Closing down the Farm:
An Experimental Analysis of Disinvestment Timing

Syster Christin Maart *, Oliver Mußhoff *, Martin Odening **, Christian Schade ***

* Georg-August-Universitaet Goettingen, Department of Agricultural Economics and Rural Development, Platz der Goettinger Sieben 5, 37073 Göttingen, Germany, Tel: +49 551 394842, Fax: +49 551 392030,
Email: syster.maart@agr.uni-goettingen.de (corresponding author)

** Humboldt-Universitaet zu Berlin, Department of Agricultural Economics, Unter den Linden 6, 10099 Berlin, Germany, Tel: +49 30 2093 6487; Fax: +49 30 2093 6465,

*** Humboldt-Universitaet zu Berlin, Institute for Entrepreneurial Studies and Innovation Management, Unter den Linden 6, 10099 Berlin, Germany, Tel: +49 30 2093 99010; Fax: +49 30 2093 99030,

Paper prepared for presentation at the EAAE 2011 Congress
Change and Uncertainty
Challenges for Agriculture,
Food and Natural Resources

August 30 to September 2, 2011
ETH Zurich, Zurich, Switzerland

Closing down the Farm: An Experimental Analysis of Disinvestment Timing

Abstract

Agrarian structures are often characterized by some kind of economic inertia. It is particularly puzzling why unprofitable farms persist over time instead of being sold. In this paper we analyze the exit decision of farmers using the real options approach. The validity of the real options theory is assessed by means of laboratory experiments. Our results show that real options models are able to predict actual disinvestment decisions better than traditional investment theory. Nevertheless, the observed disinvestment reluctance was even more pronounced as predicted by theory. This finding suggests the inclusion of bounded rationality into normative disinvestment models.

Keywords

Disinvestment, Real Options, Experimental Economics.

JEL-Code

C91, D81, D92

1. Introduction

Structural change in agriculture is frequently characterized by some kind of inertia. That means farmers respond surprisingly slowly to changes in the economic environment. The fact that land prices are often systematically higher than their fundamental value based on future cash flows from land use raises the question as to why farmers continue producing instead of selling their land (Turvey, 2002). Structural change in agriculture is, in essence, the outcome of aggregated investment and disinvestment decisions of farmers.

Several explanations for sluggish (dis)investment behavior have been developed. More recently, the Real Options Approach (ROA) has been propagated as a comprehensive explanation concept for economic inertia (cf. Dixit and Pindyck, 1994). The real options theory analyzes irreversible decisions in a dynamic context, utilizing the analogy between a financial option and a real (dis)investment. It asserts that a firm may increase its profit by deferring an irreversible investment though the expected present value of the investment cash flows exceeds the investment costs. Similarly, it may be optimal to defer an irreversible disinvestment even if the expected present value of the firm's cash flow falls below the liquidation value. The intuitive reason is that in cases of irreversible decisions, waiting has a positive value since new information about the expected cash flow arrives in subsequent periods. As long as the disinvestment has not been made, a decision maker has the flexibility to continue an ongoing project. This is valuable in the event of increasing cash flows. Termination of the project (the firm) deletes this option and reduces the decision maker's flexibility. The loss of flexibility must be covered by the liquidation value, too, before a disinvestment becomes optimal. This mechanism results in a kind of inertia, which has been called a "tyranny of the status quo" (Dixit, 1992).

The ROA has been intensively used in agricultural economics for about 15 years (e.g., Purvis et al., 1995; Odening et al., 2005); however, most of these applications are normative and thus they merely indicate the *potential* explanatory value of the ROA for observed economic inertia. A few attempts have been made to provide empirical evidence for the validity of the ROA in general and in an agricultural context in particular (e.g., Richards and Green, 2003; Hinrichs et al., 2008). Unfortunately, the econometric validation of theoretical models explaining disinvestment behavior, such as the ROA, is plagued by some fundamental difficulties. Among them are unobservable explanatory variables, ambiguity of explaining factors and unobserved heterogeneity. In view of these difficulties in econometric estimation based on field data, it seems quite natural to resort to economic experiments for a validation of the ROA. Laboratory experiments allow data collection under controlled conditions as well as the elicitation of otherwise unobservable variables. Thereby the internal validity of empirical research can be improved (Roe and Just, 2009). Despite these advantages, the experimental investigation of real options theory is still in its early stages. Rauchs and Willinger (1996) were among the first in testing 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 as well as that their willingness to pay for an investment opportunity included an option value. In a recent study, Oprea et al. (2009) investigated whether real options values in a monopolistic environment differ from those under competition. All aforementioned studies considered the value and the timing of investment decisions and the experiments were carried out with students. In the present study, we investigate if the real options approach is able to predict observed (dis)investment behavior of agricultural entrepreneurs and if these predictions are better compared to the simple Net Present Value (NPV) criterion and how risk aversion influences the decision process. The article is organized as follows: The next section derive normative hypotheses from the theoretical disinvestment model. The subsequent section describes the design of the experiments followed by a presentation of the outcome of the experiments. The article ends with a discussion on the validity of theoretical disinvestment models and directions for further research.

