# Optimal Timing of Farmland Investment

# - An Experimental Study on Farmers' Decision Behavior -

***Selected Paper prepared for presentation at the Agricultural & Applied Economics Association's 2011 AAEA & NAREA Joint Annual Meeting, Pittsburgh, Pennsylvania, July 24-26, 2011***

**Syster Christin Maart and Oliver Mußhoff**

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

**Abstract**

Optimal timing of farmland investment represents fundamental decisions for agricultural entrepreneurs. It is known that the land price value is significantly higher than the expected present value of expected future gains. In this paper we experimentally analyze the investment behavior of real farmers and contrast the observed investment decisions with theoretical benchmarks of the classical investment theory and the real options approach. Furthermore, we investigate framing effects. Our results show that the framing of the investment situation has no significant influence on the decision behavior in the experiment. Moreover, the investment behavior of farmers approximates the predictions of the real options approach if they are given an equitable chance to learn from personal experience.

**Keywords**

Experimental Economics, Investment, Real Options.

**JEL-Code**

C91, D03, D81, D92

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Structural change in agriculture is frequently characterized by some kind of inertia. That means that farmers respond surprisingly slowly to changes in the economic environment. Examples of this behavior which have been reported in the literature include the adoption of technologies (Winter-Nelson and Amegbeto 1998), the participation in land retirement programs (Isik and Yang 2004) or the conversion from conventional to organic farming (Kuminoff and Wossink 2010). Yet, perhaps the most striking example is the persistence of seemingly inefficient farms. The fact that land prices are often significantly higher than the present value of returns from land use raises the question as to why farmers continue producing instead of selling their land (Turvey 2003).

Several explanations for this observable behavior have been offered. Among them are financial constraints (Hu and Schiantarelli 1998; Hüttel, Mußhoff, and Odening 2010) and non-monetary goals of the decision maker (e.g. tradition) (Ison and Russell 2000). Recently, the real options approach (ROA) has been propagated as a comprehensive explanation concept for economic hysteresis (Dixit and Pindyck 1994). This approach analyzes investment and disinvestment decisions in a dynamic-stochastic context (Abel and Eberly 1994; Dixit and Pindyck 1994; Purvis et al. 1995; Trigeorgis 1996). The approach evaluates entrepreneurial flexibility and generates results, which differ from those of the classical investment theory. The ROA asserts that an investor will increase profits by deferring an irreversible investment decision instead of investing immediately even if the expected net present value (NPV) of the investment is positive. In the end the generated investment cash flows do not only have to compensate the investment costs but also the opportunity costs or the "profit", which would have been generated if the investment was postponed. The value of entrepreneurial flexibility is particularly pronounced if the returns of the investment are uncertain and high sunk costs are generated through the investment implementation.

The experimental investigation of real options theory is still in its early stages. Rauchs and Willinger (1996) were among the first who tested the irreversibility effect of real options in an experimental setting. Yavas and Sirmans (2005) adopted this idea and found that participants invest earlier than predicted by the ROA. Nonetheless, their willingness to pay for an investment opportunity includes an option value. The study closest to ours is Oprea, Friedman and Anderson (2009) who investigated the learning effects of participants during the investment experiment and estimated that they closely approximate optimal exercise of wait options. Denison (2009) analyzed if the consideration of the ROA in a capital investment decision can reduce the Escalation-of-Commitment-Effect of participants. All aforementioned studies considered the value of investment and the experiments were carried out with students. In a recent study, Sandri et al. (2010) also experimentally analyzed the predictive power of the ROA, but their contribution was focused on the behavior of participants in a disinvestment situation and was carried out with students and managers.

The objective of our study is to experimentally analyze the investment behavior of farmers. On the one hand, we investigate whether the NPV or the ROA is able to predict the observed decision-making behavior of agricultural entrepreneurs. On the other hand, we investigate if the decision behavior of farmers depends on the framing and the order of the investment situation as well as on the farmers' personal experience during the experiment. To achieve our objective, we consider an optimal investment problem in a non-agricultural and in an agricultural treatment stylizing a decision to take an ongoing investment opportunity. An additional experiment based on a Holt and Laury lottery is carried out to elicit the risk attitude of participants (cf. Holt and Laury 2002).

This article provides a threefold contribution to the existing literature: First of all, we compare non-agricultural and agricultural investment situations, i.e., we are analyzing framing effects. Secondly, we do not assume risk neutrality of decision makers. Rather, individual risk propensity is explicitly taken into account when determining the normative benchmark for the investment decision. Finally, to our knowledge this type of experiment has been conducted for the first time with agricultural entrepreneurs, i.e., we do not work with a convenience group but with real decision makers. This allows us to make more reasonable conclusions regarding the direction and the velocity of structural change and the impact of policy instruments in agricultural businesses.

The next section introduces the theoretical investment model in greater detail and derives normative hypotheses from it. The subsequent section describes the design of the experiments followed by a presentation of the outcome of the experiments. The paper ends with a discussion on the validity of theoretical investment models and prospects for future research in the field of real options experiments.

## Theoretical Background and Derivation of Hypotheses

More recently, the real options approach (ROA) has been propagated as a comprehensive explanation concept for economic inertia (cf. Dixit and Pindyck 1994).[1] The starting point of the real options approach is the finding that the choice to invest now or later is similar to a financial option – in particular to an American call option. In case of a real option the investor has the right to buy an investment project with uncertain returns for the payment of the investment cost until the end of a specific time period by which an investment decision can be postponed.

To derive our hypotheses, we described in the following a simple investment situation and assume risk neutral decision maker. We choose a discrete time framework. The investment can be implemented only once – either immediately or it can be postponed up to one period. If the investment is implemented the investment cost needs to be paid immediately. The invest-

[1] The real options approach can be considered as a special case of stochastic adjustment cost models. For a detailed description of the relation between both model classes we refer to Abel et al. (1996). In this paper we prefer to use the real options approach because it is easier to adopt in an experimental setting.

ment cost $I$ is constant over time (e.g. 100). The present value of investment returns in period 0 is $V_0$ (e.g. 120). The future development of the present values of the investment returns paid out one period after implementation is uncertain. The present value $V$ of the investment returns follows a binominal arithmetic Brownian motion (cf. Dixit and Pindyck 1994), i.e., in period 1 the present value will either increase by a value $h$ (e.g. 20) with probability $p$ (e.g. 0.5) or decrease by $h$ with probability $1-p$. In period 2 the present value can take the following values: $V_0 + 2 \cdot h$ with probability $p^2$; $V_0 - 2 \cdot h$ with probability $(1-p)^2$; and $V_0$ with probability $2 \cdot p \cdot (1-p)$. The question arises under which conditions this hypothetical investment should be made.

