The Impact of Price Floors
-A Real Options Based Experimental Approach-

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Contributed paper prepared for presentation at the 56th AARES annual conference, Fremantle, Western Australia, February 7-10, 2012

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Abstract

In order to stimulate investments, agricultural policies frequently use price floors, which guarantee a price above a certain limit. In some cases, however, a price floor does not have the desired effects. In this study, we experimentally analyse differences in the investment behaviour with respect to the presence of a price floor and compare the actual investment behaviour to normative benchmarks of the net present value and the real options approach. Furthermore, we look at treatment order and learning effects. The results show that the price floor has no significant impact on the decision behaviour of participants, whereas the effects of treatment order were statistically significant. Regarding the analysis of policy impacts, the latter result shows that the investment reluctance arising from an abolishment of a price floor is stronger than the investment stimulation arising from the introduction of a price floor. Consequently, neither the net present value nor the real options approach is appropriate to predict the investment behaviour in general. Nevertheless, we found out that the predictions of the real options approach enable an approximation of the participants' investment behaviour if the individuals have an adequate chance to learn from personal experience.

Keywords: *Price floors, investment decisions, real options, experimental economics.*

JEL classification: *C91, D81, E61.*

1. Introduction

Market interventions are omnipresent. Certain instruments are frequently used to redistribute income or to give incentives for commonly requested developments, e.g. investments in a particular sector. Price floors are a specific measure in this context. For instance, by passing the renewable energy law (REL), the German government implemented a price control mechanism with regard to the renewable energy sector. The legal text explicitly declares that one objective of the REL is to stimulate investments in the renewable energy sector (Bundesgesetzblatt, 2008: 2). Price floors have also been utilised in the agricultural sector to assure ongoing investments and security of supply for certain commodities. In this context, one might think of the milk income loss contract (MILC) in the United States, which guarantees a price floor to American dairy farmers (Foltz, 2004: 594) or the European intervention system, which implemented a minimum price for certain kinds of cereals, e.g. wheat (Sckokai and Moro, 2009). However, against the background that some contributions doubt the effectiveness of a minimum price (e.g. Dixit and Pindyck, 1994: 303), the question is raised if (or under which circumstances) this instrument really causes the desired effects with respect to supply security and investment behaviour. The understanding of the decision-making behaviour will be of high value since it can support an adequate prediction of the effects concerning investment conditions arising from a political change.

An econometric analysis based, e.g., on empirical single farm data before and after a political change, could be an approach to answer this question (e.g. Kuminoff and Wossink, 2010). Nonetheless, the observation of farmers' real decisions might be of little use in this context since investment decisions related to capital-intensive objects (e.g. a biogas plant, land) are relatively rare in agricultural businesses. Moreover, basic conditions like financial resources, individual preferences, etc. differ among farms (Gardebroek and Oude Lansink, 2008). Hence, it is hardly possible to draw meaningful conclusions from such an analysis. In contrast to the econometric approach, an experimental analysis allows deriving a clear relationship of cause and effect and will therefore increase the internal validity of the study's results (Roe and Just, 2009: 1268). To our knowledge, the effects of a price floor on investment behaviour have not been analysed experimentally, yet.

Moreover, one should keep in mind that in the context of investment behaviour analyses the real options approach (ROA) has recently gained attention since the predictive potential of the classical investment theory, in many cases, has not been satisfying (Dixit and Pindyck, 1994: 6). In addition to diverse econometric approaches (e.g. Turvey, 2003), the ROA has also been implemented in some experimental analyses. For instance, Oprea *et al.* (2009) investigated learning effects of participants during an investment experiment. Sandri *et al.* (2010) also analysed the predictive power of the ROA in an experimental setting. However, this study focused on a disinvestment scenario. Maart and Mußhoff (2011) investigated farmers' investment behaviour in a real options experiment but without market intervention.

The experiment implemented in this study considers an investment problem under uncertainty in a 'with price floor' (WPF) and a 'no price floor' (NPF) treatment stylising a decision to take an ongoing investment opportunity. The NPF treatment constitutes the control treatment. Because the investment behaviour could be influenced by the decision makers' risk attitudes (Fellner and Maciejovsky, 2007), an additional experiment based on a Holt and Laury lottery (HLL) is carried out (cf. Holt and Laury, 2002). The objective of this contribution is to experimentally analyse whether the presence of a price floor has a significant effect on the participants' willingness to invest. Also, the predictive potential of the traditional net present value (NPV) and the ROA is to be investigated in this context. Furthermore, we intend to elicit the investment behaviour's dependence on treatment order and personal experience during the experiment.

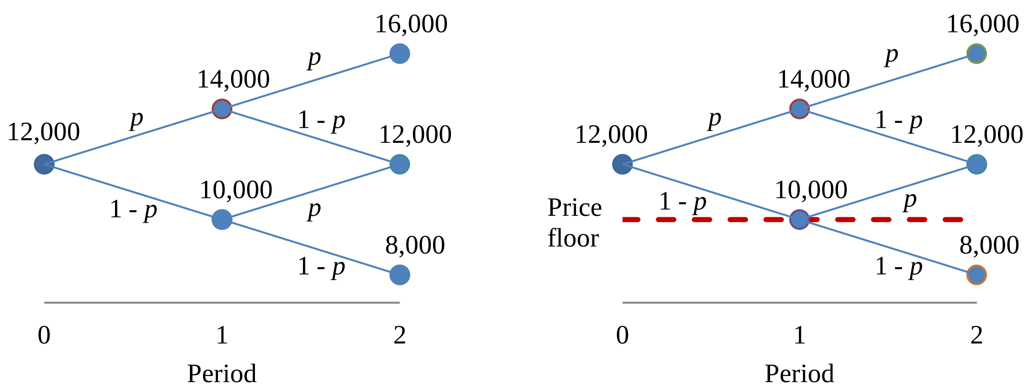
The next section 2 will describe the theoretical background concerning the ROA, the NPV, price floors as well as order and learning effects. Furthermore, the hypotheses are to be derived. Section 3 illustrates the experiment's design followed by the derivation of normative benchmarks in section 4. In section 5 the experimental results will be presented before the last section (section 6) points out conclusions, restrictions and expectations for further research.

