Investment behavior in agriculture—an analysis of the explanatory potential of the real options approach

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Dulat Tubetov
born in Astana (Kazakhstan)

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1. Name of supervisor: Prof. Dr. Oliver Musshoff

2. Name of co-supervisor: Prof. Dr. Stephan v. Cramon-Taubadel

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I. Introduction

Objectives of the study

The investment decision is the decision to allocate the company's resources to particular projects with the aim to achieve greater monetary and other profits in the future (Butler, 1993, p. 49). The investment decision represents one of the most important types of decisions for the economy as a whole and for the particular company. For the economy as a whole, aggregated investment made in the current period is the main factor determining aggregated demand and therefore the level of employment. To the particular company, investment decisions made by the entrepreneur have a great influence on the operating environment of the company for the rest of the investment's life. The survival and future prosperity of the company will therefore depend considerably on the quality of such decisions (Pike and Dobbins, 1986, pp. 3–4). Hence, it is important to be able to analyze investment decisions correctly.

The classical investment theory is an established theory that has been applied successfully for many years for the valuation of investment decisions. According to this theory, the value of the investment corresponds to its net present value (NPV), which is the present value of future cash flows minus the investment cost (Ross et al., 2008, p. 91). The basic NPV rule is to accept a project if the NPV is greater than zero or to reject a project if the NPV is less than zero (Ross et al., 2008, p. 162). However, in reality, it can be observed that companies show investment inertia, adjusting investments very slowly (Bowman and Hurry, 1993). They do not invest even if the NPV of the investment is positive. The reason as to why the classical investment theory fails to correctly predict the investment decisions of companies might be the fact that it cannot properly capture the entrepreneurial flexibility to defer investment decisions. In contrast to the classical investment theory, a new investment theory—referred to as the real options (RO) approach—allows for the entrepreneurial flexibility to postpone an investment decision. The RO approach asserts that a company may increase returns by postponing an investment decision instead of realizing the investment immediately, even if it has a positive NPV. The value of waiting is especially pronounced if the expected returns of the investment are uncertain and the investment costs are at least partially sunk or irreversible (Pindyck, 1991). When a company makes irreversible investment expenditure, it gives up the possibility of waiting for new information that might influence the desirability or timing of the expenditure. This lost option value is an opportunity cost that must be included in the cost of the investment and has to be covered by the expected investment returns. As a result, this requires a higher investment trigger than that suggested by the NPV rule in order to make an investment decision (Dixit and Pindyck, 1994, pp. 6–9).

Three preconditions must be fulfilled to meaningfully render the application of the RO approach: uncertainty of returns, irreversibility of investment costs, and flexibility regarding investment timing. These three preconditions are present in the context of many types of investments in agriculture. There are applications of the RO approach for various investment problems in agriculture, in general, including the investments in a pig-fattening farm in Finland (Pietola and Wang, 2000), the adoption of organic farming in Germany and Austria (Musshoff and Hirschauer, 2008) and a greenhouse construction project in Greece (Tzouramani and Mattas, 2004). The RO approach is also widely used to analyze investment problems in dairy farming, including the investment in the technology adoption of free-stall dairy housing in the USA (Purvis et al., 1995) or in automatic milking systems in the USA (Engel and Hyde, 2003). Tauer (2006) employs real options to assess the milk prices that affect the decisions of New York dairy farmers to enter and exit dairy farming.

The first objective of the study is to analyze if the RO approach has an explanatory potential regarding the reluctance of Kazakhstani farmers to invest in modern dairy farming. Currently, one can observe a situation when Kazakhstani farmers are not willing to invest in modern dairy farming although the investment in modern dairy farming is profitable (Agency of Statistics of the Republic of Kazakhstan (ASRK), 2011; Press center of KazAgroFinance, 2011). In particular, the following questions must be answered:

1. Does the RO approach have an explanatory potential regarding the reluctance of Kazakhstani farmers to invest in modern dairy farming?
2. How do different risk attitudes of decision makers influence the level of investment triggers in Kazakhstani modern dairy farming?
3. How do different stochastic processes influence the level of investment triggers in Kazakhstani modern dairy farming?

Despite the fact that the RO approach is more advantageous compared to the NPV approach when valuing investment decisions (Luehrman, 1998; Park and Herath, 2000), it still remains widely open if this approach is valid for explaining the investment behavior of farmers. Several econometric studies tried to provide evidence for the validity of the RO approach in an agricultural context (Wossink and Gardebroek, 2006; Hinrichs et al., 2008; Hill, 2010). The observation of farmers' investment behavior is complicated for some reasons. First, it is difficult to obtain sufficient data on investments in capital intensive objects (e.g. a cow barn or a biogas plant) as such investments are not made very often (Gardebroeck and Oude Lansink, 2008). Second, farmers have different levels of financial capability (Wale et al., 2005; Joshi and Pandey, 2006) that significantly influences their investment behavior. Experiments can be chosen as an alternative way of testing the validity of the RO approach in order to explain the investment behavior of farmers. In laboratory experiments, the researcher has the control over nearly all aspects of the economic and institutional context, which provides a high internal validity of the research (Roe and Just, 2009).

Studies using laboratory experiments for testing the validity of the RO approach in explaining the investment behavior of entrepreneurs are scarce (Rauchs and Willinger, 1996; Howell and Jägle, 1997; Yavas and Sirmans, 2005; Oprea et al., 2009; Denison, 2009; Sandri et al., 2010). Most of the existing studies conduct experiments with students and entrepreneurs in Western industrialized countries. It is still not clear to what extent the results of the experiments investigating the investment behavior of farmers in Western industrialized countries are applicable to farmers in transforming countries. Therefore, the second objective of the study is to experimentally examine the investment behavior of Kazakhstani and German farmers. In particular, the following questions must be answered:

1. Is the investment behavior of farmers consistent with the NPV approach or the RO approach?
2. Is the investment behavior of German farmers closer to the optimal investment behavior predicted by the RO approach than those of Kazakhstani farmers?
3. Do farmers learn from their experience during the experiment and time their investment decisions closer to the optimal periods predicted by the RO approach over the repetitions?

Structure of the dissertation

The dissertation consists of two articles, which answer the questions mentioned before. These two articles constitute the main part of this dissertation and each of them represents a separate study. These two articles are followed by a short summary and a discussion. Having previously been given an introduction to the concept of the RO approach and to the experimental investigation of the validity of the RO approach, subsequently a problem statement, objectives, methods and results of the two contributions are summarized.

In the first article titled “Investments in Kazakhstani dairy farming: a comparison of the classical investment theory and the real options approach”, a situation is considered in which Kazakhstani farmers are reluctant to invest in modern dairy farming although the investment in modern dairy farming is profitable. The objective of the article is to analyze if the RO approach has an explanatory potential for the observed reluctance of Kazakhstani farmers to invest in modern dairy farming. For this purpose, the authors calculate the investment triggers and the option values by taking into account the uncertainty, the irreversibility, and the entrepreneurial flexibility to postpone the investment in modern dairy farming. The obtained results are compared with those of the NPV approach. Based on the results of a comparison between the NPV approach and the RO approach, it will be possible to determine if the effects of the RO approach have a practical relevance. The risk aversion of decision makers is considered by using risk-adjusted interest rates. A further objective of the study is to analyze the sensitivity of the modeling results regarding the assumed stochastic process of the stochastic variable. A numerical option-pricing model based on the stochastic simulation and the parameterization of investment triggers is applied for the calculation of the investment triggers and the option values for a virtual, exemplarily considered farm. The results show that farmers should not invest in modern dairy farming until the present value of the investment returns considerably exceeds the investment costs. Thus, they confirm that the RO approach has an explanatory potential regarding the observed reluctance to invest. This study confirms that a more risk-averse farmer is more reluctant to invest. This can be observed from the fact that the investment triggers rise whenever the interest rates rise. This result is valid in the context of the NPV approach as well as the RO approach. In addition, it was found that the postponement of the investment is less beneficial at a higher discounting rate. This can be observed from the value of the investment multiple that decreases in comparison to a situation in which only the flexibility regarding the timing of the investment decision is taken into account and not the risk aversion at the same time. The investment multiple equals the ratio of the critical present value calculated according to the NPV approach or the RO approach to the investment costs. Furthermore, the model calculations illustrate that the results depend considerably on the type of the stochastic process underlying the valuation. The investment trigger based on the assumption of an arithmetic Brownian motion, which seems most plausible for the current application, is smaller than that based on an autoregressive process of order one and a geometric Brownian motion.

The objectives of the study presented in the second article titled “Real Options or Net Present Value? An experimental approach on the investment behavior of Kazakhstani and German farmers” are supposed to experimentally examine the investment behavior of farmers in Kazakhstan as a transforming country and in Germany as a Western industrialized country. Furthermore, it should be tested if the investment behavior of farmers is consistent with the NPV approach or with the RO approach. A further objective of the study is to analyze if the investment behavior of German farmers is closer to the optimal investment behavior predicted by the RO approach than that of Kazakhstani farmers. The presence of a learning effect in the investment behavior of farmers is also investigated. In particular, it is analyzed whether farmers learn from their experience during the experiment and time their investment decisions closer to the optimal periods predicted by the RO approach over the repetitions. To achieve the objectives of the study, an experiment on repeatedly ongoing investment opportunities in an agricultural and in a non-agricultural treatment is carried out. As the investment behavior could be influenced by the decision makers' risk attitudes (Knight et al., 2003), an additional experiment based on a Holt and Laury lottery (HLL) (Holt and Laury, 2002) is conducted. The results show that the NPV approach and the RO approach cannot exactly predict the investment behavior of Kazakhstani as well as German farmers. However, it was found that German farmers time their investment decisions closer to the investment periods predicted by the RO approach than Kazakhstani farmers. This might imply that German farmers are more likely to take into account the value of flexibility when making investment decisions than Kazakhstani farmers. Moreover, this finding shows that it is not acceptable to apply the results of the experiments investigating the investment behavior of entrepreneurs in a transforming country to entrepreneurs in a Western industrialized country and vice versa. As a result of testing the presence of a learning effect in the investment behavior of farmers, it was found that, with each repetition, the average investment period of farmers increases continuously into the direction of the optimal investment periods predicted by the RO approach. This suggests that farmers learn from their investment decisions over the repetitions and develop investment timing that is closer to the RO approach.