To answer this question the value of the investment opportunity has to be calculated. For our example the value of the investment $\hat{F}$ according to the traditional investment theory is:

$$\hat{F} = \max[\hat{E}(NPV_0);0],$$

where (1)

$$\hat{E}(NPV_0) = \left(\left(p \cdot (V_0 + h) + (1-p) \cdot (V_0 - h)\right) \cdot q^{-1}\right) - I$$

Herein $q^{-1} = \frac{1}{(1+r)}$ is a discount factor and $r$ denotes the risk-free interest rate (e.g. 10%).

That means for our example:

$$\hat{E}(NPV_0) = \left(\left(0.5 \cdot (120+20) + (1-0.5) \cdot (120-20)\right) \cdot 1.1^{-1}\right) - 100 = 9$$

Now the question arises from which present value it would be optimal to accept the investment. To answer this question we calculate the critical present value of the investment returns, the so called investment trigger. By equating the expected present value of the investment returns defined in equation (1) and the investment cost $I$ we receive the investment trigger $\hat{V}_0$:

$$\hat{V}_0 = h - 2 \cdot p \cdot h + I \cdot q \tag{2}$$

That means for our example:

$$\hat{V}_0 = 20 - 2 \cdot 0.5 \cdot 20 + 100 \cdot 1.1 = 110$$

Deferring the decision has the potential advantage that it allows the decision maker to take into account further information. That means that the investment can be implemented one period later. The intuitive reason is that waiting has a positive value since new information about the expected present value of the investment returns arrives in the subsequent period. According to the new investment theory the value of the investment $\widetilde{F}$ is:

$$\widetilde{F} = \max[\hat{E}(NPV_0); \widetilde{E}(NPV_1) \cdot q^{-1}],$$

where (3)

$$\widetilde{E}(NPV_1) = [p \cdot [(p \cdot (V_0 + 2 \cdot h) + (1-p) \cdot (V_0 + h - h)) \cdot q^{-1} - I] + (1-p) \cdot 0] \cdot q^{-1}$$

That means for our example:

$$\widetilde{E}(NPV_1) = [0.5 \cdot [(0.5 \cdot (120 + 2 \cdot 20) + (1 - 0.5) \cdot (120 + 20 - 20)) \cdot 1.1^{-1} - 100] \\ + (1 - 0.5) \cdot 0] \cdot 1.1^{-1} = 12$$

By equating (1) and (3) we receive the investment trigger $\widetilde{V}_0$:

$$\widetilde{V}_0 = \frac{q \cdot h - 2 \cdot p \cdot q \cdot h + I \cdot q^2 + 2 \cdot p^2 \cdot h - p \cdot I \cdot q}{q - p} \tag{4}$$

That means for our example:

$$\widetilde{V}_0 = \frac{1.1 \cdot 20 - 2 \cdot 0.5 \cdot 1.1 \cdot 20 + 100 \cdot 1.1^2 + 2 \cdot 0.5^2 \cdot 20 - 0.5 \cdot 100 \cdot 1.1}{1.1 - 0.5} = 127$$

The difference between the investment trigger following the NPV differs from the investment trigger following the ROA. The difference can be expressed as follows:

$$\tilde{V}_0 - \hat{V}_0 = \frac{p \cdot h}{q - p} = \frac{0.5 \cdot 20}{1.1 - 0.5} = 17 \tag{5}$$

Apparently $\hat{V}_0$ is smaller than $\tilde{V}_0$ as long as $p > 0$.[2] Against this background we formulate the following alternate hypotheses:

*H1 "NPV consistency": The investment behavior of farmers is consistent with the NPV.*

*H2 "ROA consistency": The investment behavior of farmers is consistent with the ROA.*

The aforementioned equations are applicable to all kind of investment situations. That means that the decision making is independent from the framing of the investment possibility. But in the literature we can find some references saying that framing effects are relevant for the behavior in investment situations. Decision makers e.g. are more "attached" to a project that is described in terms that are more familiar to them (Bettman and Sujan 1987; Cronk and Wasielewski 2008; Patel and Fiet 2010). One of the most prominent attempts for the framing effect, the "prospect theory", was offered by Tversky and Kahneman (1981; 1986). They found out that the decision behavior is influenced by the formulation of the choice problem and that it caused shifts of preference. This finding is reflected in the following hypothesis:

*H3 "framing effect": Farmers will show different behavioral patterns if they are confronted with a non-agricultural or an agricultural investment situation.*

A fundamental principle to reach the greatest reliability and validity of statistical estimates is the randomization of the treatments (Harrison, Lau, and Rutström 2009). That means in our experiment, that participants are confronted with two different treatments in a different order. The question arises, if the order has an impact on the decision behavior of the participants. Thus, we construct the hypothesis that:

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[2] If risk aversion is considered there are two contrary effects observable. The risk adjusted discount rate increases and the difference between the investment trigger decreases (cf. equation (5)).

*H4 "order effect": The decision behavior of farmers depends on the order in which the two investment treatments are addressed.*

In addition, many decision situations are characterized in that they are repeated. In such cases the decision behavior is influenced by previous experiences. A decision maker learns what alternatives are to be avoided and what kind of good alternatives exist in certain situations. Finally, they acquire routines for repetitive decision situations and are more effective to accomplish their objectives (cf. Tversky and Kahneman 1986; Cheung and Friedman 1998). This finding leads to our final hypothesis:

*H5 "learning effect": Farmers will closely approximate optimal exercise of the investment opportunity if they are given an equitable chance to learn from personal experience.*

## Experimental Setting

Our experimental design consisted of three parts. The first part described two investment scenarios, stylizing a non-agricultural and an agricultural option to invest in farmland. In the second part, a session of Holt and Laury lotteries (HLL) was conducted (cf. Holt and Laury 2002) to elicit the participants' risk attitudes. The third part of the experiment was related to demographic and economic factors of participants as well as business characteristics (e.g. area farmed).