2. Theoretical Background and Derivation of Hypotheses

The Real Options Approach

The ROA analyses investment situations similar to financial options in a dynamic-stochastic context. That is, in contrast to the NPV, the ROA explicitly takes irreversibility, uncertainty and entrepreneurial flexibility into account. The ROA generates results that differ from the NPV, which implies a now-or-never decision. The value of an investment option according to the ROA is called strategic NPV or option value and has two components: the intrinsic value - which is equal to the classical NPV - and the value of waiting. The basic idea of the second component is that new information arising over time can be remarkably valuable, especially when uncertainty (e.g. volatile markets) and irreversibility (e.g. high sunk costs) apply. Consequently, the temporal flexibility causes the investment trigger to rise. Waiting might be optimal even if the NPV is positive because the investment returns do not only have to compensate for the investment cost but also for additional profits which could have been generated if the investment was delayed (Dixit and Pindyck, 1994; Trigeorgis, 1996).

Further intuition for the differences between the classical investment theory and the ROA can be derived from the following example: A risk-neutral decision maker faces an investment opportunity. The investment can be implemented only once - either immediately or in the following period. Once the investment opportunity is exercised the investment cost $I = 10{,}000$ (constant over time) needs to be paid instantly. The present value of the investment returns in period 0 is $V_0 = 12{,}000$. If an investment is implemented the present value of the investment returns of the following period can be collected. The future development of the present value of the investment returns is uncertain and follows a binomial arithmetic Brownian motion (cf. Dixit and Pindyck, 1994: 68), which allows negative values. The present value will either increase by a value h = 2,000 with a probability p = 0.5 or decrease by h with the probability $1-p$ in each period. The risk-free interest rate r amounts to 10% per period. The question arises under which conditions this investment option should be exercised. Figure 1a) illustrates the corresponding binomial tree for the potential investment returns.



a) No price floor (NPF) b) With price floor (WPF)

Figure 1. Binomial tree of potential investment returns

According to the NPV, the value of the investment opportunity $\hat{F}$ can be derived as follows:

$$\hat{F} = \max\left(E(NPV_0);0\right),$$

where (1)

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

$E(NPV_0)$ is the expected net present value if the investment is realised in period 0 and $q^{-1} = 1/(1+r)$ denotes a discount factor. For the described example the expected NPV equals 909.

The critical present value of the investment returns $\hat{V}_0^*$, which triggers an immediate investment realisation, can be derived by a parameterisation of V_0. We are looking for V_0 with $E(NPV_0)$ equal zero. In the example, the critical present value $\hat{V}_0^*$ is 11,000.

Temporal flexibility (the investment can be delayed to period 1) allows the decision maker to consider additional information about the expected present value of the investment returns. Consequently, the value of the investment $\tilde{F}$ according to the ROA is defined as follows:

$$\tilde{F} = \max\left(E(NPV_0); E(NPV_1) \cdot q^{-1}\right),$$

where

$$\begin{aligned} E(NPV_1) = p \cdot \max\big(0; \big(\big(p \cdot (V_0 + 2 \cdot h) + (1-p) \cdot (V_0 + h - h)\big) \cdot q^{-1} - I\big)\big) + (1-p) \cdot \\ \max\big(0; \big(\big(p \cdot (V_0 - h + h) + (1-p) \cdot (V_0 - 2 \cdot h)\big) \cdot q^{-1} - I\big)\big) \end{aligned} \quad (2)$$

$E(NPV_1)$ is the expected net present value if the investment is realised in period 1. In the example, the value of the investment according to the ROA is 1,240. The investment trigger $\tilde{V}_0^*$ can be derived again by a parameterisation of V_0. At this point, the necessary condition for V_0 is that $E(NPV_0)$ equals $E(NPV_1) \cdot q^{-1}$. In the example, the respective investment trigger is 12,667.

The results of the example illustrate that the investment triggers derived from the two approaches differ considerably due to the consideration of temporal flexibility in the ROA while neglecting this in the NPV calculations. According to the NPV the respective decision maker should invest immediately. With respect to the ROA it is optimal to not realise the profitable investment alternative in period 0. Against this background, we derive the following alternate hypotheses:

H_1 ‘NPV consistency’: The investment behaviour of participants is consistent with the NPV.

H_2 ‘ROA consistency’: The investment behaviour of participants is consistent with the ROA.

Price Floors in the Context of the Real Options Approach

Price floors have aroused economists’ interest in different ways. For example, Chavas and Kim (2004) focused on price floor effects, on price dynamics and price volatility in a multimarket framework by applying an econometric approach to U.S. dairy markets. They state that the price support program reduces price volatility significantly, although this effect is found to disappear in the longer run. With respect to joint price dynamics, price changes have greater impacts in a liberal environment.

Moreover, diverse studies focused on price floor effects on investment behaviour by applying econometrical approaches. For instance, Sckokai and Moro (2009) used empirical data from Italy in order to estimate the producers' response to changes in the Common Agricultural Policy of the European Union. They derived that an increase in intervention prices for cereals would significantly stimulate farm investments, mainly driven by reduced price uncertainty. Foltz (2004) analysed the impacts of the MILC on entry and exit decisions as well as on farm size in the United States. This study concluded that the presence of a price floor indeed had a positive influence on cow numbers compared to a situation without market intervention. Even though one finding was that results were rather based on keeping smaller farms in business instead of increasing cow numbers on bigger farms.

Using a questionnaire, Reise *et al.* (2010) analysed the decision-making behaviour of German farmers with respect to investments in the bioenergy sector. The authors emphasise the causal connection between the REL's price floor and the respective investment boost that has been observed throughout the last years. However, this study also pointed out the bioenergy investments' dependence on classical agricultural markets (e.g. wheat prices). These markets reflect the opportunity costs for an alternative use of available assets and hence affect the difference between the price floor and the long-run average cost, i.e. the actual level of the price floor.