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II. Investments in Kazakhstani Dairy Farming: A Comparison of the Classical Investment Theory and the Real Options Approach

Authors: Dulat Tubetov, Oliver Musshoff, Ulla Kellner

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Abstract

This study analyzes the explanatory potential of the real options approach (ROA) regarding the reluctance of Kazakhstani farmers to invest in modern dairy farming. More precisely, it compares the valuation of the ROA with that of the classical investment criterion such as the net present value (NPV). A further objective is to analyze the sensitivity of investment triggers with respect to assumed stochastic processes. To do so, an option-pricing model, which combines the stochastic simulation and the parameterization of investment triggers, is suggested. The results reveal that the investment trigger given by the ROA is considerably higher than the one given by the NPV criterion. This verifies that the ROA has an explanatory potential for the reluctance of farmers to invest in modern dairy farming. In addition, it was found that the option-pricing results indicate a high sensitivity regarding different stochastic processes as well as risk attitudes.

Keywords: real options approach, stochastic simulation, stochastic process, dairy farm investment, Kazakhstan

JEL classification: D92, Q12, C15

1 Introduction

The volume of the Kazakhstani dairy market is 5.3 million tons of milk produced per year with an annual growth rate of 2% (Agency of Statistics of the Republic of Kazakhstan (ASRK), 2007-2011). This growth rate is mostly maintained by increasing the total number of cows. During the period between 2006 and 2010, the total number of cows increased by 2% per year and added up to 2.8 million heads in 2010. In this amount, the percentage of highly productive pedigree cows is only 1.4% (ASRK, 2007-2011; Press center of KazAgroFinance, 2011). It should be noted that 84% of the cows in Kazakhstan are kept by subsistence farms that exploit low productive cows. Fresh cow milk production by subsistence farms, which amounts to about 90% of the total fresh cow milk produced in Kazakhstan, is characterized by seasonality and often does not meet fresh cow milk quality requirements demanded by milk companies. As a result, only 10% of this fresh cow milk is suitable for industrial processing, which satisfies only 20-25% of the demand of milk companies (Abdishukuruli, 2011). One potential way to cover the shortage of fresh cow milk is the establishment of modern dairy farms.

A weak tendency of investing in modern dairy farming has been observable in Kazakhstan in the last few years. Today, there are only 11 modern dairy farms in Kazakhstan, which produce 55,700 tons of fresh cow milk per year. The entire investment costs for the establishment of these dairy farms equal €72.03 million (Press center of KazAgroFinance, 2011). These modern dairy farms are characterized by two main features that distinguish them from conventional dairy farms. First, the milk yield of the dairy herd is much higher than that of conventional farms because the modern dairy farms exploit highly productive foreign breeds. During the last four years, 4,443 highly productive pedigree cattle of a Holstein-Friesian breed have been imported from Canada and Hungary by 11 existing modern dairy farms. The average annual milk yield of the existing modern dairy farms is 7,000 kg per cow (Press center of KazAgroFinance, 2011). In contrast, the annual cow milk yield of conventional dairy farms is only 2,250 kg per cow (ASRK, 2007-2011). Second, the modern dairy farms possess up-to-date equipment and technology, which are on the one hand, very expensive, and, on the other hand, can lower labor costs as well as equipment operational costs up to 50% (KazAgroFinance (KAF), 2009). Furthermore, the automation of processes in cattle housing increases the quality of work performed. As a result of these characteristics, investments in Kazakhstani modern dairy farming are expected to be profitable. For example, the expected net present value (NPV) of the investment in a 1,000-cow modern dairy farm equals €1.67 million (Rodina ltd., 2010). Although the investment in modern dairy farming is profitable, no significant increase is observable in the proportion of modern dairy farms to the total amount of Kazakhstani dairy farms (ASRK, 2007-2011; Press center of

KazAgroFinance, 2011). This provides a first evidence for the reluctance of Kazakhstani farmers to invest in modern dairy farming.

For investment reluctance, different explanations can be found in the economic literature. Among these explanations are financial constraints (Hu and Schiantarelli, 1998; Huettel et al., 2010) and non-monetary intentions of the decision maker (Ison and Russell, 2000). Studies focusing on the investment behavior of farmers in post-communist economies, in general, as well as those examining the investment reluctance of Kazakhstani farmers, in particular, are scarce. There are two studies about the investment behavior of Russian farmers (Bokusheva et al., 2007) and about the problem of land development in Kyrgyz Republic (Scandizzo and Savastano, 2009). When it comes to studies about the investment reluctance of Kazakhstani farmers, two studies are worth mentioning. A study conducted by the Kazakhstani governmental marketing company, KazAgroMarketing, explains the investment reluctance by the high level of risk associated with modern dairy farming. The high level of risk in modern dairy farming is caused by demand shocks, the seasonality of fresh cow milk production, the absence of price-stabilizing policies, and animal diseases (KAM (KazAgroMarketing), 2009).Van Engelen (2011) posits limited capital access as one of the main factors that leads to a low level of investments in dairy farming.

The real options approach (ROA) is another explanatory approach for investment reluctance (Dixit and Pindyck, 1994). This approach asserts that an investor might increase returns by postponing an irreversible investment decision instead of investing instantly despite of the fact that it has a positive NPV. Therefore, in order to realize an investment project, the investment trigger according to the ROA is significantly higher than that according to the NPV criterion. The application of the ROA is only justified if an investment is characterized by the uncertainty of returns, irreversibility of the investment costs, and flexibility regarding investment timing. An investment in modern dairy farming has these properties.

There are applications of the ROA for various investment problems in agriculture, in general, including investments in the hog finishing in Germany (Odening et al., 2005), coffee planting in Vietnam (Luong and Tauer, 2006), irrigation technology adoption in the Texas High Plains (Seo et al., 2008), and food safety in the USA (Richards et al., 2009). The ROA is also widely used to analyze investment problems in dairy farming, including investment in the technology adoption of free-stall dairy housing in the USA (Purvis et al., 1995) or in automatic milking systems in the USA (Engel and Hyde, 2003). Tauer (2006) employs real options to assess the milk prices that affect the decisions of New York dairy farmers to enter and exit dairy farming.

With this background information, the objective of this study is to analyze if the ROA has an explanatory potential for the reluctance of Kazakhstani farmers to invest in modern dairy farming. For this purpose, we calculate the investment triggers as well as the option values by considering the uncertainty, the irreversibility, and the entrepreneurial flexibility to defer the investment in modern dairy farming. The results are compared to those of the NPV criterion. The determination of the differences between the ROA and the NPV allows conclusions whether option values practically matter in modern dairy farming or not. Different risk attitudes of decision makers are analyzed by using different risk premiums for the discount rate. Investment costs and stochastic patterns of gross margins generated by different groups of modern dairy farms (including subsistence farms) or even individual investment projects would be the best input data for our calculation. Since it was impossible to obtain this kind of data, we used the data obtained from just one Kazakhstani modern dairy farm. Therefore, the investment triggers and the option values are calculated for a virtual, exemplarily considered farm. Consequently, the results cannot be used as a decision support for all Kazakhstani farmers but only as preliminary evidence that the combined effects of uncertainty and sunk costs have an explanatory potential regarding the reluctance of farmers to invest in modern dairy farming.

Most applications of the ROA in agriculture as well as in dairy farming assume a priori a geometric Brownian motion underlying a stochastic variable in order to enable the use of convenient analytical option pricing methods (Purvis et al., 1995; Engel and Hyde, 2003; Tauer, 2006; Richards et al., 2009). Therefore, a further objective of our study is to analyze the sensitivity of the investment triggers with respect to the assumed stochastic process. We believe that an unbiased and open estimation of the stochastic processes needs more attention when applying real options models. Presenting the results for different stochastic processes shows the bias that might be caused by the assumption of a wrong stochastic process.

To our knowledge, this is the first study dealing with the application of the ROA in the agricultural sector of Kazakhstan. Apart from the specific application, a numerical option-pricing method based on the stochastic simulation and the parameterization of investment triggers is suggested, which enables the handling of different stochastic processes.

The remainder of the article is structured as follows: section 2 briefly describes explanatory approaches besides the ROA for the investment reluctance of Kazakhstani farmers. The theoretical background of the real options valuation is explained in section 3. Section 4 presents the model assumptions as well as the data used in this study, while section 5 describes the option-pricing model. The results of the application of the ROA are discussed in section 6. Finally, the paper ends with conclusions in section 7.

2 Classical explanatory approaches for reluctance to invest

As it has already been mentioned in the introduction, the objective of this study is to analyze if the ROA has an explanatory potential for the reluctance of Kazakhstani farmers to invest in modern dairy farming. Besides ROA effects, there is a wide range of other factors and approaches, which might explain the investment behavior of farmers. In the following, we describe the main factors and approaches.

1. *Capital access:* one of the main problems hampering investments in Kazakhstani modern dairy farming is constrained access to credit. Van Engelen (2011) indicates that most of small-sized farms in Kazakhstan have constrained access to credit because they are not able to provide enough collateral that is required by crediting organizations. Medium-sized and large farms with assets have access to credit. However, livestock development activities need a long time frame for repayment and an initial grace period. Hence, the currently available credit products and interest rates are not attractive for livestock farms (van Engelen, 2011). The Kazakhstani governmental leasing company, KazAgroFinance (KAF), provides credit and leasing products with low interest rates mainly for agricultural machinery and large-scale farming investments. The KAF prefers to financially support those farmers who already have experience in the establishment of livestock farms (KAF, 2009). In many developing countries, small-sized farms obtain credit from microcredit organizations. The Agrarian Kredit Korporatia, part of KAF, has a microcredit facility that operates through rural credit cooperatives. But van Engelen (2011) posits that such organizations have appeared in Kazakhstan recently, and it therefore is too early to tell whether they are making credit available to the people who need it most.