The design of the HLL carried out in the second part of the experiment, is presented in table 1. In this Lottery the participants could choose between two alternatives: The first alternative gave them the opportunity to either win 200 € or 160 € with a certain probability. The second alternative offered the opportunity to win 385 € or 10 € with the same probability like in alternative 1. The probabilities varied systematically and therefore created 10 possible starting situations: In the first situation there was a 10% probability of winning 200 € or 385 €, whereas in the second situation the probability rised to 20%. Until reaching a probability of 40% for alternative 1 and of 60% for alternative 2 the expected value of the less risky alternative 1 was higher. With a probability ratio of 50:50 the second alternative had the higher expected value.

**Table 1. Structure of the Holt and Laury Lottery** [a)]

| | Alternative 1 ( $A_1$ ) | Alternative 2 ( $A_2$ ) | Expected value $A_1$ | Expected value $A_2$ | Critical constant relative risk aversion coefficient [b)] |
|---|---|---|---|---|---|
| **1** | with 10% gain of **200 €**<br>with 90% gain of **160 €** | with 10% gain of **385 €**<br>with 90% gain of **10 €** | 164 € | 48 € | -1.71 |
| **2** | with 20% gain of **200 €**<br>with 80% gain of **160 €** | with 20% gain of **385 €**<br>with 80% gain of **10 €** | 168 € | 85 € | -0.95 |
| **…** | … | … | … | … | … |
| **9** | with 90% gain of **200 €**<br>with 10% gain of **160 €** | with 90% gain of **385 €**<br>with 10% gain of **10 €** | 196 € | 348 € | 1.37 |
| **10** | with 100% gain of **200 €**<br>with 0% gain of **160 €** | with 100% gain of **385 €**<br>with 0% gain of **10 €** | 200 € | 385 € | – |

a) The last three columns were not displayed in the experiment.

b) A power risk utility function is assumed.

The participants were asked to decide for one of the two alternatives in each situation. The observation of the participants, especially regarding the question of if they opted for a riskier alternative, allowed us to determine their individual risk attitude. A risk neutral decision maker would always decide in favor of the alternative with the higher expected value. In the first four situations the decision maker would have to prefer alternative 1. Later, he/she would have to prefer alternative 2. Consequently, a HLL-value (= number of safe choices) of 4 stood for risk neutrality. A HLL-value between 0 and 3 meant that the participant was prepared to take risk, whereas a HLL-value between 5 and 9 described risk-averse decision makers. The last situation was a test whether the participants understood the problem, because here obviously alternative 2 was to prefer.

The design of the real options experiment employed the model outlined in the previous section. Within each round, respondents could decide to take an ongoing investment opportunity in one of ten periods. Every participant started the experiment in each round with a deposit of 10,000 points. The investment cost was 10,000 points. According to a discrete arithmetic Brownian motion, the present value of the investment returns evolved stochastically over ten periods with no drift, i.e., $p = 0.5$. The standard deviation amounts to 2,000 points. The present values in period 0 were always 10,000 points. The risk-free interest rate was fixed at 10%. The participants were informed about all parameters and assumptions underlying the experimental setting. The binomial tree in figure 1 of potential investment returns with their associated probabilities of occurrence was displayed on a screen and accordingly adjusted. Potential present value of investment developments, which were not relevant anymore were suppressed and the probabilities for future cash flows were updated. These steps were repeated until period 10 unless the participant invested earlier.

| Period 0 | Period 1 | Period 2 | Period 3 | Period 4 | Period 5 | Period 6 | Period 7 | Period 8 | Period 9 | Period 10 |
|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | | | | | **30,000** (0.1%) |
| | | | | | | | | | **28,000** (0.2%) | |
| | | | | | | | | **26,000** (0.39%) | | **26,000** (0.98%) |
| | | | | | | | **24,000** (0.78%) | | **24,000** (1.76%) | |
| | | | | | | **22,000** (1.56%) | | **22,000** (3.13%) | | **22,000** (4.39%) |
| | | | | | **20,000** (3.13%) | | **20,000** (5.47%) | | **20,000** (7.03%) | |
| | | | | **18,000** (6.25%) | | **18,000** (9.38%) | | **18,000** (10.94%) | | **18,000** (11.72%) |
| | | | **16,000** (12.5%) | | **16,000** (15.63%) | | **16,000** (16.41%) | | **16,000** (16.41%) | |
| | | **14,000** (25%) | | **14,000** (25%) | | **14,000** (23.44%) | | **14,000** (21.88%) | | **14,000** (20.51%) |
| | **12,000** (50%) | | **12,000** (37.5%) | | **12,000** (31.25%) | | **12,000** (27.34%) | | **12,000** (24.61%) | |
| **10,000** | | **10,000** (50%) | | **10,000** (37.5%) | | **10,000** (31.25%) | | **10,000** (27.34%) | | **10,000** (24.61%) |
| | **8,000** (50%) | | **8,000** (37.5%) | | **8,000** (31.25%) | | **8,000** (27.34%) | | **8,000** (24.61%) | |
| | | **6,000** (25%) | | **6,000** (25%) | | **6,000** (23.44%) | | **6,000** (21.88%) | | **6,000** (20.51%) |
| | | | **4,000** (12.5%) | | **4,000** (15.63%) | | **4,000** (16.41%) | | **4,000** (16.41%) | |
| | | | | **2,000** (6.25%) | | **2,000** (9.38%) | | **2,000** (10.94%) | | **2,000** (11.72%) |
| | | | | | **0** (3.13%) | | **0** (5.47%) | | **0** (7.03%) | |
| | | | | | | **-2,000** (1.56%) | | **-2,000** (3.13%) | | **-2,000** (4.39%) |
| | | | | | | | **-4,000** (0.78%) | | **-4,000** (1.76%) | |
| | | | | | | | | **-6,000** (0.39%) | | **-6,000** (0.98%) |
| | | | | | | | | | **-8,000** (0.2%) | |
| | | | | | | | | | | **-10,000** (0.1%) |

a) The associated probabilities of occurrence are indicated in brackets.