A theoretical framework concerning price floors has been provided by Chavas (1994). He investigated the effects of sunk costs and uncertainty on production and investment decisions in a normative approach. The study derives a model that is based on Jorgenson's neoclassical theory of investment but also accounts for sunk costs and temporal uncertainty. The results show that sunk cost and temporal uncertainty affect the implicit rental value of capital as well as the investment and entry-exit decisions. Furthermore, the author argues that production efficiency could be increased by government-provided price floors because they reduce the number of firms facing sunk costs and affect the distribution of market price uncertainty.

Dixit and Pindyck (1994: 296 ff.) provided a theoretical framework concerning the ROA and price floors under perfect competition. They assume a time-continuous geometric Brownian motion for the demand development. The effects' dependence on the actual level of the price floor is strongly emphasised. It is stated that a rising price floor causes a reduction of an investment's downside risk. Hence, the investment trigger decreases and the willingness to enter the respective market will be increased. Nevertheless, a price floor that does not cover the long-run average cost would keep the investment trigger above the long-run average cost because new firms need periods with profits to compensate for periods with losses. Only if the price floor rises to the level of long-run average cost the investment trigger would fall to that same level.

With respect to the aforementioned example (i.e. exclusive investment option, I = 10,000, V_0 = 12,000, r = 10% etc.), we now introduce a price floor $V_{\min}$ equal to the investment cost ($V_{\min}$ = 10,000). In figure 1b), the price floor is illustrated by the dashed line which truncates the present values below 10,000. Due to interest effects, long-run average costs are not fully covered by the price floor. The equations (1) and (2) have to be modified for the price floor case. The value of the investment with price floor according to the NPV $\hat{F}^{WPF}$ can be calculated as follows:

$$\hat{F}^{WPF} = \max\left(E(NPV_0)^{WPF};0\right),$$

where (3)

$$E(NPV_0)^{WPF} = \left(\left(p \cdot \max\left(V_{\min};V_0 + h\right) + (1-p) \cdot \max\left(V_{\min};V_0 - h\right)\right) \cdot q^{-1}\right) - I$$

The value of the investment with price floor according to the ROA $\tilde{F}^{WPF}$ is:

$$\tilde{F}^{WPF} = \max\left(E(NPV_0)^{WPF};E(NPV_1)^{WPF} \cdot q^{-1}\right),$$

where (4)

$$\begin{aligned} E(NPV_1)^{WPF} = {} & p \cdot \max\left(0;\left(\left(p \cdot \max\left(V_{\min};V_0 + 2 \cdot h\right) + (1-p) \cdot \max\left(V_{\min};V_0 + h - h\right)\right) \cdot q^{-1} - I\right)\right) \\ & + (1-p) \cdot \max\left(0;\left(\left(p \cdot \max\left(V_{\min};V_0 - h + h\right) + (1-p) \cdot \max\left(V_{\min};V_0 - 2 \cdot h\right)\right) \cdot q^{-1} - I\right)\right) \end{aligned}$$

The investment triggers can be derived analogously to the procedures described above. The investment trigger $\hat{V}_0^{WPF*}$ according to the NPV equals 10,000. The investment trigger $\tilde{V}_0^{WPF*}$ according to the ROA equals 13,143. Due to a higher expected value of the investment returns, the NPV trigger is substantially lower in the WPF scenario. Interestingly, the ROA triggers are almost the same for both scenarios. The ambiguous effects of reduced uncertainty and higher opportunity cost caused by higher expected values of future investment returns outweigh each other to a certain extent in the WPF scenario. Under the assumption that the ROA is superior to the NPV, we derive the third hypothesis:

H_3 'price floor effect': Price floors do not stimulate significantly the decision maker's willingness to invest.

Behavioural Economic Hypotheses

The investigation of two different scenarios in one experiment makes it more complicated to maintain the internal validity of the study (Loewenstein, 1999). The decisions in the one treatment could be influenced by the decisions in the other treatment. That would mean that the observations of both treatments cannot be seen as independent of one another. A fundamental principle to reach the greatest reliability and validity of statistical estimates is therefore the randomisation of the treatments (Harrison *et al.*, 2009) meaning that participants are confronted with different treatments in a different order. Here, the question arises if the order of the WPF and the NPF treatment has an impact on the participants' decision behaviour. Thus, we construct the following hypothesis:

H_4 'order effect': The decision makers' behaviour is dependent on the order of the two investment treatments.

In case *H_4 'order effect'* is confirmed, different effects have to be considered for possible political implications. The reason for this is that the introduction of a price floor is followed by another decision behaviour than the abolishment.

In addition, a general characteristic of many decision situations is that they are repetitive and will often recur several times during an individual's lifetime. In such cases, the decision behaviour is influenced by previous experiences. Over time decision makers learn which options or offers should better be rejected and what kind of good alternatives exist in certain situations. Finally, a certain level of experience is built up regarding repetitive decision situations and individuals make decisions in a more practised manner leading to a higher effectiveness in meeting their objectives (cf. Camerer, 2003; Cheung and Friedmann, 1998). That is why participants in an experiment are often confronted several times with the same treatment. This kind of 'stationary replication' limits the complexity of the tasks carried out in an experiment, but it also is a useful tool to investigate how participants learn in repetitive situations (Loewenstein, 1999). These findings lead to the final hypothesis:

H_5 'learning effect': The decision makers' investment behaviour depends on the number of repetitions of the investment decisions.

In other words: given the complexity of the decision problem, the participants are not capable to make optimal decisions immediately. However, with a rising number of repetitions the efficiency of the actual decision making behaviour will increase more and more.

3. Experimental Setting

The experiment was divided into three parts. The first part consisted of two investment scenarios stylising a WPF (i.e. with price floor) and a NPF (i.e. no price floor) option to invest in farmland. Compared to a between-subject design, the within-subject design has the advantage that there is a considerable gain in statistical power since the two treatments can be compared directly (Abdellaoui *et al.*, 2011). In order to detect the participants' risk attitudes, the second part consisted of a HLL (cf. Holt and Laury, 2002). The last part mainly referred to the participants' socio-demographic characteristics and also included general questions concerning the perception of the experiment.