2. *Production parameters and managerial abilities:* since the herd size is one of the factors influencing the cost structure of a dairy farm, different herd sizes might cause different investment behaviors of farmers. Compared to dairy farms with large herd sizes, dairy farms with a small herd size need a higher milk price to invest in dairy farming (Tauer, 2006). The milk productivity per cow is another factor, which has a positive impact on a farmer's decision to invest (Stokes, 2006).

It is very important to have experienced managers and workers who are able to manage a modern dairy farm with a large herd size. Unfortunately, nowadays, the Kazakhstani agricultural sector is facing a pressing problem of shortage of qualified workers. This is caused by a wide range of factors including low wages, shortage of educational and training grants, and lack of social support of young specialists in the village (MAK (Ministry of Agriculture of Kazakhstan), 2009). Therefore, the farms have to pay the costs of hiring consultants and/or sending its personnel abroad for training in order to be able to handle a modern dairy farming technology. Perez and Soete (1988) assert that it is well established that the larger the amount of relevant knowledge already possessed, the greater the capacity to absorb new knowledge. Drawing on this assertion, we can imply that farmers who have already invested in modern dairy farming and, therefore, possess more technological and managerial knowledge have a comparative advantage in terms of lower entry costs because it will be less costly for them to acquire an additional “unit” of information (Perez and Soete, 1988). In addition, the managerial skills of the farmer play an important role in running large herd sizes. Sumner and Leiby (1987) revealed a positive relationship between human capital, herd size, and growth for a large sample of dairy farms in the USA. In particular, results revealed that older farmers with more years of experience have a larger herd size than younger farmers with less years of experience. An additional finding of this study was that the managerial skills of the farmer have a significant impact on the growth of the herd size.

3. *Risk attitudes of farmers and instability on the dairy market:* different risk attitudes of farmers may cause different investment decisions. The phenomenon that few Kazakhstani farmers invested in modern dairy farming might be explained by a high proportion of subsistence farms in the Kazakhstani dairy sector. According to the literature, subsistence farmers have a higher level of risk aversion, especially in developing countries because they are usually constrained in resources and, therefore, affected by downside consumption risk. Studies on the adoption of technologies reveal a negative relation between a downside consumption risk and modern technology adoption (Dercon and Christiaensen, 2011; Gebregziabher and Holden, 2011). Although modern technologies enhance the productivity, they also increase the income variability. Hence, subsistence farmers preoccupied in ensuring food security may prefer conventional technologies which are more stable and predictable (Kaliba et al., 2000).

Sauer and Zilberman (2012) found that the cross effect of different risk proxies with farmers’ experiences influences the farmers’ decisions to adopt automatic milking systems. Particularly, the experience of the farmer gained in running the current dairy business helps him or her to adjust too high profit expectations. In addition, the authors revealed that the more experienced the farmer is in relation to the operation of the current dairy business, the less responsive he or she is to milk profit variances and infrequent milk profit deviations. As a result, the probability that the farmer will adopt a new dairy milking technology to hedge against profit outlier activity rises.

The instability on the dairy market of Kazakhstan is a factor that hinders the investment activity of farms. It is mostly caused by demand shocks, seasonality of milk production, animal deceases, the omissions of policymakers, and uneven availability of marketing channels for dairy farms (KAM, 2009). Fresh cow milk production in Kazakhstan is characterized by seasonality, which depends on the cow milk yield during the year. In the winter when the milk yield is low, the increase of milk prices is observed, and then the milk price decreases from April to September. This trend takes place annually and has a negative effect on the profitability of dairy farms (KAM, 2009). In addition to this problem, uncertainty created by policymakers also decreases the attractiveness of the Kazakhstani dairy market for potential risk-averse investors. In particular, vague terms in state standards regulating the quality and the identification of milk and milk products lead to the wrong interpretation and the applications of these standards. Another problem is the absence of standards regulating the methods that are used for the identification of the imitation of milk and milk products with the components of non-dairy origin (MAK, 2009).

Uneven availability of marketing channels for dairy farms creates constraints as well as comparative advantages for potential investors. In Kazakhstan, the milk of dairy farms is usually sold through three main marketing channels. First, dairy farms sell their milk under the supply agreement directly to dairy factories if they are situated in the vicinity of the farm. This type of marketing channel is the most effective and profitable one for dairy farms. Second, farms sell milk to intermediaries if a dairy farm is situated far away from dairy factories. Purchasing prices for milk offered by intermediaries are generally significantly lower than the prices offered by dairy factories. Furthermore, this marketing channel is dependent on weather conditions and transporting conditions and is susceptible to various kinds of force majeure. Therefore, it is considered to be instable. Third, dairy farms sell milk through the network of catering directly to consumers. This type of marketing channel is used by those dairy farms that are specifically designed to provide fresh milk to health centers, schools, and hospitals located away from cities and dairy companies. Milk prices may slightly exceed the purchase price offered by dairy factories. However, few dairy farms can use this type of marketing channel because mostly final products of dairy factories are sold through this type of marketing channel (KAM, 2009). Thus far, only few large and successful dairy farms have their own milk processing capacities and established marketing channels in Kazakhstan, which allows them to sell their final products directly to consumers.

4. *Non-monetary goals*: farmers may prefer to have more free time rather than to have a more profitable farm. Furthermore, farmers, in keeping with family tradition, are often reluctant to change their conventional practices. Therefore, non-monetary goals may give an explanation as to why some farmers prefer subsistence farming even though they could get a higher profit if they increased their farm size. This suggestion is supported by the finding of Barlett (1986). The study points out that subsistence farming is not only an agricultural business but also an integral part of rural lifestyle for households in villages. The relative importance of commercial and lifestyle considerations becomes clearer as farm losses continue, and farm debts must be recovered with off-farm income. For those who consider a farm as only business, the incurred losses will lead to renting out or selling the farm. But if

the number of farms is not reduced significantly during the next few years despite the incurring losses, it is possible to conclude that the lifestyle and consumption aspects outweigh the economic disadvantages (Barlett, 1986). Since life-style farmers are relatively unconcerned about farm profitability, they might not be very motivated to adopt economically effective modern technologies.

5. *Bounded rationality:* appraising decisions to invest in modern dairy farming is a process during which farmers encounter bounded rationality because of their limited ability to process numerous alternatives for choice during the finite amount of time. Simon (1979) posits two concepts, which are important for the characterization of bounded rationality: *search* and *satisficing*. The decision maker must search for the alternatives for choice if they are not given at the outset. At the beginning of the search process the decision maker specifies some *aspiration* regarding the quality of an alternative in his or her opinion (Simon, 1979). As soon as the decision maker has found the alternative for choice that satisfies his or her level of aspiration, he or she would then stop the search and choose that alternative. This mode of selection of alternatives for choices is known as *satisficing* (Simon, 1979).

Tiwana et al. (2007) suggest that when assessing prospective investment alternatives managers follow the *satisficing* concept, which is governed by the NPV criterion that then becomes a salient judgmental heuristic. Such reliance on a restricted amount of heuristic principles simplifies the difficult problem of project assessment to an easier judgmental operation (Kahnemann, 2003). Drawing on this more general assumption, Tiwana et al. (2007) hypothesize that managers are more likely to associate embedded deferral options with the value of a prospective project only when projects have an unsatisfactory low NPV. However, they could not detect a significant relationship between deferral options and NPV values. They interpret this with the fact that uncertainty, in general, and technical uncertainty, in particular, cannot easily be resolved without gaining a direct experience with the technology. In contrast to the results of Tiwana et al. (2007), the study by Hult et al. (2010) detected a relationship between deferral options and NPV values of supply chain investment projects. They explain the finding by the higher level of exogeneity of supply uncertainty in comparison to the uncertainty surrounding firm decisions. Therefore, the authors suggest that a lack of managerial control is more likely to lead supply chain managers exposed to bounded rationality to defer a project until external events unfold.

6. *Diffusion theory:* another reason for rare investments in Kazakhstani modern dairy farming might be the low readiness of farmers for innovation together with a slow diffusion of information with regards to new technologies. Diffusion theory was described by Rogers (2003). The author postulates that differences in the adoption of technologies are explained by differences in the personal trait of adopters rather than by differences in the

characteristics of technologies. Diffusion theory suggests that persons have different levels of readiness to adopt innovations. In addition, it is possible that the cognitive skills of persons, who have low readiness to innovations, are more specific, and they learn by observing outcomes. Bishop et al. (2010) employed a model in order to investigate the characteristics of dairy farmers, who are likely to adopt manure digester technologies. The model included the innovation readiness of farmers as one of several aggregated variables. The model showed that innovation readiness has a positive and moderate impact on the probability of adoption of manure digester technologies by farmers.

Table I.
Explanation approaches for the reluctance of Kazakhstani farmers to invest in modern dairy farming

	Explanation approach	Description	Authors
1	Capital access	constrained access to credit of farms caused by the shortage of collateral and an inappropriate time frame for repayment for livestock breeders; weak development of microcredit organizations	KAF, 2009; van Engelen, 2011
2	Production parameters and managerial abilities	worse cost structure of smaller dairy farms; low milk productivity of cows; shortage of experienced managers and workers	MAK, 2009; Perez and Soete, 1988; Stokes, 2006; Sumner and Leiby, 1987; Tauer, 2006
3	Risk attitudes of farmers and instability on the dairy market	high proportion of subsistence farmers in Kazakhstani dairy farming, who might be highly risk averse; instability caused by demand shocks, seasonality of milk production, animal deceases and the omissions of policymakers; uneven availability of marketing channels for farms	Dercon and Christiaensen, 2011; Gebregziabher and Holden, 2011; Kaliba et al., 2000; KAM, 2009; MAK, 2009; Sauer and Zilberman, 2012
4	Non-monetary goals	lifestyle considerations; family tradition	Barlett, 1986
5	Bounded rationality	limited ability of entrepreneurs to process numerous alternatives for the choice during the finite amount of time	Hult et al., 2010; Simon, 1979; Tiwana et al., 2007
6	Diffusion theory	low innovation readiness of farmers in complex with a slow diffusion of information about new technologies among farmers	Bishop et al., 2010; Rogers, 2003
7	Path dependency	difficulty encountered by entrepreneurs in changing a technology and/or an innovation pathway once they are chosen and well established	Balmann et al., 1996; Kay, 2003; McGuire, 2008

Source: own summary

7. *Path dependency:* path dependency highlights the importance of positive feedback, network externalities, and sunk investment costs in explaining technology adoption patterns.