**Figure 1. Binomial tree of potential investment returns [a)]**

The participants had three possibilities: Firstly, they could invest immediately, i.e., in period 0 and receive the present value of period 1. Secondly, they could postpone the investment decision until period 9, i.e., they invest later. Thirdly, participants could invest in none of the 10 periods and save the investment cost of 10,000 points. If the participant decided to invest e.g. in period 0, he or she would pay the investment cost of 10,000 points. The present value that the participant received from the investment, in period 1 could have been increased to 12,000 or decreased to 8,000 points, each with a probability of 50%. If investment was made in period 0, the further development of the present value after period 1 would have been irrelevant. In case a participant did not invest in period 0, he/she would have been faced again with the investment decision in period 1. It would have been randomly determined if the present value in the following period 2 increased or decreased starting from the value of the former period. This procedure could be repeated until expiration of the investment option in period 9. The deposit and the present value of investment returns less the investment costs increased by 10% for each round left in the game, i.e., the total score would increase by an interest payment of one tenth.

The real options experiment consisted of two scenarios differing in the framing of the investment situation. One scenario described an investment situation in a non-agricultural framing while the other had an agricultural context. In the non-agricultural investment situation it was possible to buy the right to earn money during a coin tossing game. In that last mentioned situation the farmers had the hypothetical possibility to invest in farmland. For agricultural production farmland is one of the essential production factors (Turvey 2003). Besides the different wording of the investment situations the parameters in the experiment (e.g. investment cost and discount rate) were exactly the same. It was randomly determined in which order the individuals were confronted with both investment situations.

Each participant was confronted with ten (individually) randomly determined paths of the binominal tree for each scenario. The entire binomial tree was newly determined by a random mechanism. Hence, over the course of the entire experiment each respondent was confronted with 20 potentially different, randomly determined paths of the binomial tree. For further investigation we used within-subjects comparison.

The computer-based experiment was conducted in 2010 at the leading agricultural exhibition in Germany on a separate stand. To encourage attendance every participant received a participation allowance of 10 € for completing the experiment. In total 106 agricultural entrepreneurs were randomly recruited during the exhibition. That means that in total 2,120 investment decisions (2·10 repetitions for each of the 106 participants) and 106 HLL-values were observed. To ensure incentive compatibility of the experiment the hypothetical investment decisions were related to an actual payment. After all experiments had been carried out two players were randomly selected from all participants as winners. The reward of the first winner was based on his/her individual score attained in the real options experiment, i.e., the number of points that had been accumulated in a randomly chosen round of the game. For each 2,500 points the winner received 100 €. The earnings varied between 200 and 1,800 €. For HLL a second participant was randomly selected. He/She would also receive a payoff that was dependent on his/her expressed preference for or aversion against various risky, mutually exclusive alternatives. The earnings varied between 10 and 385 €. With a chance of approximately 1% in the real options experiment and in the HLL two of the 106 farmers were selected as winners. The whole experiment took about 60 minutes per individual. Choices made by participants were not time constrained. Before the incentive compatible part of the real options experiment started, the participants had to answer some questions regarding the investment situation according to the aforementioned instruction. Furthermore, a trial round gave the participants the opportunity to become acquainted with the experiment.

**Normative Benchmarks**

For the evaluation of the investment behavior observed in the experiments and for an evaluation of our hypotheses we have to derive normative benchmarks which reflect the NPV and the ROA, respectively. For this purpose equations (2) and (4) can be used; in view of the experimental design, however, an extension is necessary. Especially, the equations need to be adapted to the number of potential investment times of ten instead of one. Moreover, the risk-adjusted discount rate $r^*$ has to be determined using the results of the HLL. In the following these two steps are briefly described.

*Determination of the risk-adjusted discount rate*

The determination of the risk-adjusted discount rate is based on the results of HLL. In accordance with Holt and Laury (2002) we assume a power risk utility function, which implies decreasing absolute risk aversion (DARA) and constant relative risk aversion (CRRA):

$$U(V) = V^{1-\theta} \tag{6}$$

Here $U$ denotes utility and $\theta$ is the risk aversion coefficient. Based on equation (6) $\theta$ can be inferred for each individual from his/her choices in the HLL. With this information the certainty equivalent $CE$ of a risky prospect can be determined:

$$CE = V\left[E\left(U\left(V\right)\right)\right] = E\left[U\left(V\right)\right]^{\frac{-1}{\theta-1}} = E\left(V\right) - RP \tag{7}$$

where $E(\cdot)$ denotes the expectation operator and $RP$ is a risk premium. From the definition of the present value of the certainty equivalent $CE_0$ of an uncertain payment $V_N$ at time $N$:

$$CE_0 = CE_N \cdot \left(1+r\right)^{-N} = \left[E\left(V_N\right) - RP_N\right] \cdot (1+r)^{-N} \tag{8}$$

One can derive an equivalent risk-adjusted discount rate $r^* = r + v$ using the equation:

$$\begin{aligned} &\left[E\left(V_N\right) - RP_N\right] \cdot \left(1+r\right)^{-N} = E\left(V_N\right) \cdot (1+r+v)^{-N} \\ &\Rightarrow v = \left(1+r\right) \cdot \left[\left(\frac{E\left(V_N\right)}{E\left(V_N\right) - RP_N}\right)^{1/N} - 1\right] \end{aligned} \tag{9}$$

Here, $r$ is a riskless interest rate. Obviously, the risk loading $v$ and thus the risk adjusted discount factor $r+v$ depend on the risk premium $RP$ (see equation (7)) as well as on the length of the discounting period.