2. Derivation of Hypotheses

Here we describe the disinvestment decision as a simple optimal stopping problem.[1] In contrast to standard options models we prefer a discrete time framework. Moreover, we assume an additive model of risk instead of a multiplicative one. Both assumptions ease the design of the subsequent experiments and they do not affect the qualitative insights of the model.

The basis of the following considerations are an already existing project with a finite lifetime of three periods that currently earns an annual cash flow X_0. The cash flow follows a binomial process, i.e., in period 1 the cash flow will either increase by a value $h > 0$ with probability p or decrease by h with probability $1-p$. In period 2 the cash flow can take the following values: $X_0 + 2h$ with probability p^2; $X_0 - 2h$ with probability $(1-p)^2$; and X_0 with probability $2p(1-p)$. We first assume a risk neutral decision maker who has to decide whether to continue or to abandon the project. Termination of the project yields a salvage value L in addition to the cash flow of the current period. The project cannot be restarted once it has been terminated. In other words, the decision to abandon the project is irreversible. Traditional investment theory asserts that the project should be terminated if the liquidation value $L + X_0$ exceeds the continuation value $\hat{C}$. Consequently, the value of the project, F_0, is:

$$D_1 : \max(\hat{C}; L + X_0) = \hat{F}_0 ,$$

where

$$\hat{C} = X_0 + (p \cdot (X_0 + h) + (1-p) \cdot (X_0 - h)) \cdot q^{-1} + (p^2 \cdot (X_0 + 2h) + 2 \cdot (p \cdot (1-p) \cdot X_0) + (1-p)^2 \cdot (X_0 - 2h) + L) \cdot q^{-2} \quad (1)$$

Here $q^{-1} = \frac{1}{(1+r)}$ is a discount factor and r denotes the interest rate. By equating the continuation value $\hat{C}$ defined in equation (1) and the liquidation value $L + X_0$ we receive the disinvestment trigger $\hat{X}_0$:

$$\hat{X}_0 = L \cdot r - h \cdot (2p-1) \cdot \left(1 + \frac{1}{1+q}\right) \quad (2)$$

According to the NPV, the project should be terminated if the current cash flow falls below $\hat{X}_0$. The situation is different if the decision on the termination of the project can be deferred to period 1. Using financial wording, the decision maker now has an abandonment option in period 0 that he/she can either exercise or retain until maturity. Deferring the decision has the potential advantage that it allows the decision maker to take into account information which may emerge in period 1. Of particular interest is the situation where $X_0 - h < L \cdot r < X_0 + h$, which implies that continuation (termination) is the favorable decision if the cash flow in period 1 increases (decreases). According to the ROA the project value is given by:

$$D_2 : \max(\tilde{C}; L + X_0) = \tilde{F}_0 \quad (3)$$

with a continuation value of

$$\tilde{C} = X_0 + (p \cdot (X_0 + h) + (1-p) \cdot (X_0 - h + L)) \cdot q^{-1} + (p^2 \cdot (X_0 + 2h + L) + p \cdot (1-p) \cdot (X_0 + L)) \cdot q^{-2} \quad (4)$$

---

[1] We employ dynamic programming for deriving our hypotheses. This covers the analogy between real options and financial options. However, a contingent claim approach would complicate the model and introduce parameters that are difficult to handle in an experiment, particularly the convenience yield.

The optimal disinvestment trigger referring to the ROA is:

$$\tilde{X}_0 = L \cdot r - h \cdot \left(2p - \frac{q}{p+q} \right) \quad (5)$$

Thus, the myopic NPV differs, in general, from the ROA. The difference between the two disinvestment triggers is:

$$\hat{X}_0 - \tilde{X}_0 = \frac{h \cdot (1-p) \cdot (2p+q)}{(1+q) \cdot (p+q)} > 0 \quad (6)$$

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

H0: The disinvestment behavior of farmers is consistent with the NPV.

H1: The disinvestment behavior of farmers is consistent with the ROA.

Equation (5) also allows investigating the impact of increasing uncertainty on the optimal disinvestment trigger. Increasing uncertainty is considered via a mean preserving spread of the cash flow. A mean preserving spread can be implemented in our simple model framework by increasing the additive shock h, i.e., by using $h' > h$.The optimal disinvestment trigger now is:

$$\tilde{X}'_0 = L \cdot r - h' \cdot \left(2 \cdot p - \frac{q}{p+q} \right) \quad (7)$$

Obviously the relation $\tilde{X}_0 > \tilde{X}'_0$ holds for $p = 50\%$. This finding is reflected in the following hypothesis:

H2: Farmers tolerate lower cash flows before disinvesting if the volatility of investment returns increases.