Following Kay (2003, p. 406), “a system is path dependent if initial moves in one direction elicit further moves in that same direction; in other words there are self-reinforcing mechanisms or positive feedbacks”. Network externalities result in positive feedback that is caused by interrelations between parts of the system (Balmann et al., 1996). Each part of the system reinforces other parts, which helps to maintain technological pathways (McGuire, 2008). Balmann et al. (1996) have presented a simple model showing that complementarity and sunk costs can lead to the path dependency of infinite duration. In particular, they have introduced a simple production model where initial outlays, which are considered as sunk costs, cause the path dependency of an infinite duration in the input asynchronicity case. That means that a firm that has inherited input asynchronicity has to continue production even though the price is lower than the cost of the production for newly established firms or for firms with input synchronicity. We suppose that path dependency might partly explain why Kazakhstani farmers still stick to conventional dairy technologies and demonstrate reluctance regarding investments in modern dairy farming. Technologies of Kazakhstani conventional dairy farms are well established and subject to high sunk costs. Under these circumstances, it might be difficult for Kazakhstani farmers to shift from conventional to modern dairy farming technologies. The summary of these explanation approaches can be seen in Table I.

3 Valuation of real options

The classical investment theory is used as a baseline analysis in our study. According to this theory, the value of the investment in the current time period corresponds to NPV_0, which is determined as the difference between the present value V_0 of the expected incremental cash flows x_t and the investment costs I:

$$NPV_0 = V_0 - I, \qquad \text{with } V_0 = \sum_{t=1}^{Z} x_t \cdot (1+r)^{-t}, \tag{1}$$

where Z corresponds to the exploitation period of an investment object, and r is the discounting rate. The NPV criterion recommends conducting an investment if its NPV is greater than zero (Brealey et al., 2008, p. 17). On the basis of equation (1), it is easy to define the appropriate amount of the incremental cash flow providing a NPV equal to zero. This amount of the incremental cash flow serves as the investment trigger. The investment should be made if the expected incremental cash flow is higher than the investment trigger. The NPV rule, however, makes an implicit assumption: the irreversible investment cannot be postponed but must be made immediately or needs to be cancelled (Dixit and Pindyck, 1994, chapter 4).

The investments in dairy farming in Kazakhstan do not meet this assumption because they are characterized by the uncertainty of returns, irreversible investment costs, and the flexibility with regard to investment timing (KAM, 2009; KAF, 2009). Given these characteristics, the ROA is more advantageous for the valuation of the decision to invest in modern dairy farming by comparison with the classical investment theory because the ROA can consider these characteristics of the investment simultaneously when valuating the investment decision. According to the ROA, the decision to invest is considered to be analogous to an American call option. Similar to the holder of an American call option, the investor has the right but not the obligation to invest in a project with uncertain returns for the payment of the investment costs until the end of a specific time period by which an investment decision can be postponed. Carrying out the investment "kills" the investment option. Thereby, the investor sacrifices the option to wait for new information, which might change the investment decision. This lost option value must be included as a part of the investment cost and needs to be covered by the expected investment cash flows. As a result, this can require a higher investment trigger as well as a higher present value than the NPV rule suggests in order to make an investment decision (Dixit and Pindyck, 1994). But how high should the investment trigger be to cause the investment decision according to the ROA? The answer to this question can be found by solving the Bellman equation (Dixit and Pindyck, 1994):

$$F(x,t) = \max[NPV_t;\ \mathrm{E}(NPV_{t+dt}) \cdot (1+r)^{-dt} | x_t)], \tag{2}$$

where $F(x,t)$ denotes the value of the investment option, $\mathrm{E}(\cdot)$ indicates the expectations operator, and $\max(\cdot)$ is a maximum operator. The first term on the right-hand side is the intrinsic value of the investment option, which is defined as the maximum of zero and the net present value that can be realized if the investment is carried out at time t (Hull, 2009, p. 186). The second term constitutes the continuation value, which is similar to the discounted expected value of the investment at the next possible chance to invest. The option should only be exercised if the intrinsic value exceeds the continuation value. The difference between the options value and the classical NPV is the so-called value of waiting.

4 Model assumptions and data

We model a private company, which has approximately 35,000 hectares of arable land on which mainly wheat is cultivated as a cash crop. The company considers a decision to invest in modern dairy farming. The investments include the construction of two dairy barns for 1,000 cows, the purchase of 408 inseminated heifers, and 344 non-inseminated heifers of a Holstein-Friesian breed imported from Canada as well as advanced dairy farm equipment. Together with their future heifer calves, these heifers will form a herd of 1,000 cows. In total, the investment costs amount to €4,821,284 (Rodina ltd., 2008). The investment outlay is financed from the own resources of the company. The total investment costs vary among the already established Kazakhstani modern dairy farms mostly depending on the amount of purchased animals. However, the presented structure of the dairy investment package is common in Kazakhstan (KAF, 2009). The lifetime of the investment project is 20 years. After this lifetime the investment project does not have any residual value.

The farmer can postpone the decision to invest in dairy farming for an infinite time during which the investment can only be implemented at discrete exercise dates (once a year). First, this is because it is only possible to start construction after cash crops have been harvested as there are not any workers available during the time of field work. Second, in Kazakhstan, building usually cannot start in winter because the frozen ground complicates the foundation laying process.

We analyze a 1,000-cow herd with an annual milk yield of 7,170 kg per cow (Rodina ltd., 2010), which is assumed to be stable as a result of enhanced cow comfort, buffering against weather changes (heat, humidity, wind or rain), and the assumption of no improvement in genetic production potential. The annual milk yield equals the average yield of the milking herd, which includes cows of various ages and, therefore, with varying productivity levels. Besides milk, the modern dairy farm sells male calves, female calves, and beef as by-products. It is assumed that a cow has both bull calves and heifer calves during her exploitation period. Cows are exploited for up to 5 calving years (400 days are one calving period; cf., Rodina ltd., 2010), which is a usual practice in Kazakhstan. A constant 20% of each calf crop is saved as replacement heifers. The remaining calves are sold when weaned. A constant 20% of cows with the weight of 680 kg are culled each year given a constant cow slaughter outcome and a death loss of 55% and 2%, respectively (Rodina ltd., 2010).

The farm produces its own roughage on 870 hectares. The cost of the roughage production is included in the fodder costs (Rodina ltd., 2010), while the area for the roughage production is obtained by reducing the area, which is sown with wheat. Subsequently, the opportunity cost of the roughage equals the lost sum of the gross margin of wheat.

Wheat yields, prices for wheat, milk, and mixed fodder are taken for the years from 1995 to 2009 in order to create an inflation-adjusted time series of the incremental cash flow of the modern dairy farm. In particular, the national average prices for milk for the years from 1995 to 2008 are derived from FAO (Food and Agriculture Organization of the United Nations) (2010). The milk price is the main stochastic factor affecting the revenue of the dairy farm. The national average data on wheat yields for the years from 1995 to 2009 and the prices for wheat for the years from 1995 to 2008 (FAO, 2010) are used to calculate the opportunity cost of the roughage production. The national average prices for milk and wheat for the year 2009 are derived from the Agency of Statistics of the Republic of Kazakhstan (ASRK, 2010a; ASRK, 2010b) because these data were not available from FAO. A time series of the mixed fodder price is created on the basis of the historical wheat prices considering the ratio of the mixed fodder price (Rodina ltd., 2010) and the wheat price for the year 2009. We have to do so because of the lack of historical data for the mixed fodder price. We think that the performed approximation is realistic because wheat is the main ingredient of mixed fodder; therefore, it takes the largest share in the cost of the mixed fodder. It should be noted that we cannot take a longer historical time horizon because of the structural breaks in an earlier time series. Before 1991, Kazakhstan had a centrally planned economy, and then the country switched to a free market economy. This was followed by a three-year period of high inflation (1,784% on average), which distorts the results of a time series analysis (ASRK, 2010c).

The model does not take into account stochastic variability in prices for calves and cow meat, wheat production costs, and the costs of the modern dairy farm with the exception of mixed fodder costs. The national average data on wheat production costs (ASRK, 2010a) and prices for calves and cow meat are taken from the ASRK only for the year 2009 (ASRK, 2010d) and mostly as a result of a lack of historical data. In addition, the shares of the sales revenues of calves and cow meat are not large in the total sum of the incremental cash flow of the dairy farm. In our opinion, they therefore do not have a strong influence on the development pattern of the incremental cash flow. The average variable annual costs of the modern dairy farm are based on the data of the year 2009 obtained from Rodina ltd. (2010). It would have been more practical to use the national average data of the performance of Kazakhstani modern dairy farms for several years. The data availability is a common problem occurring in most of the studies focusing on Kazakhstan as well as other former Soviet Republics (Lerman et al., 2003; Milner-Gulland et al., 2006).

The modern dairy farm generates an incremental cash flow, which was modeled as a random variable. The incremental cash flow is the difference between the total gross margin of the modern dairy farm and the opportunity cost of roughage. Inflation-adjusted incremental cash flows of the modern dairy farm for the years from 1995 to 2009 are depicted in Figure 1.