In the NPF investment scenario the participants had the opportunity to invest in farmland in one of ten years (analogue to an American call option). This means that the participant could either exercise the investment option in one of the years 0 to 9 and receive the present value determined in the following year or not invest at all and save the investment cost (compounded over 10 years). The initial cost was fixed at 10,000 €, which were made available to the participants at the beginning of each repetition. In year 0, the present value of the investment returns was always 10,000 €. In the following years, the present value of the investment developed stochastically according to a discrete arithmetic Brownian motion with no drift, i.e. the probabilities of an up and down movement were equal ($p = 1 - p = 0.5$). The standard deviation of the investment returns amounted to 2,000 €. The risk-free interest rate was set at 10% per year.

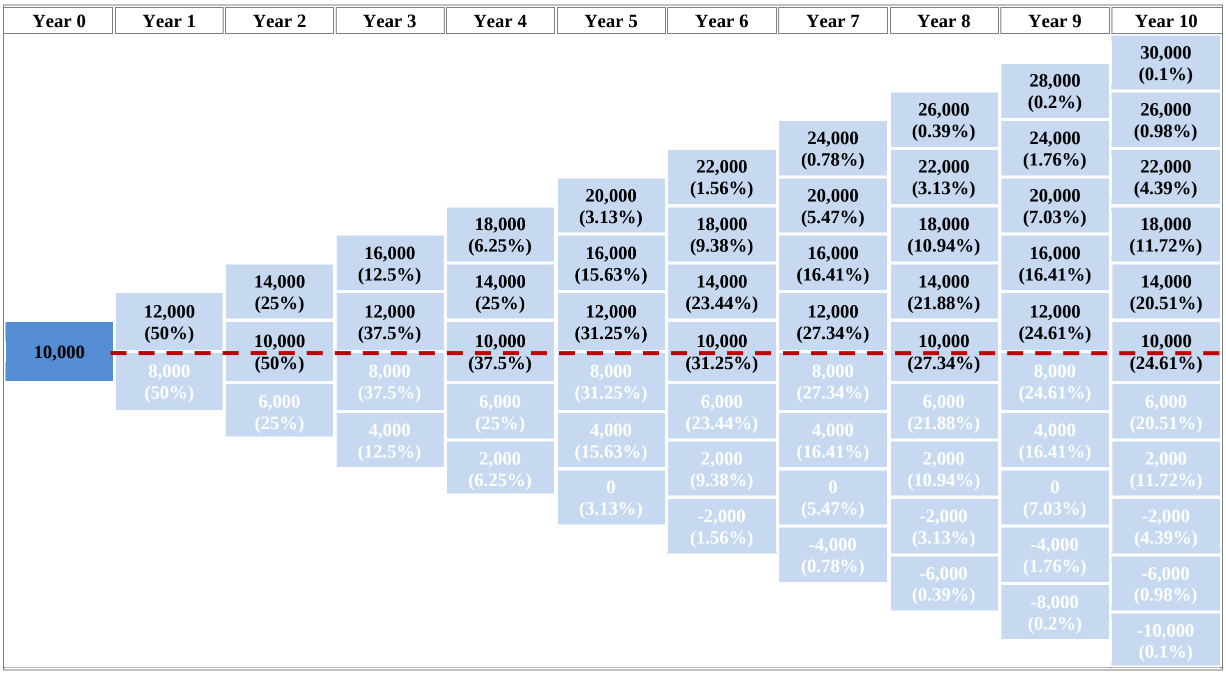
Figure 2 illustrates the binomial tree of potential investment returns (including the corresponding occurrence probabilities) that was shown to the participants. For instance, if the participant decided to invest in farmland in year 0, he/she would have paid the investment cost of 10,000 €. It would have been randomly determined if he/she received either 8,000 € or 12,000 € in year 1. The realised investment returns then gained 10% per year until year 10. The further development of the present value became irrelevant once the investment option was exercised. If the participant decided to wait at first, the analogue investment situation would have been faced in the following year but would start from the randomly determined present value in year 1. Furthermore, irrelevant present values were removed and the remaining probabilities have been adjusted accordingly. This procedure could have been repeated until the expiration of the investment option in year 9.

Year 0	Year 1	Year 2	Year 3	Year 4	Year 5	Year 6	Year 7	Year 8	Year 9	Year 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%)

Note: The associated probabilities of occurrence are indicated in brackets.

Figure 2. Binomial tree of potential investment returns in the NPF treatment (in €)

In the WPF investment scenario, a minimum present value of returns from the farmland investment was guaranteed. The minimum present value of returns was equal to the investment cost. More precisely, the present value develops in accordance with the discrete arithmetic Brownian motion described above. Only if the participant decided to exercise the investment option and indeed observed in the following year a present value less than 10,000 €, a fictional authority would compensate for the difference to 10,000 €. In this case, the participant would only lose one annual interest payment on the investment cost compared to a situation where the participant does not implement the investment. Accordingly, the price floor modelled in this experiment is slightly below the long-run average cost. Besides the price floor, both investment scenarios were absolutely identical. The binomial tree which was shown to the participants in the WPF scenario is illustrated in figure 3.



Note: The associated probabilities of occurrence are indicated in brackets. If the values are shaded 10,000 € will be realised through an investment.

Figure 3. Binomial tree of potential investment returns in the WPF treatment (in €)

Every participant faced ten (individually) randomly determined paths of the binomial tree for each scenario. The scenario without price floor (NPF) is the control treatment. The order in which the two treatments were addressed to the participants was randomised. Before the experiment started the participants were informed about all parameters and assumptions underlying the experimental setting. In order to assure the participant's understanding of the investment experiment a few control questions had to be answered. An additional trial round at the beginning of each treatment gave the opportunity to become familiar with the experimental setting.

Table 1 illustrates the design of the HLL which was imposed in the second part of the experiment in order to elicit the participants' risk attitudes. At this point, participants had to choose between two different lotteries. The 'safe' option A provides the opportunity to either win 200 € or 160 € with certain probabilities. The 'risky' option B provides the opportunity to either win 385 € or 10 € with the same probabilities. In the first situation 200 € and 385 € will be achieved with a probability of 10%, the probability for 160 € and 10 € is 90%, respectively. The probabilities vary systematically by 10%. That is, in the second situation the probabilities amount to 20% and 80%, etc. The participants were confronted with ten different decision situations. The last situation was meant to test whether the participant understood the problem or not. Since the respective high values had a probability of 100% any participant should have preferred option B.