Note that a higher volatility does not inevitably result in a later termination of the project. The reason is that a higher volatility reduces the optimal disinvestment trigger, but at the same time the probability of passing a certain trigger level increases. Thus, the effect of the volatility on the first passage time of the stochastic process is ambiguous.

So far, the disinvestment triggers have been derived assuming a risk neutral decision maker; however, there is empirical and experimental evidence questioning this assumption (e.g., Yesuf and Bluffstone, 2009). As mentioned above, risk preferences are also relevant for the valuation of real options if it is impossible to set up a replicating portfolio of traded assets which duplicates the stochastic outcome of the investment project (Dixit and Pindyck, 1994). The valuation of a risky prospect can be conducted in an expected utility framework either by replacing uncertain outcomes by their certainty equivalent or by using risk-adjusted discount rates. Let $r^* > r$ denote the risk-adjusted discount rate and $q^* = 1 + r^*$. In this case, the modified disinvestment triggers for the NPV and the ROA are:

$$\hat{X}^*_0 = L \cdot r^* - h \cdot (2p-1) \cdot \left(1 + \frac{1}{1+q^*} \right) \quad (8)$$

and

$$\tilde{X}^*_0 = L \cdot r^* - h \cdot \left(2p - \frac{q^*}{p+q^*} \right) \quad (9)$$

respectively. A comparison of the equations (8) and (9) with the equations (2) and (5) shows that risk aversion increases the disinvestment trigger of both decision rules. This finding leads to our final hypothesis:

H3: Risk averse farmers disinvest earlier.

As mentioned earlier, it is difficult to disentangle the effect of uncertainty on the timing of investments and disinvestments if a risk neutral valuation is not possible. The reason is that uncertainty influences the time value of the real option as well as the certainty equivalent of the project's cash flows. While both effects have the same direction for an investment, they may compensate each other in the case of a disinvestment. In any case, testing of H2 and H3 requires knowledge of the decision makers' risk attitude, which must be taken into account in the design of the laboratory experiments.

3. Experimental Design

Our experimental design follows Sandri et al. (2010) and consists of two parts. The first part describes a problem of optimal stopping, stylizing a context-free choice to abandon a project for a constant termination value. In the second part, a session of Holt and Laury (2002) lotteries (HLL) was conducted with real payments to elicit risk attitudes of the participants. Lottery comparisons have been preferred over a certainty equivalent method because they avoid possible distortions by a certainty effect (Levy and Levy, 2002). This method has also been favored over psychometric scales (e.g., Zuckerman, 1971), as lottery comparisons are consistent with the experimental disinvestment task, being based on monetary choices under risk with real payoffs at stake. Furthermore, some general information about the participants' characteristics (e.g., gender, education and age) was collected.

The design of the optimal stopping experiment employed the model outlined in the previous section. Within each round, respondents could decide to stop an ongoing project in one of ten periods. This task was repeated over multiple rounds. Returns from the existing project followed a binomial arithmetic Brownian motion with $p = 50\%$, no drift and a standard deviation of 500 (200). First period cash flows were always 1,000 points. To simplify matters for the participants, the risk-free interest rate was fixed at 10%. Abandoning the project yielded a constant revenue of 11,000 points, was allowed in each of the 10 periods and was made compulsory in the last period to limit the planning horizon for all participants.

The binomial tree in Figure 1 visualizes possible realizations of the stochastic returns and their probabilities. In period 0 the participant will receive 1,000 points. If the participant decides to disinvest in period 0, he receives the initial cash flow of 1,000 points plus the salvage value of 11,000 points. In such a case, the cash flow in subsequent periods is not relevant for this investor. If the participant opts for a continuation, the cash flow in period 1 increases to 1,500 or decreases to 500 points, each with a probability of 50%. The binomial tree will be adjusted accordingly. Irrelevant states are suppressed and the probabilities for future cash flows are updated. These steps are repeated until period 10 unless the participant terminates the project earlier. There were 20 repetitions of the experiment per individual carried out because we wish to discriminate between different decision rules. For a single realization of the stochastic process the NPV and the ROA (or a heuristic) may lead to the same optimal decision. Hence, it would not be possible to infer which rule underlies the actual decision of the participant. For each of the 20 rounds, the entire binomial tree was newly determined via a random mechanism. Hence, over the course of the entire experiment each respondent was confronted with 20 different, randomly determined paths of the binomial tree. The respondents did not receive immediate payoff feedback, except in a trial run. The random cash flow developments were separately determined for each individual. With no immediate payoff feedback and randomly determined paths of revenues, we limited reinforcement learning from outcomes.