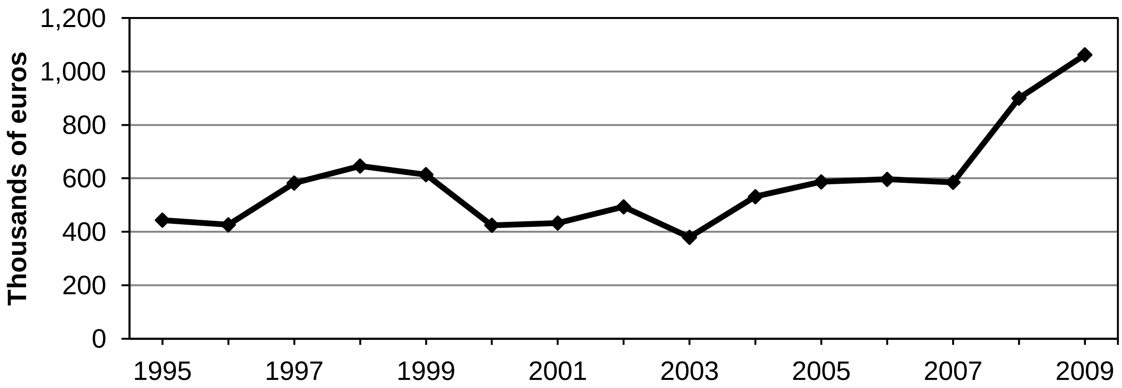

Figure 1. Inflation-adjusted incremental cash flows of the modern dairy farm
Source: Authors' own calculations based on data from the Agency of Statistics of the Republic of Kazakhstan, Food and Agriculture Organization of the United Nations, and the financial report of Rodina ltd.

The averages of disaggregated variables of the inflation-adjusted incremental cash flows for the years from 1995 to 2009 are presented in Table II.

Table II.
Averages of disaggregated variables of the inflation-adjusted incremental cash flows of the modern dairy farm (per herd and year)

Description	Value (€)	%
Revenues	**1,612,722**	**100.00**
Sale of milk	1,351,633	83.81
Sale of cull cows meat	168,692	10.46
Sale of male calves	57,748	3.58
Sale of female calves	34,649	2.15
Costs	**1,032,229**	**100.00**
Mixed fodder	524,662	50.83
Labor	100,680	9.75
Hygienic means and medicines	86,679	8.40
Insemination	60,356	5.85
Fodder	45,786	4.44
Heifer	42,217	4.09
Fuel	33,984	3.29
Transport costs	27,802	2.69
Electricity	24,367	2.36
Heating	15,980	1.55
Other costs	10,758	1.04
Opportunity cost of roughage	58,958	5.71
Incremental cash flow	**580,493**	**-**

Source: own calculations

The incremental cash flows shown in Figure 1 are taken as an input for an augmented Dickey-Fuller test (Enders, 2003, pp. 76-79) as well as for a variance ratio test (Campbell et al., 1997, pp. 68-74). These tests are performed to check for a presence of a random walk in the time series. A random walk is a stochastic process where a value of the next period is obtained as a value of this period plus an independent (or at least an uncorrelated) error term (Wooldridge, 2009, p. 844). The results of both tests show that the incremental cash flows follow a random walk with 5% probability of error. Given that a time series of the incremental cash flow follows a random walk process and the incremental cash flow can fall below zero, the future development of the incremental cash flow is modeled by an arithmetic Brownian motion (ABM), which satisfies the Markov property. The Markov property suggests that the probability distribution for the random variable only depends on the last value observed (Dixit and Pindyck, 1994). A time-discrete version of an ABM can be represented as follows (Luenberger, 1998, p. 310):

$$x_t = x_{t-1} + \alpha + \sigma \cdot \varepsilon_t, \quad (3)$$

where x_t denotes the incremental cash flow taken as a stochastic variable in any period of time t, α is the absolute drift of the incremental cash flows, σ is the standard deviation of the incremental cash flows, and ε_t is a random variable with a standard normal distribution. The expected value of x_t for an ABM is defined as follows:

$$\mathrm{E}(x_t) = x_{t-1} + \alpha, \quad (4)$$

Based on a t-test, the drift parameter of an ABM α is not different from zero at a significance level of 5% (p-value = 0.213; two-tailed t-test), which means that the expected value of the future incremental cash flows is equal to its current value.

Despite the empirical evidence in favor of an ABM, we introduce, in addition, a GBM and an autoregressive process of order one (an AR(1) process) to analyze the sensitivity of the option-pricing results regarding assumed stochastic processes. We choose a GBM because it has been commonly assumed as an underlying process for modeling the future development of a random variable in real options applications (e.g. Purvis et al., 1995; Engel and Hyde, 2003; Richards et al., 2009; Tauer, 2006). By the means of an AR(1) process, we want to show how the results of the investment calculations change when assuming that the future incremental cash flows fluctuate in a more systematic pattern. Typically, a special case of an AR(1) process, namely a Mean Reverting Process (MRP), is applied for modeling the future development of the values of real assets. According to a MRP, it is supposed that after a random shock, commodity prices return to a “normal” level, which is related to the long-run marginal production costs and contradicts the nonstationarity of a random walk (Pindyck and Rubinfeld, 1998, p. 510). However, in our case, a MRP is not suitable for modeling the future development of the incremental cash flows because the parameters of the process cannot be specified. Therefore, we used a more general AR(1) process.

The future development of the incremental cash flows according to a GBM can be modeled as follows:

$$x_t = x_{t-1} \cdot e^{\left[\left(\alpha - \frac{\sigma^2}{2}\right) + \sigma \cdot \varepsilon_t\right]}, \quad (5)$$

where α is the drift rate of the incremental cash flows, and σ is the standard deviation. The expected value of x_t under the assumption of a GBM can be defined as follows:

$$\mathrm{E}(x_t) = x_{t-1} \cdot e^{\alpha}, \quad (6)$$

Based on a t-test, the drift parameter of a GBM α is not different from zero at a significance level of 5% (p-value = 0.304; two-tailed t-test).

An AR(1) process can be stated as follows:

$$x_t = a_1 \cdot x_{t-1} + \chi_t, \quad \text{with } |a_1| < 1 \text{ and } \chi_t = \sigma \cdot \varepsilon_t \tag{7}$$

where a_1 is the weighting factor of the process estimated on the basis of the last observed values x_{t-1}, χ_t is an error term, and σ is the standard deviation of the incremental cash flows. The expected value of x_t under the assumption of an AR(1) process can be estimated by:

$$\mathrm{E}(x_t) = a_1 \cdot x_{t-1} \tag{8}$$

There are ROA applications in which an AR(1) process is used. For example, Cobb and Charnes (2003) assume that stochastic variables follow an AR(1) process to analyze the fluctuations of the value of a portfolio of real investment projects caused by systematic changes in the autocorrelation as well as in cross-correlation parameters.

The parameters of the stochastic processes are summarized in Table III.

Table III.
Estimated parameters of the stochastic processes

Parameter	Arithmetic Brownian motion	Geometric Brownian motion	Autoregressive process of order one
Drift rate α	€0 p.a.	0% p.a.	-
Standard deviation σ	€126,163 p.a.	21.79% p.a.	€133,651 p.a.
Weighting factor a_1	-	-	0.99 p.a.

Source: own calculations

The future incremental cash flows of the investment are discounted by the risk-free real interest rate, which is calculated on the basis of the average return of medium-term treasury bonds issued by the Ministry of Finance of the Republic of Kazakhstan with maturities of 1 to 10 years. From 1998 to 2009, the average return rate r is 9.89% p.a. (NBRK (National Bank of the Republic of Kazakhstan), 2010). The usage of the risk-free interest rate would only be justified if farmers were risk neutral. Therefore, two additional risk-adjusted interest rates are used to analyze the effect of different levels of risk aversion on the farmers' investment decision: 14.89% p.a. (risk averse) and 19.89% p.a. (highly risk averse). A risk premium is often parameterized because of the difficulties related to the empirical estimation of risk attitudes of decision makers (Hudson et al., 2005). The level of the selected risk premium is in accordance with the literature, which frequently analyzes a range of risk-adjusted discount rates from approximately 8% p.a. to 12% p.a. (e.g. Gebremedhin and Gebrelul, 1992; Zhuang et al., 2005).

5 Description of the option-pricing model

Given the model assumptions described in the previous section, we can interpret the investment decision in dairy farming as the real option with an infinite exercising period during which the investment trigger remains constant at each discrete exercise date. The valuation of this type of option is not an easy task. Analytical solutions are available if situations in which the value of a stochastic variable follows a geometric Brownian motion (GBM), and the option can be exercised continuously (McDonald and Siegel, 1986). A GBM is characterized by two properties. First, the process does not allow the value of the stochastic variable to change its sign and, second, changes of the asset are proportional to its level, i.e., the stochastic variable demonstrates an exponential behavior. On the assumption of these properties it is theoretically unacceptable to apply a GBM in order to model, for example, the future development of a cash flow or a profit, which can take negative values.

In contrast to an analytical option pricing method, there are various numerical option pricing methods that allow the handling of different stochastic processes. Among them is the binomial tree valuation approach, which involves the division of the option's lifetime into a large number of small time intervals. This approach assumes that in each time interval the price of the underlying asset moves from its initial value to one of two values (Hull, 2009, p. 407). The accuracy of the option valuation is positively influenced by the number of time intervals. Thus, obtaining an accurate option value by using the binomial tree method requires the increase of the number of time intervals, resulting in an increase of computation time (Broadie and Detemple, 1996). Hence, if the investment option can be postponed during a long time horizon, its valuation is very time consuming. Furthermore, only few stochastic processes can be handled by the binomial tree method. Another flexible numerical method is the stochastic simulation. The advantage of the method is that any stochastic process can be accommodated with this method (Hull, 2009, p. 428). This is an especially useful characteristic considering the fact that, in practice, we do not know the results of a statistical analysis beforehand. The disadvantage of the method is that it does not contain an optimization algorithm; therefore, a stochastic simulation needs to be applied in combination with dynamic programming (Ibanez and Zapatero, 2004; Odening et al., 2005). This combination of two methods can be used to valuate an option with a finite lifetime during which the optimal exercising value is dependent on the maturity. Otherwise, if the exercising value of an option remains constant over the whole infinite lifetime of an option, the option-pricing method based on the stochastic simulation and the parameterization of investment triggers is an appropriate method for the valuation of such options.