Table 1
Structure of the Holt and Laury lottery

	Lottery A (L_A)	Lottery B (L_B)	Expected gain L_A	Expected gain L_B	Critical constant relative risk aversion coefficient
1	with 10% gain of 200 € with 90% gain of 160 €	with 10% gain of 385 € with 90% gain of 10 €	164 €	48 €	-1.71
2	with 20% gain of 200 € with 80% gain of 160 €	with 20% gain of 385 € with 80% gain of 10 €	168 €	85 €	-0.95
…	…	…	…	…	…
9	with 90% gain of 200 € with 10% gain of 160 €	with 90% gain of 385 € with 10% gain of 10 €	196 €	348 €	1.37
10	with 100% gain of 200 € with 0% gain of 160 €	with 100% gain of 385 € with 0% gain of 10 €	200 €	385 €	-

Note: The last three columns were not shown to the participants. A power risk utility function is assumed.

Option A delivers a higher expected gain in the first four situations. Once the probability ratio amounts to 50:50, option B has a higher expected value. The participants were asked to make a choice in each of the ten situations. A risk-neutral decision maker would focus on the expected value and hence prefer option A in the first four situations and opt for option B in the last six situations. Correspondingly, risk neutrality yields a HLL-value (number of safe choices) of 4. HLL-values below 4 reflect risk seeking behaviour, whereas HLL-values above 4 reveal risk aversion. The respective critical constant relative risk aversion coefficients derived from the power risk utility function are shown in the last column. However, the last three columns in Table 1 were not shown to the participants.

The computer-based experiment was conducted online in June 2011. In total, the experiment took about 30 minutes per subject, whereas participants' choices were not time constrained. In order to encourage attendance, participants received an allowance of 10 €. Moreover, the hypothetical decisions were related to actual payments to ensure incentive compatibility. After all experiments were finished, two attendants were randomly selected. The expected attendance of 100 participants was communicated before the experiment started to allow for a calculation of the expected returns of participation. The first selected attendant received a reward based on the score he/she achieved in a randomly selected repetition of the investment experiment. 2,500 fictional € complied with 100 € of actual payment. Potential payments varied between 200 € and 1,800 €. The second winner received a reward based on the HLL-decisions. In this case, potential payments varied between 10 € and 385 €.

4. Normative Benchmarks

For a feasible evaluation of the actual investment behaviour, normative benchmarks that represent the NPV and the ROA have to be derived. In order to derive the benchmarks, the procedures described in section 2 can be used. However, in the particular context of the experiment, the equations need to be adjusted to the potential number of investment times. Furthermore, we take into account the individual risk attitude.

On the basis of the results from the HLL, the respective risk-adjusted discount rates are determined. In accordance with Holt and Laury (2002), we assume a power risk utility function, which implies a decreasing absolute risk aversion (DARA) and a constant relative risk aversion (CRRA):

$$U(V) = V^{1-\theta} \tag{5}$$

Here U stands for utility, while θ is the relative risk aversion coefficient. On the basis of equation (5), θ can be inferred for each individual from his/her choices in the HLL. Using this information the certainty equivalent CE of a risky prospect and the risk premium *RP* can be determined:

$$CE = V\left(E\left(U\left(V\right)\right)\right) = E\left(U\left(V\right)\right)^{\frac{1}{1-\theta}} = E\left(V\right) - RP \tag{6}$$

$E\left(V\right)$ is defined as the expected value of the investment returns. From the definition of the present value of the certainty equivalent CE_0 of an uncertain payment V_T at time T defined as

$$CE_0 = CE_T \cdot \left(1+r\right)^{-T} = \left(E\left(V_T\right) - RP_T\right) \cdot (1+r)^{-T}, \tag{7}$$

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

$$\begin{aligned} &\left(E\left(V_T\right) - RP_T\right) \cdot \left(1+r\right)^{-T} = E\left(V_T\right) \cdot (1+r+v)^{-T} \\ &\Rightarrow v = \left(1+r\right) \cdot \left(\left(\frac{E\left(V_T\right)}{E\left(V_T\right) - RP_T}\right)^{1/T} - 1\right). \end{aligned} \tag{8}$$

As it can be seen, the risk loading v and hence the risk-adjusted discount rate $r+v$ are dependent on the risk premium *RP* as well as on the length of the discounting period *T*

For determining the risk-adjusted discount rate, we impose a simplification to make the calculation of the exercise frontier tractable. First, when determining the risk-adjusted discount rate by equation (8), we fix the level of the returns at its initial value. Second, we fix *T* at five periods in equation (8). The risk adjusted discount rates which have been derived for the specific cases of the experiment vary between 9.3% (HLL-value = 0) and 10.6% (HLL-value = 9) in the NPF treatment and 7.8% and 8.1% in the WPF treatment, respectively. The lower level and the smaller range of the discount rates in the WPF treatment can be explained by higher expected values of the investment returns and reduced uncertainty.

Whereas the normative benchmark of the NPV can be derived relatively easy, the exercise frontier of the ROA needs to be identified using dynamic stochastic programming (Trigeorgis, 1996: 312). The determined normative benchmarks stand for the ‘optimal’ solutions for the investment triggers according to the NPV and the ROA. Figure 4 depicts the exercise frontiers of a risk-neutral decision maker for both investment scenarios, i.e. with and no price floor.