Figure 1: Binomial tree of potential revenues together with the associated probabilities of occurrence (standard deviation 500 points)

Period 0	Period 1	Period 2	Period 3	Period 4	Period 5	Period 6	Period 7	Period 8	Period 9	Period 10
										6,000 **0.1%**
									5,500 **0.2%**	
								5,000 0.39%		**5,000** 0.98%
							4,500 0.78%		**4,500** 1.76%	
						4,000 1.56%		**4,000** 3.13%		**4,000** 4.39%
					3,500 3.13%		**3,500** 5.47%		**3,500** 7.03%	
				3,000 6.25%		**3,000** 9.38%		**3,000** 10.94%		**3,000** 11.72%
			2,500 12.5%		**2,500** 15.63%		**2,500** 16.41%		**2,500** 16.41%	
		2,000 25%		**2,000** 25%		**2,000** 23.44%		**2,000** 21.88%		**2,000** 20.51%
	1,500 50%		**1,500** 37.5%		**1,500** 31.25%		**1,500** 27.34%		**1,500** 24.61%	
1,000		**1,000** 50%		**1,000** 37.5%		**1,000** 31.25%		**1,000** 27.34%		**1,000** 24.61%
	500 50%		**500** 37.5%		**500** 31.25%		**500** 27.34%		**500** 24.61%	
		0 25%		**0** 25%		**0** 23.44%		**0** 21.88%		**0** 20.51%
			-500 12.5%		**-500** 15.63%		**-500** 16.41%		**-500** 16.41%	
				-1,000 6.25%		**-1,000** 9.38%		**-1,000** 10.94%		**-1,000** 11.72%
					-1,500 3.13%		**-1,500** 5.47%		**-1,500** 7.03%	
						-2,000 1.56%		**-2,000** 3.13%		**-2,000** 4.39%
							-2,500 0.78%		**-2,500** 1.76%	
								-3,000 0.39%		**-3,000** 0.98%
									-3,500 0.2%	
										-4,000 0.1%

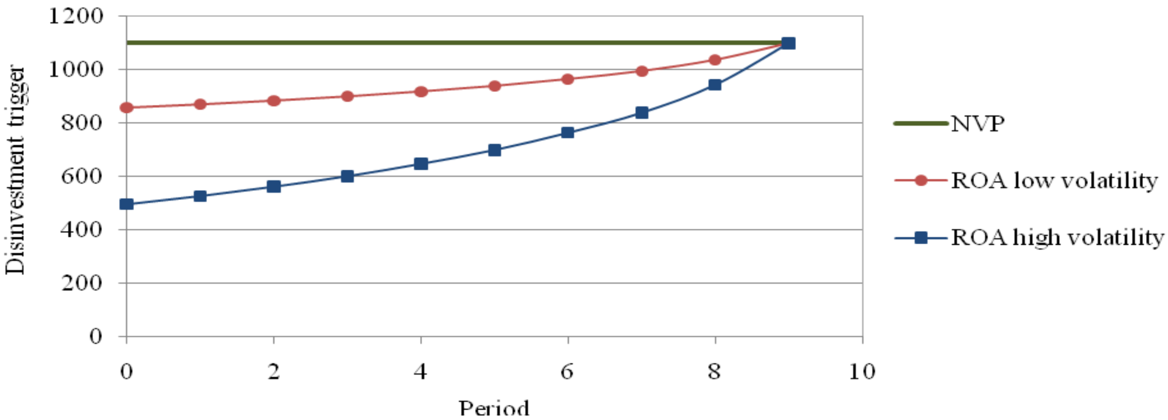
The disinvestment experiment was carried out in two treatments (between subjects), differing in the size of potential gains and losses, i.e., the volatility. Specifically, the potential gains and losses were 200 points in the low volatility treatment and 500 points in the high-volatility treatment. The participants were informed about all parameters and assumptions underlying the experimental setting. The binomial tree of potential revenues with their associated probabilities of occurrence was displayed on their screen. Respondents learned the development of payoffs (the outcome of the random process) from period to period. After each period and before the decision whether or not to disinvest had to be made, the binomial tree was updated based on the random outcome that had occurred in the previous period.

To ensure incentive compatibility of the experiment the hypothetical disinvestment decisions were related to an actual payment. A randomly selected participant could win between 300 and 1,000 € depending on the scores attained in the real options experiment. For HLL the selected respondent will also receive a payoff that is dependent on his/her expressed preference for or against various risky, mutually exclusive alternatives. The whole experiment took about 60 minutes per individual. Choices made by participants were not time constrained. A trial run gave the participants the opportunity to become acquainted with the experiment. The experiment was conducted in 2009 as an online experiment in which 63 agricultural entrepreneurs participated. That means that in total 1,260 decisions (20 repetitions for each of the 63 participants) were observed.

4. Normative benchmarks

For the evaluation of the disinvestment 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. Therefore, we determined the risk-adjusted discount rate and calculated the exercise frontiers. The determination of the risk-adjusted discount rate is based on the results of HLL. While the exercise frontier for the NPV can be easily calculated, the normative benchmark of the ROA has to be determined by backward dynamic programming (cf. Trigeorgis, 1996:312). The resulting normative benchmarks, i.e., the "optimal" solutions for the disinvestment trigger according to the NPV and the ROA, are presented exemplarily in Figure 2 for a risk neutral decision maker. The exercise frontiers of the ROA increase exponentially reflecting the diminishing time value of the disinvestment option. The trigger values start at 858 and 495 points for the low and the high volatility scenario, respectively. Both curves coincide with the NPV criterion (1,100 points) at maturity, as is required by theory.