*Calculation of the exercise frontiers*

While the normative benchmark for the NPV can be easily calculated by means of equation (2), the exercise frontier of the ROA has to be determined by dynamic stochastic programming (cf. Trigeorgis 1996: 312). When applying dynamic programming to the binomial tree depicted in figure 1 using the risk-adjusted discount rates following equation (9), one faces the problem that the certainty equivalent of the up and down movements are not constant over time. This would lead to a non-recombining binomial tree for the present value of the project in which the number of potential states grows exponentially with the number of time periods (cf. Longstaff and Schwartz 2001). We impose a simplification making the calculation of the exercise frontier tractable. Firstly, we fix the level of the present value of investment returns at its initial value when determining the risk-adjusted discount rate via equation (9). Secondly, we fix $N$ at one period in equation (9). Finally, ten different discount rates representing different risk attitudes are obtained. The risk-adjusted discount rate varies between 6.8% (HLL-value = 0) and 13.1% (HLL-value = 9).

The resulting normative benchmarks, i.e., the "optimal" solutions for the investment trigger according to the NPV and the ROA for a risk neutral decision maker are presented in figure 2 and depict the exercise frontiers.

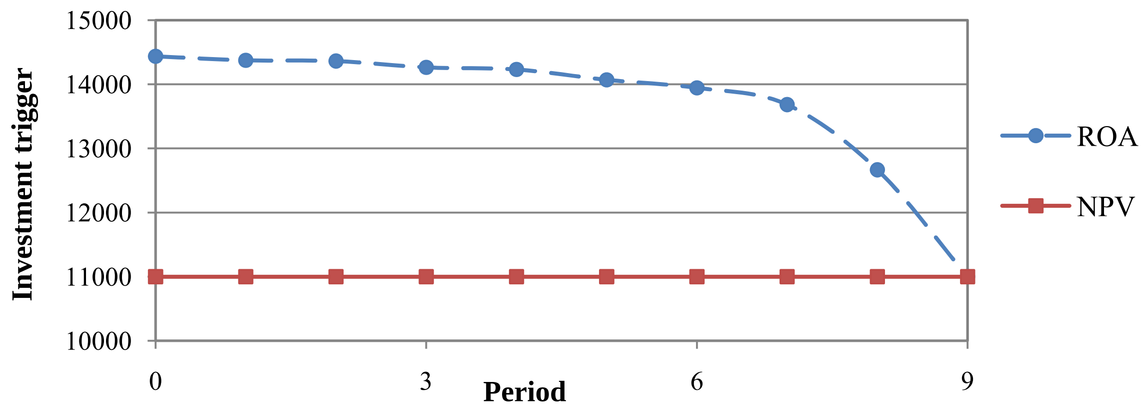


**Figure 2. Investment trigger for a risk neutral decision maker**

The exercise frontiers of the ROA decrease exponentially reflecting the diminishing time value of the investment option. The trigger value starts at 14,436 points in period 0. The curves coincide with the NPV criterion (11,000 points) at period 9, as is required by theory. The curve shape of the ROA and the NPV criterion would change slightly according to different risk attitudes of the participants.

## Experimental Results

The following table 2 provides an overview about some selected facts of the normatively expected and the observable decision behavior during the experiment. Furthermore, information about characteristic variables of the participants is provided.

**Table 2. Descriptive Statistic**

| Parameter | Agricultural treatment (1,060 decisions) | Non-agricultural treatment (1,060 decisions) |
|---|---|---|
| Average age of participant | 30.1 years | |
| Average farm size | 300 ha | |
| Farmers studied | 37.7% | |
| Female participants | 19.8% | |
| Average risk attitude of participant (HLL-value) | 4.9 | |
| Experimentally observed period of investment | 3.0 | 3.2 |
| Experimentally observed percentage of non-investment | 12.1% | 9.5% |
| Normative investment period following NPV | 2.3 | 2.4 |
| Normative percentage of non-investment following NPV | 27.8% | 27.8% |
| Normative investment period following ROA | 6.1 | 6.0 |
| Normative percentage of non-investment following ROA | 48.3% | 46.7% |

The 106 participating farmers were relatively young with an average age of 30 years, a minimum of 19 years and a maximum of 60 years. One explanation for the relatively young survey group might be that the experiment was computer-based. The average farm size of the farmers in the survey group was 300 ha. The farm sizes ranged between 2 ha and 3,200 ha. Survey results showed that the dominant farm type is crop production with 32.0%, followed by pig and poultry farms with 24.3% and mixed farms with 24.3%. A smaller percentage of 12.6% ran a livestock farm and 6.8% other kinds of farms. 37.7% of the participants studied at a university and 19.8% were female. Given the non-random sampling procedure and according to the characteristics of the farmers, the sample was unrepresentative for German agricultural entrepreneurs. Hence, results are only indicative and should not be generalized to the whole farm operating group. Considering the responses of entrepreneurs, the Holt and

Laury lotteries revealed the predominance of risk-averse attitudes. Out of the 106 individuals, 59 revealed risk aversion, 17 were risk neutral and 30 were risk seeking. On average, the participants were slightly risk-averse (HLL-value = 4.9).

The aforementioned investment rules were applied to 2,120 random realization of the discrete arithmetic Brownian motion generated during the experiment. The NPV criterion predicted optimal (risk-adjusted) investment time of period 2.3 (period 2.4) on average and no investment in 27.8% of the cases in the agricultural treatment and the non-agricultural treatment. The corresponding predictions from the ROA amounted to period 6.1 (period 6.0) in both treatments and no investment was predicted in approximately 48% of the cases. The actual investment time chosen by the participants was period 3.0 (agricultural treatment) and period 3.2 (non-agricultural treatment). In around 12.1% of the observations of the agricultural treatment the participants did not invest prior to expiration, while in the non-agricultural treatment only around 9.5% did not invest.

In some cases of the 2,120 investment situations a defined period of investment was not observed. Therefore, a fundamental part of the following data analysis is based on Kaplan-Meier survival estimator, also known as the product limit estimator (Kaplan and Meier 1958). This is an established non-parametric method for analyzing data with sampling bias which is mainly used in survival studies of medical research to estimate the survival function from life-time data. In what follows we investigated the aforementioned hypothesis. We started with comparing the actual decision behavior with the benchmark according to the NPV and the ROA.

*Test of H1 "NPV consistency" and H2 "ROA consistency"*

To test H1 and H2 we compare the observed investment behavior with the optimal investment behavior according to the NPV criterion and the ROA. Table 3 shows the hit ratio of the comparison, i.e., in how many cases farmers invested earlier, optimal and later as predicted by theory.