In the framework of this method, a parameterization range for the potentially optimal investment strategy is given. Test triggers $x_1^* \ldots x_N^*$ (e.g. an incremental cash flow) are obtained by dividing the parameterization range into equal-sized intervals. The boundaries of these intervals are defined by test triggers. The lower limit of the parameterization range corresponds to the investment trigger according to the NPV criterion. The upper limit is set arbitrarily. The value of the option is determined for each given test trigger of the range. That is, stochastic simulation is used to determine the development of the stochastic variable, while the options value is calculated for each simulation run. The option value that is obtained with the corresponding test trigger equals the average of the option values of simulated paths. In Figure 2, the option values are presented as a function of potential investment triggers. The exercise point corresponding to the highest average option value of all simulated paths is closest to the most "true" exercise value. As shown in Figure 2, x_7^* delivers the highest option value.

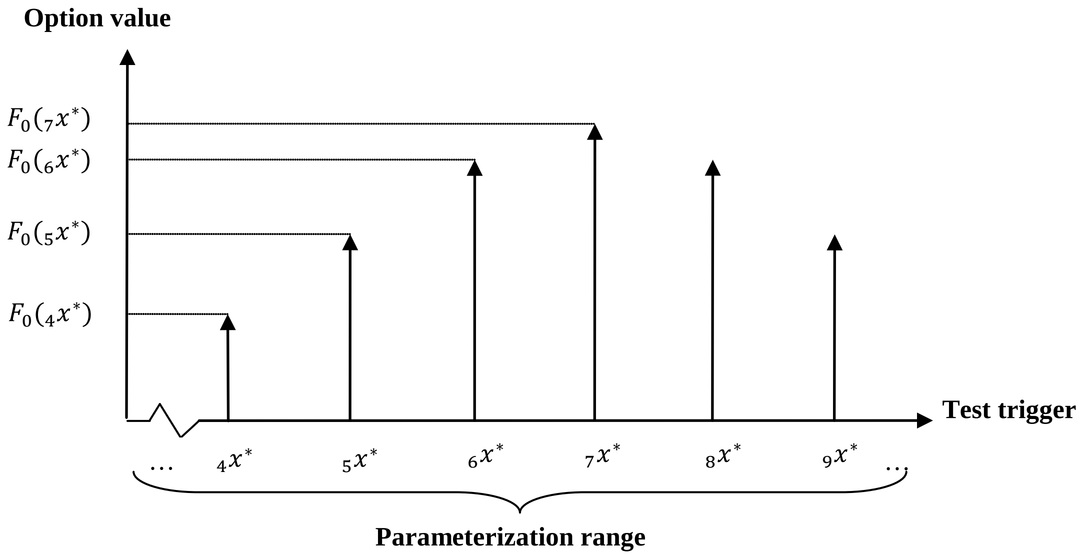

Figure 2. Option values and investment triggers
Source: designed by the authors

In the next step, the parameterization range is adopted to x_7^* in order to find a more precise investment trigger. This is performed by limiting the parameterization range by two exercise points located on the right and on the left of x_7^*. The limitation gives us a new parameterization range within which we search for a more precise investment trigger. This approach is repeated if necessary, and a relatively small parameterization range is obtained depending on the degree of narrowing. Mathematically, this can be represented by the following stochastic-dynamic decision model:

$$F_0 = \max(V_t - I; 0) \cdot (1+r)^{-t} \rightarrow \max_{x^*}!, \qquad \text{with} \tag{9}$$

$$t = \begin{cases} 0, & \text{if } x_0 \geq x^* \\ 1, & \text{if } x_1 \geq x^* \wedge x_0 < x^* \\ & \ldots \\ 500, & \text{otherwise} \end{cases}$$

According to equation (9), the optimal investment strategy is shown as the critical incremental cash flow x^* of the modern dairy farm, which triggers the investment. The investment trigger x^* remains constant at each time of investing over the whole approximate infinite lifetime of the real option, which equals to $T = 500$ years. The resulting approximation error can be assessed as small because, for example, the present value of €10 million, which is achieved in 500 years at an interest rate of 9.89%, amounts to less than €0.01. The investment decision can be made once a year during this period. The purpose of the model in equation (9) is the maximization of the option value F_0. In order to achieve this purpose the investment is realized

- immediately if the incremental cash flow in year zero x_0 is higher than or equal to the investment trigger x^*;
- in year one if the incremental cash flow in year one x_1 is higher than or equal to the investment trigger x^*, and if the incremental cash flow in a previous year was less than the investment trigger x^*;
- in any of the following years if the incremental cash flow in the respective year is higher than or equal to the investment trigger x^*, and if the incremental cash flows in previous years were less than the investment trigger x^*;
- in year 500, otherwise.

6 Results

The option-pricing method based on the stochastic simulation and the parameterization of triggers described in section 5 is now applied to determine the investment triggers as well as the option values associated with the investment in modern dairy farming. The option values presented in Table IV are calculated given an initial incremental cash flow x_0 of €580,493, which equals to the averages of disaggregated variables of the incremental cash flows of the modern dairy farm (cf. Table II). Fifty thousand sample runs of the incremental cash flow x of the project are generated according to a chosen type of a stochastic process, and the option values for each of these runs are calculated. Haug (1998, p. 40) stipulates that at least 10,000 runs should be carried out. Hence, the number of our simulations satisfies this requirement.

The first row shows the results of the valuations when an ABM is used for modeling the future stochastic incremental cash flows and a risk-free interest rate of 9.89% is assumed:

- The results in columns 3 to 5 are presented for a situation when the flexibility regarding the investment decision is ignored (“now-or-never-decision”). It is clear from column 3 that a risk-neutral farmer should invest if the incremental cash flow is higher than or equal to €561,907. The corresponding critical present value is €4,821,284, which is equal to the investment costs. The initial incremental cash flow of the project of €580,493 yields a present value of €4,980,762 and a positive NPV of €159,478. This means that the investment project is profitable and should be realized immediately following the classical investment theory.

- The results in columns 6 to 8 are presented for a situation in which the investment decision can be postponed and adopted annually. The ROA states that the incremental cash flow of the investment of at least €766,992 is required for the farmer to optimally initiate the modern dairy farm establishment project. When achieving such an amount of the incremental cash flow, it makes no sense for the farmer to wait longer and to expect higher gains. At this amount of the incremental cash flow, the present value of the investment is €6,580,958, and the value of the option corresponds to €963,051. The value of waiting is €803,573 (= €963,051 - €159,478). The investment multiple equals the ratio of critical present value calculated according to the ROA to the investment costs, respectively. For the farmer, it is only optimal to invest if the investment multiple equals or exceeds 1.36. Subsequently, the incremental cash flow of €580,493 is lower than the optimal investment trigger and cannot compensate the value of waiting for the farmer.

The impact of risk aversion on the decision of farmers with different risk attitudes is shown in rows 2 and 3 of Table IV:

- A risk-averse farmer, who uses a risk-adjusted interest rate of 14.89% p.a. in order to discount the future incremental cash flows and ignores the decision flexibility regarding the investment time (columns 3 to 5 of row 2), should invest if the incremental cash flow of the dairy farm is higher than or equal to €765,400. The NPV of the investment is equal to €-1,164,734 with the assumption of the initial incremental cash flow of the project to be €580,493. Therefore, the farmer should reject the investment. The investment trigger increases even more for a more risk-averse farmer at a discount rate of 19.89% p.a.

- The investment triggers according to the ROA for a risk-averse farmer, which are calculated with discount rates of 14.89% p.a. and 19.89% p.a., are illustrated in columns 6 to 8. These investment triggers are higher than those for the risk-neutral farmer. On the contrary, the investment multiple decreases, meaning that the postponement of a profitable investment at higher discounting rates does not benefit appreciably.

Table IV.
Investment triggers and option values (per herd and year)

	Column 1	Column 2	Column 3	Column 4	Column 5	Column 6	Column 7	Column 8	Column 9
			Without consideration of time flexibility			With consideration of time flexibility			
	Stochastic process	Interest rate (% p.a.)	Critical cash flow (€)	Critical present value (€)	NPV (€)	Critical cash flow (€)	Critical present value (€)	Option value (€)	Investment multiple
1	ABM	9.89	561,907	4,821,284	159,478	766,992	6,580,958	963,051	1.36
2	ABM	14.89	765,400	4,821,284	-1,164,734	919,440	5,791,589	246,669	1.20
3	ABM	19.89	984,946	4,821,284	-1,979,784	1,123,900	5,501,463	50,220	1.14
4	GBM	9.89	561,907	4,821,284	159,478	801,380	6,876,017	919,335	1.43
5	AR(1)	9.89	618,684	4,821,284	-297,611	813,132	6,336,586	649,367	1.31

Note: The NPV as well as the option values are calculated for an incremental cash flow of €580,493. The parameterization interval for the investment trigger is refined up to €37.11.
Source: own calculations

The comparison of the results given in rows 1, 4, and 5 illustrates the impacts of different stochastic processes on the option-pricing results. The NPV, option value, and investment multiple of the investment in modern dairy farming on the assumption of an AR(1) process are lower than for an ABM as well as for a GBM. This can be explained by the specificity of each process with regard to the way future positive changes of the stochastic incremental cash flow are modeled. When it comes to an AR(1) process, there is a negative trend in the development of the expected values caused by the estimated weighting factor, which is less than one and equals 0.99. Furthermore, under the assumption of Brownian motions, the stochastic incremental cash flow can drift freely, while AR(1) is a stationary process. The investment multiple according to a GBM is slightly higher compared with that according to an ABM. This can be explained by the property of a GBM, which excludes a sign change of the stochastic variable. On the one hand, the comparison of the results indicated in Table IV clarifies the flexibility of the suggested option valuation model with regard to the type of the underlying stochastic process. On the other hand, the sensitivity of the results regarding the stochastic process becomes clear when comparing the investment multiples.