Figure 2: Disinvestment trigger for a risk neutral decision maker



As mentioned earlier, a higher volatility of the cash flow leads to a lower disinvestment trigger for the ROA, but this difference does not necessarily translate into a later disinvestment time. Actually, when simulating the binomial tree and applying the optimal decision rule for a risk neutral decision maker we found that an optimal disinvestment should take place in period 4.09 in the low volatility scenario and in period 4.18 in the high volatility scenario. However, the difference in optimal disinvestment times widens if the calculation is based on the observed risk aversion of the participants, which facilitates statistical testing of hypothesis 2.

5. Results

Table 1 summarizes the main results of our experiments and provides information about the characteristic variables of the participants. In total, 63 farmers participated in the experiments; 30 were assigned to the high volatility treatment and 33 to the low volatility treatment. Participants were recruited through alumni networks of German universities. The alumni provided us with addresses of active farmers who were invited to participate in the online experiments. The participants were also asked to suggest other farmers who might be willing to conduct the experiments. The participating farmers were relatively young with an average age of 30 years, a minimum of 21 years and a maximum of 65 years. The proportion of farmers with an academic background was relatively high. Both features reflect a kind of sample selection that can be related to the fact that the experiments were conducted online and the manner in which participants were recruited. On average, the participants were slightly risk averse.

Table 1: Descriptive statistic

Variable	High volatility (N=30)		Low Volatility (N=33)		Total (N=63)	
	Mean	Standard deviation	Mean	Standard deviation	Mean	Standard deviation
Normative disinvestment following NPV	0.913	2.525	0	0	0.435	1.801
Normative disinvestment following ROA	4.777	3.807	4.124	3.758	4.435	3.794
Experimentally observed time of disinvestment	6.412	3.448	6.091	3.734	6.244	3.603
Variance between observation and NPV	5.499	4.145	6.091	3.734	5.809	3.945
Variance between observation and ROA	1.635	4.556	1.967	4.604	1.809	4.582
Correlation between observation and ROA (Kendall's Tau)	0.275	0.278	0.306	0.283	0.292	0.334
Risk attitude of participant	4.930	1.946	5.090	1.684	5.020	1.800
Age of participant	30	10	31	11	30	10
Percentage of farmers studied	72.41	–	81.25	–	77.05	–
Percentage of female participants	24.14	–	21.88	–	22.95	–

The aforementioned disinvestment rules were applied to 1,260 random applications of the discrete arithmetic Brownian motion. The NPV criterion predicts a (risk-adjusted) disinvestment time of 0.91 periods on average in the high volatility scenario and an immediate disinvestment in period 0 in the low volatility scenario. The corresponding predictions from the ROA amount to 4.78 and 4.12 periods, respectively. The actual disinvestment time chosen by the participants was period 6.41 (high volatility) and 6.09 periods (low volatility). In the following, we discuss whether or not these findings support our hypotheses on the disinvestment behavior.

Test of H0

The disinvestments took place in the period which is suggested by the NPV in only 8.1% of all 1,260 observations. In the majority of all cases farmers chose to disinvest later. The average deviation between the predicted and the actual disinvestment time is 5.81 periods. This difference in the means of the disinvestment time is statistically significant (p-value < 0.001, two-sided t-test). On this basis, we reject H0 and conclude that the NPV criterion, in general, is not appropriate for predicting actual (experimentally observed) disinvestment behavior.

Test of H1

The average deviation between observed and optimal disinvestment time according to the ROA amounts to 1.81 periods. This deviation is also significantly different from zero (p-value < 0.001, two-sided t-test). Nevertheless, in 26.1% of the observations the participants disinvest during the optimal period. That means that more than one-fourth of all of the disinvestment decisions are correctly predicted by the ROA, which is significantly higher compared to the NPV. In 51.8% (22.1%) of all cases farmers decided to disinvested later (earlier) than optimal. Nevertheless, these figures treat all responses as independent observations and thus ignore the panel structure of the data. Figure 3 provides additional information on individual's decision behavior. Panel 3a depicts the empirical distribution of the average deviation between the actual disinvestment time and the optimal disinvestment time for all 63 participants. Means are calculated from the 20 repetitions observed per individual. The majority of the farmers (24 people) tend to hold on too long, for 2.50 periods on average, while a small group disinvests prematurely (4 people). Interestingly, there are 11 farmers who act on average in accordance with the ROA. The differences shown in Figure 3a are significant from zero for 41 farmers (65%) at a significant level of 5%. It is notable that the educational level of farmers did not have any significant influence on the deviation between the optimal and actual disinvestment time.