**Table 3. Hit Ratio of the Observed and the Optimal Investment Behavior**

| Parameter | Agricultural treatment (1,060 decisions) | Non-agricultural treatment (1,060 decisions) |
|---|---|---|
| Earlier investment than predicted by the NPV | 49.3% | 47.2% |
| Optimal investment as predicted by the NPV | 13.3% | 16.0% |
| Later investment than predicted by the NPV | 37.4% | 36.8% |
| Earlier investment than predicted by the ROA | 74.8% | 76.7% |
| Optimal investment as predicted by the ROA | 5.8% | 13.5% |
| Later investment than predicted by the ROA | 19.4% | 9.8% |

In 13.3% of the cases in the agricultural treatment farmers decided in accordance with the classical investment theory and invested in the optimal period of this approach. But only in 5.8% of the cases they invested in accordance with the ROA. The ratio between investments which were implemented too early and too late according to the NPV criterion was more or less balanced. An imbalance of the ratio was observable by comparing the actual investment behavior and the optimal investment behavior according to the ROA. Farmers decided to invest too early in 75% of all cases. Figure 3 shows the survival functions of the observed and the optimal investment decisions according to the NPV and the ROA. The staircase-shaped curves illustrate the cumulative option exercise over the periods, i.e., the curve shapes indicate how many investments in which period were implemented. A log-rank test of the equality of both survival functions estimated that the observed behavior is significantly different according to both normative benchmarks (p-value < 0.001, log-rank test).

**a) Net present value** **b) Real options approach**

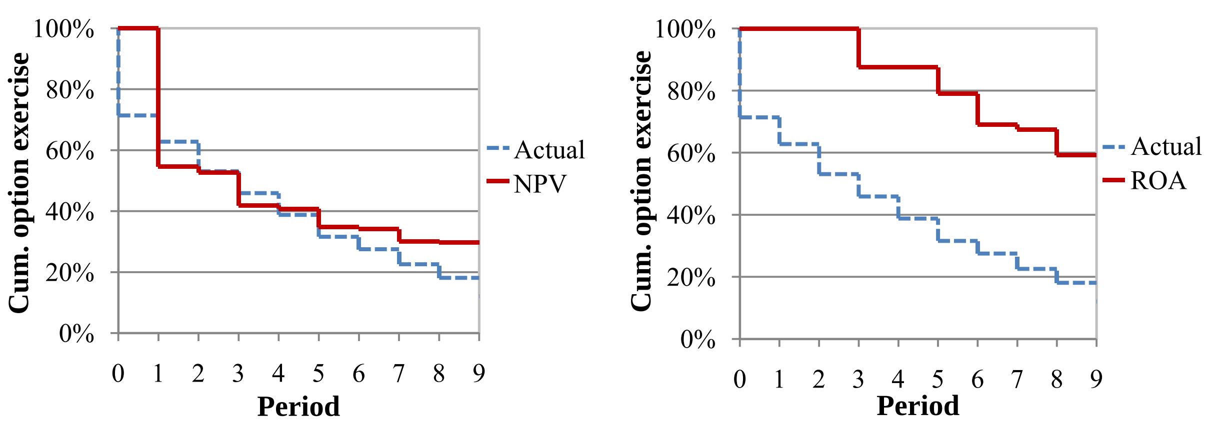


**Figure 3. Survival functions of observed and optimal investment behavior according to the NPV and the ROA in the agricultural treatment**

An objection for that result might be that in the agricultural treatment the participants were confronted with the opportunity to invest in farmland. As aforementioned, in reality farmers tended to pay a comparatively high price for land because it is an important and scarce production factor (Turvey 2003). Therefore, it is possible that the decision behavior of farmers was influenced by this experience regarding farmland investment in real life. To investigate this assumption we compared the results of the non-agricultural treatment with the results of the agricultural treatment. The observed and the optimal investment behavior according to the NPV and the ROA indicated similar results as in the agricultural treatment. Nevertheless, in 13.5% of the observations the participants invested in the optimal period according to the ROA. That means that the hit rate droped to more than one-half in comparison to the agricultural treatment (cf. table 3). The survival functions of the observed and the optimal investment decisions according to the NPV and the ROA showed similar curve shapes. The log-rank test of the equality of both survival functions estimated that the observed behavior was significantly different according to both normative benchmarks (p-value < 0.001, log-rank test). The NPV and the ROA not fared better as in the agricultural treatment. On this basis, we rejected H1 and H2 for both treatments and concluded that the NPV and the ROA criterion were not appropriate in general for predicting the actual (experimentally observed) investment behavior.

*Test of H3 "framing effect"*

For further investigation of the "framing effect" we calculated the survival function of the observed decisions of the farmers in the agricultural and in the non-agricultural treatment. The comparison of this two curves revealed that the difference is not statistically significant (p-value > 0.05, log-rank test). The farmers showed similar decision behavior in the two treatments. That means that the "framing effect" was unverifiable, but we have to consider that the investment in farmland and the investment to participate in a coin tossing game were only hypothetical. Framing might be helpful in making a laboratory experiment more realistic and thereby increases its external validity, nonetheless the decisions in experiments still remain hypothetical.

*Test of H4 "order effect"*

The farmers in the survey group were confronted with both treatments but in a different order. For example, in one survey group the farmers first had the opportunity to invest in farmland and after ten repetitions of this agricultural treatment they again had ten times the opportunity to decide to take part in a coin tossing game (non-agricultural treatment). In the other survey group the farmers were confronted with both treatments in reverse order. To test the H4 "order effect" in a first step we consider the order in which the treatments were allocated to the participants as two groups. One group represented the results of the first allocated treatment and the other of the second allocated treatment. In a second step we compared both groups within the agricultural and the non-agricultural treatment.

Figure 4 shows the survival functions of the Kaplan and Meier estimation. The bottom curve in figure 4a) represents the decision behavior of farmers which were confronted with the agricultural treatment in the first place (N = 520) and the other curve represents the decision behavior of farmers which were confronted with the treatment at last (N = 540). Figure 4b) shows the same but for the non-agricultural treatment (firstly: N = 540 and lastly: N = 520).