7 Conclusion

Although the investment in modern dairy farming is profitable, Kazakhstani farmers are reluctant to invest in it. To explain the phenomenon of the observed reluctance to invest, different explanatory approaches are discussed. This study aims to analyze the explanatory potential of the ROA regarding the reluctance of Kazakhstani farmers to invest in modern dairy farming. It is assumed that a cash crop producing company considers a decision to invest in modern dairy farming. The investment triggers as well as the option values are determined for a virtual, exemplarily considered Kazakhstani farm by applying a numerical option-pricing method based on the stochastic simulation and the parameterization of investment triggers.

The optimal investment triggers according to the traditional NPV criterion differ considerably from the option-based investment triggers. Following the NPV criterion, it is optimal to invest when the incremental cash flow is equal to the averages of disaggregated variables of the incremental cash flows of the last years because it is higher than the optimal investment trigger given by the NPV criterion. To initiate the investment, the ROA requires a substantially higher investment trigger. Therefore, the incremental cash flow equal to the averages of disaggregated variables of the incremental cash flows does not compensate a farmer for giving up the investment option. The result shows that the ROA has an explanatory potential regarding the observed reluctance to invest.

This study confirmed that a more risk-averse farmer is more reluctant to make an investment decision even in the context of the ROA. This can be seen from the fact that the investment triggers rise whenever the interest rates rise. A further result is that the postponement of the investment at higher discounting rates is less beneficial than at lower rates. That can be observed from the declining value of the investment multiple.

The magnitude of the difference between the investment triggers according to the NPV criterion as well as the ROA depends significantly on the stochastic process underlying the stochastic variable. In the case of a GBM, which is commonly applied in most studies regarding the application of the ROA, the investment triggers as well as the investment multiple are very high. On the contrary, the investment trigger as well as the investment multiple are low when an AR(1) process is assumed. These results illustrate the importance of the proper identification of a stochastic process because false values lead to wrong decisions.

The option-pricing method used in the present study can be applied to solve decision problems related to investments in other branches of agriculture apart from dairy farming, such as bio-energy production, irrigation technologies, organic plant breeding or hog finishing. This is achieved owing to the flexibility of the model with regards to handling different investment planning assumptions. The applicability of the method is maintained by the flexibility of the method regarding a wide range of stochastic processes. In addition, the method makes it possible to accommodate the real options that are exercised at discrete time periods. This property of the method is of practical importance because in the real world most investments can be exercised at discrete time periods but not continuously.

Up to now, policymakers have focused on transfer payments, such as investment subsidies and other forms of direct financial support, as instruments for promoting modern dairy farming in Kazakhstan. The results of this study are important for agricultural policymakers because the results reveal the crucial impact of volatile returns and investment flexibility on the investment trigger of farmers and, consequently, emphasize the importance of temporal opportunity costs. Based on this result, it would be worthwhile considering alternative ways of promoting modern dairy farming in Kazakhstan. For example, the effect of transfer payments might be enlarged if the payments were limited in time. Eventually, the opportunity costs would be reduced over time and the decision to invest would be moved closer to a "now-or-never-decision". For the government, it would be the wrong sign to promise more payments to farmers to promote modern dairy farming. This would result in a rise of the intertemporal opportunity costs and would therefore cause an increased reluctance to invest.

Besides uncertainty, flexibility, and irreversible costs, there are, of course, other factors that influence the investment decision in dairy farming. In the model assumptions of the present study, we have not included personal preferences different from profit maximization and risk aversion (Wale et al., 2005), perceptions (Joshi and Pandey, 2006), and other behaviorist features possibly inherent in each decision maker (Sandri et al., 2010). Hence, an experimental investigation of the investment decision patterns of Kazakhstani farmers that is aimed at the differentiation of behavioristic factors from option-based factors might be a motivation for future research. Furthermore, climatic and market conditions vary across the regions of Kazakhstan. In further studies, it would thus be interesting to analyze to what extent the results are specific for the set assumptions of the current study and how strongly they are influenced by location conditions.

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III. Real Options or Net Present Value? An Experimental Approach on the Investment Behavior of Kazakhstani and German Farmers

Authors: Dulat Tubetov, Syster Christin Maart, Oliver Musshoff

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Abstract

Purpose – The objectives of our study are to compare the investment behavior of farmers in Kazakhstan as a transforming country and in Germany as a Western industrialized country as well as to analyze whether the investment behavior of farmers is consistent with the normative benchmarks of the net present value (NPV) approach or the real options (RO) approach.

Design/methodology/approach – We conducted an experiment with 100 Kazakhstani and 106 German farmers. The first part of the experiment describes an investment opportunity in an agricultural and in a non-agricultural treatment. The second part refers to a Holt and Laury lottery to determine farmers' risk attitude that could influence the investment behavior.

Findings – Our results show that both approaches do not provide an exact prediction of the investment behavior of farmers. However, German farmers invest later than Kazakhstani farmers meaning that the investment behavior of German farmers is closer to the RO approach. This might imply that German farmers are more likely to take into account the value of flexibility when making investment decisions than Kazakhstani farmers.

Further research – Since investment behavior is country-specific, it is worth investigating if farmers from other transforming countries would show different investment behavior compared to farmers from other Western industrialized countries. Furthermore, decision-making behavior related to investments could be different from that related to disinvestments. Therefore, it may be interesting to analyze the disinvestment decisions of farmers in transforming and Western industrialized countries.

Practical implications – Our results show that it is not acceptable to apply the results of experiments investigating the investment behavior of entrepreneurs in a transforming country to entrepreneurs in a Western industrialized country and vice versa. Furthermore, training for farmers is needed because there is still room for improvement in order to achieve the RO benchmark. Finally, taking into account real options effects could improve the results of policy impact analysis.

Originality – This is the first experimental study comparing the investment behavior of farmers from a transforming country and from a Western industrialized country.

Keywords: experiments, investment timing, real options, Kazakhstan, Germany

JEL classification: C91, D03, D81, D92

1 Introduction

Investment decisions represent one of the most important types of decisions for the economy as a whole and for the company in particular (Pike and Dobbins, 1986, pp. 3–4). It is important to be able to analyze them correctly. There is rising interest in investigating real options (RO) values for agricultural investments (Hyde et al., 2002; Pederson and Zou, 2009; Gloy and Dressler, 2010; Hachicha et al., 2011; Power et. al., 2012). Although, the RO approach is more advantageous for the valuation of investment decisions than the net present value (NPV) approach (Luehrman, 1998; Park and Herath, 2000), it is not certain if investors make investment decisions in accordance with the RO approach or the traditional NPV approach. There are econometric studies on the analysis of investment behavior (O'Brien et al., 2003; Hinrichs et al., 2008). The observation of farmers' investment decisions might be of limited use in this context since investment decisions for a capital-intensive object (such as a cow barn or a biogas plant) are relatively rare in the agricultural business (Gardebroeck and Oude Lansink, 2008). Moreover, basic conditions, such as financial resources, differ among farms (Wale et al., 2005; Joshi and Pandey, 2006). Hence, it is hardly possible to draw meaningful conclusions from econometric analyses regarding investment behavior. An experimental analysis of the investment behavior of entrepreneurs could be used to avoid these problems.

An advantage of economic experiments is that they give the researcher the possibility to collect the data under controlled conditions. An experiment can be designed in a way that it allows the researcher to change desired variables and keep the other variables permanent. A review of the existing literature shows that, in spite of its relevance, experimental studies on investment behavior are still rare. Rauchs and Willinger (1996) were among the first who experimentally investigated the effects of the RO approach. They tried to identify how irreversibility of choices influences the investment behavior of students under uncertainty. They found that students chose a more flexible current position when expecting more information. Howell and Jägle (1997) conducted a laboratory experiment with practicing managers. During the experiment managers were asked to take hypothetical decisions on a series of investment case studies. A manager had to value a growth option in each case study. The results of the study revealed that managers on average tend to value growth options inconsistently, i.e., over- as well as under-valuations occurred. Yavas and Sirmans (2005) used an experimental methodology to investigate the optimal timing of an investment and found that students invest earlier than predicted by the RO approach. However, when students competed with each other for the right to invest, their willingness to pay for an investment opportunity reflected an option value. Oprea et al. (2009) experimentally examined whether the optimal exercise of wait options can be closely approximated if a student has the opportunity to learn from personal experience. Findings indicate that students tended to exercise the wait option prematurely in the beginning, but over time their average behavior comes closer to the optimum. Denison (2009) applied experimental methods in order to analyze whether the application of the RO approach in capital budgeting reduces the tendency of students to continue a project after incurring losses. They revealed that users of real options showed less escalation of commitment than users of the classical capital budgeting theory. In a recent study, Sandri et al. (2010) carried out an experiment with students and high-tech entrepreneurs to analyze their disinvestment decisions, which were modeled as a dynamic problem of optimal stopping. The study revealed a relationship between the disinvestment decisions given by participants and the disinvestment triggers calculated according to a formal optimal stopping benchmark compatible with real-options reasoning. The findings of this study are consistent with those reported by Musshoff et al. (2012), who carried out a disinvestment experiment with farmers. All these aforementioned studies mainly focus on the investment behavior of students and entrepreneurs in Western industrialized countries. They neither analyzed the investment behavior of farmers nor compared it between farmers in Western industrialized and transforming countries. It still remains widely open to what extent the results of the experiments investigating the investment behavior of farmers in Western industrialized countries are applicable to farmers in transforming countries and vice versa.

