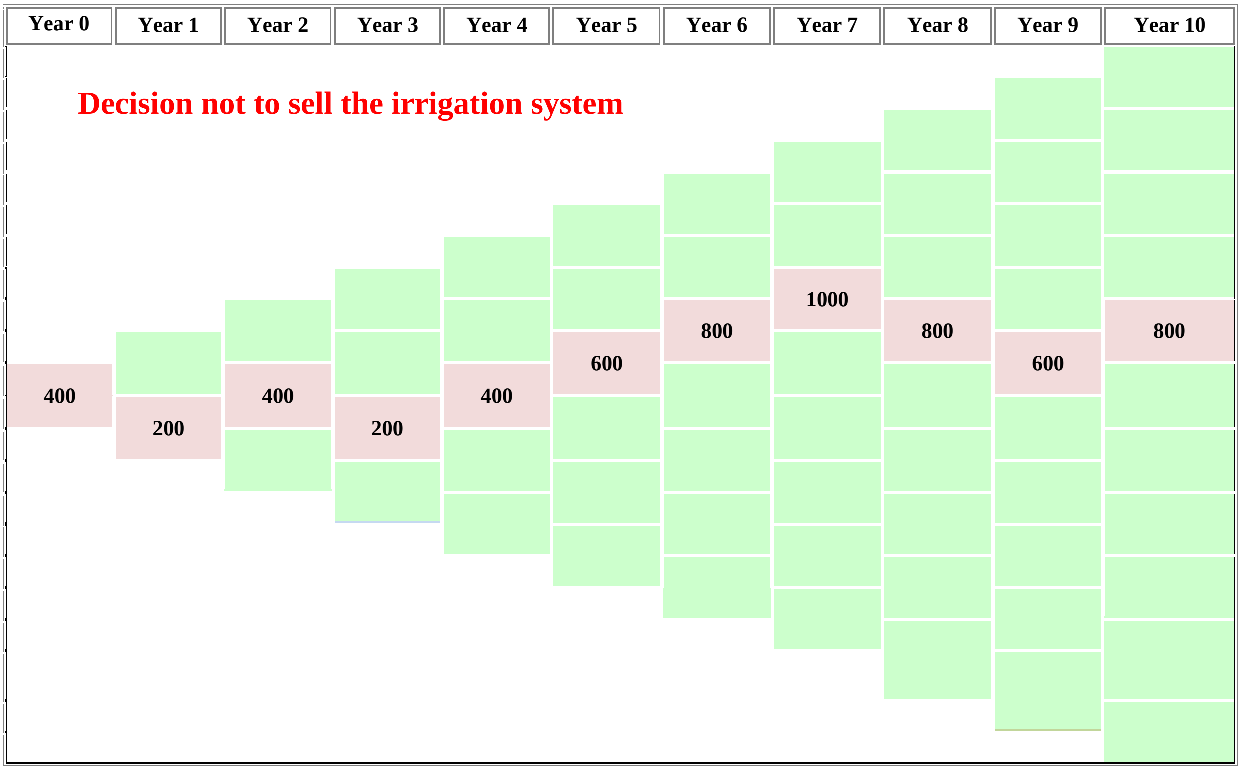
In this example, your total balance in year 10 will correspond to the following:

1037 € + 472 € + 857 € + 390 € + 709 € + 966 € + 8053 € = 12,484 €.

In this example, your account balance would be 499 €. If this game was randomly selected for the cash premium, you would receive 499 € (= 12,484 € : 2,500 €) · 100 €).

A No-Selling Decision

Imagine you decide not to sell the irrigation system within the 10 years (between year 0 and year 9), your chance to sell expires and you will leave the game with the gross margins that has increased by 10% for each of the remaining years up to year 10. The gross margin has developed randomly as shown below:



In this case, your total balance of year 10 would be calculated as follows:

- The gross margin of 400 € of year 0 increases by 10% for each of the remaining years up to year 10, i.e. 400 € · 1.1^{10} = 1,037 €

- The gross margin of 200 € of year 1 increases by 10% for each of the remaining years up to year 10, i.e. 200 € · 1.1^9 = 472 €
- The gross margin of 400 € of year 2 increases by 10% for each of the remaining years up to year 10, i.e. 400 € · 1.1^8 = 857 €
- The gross margin of 200 € of year 3 increases by 10% for each of the remaining years up to year 10, i.e. 200 € · 1.1^7 = 390 €
- The gross margin of 400 € of year 4 increases by 10% for each of the remaining years up to year 10, i.e. 400 € · 1.1^6 = 709 €
- The gross margin of 600 € of year 5 increases by 10% for each of the remaining years up to year 10, i.e. 600 € · 1.1^5 = 966 €
- The gross margin of 800 € of year 6 increases by 10% for each of the remaining years up to year 10, i.e. 800 € · 1.1^4 = 1,171 €
- The gross margin of 1,000 € of year 7 increases by 10% for each of the remaining years up to year 10, i.e. 1,000 € · 1.1^3 = 1,331 €
- The gross margin of 800 € of year 8 increases by 10% for each of the remaining years up to year 10, i.e. 800 € · 1.1^2 = 968 €
- The gross margin of 600 € of year 9 increases by 10% for each of the remaining years up to year 10, i.e. 600 € · 1.1^2 = 660 €
- In year 10, you receive a gross margin of 800 €. Given that we assume an infinite useful lifetime continuing using the irrigation system will earn 8,000 € (= 800 € · 10)

In this example, your total balance in year 10 will correspond to the following:

1037 € + 472 € + 857 € + 390 € + 709 € + 966 € + 1,171 € + 1,331 € + 968 € + 660 € + 800 € + 8000 € = 17,361 €

In this example, your account balance would be 17,361 €. If this game was randomly selected for the cash premium, you would receive 694 € (= 17,361 € : 2,500 € · 100 €)

Before the game starts, we would like to ask you to answer some control questions. This is to ensure that you understand all instructions.