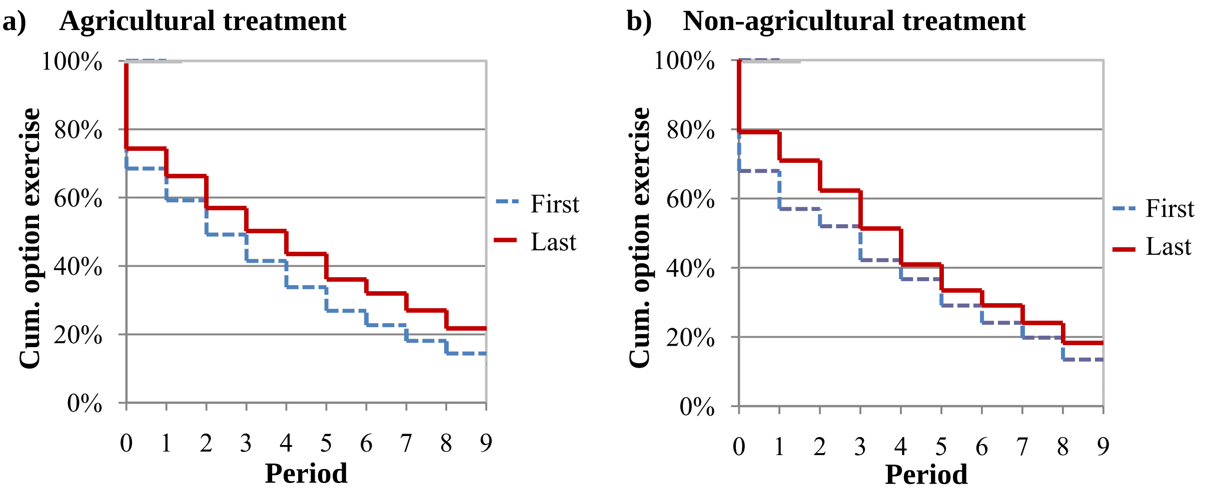


**Figure 4. Survival functions of observed investment behavior in both treatments in different order**

The difference of the survival curves in the agricultural treatment in figure 4a) was statistically significant at a significant level of 1% (log-rank test). The difference in the non-agricultural treatment in figure 4b) was statistically significant at a significant level of 0.1% (log-rank test). The order of both treatments had an influence on the decision behavior of the participants. On this basis, hypothesis 4 was not rejected. The results showed a tendency that participants invested later in the last treatment than in the first.

*Test of H5 "learning effect"*

The occurrence of "order effects" might be an initial evidence for "learning effects". Farmers which were confronted at first with the agricultural treatment (non-agricultural treatment) showed different decision behavior as if they were confronted at last with the agricultural treatment (non-agricultural treatment). An explanation might be that they used their experience from the previous investment situation in the decision process for the second investment situation.

Against this background figure 5 illustrates the average investment period for each of the 20 repetitions of both treatments.

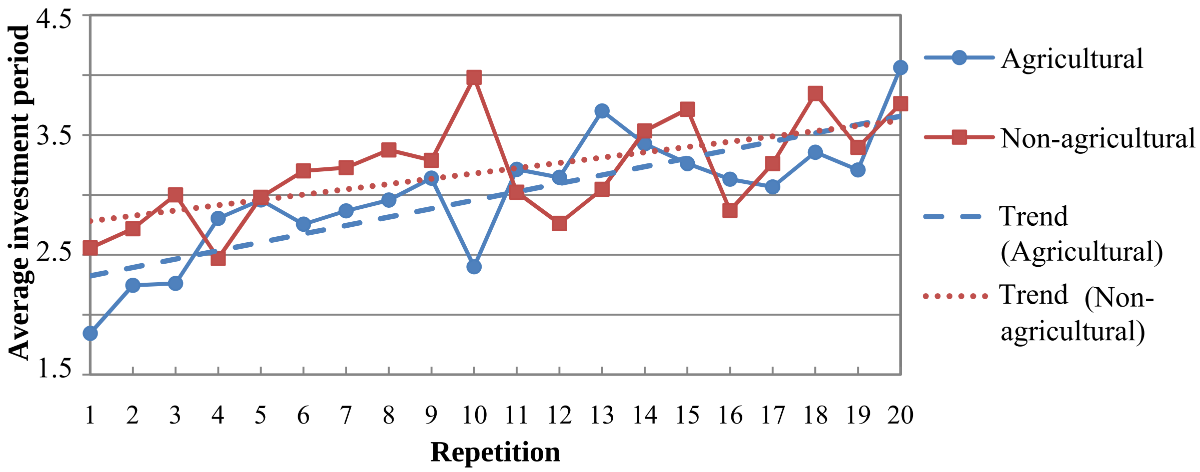


**Figure 5. Average investment period depending on repetition**

The trend of the two curves clearly increased, i.e., farmers invested later over the repetition. After 20 repetitions the agricultural entrepreneurs invested in the agricultural treatment on average in period 4.1, i.e., they invested 2.3 periods later than in the first investment situation.

The difference of the investment periods between the first (period 2.6) to the last (period 3.8) repetition in the non-agricultural treatment amounts to 1.2 periods. Furthermore, the following table 4 indicates the average observed investment periods of the first and the last repetition as well as the normative investment periods following the NPV and the ROA.

**Table 4. Average Investment Period over the Repetitions**

| Parameter | Agricultural treatment | | Non-agricultural treatment | |
|---|---|---|---|---|
| | Repetition 1 (mean) | Repetition 20 (mean) | Repetition 1 (mean) | Repetition 20 (mean) |
| Experimentally observed period | 1.8 | 4.1 | 2.6 | 3.8 |
| Normative investment period following NPV | 1.9 | 2.6 | 2.4 | 2.0 |
| Normative investment period following ROA | 5.8 | 6.3 | 5.4 | 6.0 |