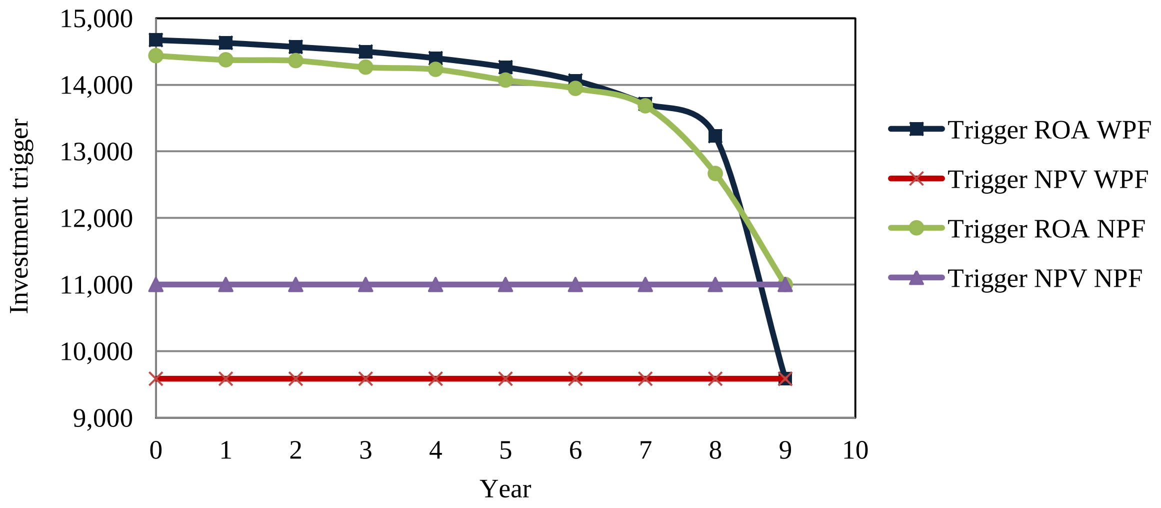


Figure 4. Investment triggers for a risk-neutral decision maker

The exercise frontiers of the ROA decrease exponentially reflecting the diminishing time value of the investment option. As required by theory, the respective ROA trigger equals the NPV trigger in year 9 when no further delay is possible and the value of waiting is 0. The exercise frontiers change slightly according to the risk attitude but the basic structure is maintained.

5. Experimental Results

We carried out the experiment with students as a convenience sample. Due to the announcement process, the vast majority of the participants are German students of agricultural sciences, even though access was not restricted to this group. Altogether, 101 students completed the entire experiment. Therefore, the dataset contains 2,020 investment decisions and 101 HLL-values.

Table 2 summarises some selected characteristics of the sample group as well as the general investment behaviour observed during the experiment. The average HLL-value of 5.7 reveals that the sample was on average risk-averse. Against the background that students have been acquired for the experiment, the relatively young average age of 23.9 years and the low standard deviation of 2.9 years are easily explicable. The same reason accounts for the balanced gender share. Interestingly, almost 60% of the participants have an economic background.

Since it is relatively difficult to acquire agricultural entrepreneurs for experimental research, we utilised students as a convenience sample in this case. However, 96% of the participants study agricultural sciences, 18.8% completed an agricultural training program before they took up their academic studies and 38.6% will take over the farm of their parents in the (near) future. Hence, we analyze the decision-making behaviour of participants with an agricultural background or a strong relation to the agricultural sector. Therefore, a pronounced share of the participants represents the farmers of tomorrow.

Table 2
Descriptive statistics

Parameter	**NPF treatment with 1,010 decisions**	**WPF treatment with 1,010 decisions**
Average HLL-value	5.7 (1.9)	
Average age of participants	23.9 years (2.9 years)	
Share of female participants	47.5%	
Share of economical education	59.6%	
Share of agricultural training	18.8%	
Share of farm successor	38.6%	
Actual average investment year without cases in which non-investment is observed	3.9 (2.8)	4.2 (3.0)
Actual share of non-investment	23.6%	22.2%
Normative average investment year according to the NPV without cases in which non-investment is predicted	2.3 (2.1)	0.0 (0.0)
Normative share of non-investment according to the NPV	22.3%	0.0%
Normative average investment year according to the ROA without cases in which non-investment is predicted	5.9 (2.1)	7.6 (2.2)
Normative share of non-investment according to the ROA	43.7%	0.0%

Note: The respective standard deviations are indicated in brackets.

The actual average investment year (excluding non-investment cases) was 3.9 in the NPF and 4.2 in the WPF treatment. The investment option was not exercised in approximately 23% of all cases. The optimal average investment year (excluding non-investment cases) predicted by the NPV was year 2.3 in the NPF treatment and year 0.0 in the WPF treatment. Respectively, non-investment was predicted in 22.3% and 0.0% of the cases. The remarkable predictions made by the NPV in the WPF scenario can be explained by the low discount rates, which cause a drop of the investment trigger below the initial present value of the investment returns as well as the price floor. The optimal average investment year (excluding non-investment cases) predicted by the ROA for the NPF treatment was year 5.9 and the share of non-investment amounted to 43.7%. The respective values for the WPF treatment are 7.6 and 0.0%. One has to keep in mind that the latter figures are predominantly biased by the predictions made for the last year. At this point, the ROA benchmark equals the NPV benchmark and an investment is predicted in any case in the WPF treatment. Moreover, the actual standard deviations (approximately 2.9) were remarkably higher than the expected standard deviations.

Test of H_1 'NPV consistency' and H_2 'ROA consistency'

A first hint for the validity of the hypotheses H_1 *'NPV consistency'* and H_2 *'ROA consistency'* is given by Table 2, which illustrates that participants invested on average much later than predicted by the NPV and much earlier than predicted by the ROA in either treatment. However, for an exact analysis one has to keep in mind that in approximately 23% of the 2,020 investment situations a defined year of investment was not observed. In these cases, the data point is above a certain value, i.e. the data is right-censored. Hence, ordinary comparisons of means were not applicable and, therefore, a fundamental part of the following data analysis is based on the Kaplan-Meier survival estimator (Kaplan and Meier, 1958). The latter is a well-known non-parametric method for analysing data with sampling bias that takes into account censored data. Moreover, it is principally used in medical research to estimate the survival function from life-time data (Hougaard, 1999).

Figure 5 compares the actual survival function to the survival functions of the respective NPV and ROA benchmarks. These curves illustrate the cumulative survival of the investment options. The size of each step reflects the share of investment options executed in the respective year.