If the gross margin of the irrigation system is 800 € in one year, which two gross margins can occur in the next year?

Please indicate the two gross margins here:

____ €

____ €

What is the probability (in %) that the gross margin in the tree chart increases by 200 € from one year to another?

Please indicate your answer here: ____ %

What is the probability (in %) that the gross margin in the tree chart decreases by 200 € from one year to another?

Please indicate your answer here: ____ %

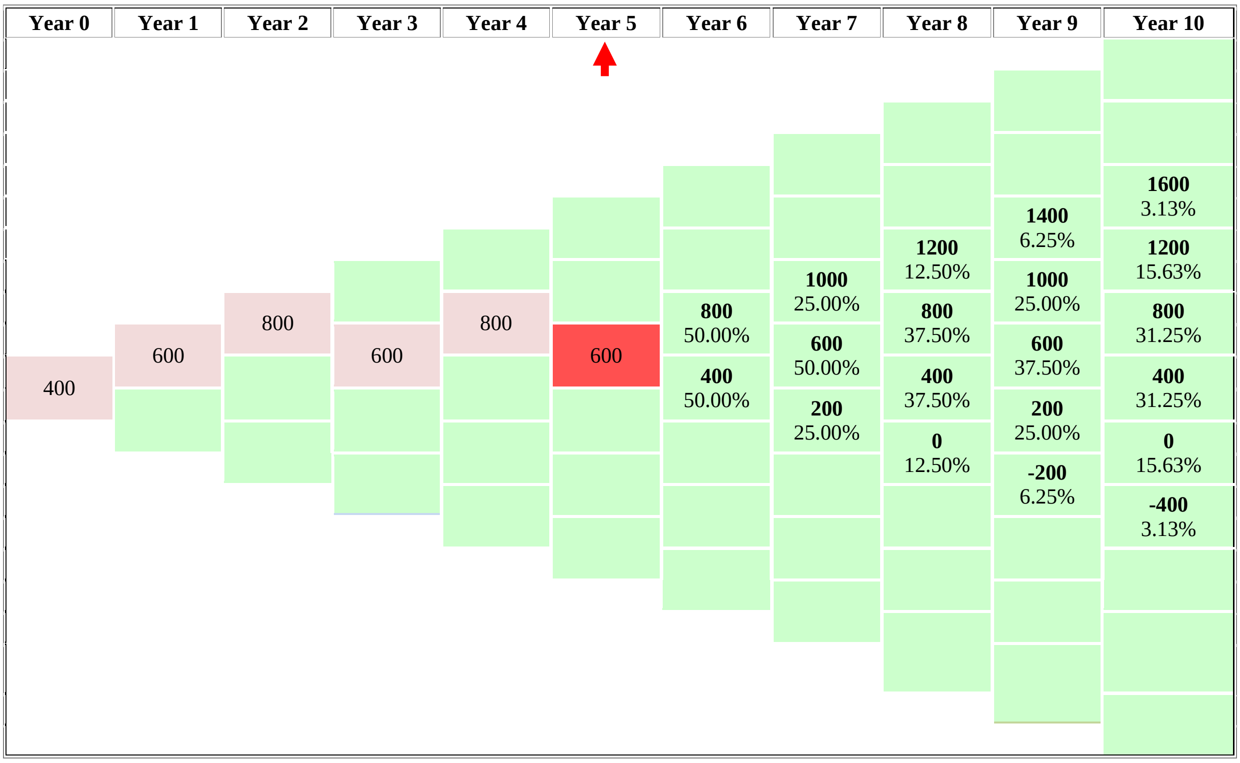
How much interest (in %) do your liquid assets in your account yield per year?

Please indicate your answer here: ____ %

What is the sales revenue of the irrigation system?

____ €

In the observed year 5, the gross margin in the tree chart is 600 €. The possible gross margins which can be realized in the next years are indicated in bold.



Which of the two gross margins can potentially be realized in the coming year (year 6)?

Please indicate the two gross margins here:

_____ €

_____ €

You answered all control questions correctly!

Please click “continue” to start the game.

- Here, the experiment starts –

[It is randomly determined in which order the individuals were faced with the investment and disinvestment situations. The farmers repeated both treatments (investment and disinvestment in irrigation technology) 10 times.]

Third Part *(Instruction: Holt and Laury lottery)* [cf., Holt and Laury, 2002]

Even for the third part of the game a player who receives a cash premium is selected randomly. Your cash premium only depends on your own decisions and on chance. […]

Fourth Part *(Ex post perception of the experiment and personal information)*

Finally, we would like to ask you some questions about personal details. All results of the survey will be presented anonymously and it will not be possible to draw any inferences about the actual persons or farms providing the information. […]