The deviations between the experimentally observed and the normative investment period following NPV and ROA changed over the repetitions. On the one hand, the deviation between the observed and the investment period following NPV increased from a deviation of 0.1 periods (0.2 periods) in the first repetition to a deviation of 1.5 periods (1.8 periods) in the last repetition in the agricultural treatment (non-agricultural treatment). On the other hand, the deviation between the observed and the investment period following ROA decreased from a deviation of 4.0 periods (2.8 periods) in the first repetition to a deviation of 2.2 periods (2.2 periods) in the last repetition in the agricultural treatment (non-agricultural treatment). Considering, the fact that farmers invested too early according to the ROA (cf. table 3) the increasing trend of the average investment period enhanced the assumption that the decision behavior of the participants diverged from the predictions of the NPV and approximated the predictions of the ROA. In other words, the difference between the observed investment period and the optimal investment period according to the NPV increased and the difference according to the ROA decreased. For further testing of H5 "learning effect" we ran a linear regression model for both treatments in which we regressed the observed investment periods on the repetition. The results of the model for the agricultural treatment (N = 1,060,

$R^2 = 0.019$, F-value = 17.580) and the non-agricultural treatment (N = 1,060, $R^2 = 0.007$, F-value = 7.050) revealed that the estimated coefficient of the repetition variable was significant and had a positive sign (p-value < 0.001 and p-value < 0.01, two-sided t-test), i.e., the increasing trend in the curve was significant. This result supported that farmers indeed invested later during the repetitions. Nevertheless, the aforementioned analysis did not consider the cases of not investing at all.

Therefore, we used in a next step the method of Kaplan and Meier. We divided the 20 repetitions into four parts as follows: 1) repetition 1 to 5, 2) repetition 6 to 10, 3) repetition 11 to 15 and 4) repetition 16 to 20. A comparison of the survival functions revealed that the difference between the curve shapes was statistically significant in each of the four cases (p-value < 0.001, log-rank test), i.e., the results of the linear regression were confirmed. For the final test of the "learning effect" we used the technique of the Cox-Regression (Cox 1972). A Cox-regression also considers the cases of non-investment. It is an extension of the Kaplan-Meier estimator, which is primarily used in medical research and investigates the relationship between the 'survival of a patient' and other variables. In our experiment 'survival of a patient' was translated into 'survival of an investment option', i.e., cases in which a participant did not invest and by analogy 'hazard rate' was translated into 'rate of investment'. Table 5 contains the result of a Cox-regression for each treatment. It analyzed the influence of parameter repetition on the 'rate of investment'.

**Table 5. Cox-Regression of the 'Rate of Investment' (N = 1,060)**

| Treatment | Parameter | Coefficient | Robust standard error | p-value | chi² |
|---|---|---|---|---|---|
| Agricultural | Repetition | -0.018 | 0.006 | 0.002 | 9.654 |
| Non-agricultural | Repetition | -0.022 | 0.006 | 0.000 | 14.720 |

The coefficient of the parameter repetition was negative and had a significant influence on the 'rate of investment' in both treatments. That means that with the repetition the 'rate of investment' decreased, i.e., there were more cases observable in which farmers did not invest. This result reinforces our fifth hypothesis that farmers learned from their previous decisions and closely approximated optimal exercise of wait options according to the ROA. On this basis, hypothesis 5 was not rejected.

Table 6 summarizes the empirical results with regard to the validity of our hypotheses.

**Table 6. Validity of Hypotheses on Investment Behavior**

| Hypotheses | | Validity |
|---|---|---|
| H1: "NPV consistency" | The investment behavior of farmers is consistent with the NPV. | Reject |
| H2: "ROA consistency" | The investment behavior of farmers is consistent with the ROA. | Reject |
| H3: "framing effect" | Farmers will show different behavioral patterns if they are confronted with a non-agricultural or an agricultural investment situation. | Reject |
| H4: "order effect" | The decision behavior of farmers depends on the order in which the two investment treatments are addressed. | Fail to reject |
| H5: "learning effect" | Farmers would closely approximate optimal exercise of the investment opportunity if they are given an equitable chance to learn from personal experience. | Fail to reject |

## Discussion und Conclusions

Investments and, in particular, the optimal timing of a farmland investment represent fundamental decisions for agricultural entrepreneurs. The understanding of investment and disinvestment decisions on a farm is very important for the forecast of structural change in agriculture. However, so far the analysis of such decisions has not often been carried out extensively enough, meaning applying in the NPV approach uncertainties, irreversibility and entrepreneurial flexibility have not been considered simultaneously. The ROA is a corresponding integrative approach and as it has been clarified by multiple normative applications has an explanatory potential for many observed economic hysteresis. Nevertheless, it is difficult to determine econometrically the explanatory content of the ROA on the basis of empirical farm data. In view of these aspects, we pursued a different approach in this paper and studied the investment behavior of farmers in a computer-based experiment. The observed investment decisions were contrasted with theoretical benchmarks, which were derived from static (NPV) and dynamic investment models (ROA). The experiment considers an investment problem in a non-agricultural and in an agricultural treatment, stylizing a decision to take an ongoing investment opportunity.

The main findings from this experimental study are first that the decision behavior of agricultural entrepreneurs is neither predictable with the NPV nor with the ROA criterion. According to the ROA criterion in the non-agricultural treatment three quarter of the farmers invest too early. We expect that farmers will show another decision behavior in a more familiar investment situation. But the results show, that the decision behavior in the agricultural treatment does not differ significantly from the behavior in the non-agricultural treatment. An important aspect is the order in which the two treatments were allocated to the participants. Experiences from the first treatment influence the decision behavior in the second treatment. Moreover, we found out that participants learn from their experience. The decision behavior of the participants diverges from the predictions of the NPV and approximates the predictions of the ROA. This finding reinforces the predictive power of the ROA.

As already mentioned, the experimental examination and testing of real options settings is in its beginning. A lot of work needs to be done for a better understanding of what exactly drives different individuals' decision making in investment situations. It is possible that the Escalation-of-Commitment-Effect is relevant (Staw 1981; Denison 2009). This effect describes the phenomenon that it is very difficult to dissuade somebody from a course that he or she once adopted. This still seems to be nearly impossible even if it becomes more and more apparent that this course is misleading. It requires further investigation if these effects also apply to farmers. It is also interesting to investigate if different groups of participants e.g. farmers,students, entrepreneurs, decision makers in developed countries and decision makers in developing countries would show similar behavioral patterns. Furthermore, it would be interesting to reveal the heuristics, which entrepreneurs apply to make their investment decisions.

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