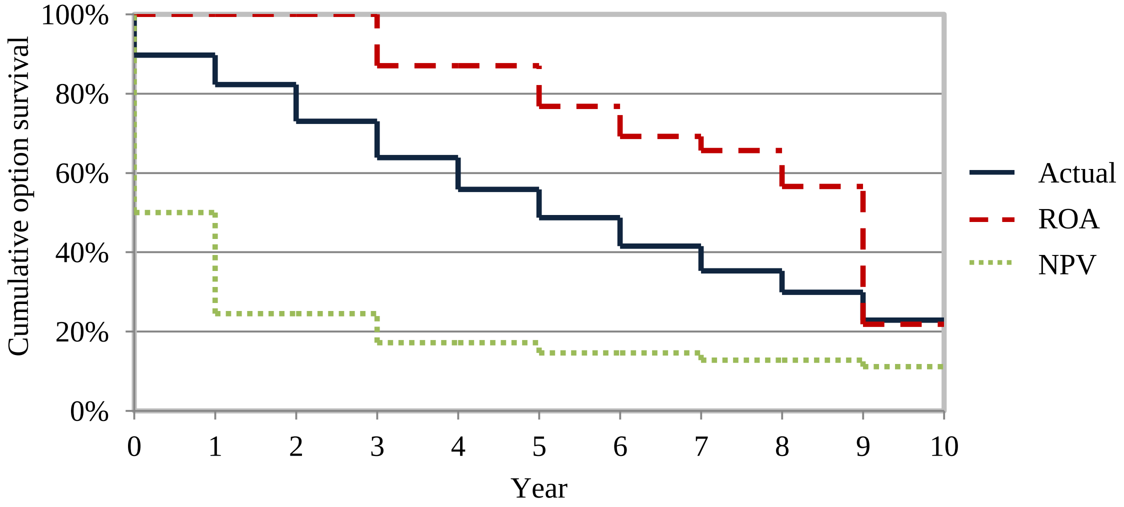


Figure 5. Survival functions of actual and optimal investment behaviour according to the ROA and the NPV

The Kaplan-Meier analysis reveals that the actual and the predicted survival functions differ significantly from each other. A log-rank test with regards to the equality of the respective survival functions derives a p-value smaller than 0.001. An additional analysis that investigated both treatments separately derives similar results. As it can be seen in Figure 5, the actual survival function is constantly above the NPV-predicted survival function and below the ROA-predicted survival function. That is, participants tended to invest too late according to the NPV and too early according to the ROA (cf. also Table 2). Against this background, H_1 *'NPV consistency'* and H_2 *'ROA consistency'* have to be rejected for the aggregated dataset as well as for the separate treatments. The actual investment behaviour has neither been consistent with the predictions made by the NPV nor with the predictions made by the ROA.

Test of H_3 'price floor effect'

In order to test H_3 *'price floor effect'* we compare the investment behaviour in both treatments. The investment behaviour did not differ substantially in any of the scenarios. In both treatments the actual average investment year (excluding non-investment cases) was nearly 4 and approximately 23% of all investment options were not executed (cf. Table 2). Figure 6 illustrates the survival functions for both treatments. The log-rank test reveals a p-value of 0.690 and hence gives statistical evidence for the equality of the survival functions.

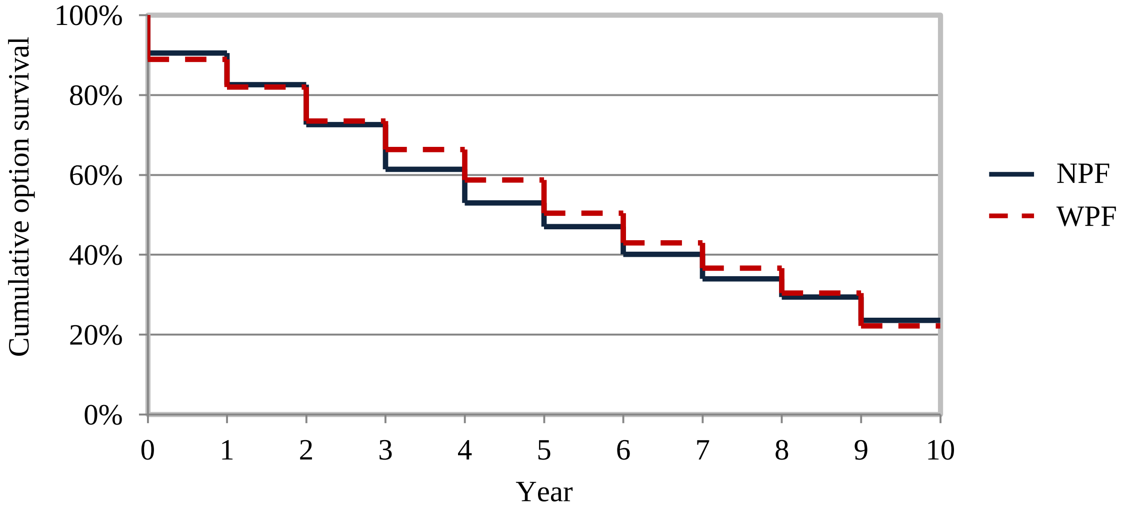


Figure 6. Comparison of the survival functions for WPF and NPF treatment

These results lead to the conclusion that the price floor does not affect the participants' behaviour. That is, H_3 *'price floor effect'* is not rejected: In our experiment price floors do not stimulate investments. At this point, however, one has to keep in mind that the price floor implemented in this experiment is slightly below the long-run average cost. The above mentioned analyses regarding the impacts of price floors referred either directly or indirectly to the importance of the price floor's actual level. For instance, Sckokai and Moro (2009) stated that an increasing intervention price would significantly stimulate farm investments. The level of the price floor assumed in our experiment might still be too low to cause significant effects.

Test of H_4 'order effect' and H_5 'learning effect'

Each participant was confronted with ten repetitions of two scenarios. In order to reach greater reliability and validity of the statistical data the treatment order has been randomised. One part of the sample (group 0; N = 43) faced at first the NPF scenario without any market intervention. After ten repetitions the participants played the WPF scenario. The other part of the sample (group 1; N = 58) faced both treatments in reverse order.

In order to investigate H_4 *'order effect'* and H_5 *'learning effect'* a nonlinear Tobit regression which regressed the actual investment year on the group-variable and the variable 'repetition' was carried out. Further explanation variables are a treatment dummy as well as socio-demographic variables. In our case, the Tobit regression is advantageous in contrast to ordinary least squares (OLS) regression models because the dependent variable is limited. OLS estimators would be biased since they neglect censored data. The Tobit regression includes a correction mechanism for this error of estimation (Tobin, 1958).