Figure 3: Distribution of the differences between observed and optimal disinvestment periods (N=63)

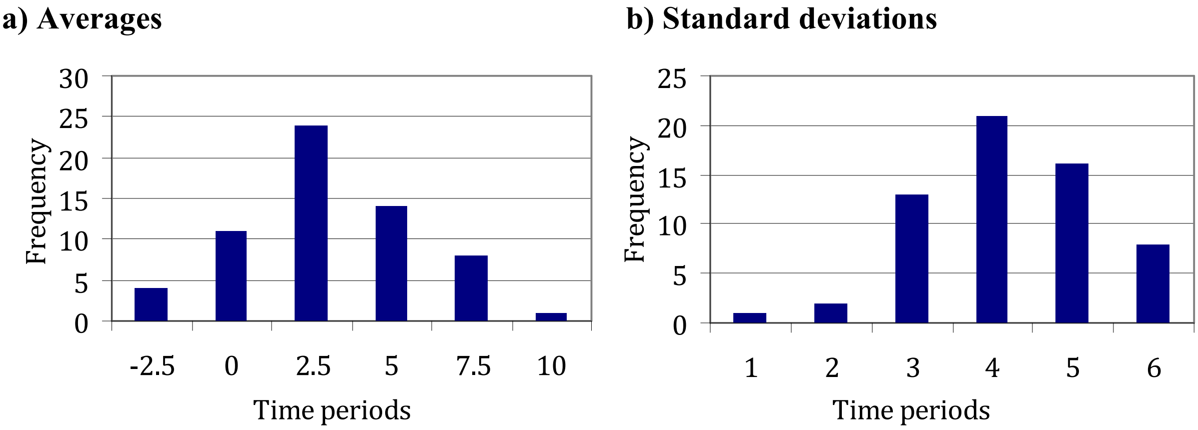
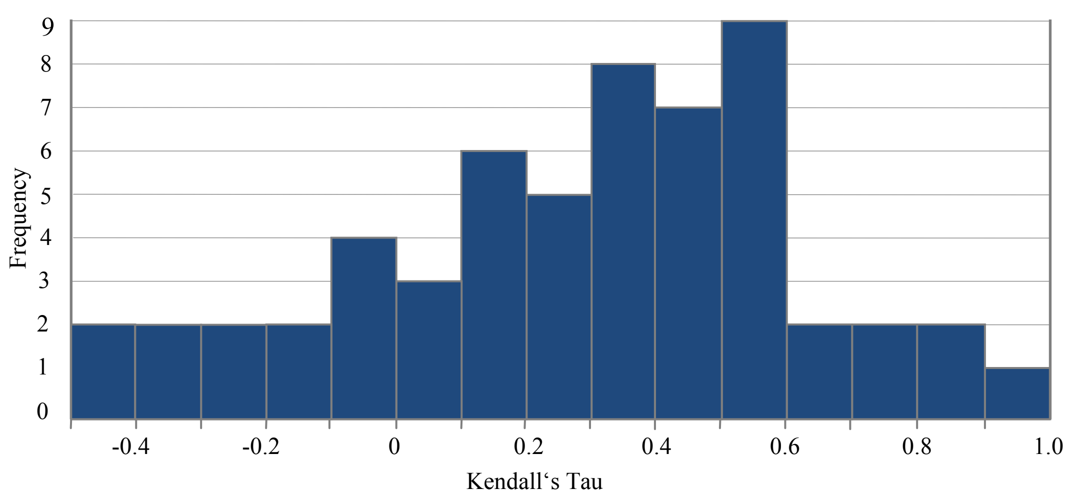


Figure 3b sheds some light on the regularity of individual decision making by displaying the distribution of the standard deviation of the differences in disinvestment time. Apparently, the standard deviation is rather high. About 75% of the participants have a standard deviation of 4 periods or more, which means that the deviation of their decisions relative to the ROA is rather unstable. In other words, individual decision rules are not characterized by a constant bias relative to the ROA. Instead, overestimation and underestimation of the optimal disinvestment period may occur for the same individual. Given the complexity of the decision problem, the observed deviations between actual and optimal behavior are not very surprising. Nevertheless, one would expect that the ROA is able to predict an individual's propensity to postpone a disinvestment conditional on a particular application of the stochastic process. Thus, for a further investigation of the predictive power of the ROA we calculate rank correlation coefficients (Kendall's tau) between optimal and actual disinvestment periods for each individual (see Figure 4).

Figure 4: Correlation between optimal disinvestment date after ROA and experimentally observed behavior of individuals



The mean of Kendall's tau for all farmers is 0.29, meaning that the higher the optimal disinvestment period is the later observed disinvestment occurs. The rank correlation is positive for 87.9% of the participants and in 53.5% of all cases the correlation is significantly different from zero (at a significance level of 5%). Again we observe a pronounced variability over individuals: Kendall's tau ranges from -0.43 to 1.00. This finding emphasizes the large heterogeneity in individual decision making procedures. On this basis, hypothesis 1 is rejected, but ROA outperforms NPV.