The results of the Tobit regression are shown in Table 3. Regarding the socio-demographic characteristics, Table 3 depicts positive and significant coefficients for the variables 'HLL-value', 'age', 'gender', and 'economical education'. That means people with a higher risk aversion and/or a higher age tended to invest later. Also, female participants and participants that received an economic education invested later. A completed agricultural training program and the fact that a student will take over the farm in the future did not affect the participants' investment behaviour significantly. The insignificant coefficient of the variable 'treatment' reinforces the results of the H_3-analysis.

Table 3
Tobit regression of the actual individual investment year on selected variables (N = 2,020)

Parameter	**Coefficient**	**Standard error**	**p-value**	
Constant	0.204	0.941	0.828	
HLL-value	0.356	0.052	<0.001	***
Age	0.073	0.039	0.063	*
Gender (0 = male; 1 = female)	0.613	0.234	0.008	***
Economical education (0 = no; 1 = yes)	0.504	0.209	0.016	**
Agricultural training (0 = no; 1 = yes)	0.249	0.302	0.410	
Farm successor (0 = no; 1 = yes)	0.347	0.215	0.107	
Treatment (0 = NPF; 1 = WPF)	0.258	0.195	0.187	
Group (0 = NPF-WPF; 1 = WPF-NPF)	0.478	0.202	0.018	**
Repetition	0.077	0.017	<0.001	***

Note: $\chi2$ = 120.027; Log-Likelihood = -4,955.172. *; **; *** marks significance at the 10%-, 5%- and 1%-level, respectively.

The coefficient of the dummy-variable 'group' is positive and significant at the 5%-level. Accordingly, the sample group which was confronted first with the WPF treatment and second with the NPF treatment tended to invest later over both treatments than the sample group which received the treatments in reverse order. That means that the treatment order did indeed affect the participants' investment behaviour and H_4 *'order effect'* is not rejected.

The test of H_4 *'order effect'* reveals that participants who moved from the WPF to the NPF treatment were more inert over both treatments than participants that moved from the NPF to the WPF treatment. With respect to policy impact analyses, we draw the conclusion that there are comparatively minor increases in the willingness to invest, which can be expected from introducing price floors (change from NPF to WPF), but comparatively pronounced increases of inertia, which can be expected from the abolishment of price floors (change from WPF to NPF).

The H_5 *'learning effect'* can be investigated by considering the variable 'repetition'. This variable has values between 1 and 20 and reflects the respective investment situation for each participant independently from the treatment order. The coefficient is positive and significant at the 1%-level. The more repetitions an individual participant has passed the later he/she invested. Regarding the outcomes of the H_2 *'ROA consistency'* that participants invested too early in comparison to the ROA-predicted investment behaviour, the observed development can be interpreted as a learning effect in favour of the ROA: Participants invested later and learned from their experiences in previous repetitions. Therefore, the ROA can approximate the actual investment behaviour better and better over time. Against this background, H_5 *'learning effect'* is not rejected.

The following Table 4 summarises the experimental results with regard to the validity of the outlined hypotheses.

Table 4
Validity of hypotheses

Hypothesis	**Validity**
H_1 'NPV consistency': The investment behaviour of participants is consistent with the NPV.	Rejected
H_2 'ROA consistency': The investment behaviour of participants is consistent with the ROA.	Rejected
H_3 'price floor effect': Price floors do not stimulate significantly the decision maker's willingness to invest.	Failed to reject
H_4 'order effect': The decision makers' behaviour is dependent on the order of the two investment treatments.	Failed to reject
H_5 'learning effect': The decision makers' investment behaviour depends on the number of repetitions of the investment decisions.	Failed to reject

6. Conclusions

Price floors are a common instrument for public market intervention. Especially agricultural policies have frequently used this mechanism to stimulate investments and hence assure supply security for respective commodities. In order to adequately predict the impacts of a political change on investment conditions, the understanding of the relationship between price floors and actual investment behaviour is of remarkable importance. The existing literature mainly includes normative and econometric approaches which derived partially conflicting results. In view of these aspects, this study experimentally investigates price floor effects on investment behaviour. The implemented experiment is computer-based and considers an investment problem, stylising a decision to take an ongoing investment opportunity. Each participant faced one treatment with a price floor. Another treatment without market intervention constituted the control treatment. The price floor was set slightly below the long-run average cost. Since the ROA has received increasing attention with regards to investment behaviour analyses, this framework is also considered as a benchmark additionally to the classical investment theory.

The main results derived from the experiment were at first that the participants' investment behaviour differed substantially from the predictions made by the NPV and the ROA. Predominantly, investment options were exercised too late according to the NPV and too early according to the ROA. However, a second finding that reinforces the predictive power of the ROA was that participants learned from personal experience during the experiment and approached the ROA benchmarks over time. Third, the actual investment behaviour did not differ significantly in general with respect to the presence of a price floor. An explanation for this finding could be the actual level of the implemented price floor. A higher price floor level could have a significant impact on investment decisions. Fourth, we derived from the order effect analysis that those participants who were first faced with the WPF treatment and second with the NPF treatment tended to invest more inert over both treatments than participants who faced the treatments in reverse order. With regards to the analysis of policy impacts, this result shows that the changes arising from an abolishment of a price floor are relatively big compared to the changes arising from the introduction of a price floor.

The apparently high relevance of the actual level of the price floor provides a hint for further research. A modified experiment with, e.g., changing price floor levels might be revealing. Potential interdependencies of a price floor and, e.g., the investment cost, which have not been in the focus of this study, could be investigated in this framework as well. Also, the impacts of other intervention tools, e.g., investment aids could be analysed experimentally in a real options context. Furthermore, one has to keep in mind that this contribution is based on a convenience sample (i.e. students) and a very specific framing (i.e. farmland investments). In order to increase the results' validity it would be helpful to investigate the behaviour of different groups in different framing situations, e.g., investment decisions of farmers in a livestock context.

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