Test of H2 and H3

To test hypotheses 2 and 3 we ran a model in which we regress the observed disinvestment periods on the risk aversion, age and gender of farmers, as well as the volatility of the project's cash flow. The results of this regression are presented in Table 2.

Table 2: Regression of the observed individual disinvestment period (N=1,260) [a)]

Parameter	Coefficient	Robust standard error	p-value
Constant	8.520	1.835	0.000
HLL-value	-0.419	0.165	0.011
Volatility (0: low volatility1: high volatility)	0.194	0.604	0.748
Age	-0.030	0.032	0.354
Gender (0: female, 1: male)	0.571	0.767	0.457

a) $R^2 = 0.111$

The estimated coefficient of the risk aversion parameter is significant and has a negative sign. This result confirms our third hypothesis. Age and gender of farmers did not affect the disinvestment period significantly. The sign of the dummy variable representing the volatility treatment is positive, but not significant. If one argues that the difference of the average optimal disinvestment times between the high and the low volatility scenario is rather small (4.77 – 4.12 = 0.65 periods), this result seems to be quite plausible. To test hypothesis 2 we had to compare the individual disinvestment triggers for both scenarios. Unfortunately, these disinvestment triggers are not directly observable, yet we can approximate them by measuring the minimal project cash flow that has been observed for a participant while he/she was willing to continue the project. Clearly, this proxy lies above the true disinvestment trigger and ignores the time dependence of the exercise frontier; however, these errors prevail in both volatility treatments. The result is that the mean of the minimal cash flow is 858 for all farmers in the low volatility scenario. In line with theoretical arguments, the corresponding value in the high volatility scenario is considerably lower (587). Table 3 summarizes the empirical results with regard to the validity of our hypotheses. On this basis, hypotheses 2 and 3 are not rejected.

Table 3: Validity of hypotheses on disinvestment behavior

	Hypotheses	Validity
H0	The disinvestment behavior of farmers is consistent with the NPV.	Reject
H1	The disinvestment behavior of farmers is consistent with the ROA.	Reject, but ROA outperforms NPV
H2	Farmers tolerate lower cash flows before disinvesting if the volatility of investment returns increases.	Fail to reject
H3	Risk averse farmers disinvest earlier.	Fail to reject

6. Discussion und Conclusions

Disinvestments and, in particular, farm exits represent basic decisions for agribusiness practices involving substantial risk. Due to their irreversibility, these decisions are important for understanding structural change in agriculture. Advocates of the ROA have argued that uncertainty and irreversibility cause inertia. Thus, policy instruments designed to provide incentives for a disinvestment should take this into account and compensate the adjustment cost and value of waiting related to the disinvestment option. Otherwise, they will fail to trigger the desired behavior of farmers.

Unfortunately, the econometric validation of theoretical models explaining disinvestment behavior, such as the ROA, is plagued by some fundamental difficulties. Among them are unobservable explanatory variables, ambiguity of explaining factors and unobserved heterogeneity. In view of these problems, we pursued a different approach in this paper and studied the disinvestment behavior of farmers in a laboratory experiment under controllable conditions. The observed disinvestment decisions were contrasted with theoretical benchmarks derived from static (NPV) and dynamic investment models (ROA).

The main findings from this experimental study are first that participants (farmers) postpone taking an irreversible decision, such as project termination even, if the risk adjusted NPV of the project cash flow falls below the liquidation value, hence rejecting traditional investment theory. A further insight from our experiments was the superiority of the ROA in explaining disinvestment behavior in comparison with the NPV. The predicted disinvestment period was on average closer to the observed disinvestment period and we found a significant positive correlation between the two. Moreover, the hypothesized impact of the volatility on the disinvestment trigger was confirmed by our results. Basically, we do not expect individuals to carry out the computations necessary to make disinvestment choices fully consistent with real options reasoning. Nevertheless, we have evidence that many participants understand at least intuitively the value of waiting and apply decision rules that result in choices somewhat consistent with those that would have occurred if they had applied such real options reasoning.

However, even though (intuitive) real options reasoning seems to be more appropriate to account for individuals' behavior than the NPV approach, an "options-based" inertia appears not to be the entire story, at least for two reasons. Firstly, farmers tend to disinvest even later than suggested by the ROA. The observed bias is smaller than for the NPV, but it is significant on average. Secondly, the heterogeneity of deviations between respondents raises the question as to if a single microeconomic model is capable to explain individuals' disinvestment behavior. Several studies question the rationality assumption underlying most microeconomic models (Conlisk, 1996; Gardebroek and Oude Lansink, 2008) and it appears that "psychological inertia" also plays a role in explaining reluctance towards (dis)investment decisions. In behavioral economics several drivers for this phenomenon have been discussed, such as sunk-cost fallacy (Ross and Staw, 1993) or the status quo bias (Burmeister and Schade, 2007). It would be interesting (and challenging) to disentangle these very different perspectives on inertia in disinvestment decisions from the option-based inertia focused on in our experiments.

As already mentioned, the experimental examination and testing of real options settings still is in its early stages. Moving on a rather unexplored terrain, we consider our study a small but important first step on the way towards a better understanding and rationalizing of termination choices. A lot of work remains to be done to better understand what exactly drives different individuals' decision making in disinvestment situations. With regard to possibly bounded rationality of decision makers, it would be interesting to test whether simple heuristics can predict disinvestment behavior with the same precision or even better than sophisticated microeconomic models. Stop-Loss-rules or rules such as "terminate the project if the project returns fall x-times in a row" could be candidates for such heuristics. Another interesting path to be taken is comparing the behavior of farmers with other entrepreneurs, as farmers have been alleged to be particularly conservative and averse to changes (e.g., Jose and Crumly, 1993). Finally, we suggest investigating the effect of framing on disinvestment choices: Will farmers be more "attached" to a project that is described in terms that are more familiar to them? Framing might also be helpful in making a laboratory experiment more realistic and, thereby, increasing its external validity.

References

Burmeister, K. and Schade, C. 2007. "Are Entrepreneurs' Decisions More Biased? An Experimental Investigation of the Susceptibility to Status Quo Bias". *Journal of Business Venturing* 22:340−362.

Conlisk, J. 1996. "Why Bounded Rationality?" *Journal of Economic Literature* 34 (2):669−700.

Dixit, A.K. 1992. "Investment and Hysteresis." *Journal of Economic Perspectives* 6:107−132.

Dixit, A.K. and Pindyck, R.S. 1994. "*Investment under Uncertainty"*. Princeton: Princeton University Press.

Gardebroek, C. and Oude Lansink, A.G.J.M. 2008. "Dynamic Microeconometric Approaches To Analysing Agricultural Policy." Paper presented at the 107th Seminar of the European Association of Agricultural Economists (EAAE) in Sevilla, Spain.

Hinrichs, J., Mußhoff, O. and Odening, M. 2008. "Economic Hysteresis in Hog Production". *Applied Economics* 40:333−340.

Holt, C. A. and Laury, S. K. 2002. "Risk Aversion and Incentive Effects". *American Economic Review* 92:1644−1655.

Jose, D. H. and Crumly, J.A. 1993. "Psychological type of farm/ranch operators: Relationship to financial measures". *Review of Agricultural Economics* 15:121−132.

Levy, M. and Levy, H. 2002. "Prospect theory: Much ado about nothing". *Management Science* 48:1334–1349.

Odening, M., Mußhoff, O. and Balmann, A. 2005. "Investment Decisions in Hog Finishing: an Application of the Real Options Approach". *Agricultural Economics* 32:47−60.

Oprea, R., Friedman, D. and Anderson, S.T. 2009. "Learning to Wait: A Laboratory Investigation". *The Review of Economic Studies* 76:1103−1124.

Purvis, A., Boggess, W.G., Moss, C.B. and Holt, J. 1995. "Technology Adoption Decisions Under Irreversibility and Uncertainty: An Ex Ante Approach". *American Journal of Agricultural Economics* 77(3):541−551.

Rauchs, A. and Willinger, M. 1996. "Experimental Evidence on the Irreversibility Effect". *Decision and Theory* 40:51−78.

Richards, T.J. and Green, G. 2003. "Economic Hysteresis in Variety Selection". *Journal of Agricultural and Applied Economics* 35:1−14.

Roe, B.E. and Just, D.R. 2009. "Internal and External Validity in Economics Research: Tradeoffs between Experiments, Field Experiments, Natural Experiments and Field Data". *American Journal of Agricultural Economics* 91(5):1266−1271.

Ross, J. and Staw, B.M. 1993. "Organizational escalation and exit – Lessons from the shoreham nuclear-power-plant". *Academy of Management Journal* 36:701−732.

Sandri, S., Schade, C., Mußhoff, O. and Odening, M. 2010. "Holding on for too Long?" Working Paper, Dept. of Agr. Econ., Humboldt-Universität zu Berlin, Berlin.

Trigeorgis, L. 1996. "Real Options". Cambridge: MIT Press.

Turvey, C.G. 2002. "Can Hysteresis and Real Options Explain the Farmland Valuation Puzzle?" Working Paper 02/11, Dept. of Agr. Econ. and Bus., University of Guelph, Ontario.

Yavas, A. and Sirmans, C.F. 2005. "Real Options. Experimental Evidence". *The Journal of Real Estate Finance and Economics* 31:27−52.

Yesuf, M. and Bluffstone, R.A. 2009. "Poverty, Risk Aversion, and Path Dependence in Low-Income Countries: Experimental Evidence from Ethiopia". *American Journal of Agricultural Economics* 91(4):1022−1037.

Zuckerman, M. 1971. "Dimensions of sensation seeking". *Journal of Consulting and Clinical Psychology* 36.