Hence, the objectives of the present study are to experimentally examine the investment behavior of farmers in Kazakhstan as a transforming country and in Germany as a Western industrialized country as well as to analyze whether the investment behavior of farmers is consistent with the NPV approach or the RO approach. A further objective of our study is to test whether the investment behavior of German farmers is closer to the optimal investment behavior predicted by the RO approach than that of Kazakhstani farmers. We also investigate the presence of a learning effect in the investment behavior of farmers. In particular, we analyze if farmers learn from their experience during the experiment and time their investment decisions closer to the optimal periods predicted by the RO approach over the repetitions. To achieve the objectives of our study, we run an experiment on repeatedly ongoing investment opportunities in an agricultural and in a non-agricultural treatment. We chose farmland as an exemplary investment object in the agricultural treatment because of two reasons. First, it is a major input in agriculture (Schmitz and Just, 2003, p. 53). Second, there is a range of literature investigating the effect of real options on the value of farmland (Tegene et al., 1999; Plantinga et al., 2002; Turvey, 2003). Within each repetition, farmers should decide to postpone or realize an investment. As investment behavior could be influenced by the decision makers' risk attitudes (Knight et al., 2003), an additional experiment based on a Holt and Laury lottery (HLL) is carried out (Holt and Laury, 2002). We suppose that this comparative study could be interesting for readers considering the fact that this is the first study, which experimentally compares investment behavior between farmers in a transforming country and a Western industrialized country. Furthermore, as stated by Gardebroek and Oude Lansink (2004), it is necessary to understand investment decisions at the farm level to be able to analyze structural developments in farming.

Section 2 presents the derivation of hypotheses. Section 3 describes the experimental settings, while Section 4 shows how normative benchmarks were calculated. In section 5, descriptive statistics and the approach to data analysis are presented. The results of the experiments are discussed in Section 6, before the paper ends with conclusions in Section 7.

2 Derivation of hypotheses and theoretical background

The classical investment theory has been frequently used for valuing the investment behavior of entrepreneurs (Singh et al., 2010; Wu et al., 2010). It suggests that investment should be realized immediately as soon as its NPV has a positive value; otherwise it should be cancelled. In contrast to the NPV approach, the RO approach states that the investor may increase profits by deferring an investment decision instead of realizing the investment immediately, even if the NPV is positive. The value of deferring an investment decision is especially pronounced if investment is at least partially sunk or irreversible [1] and the expected returns of the investment are uncertain [2] (Pindyck, 1991). When the investor carries out the investment he or she loses the option to wait for new information, which might have changed an investment decision. This lost option value has to be included in the investment cost and has to be covered by the expected investment returns. As a result, this requires a higher investment trigger than that suggested by the NPV rule in order to make an investment decision (Dixit and Pindyck, 1994, pp. 6–7).

In the following, we describe an investment situation to derive the NPV approach and the RO approach related hypotheses. Imagine a rational farmer, who plans to invest in farmland. The investment can be made only once—either immediately or it can be postponed up to one period. The cost of the investment I is fixed at 100,000 and must be paid immediately after making the investment decision. The costs of the investment are completely sunk once it has been implemented. The future development of the present value of the investment returns paid out one period after the investment implementation is uncertain and modeled by a binomial approximation of the arithmetic Brownian motion in discrete time (Dixit and Pindyck, 1994, p. 68). We assume that the present value of the investment in period 0 is $V_0 =$ 120,000, whereas the present value in period 1 will change. With a probability of $p = 50\%$, the present value in period 1 will rise by h =20,000, and with a probability of $1 - p$, it will fall by h. In period 2, the present value can take the following values: $V_0 + 2 \cdot h$ with a probability of p^2; $V_0 - 2 \cdot h$ with a probability of $(1-p)^2$; and V_0 with a probability of $2 \cdot p \cdot (1-p)$. With this in mind, 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. The value of the investment $\hat{F}$ according to the NPV rule can be calculated as follows:

$$\hat{F} = \max(E(NPV_0); 0), \qquad (1)$$

where

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

$E(\cdot)$ indicates an expectation operator and $q^{-1} = 1/(1 + r^*)$ is a discount factor and r^* denotes a risk-adjusted discount rate. In the example, we assume a risk-neutral decision maker with a risk-adjusted discount rate equal to a risk-free interest rate of 10%. That means for our example:

$$E(NPV_0) = \Big(\big(0.5 \cdot (120{,}000 + 20{,}000) + (1 - 0.5) \cdot (120{,}000 - 20{,}000)\big) \cdot 1.1^{-1}\Big)$$
$$-100{,}000 = 9{,}091$$

Since $E(NPV_0)$>0 the investment should be realized. But how high must the present value be to induce farmers to invest? To answer this question, it is necessary to calculate the investment trigger, which is the critical present value of the investment returns that initiates the investment. The investment trigger $\hat{V}_0$ can be derived by equating the expected present value of the investment returns defined in equation (1) and the investment cost I:

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

That means for our example:

$$\hat{V}_0 = 20{,}000 - 2 \cdot 0.5 \cdot 20{,}000 + 100{,}000 \cdot 1.1 = 110{,}000$$

The optimal investment behavior changes if it is taken into account that the decision to invest can be postponed up to one period. The postponement of the investment decision is valuable since new information about the expected present value may become available in the subsequent period. A rational decision maker would only invest immediately if the current expected NPV is higher than the discounted expected NPV of investing one period later. The value of the investment $\tilde{F}$ according to the RO approach is defined as follows:

$$\tilde{F} = \max(E(NPV_0); E(NPV_1) \cdot q^{-1}), \tag{3}$$

where

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

The first term on the right-hand side of equation (3) is the expected NPV in period 0. The second term is the discounted expected NPV of investing one period later. For our example, this means the following:

$$E(NPV_1) = \big(0.5 \cdot \big((0.5 \cdot (120{,}000 + 2 \cdot 20{,}000) + (1-0.5) \cdot (120{,}000 + 20{,}000 - 20{,}000)\big) \cdot 1.1^{-1} - 100{,}000\big) + (1-0.5) \cdot 0\big) \cdot 1.1^{-1} = 12{,}397$$

If we wait one period before deciding whether to invest in farmland or not, the discounted expected value of the NPV in period 1 is 12,397, whereas, the expected value of the NPV in period 0 is 9,091. Therefore, in our example, it is clearly better to wait one period instead of investing immediately. From equations (1) and (3), we derive the investment trigger $\tilde{V}_0$:

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

This means for our example:

$$\tilde{V}_0 = \frac{1.1 \cdot 20{,}000 - 2 \cdot 0.5 \cdot 1.1 \cdot 20{,}000 + 100{,}000 \cdot 1.1^2 + 2 \cdot 0.5^2 \cdot 20{,}000 - 0.5}{1.1 - 0.5} \frac{\cdot 100{,}000 \cdot 1.1}{1.1 - 0.5} = 126{,}667$$

The investment trigger following the NPV approach differs from the investment trigger following the RO approach. The difference between the two triggers amounts to

$$\tilde{V}_0 - \hat{V}_0 = \frac{p \cdot h}{q - p} = \frac{0.5 \cdot 20{,}000}{1.1 - 0.5} = 16{,}667 \tag{5}$$

It can be seen that $\hat{V}_0$ is smaller than $\tilde{V}_0$ as long as p >0. With this in mind, we can formulate the following hypotheses:

Hypothesis H1 "NPV conformity": The investment behavior of farmers is consistent with the NPV approach.

Hypothesis H2 "RO conformity": The investment behavior of farmers is consistent with the RO approach.

Kazakhstan and Germany have a different political and economic situation. Kazakhstan declared its independence only 20 years ago, as a result of the dissolution of the Soviet Union. Before the declaration of its independence, Kazakhstan had had a centrally-planned economy for almost 70 years. Centrally-planned economies are often characterized by a strong governmental intervention with respect to a resource allocation process across the whole economy (Makhija and Stewart, 2002). A public company does not have to take into account changes in consumer demand, price, or cost because they are determined in the centralized economic plan. Managers of these companies are more engaged in the compliance with guidelines regarding the generation and conversion of inputs than in the handling of unforeseen market demands (Siegel-Jacobs and Yates, 1996). Although Kazakhstan has launched significant reforms during a short period of time, it still has a relatively young market economy. In contrast, Western Germany is considered to be a country with a well-established market economy, which has not experienced shocks since World War II. Unlike a centrally-planned economy, managers in a market economy encounter considerably more uncertainty in their decision making. As adequate decision-making processes are not always certain, it must be ensured for managers that they can make discrete, organizational decisions (Ouchi, 1977; Sharpman and Dean, 1997; Makhija and Stewart, 2002). Companies enable managers to make a broader variety of managerial decisions as necessary by making them focus on the results of their decisions instead of predefined processes (Eisenhardt, 1985; Siegel-Jacobs and Yates, 1996). Therefore, we suppose that German farmers are more likely to take into account the value of flexibility and, hence, the content of the RO approach than Kazakhstani farmers when making investment decisions. Therefore, we want to test the following hypothesis:

Hypothesis H3 "country differences": The investment behavior of German farmers is closer to the optimal investment behavior predicted by the RO approach than that of Kazakhstani farmers.

In reality, entrepreneurs tend to perform various operations repeatedly. During these repetitions they are learning from their previous experience, which helps them to make optimal decisions. This phenomenon was studied and described by Brennan (1998), Oprea et al. (2009) and Gilbert and Harris (1981) with reference to investment decisions. In our experiment, farmers deal with repeating investment opportunities and we investigate the presence of a learning effect in their investment behavior. In particular, we test the following hypothesis:

Hypothesis H4 "learning effect": With an increasing number of repetitions farmers time their investment decisions closer to the optimal investment periods predicted by the RO approach.

Farmer-specific variables could also have a considerable impact on the investment behavior of farmers. Therefore, our fifth hypothesis is formulated as follows:

Hypothesis H5 "farmer-specific variables": Farmer-specific variables have a significant influence on the investment behavior of farmers.

We focus on nine farmer-specific variables, which are selected from the literature related to investment behavior. They are reputed to have an influence on the investment behavior of farmers:

- The variable "farm size" measures the size of the arable land of a farm. Savastano and Scandizzo (2009) found out that the larger farmer's present use of land, the higher is the threshold value of the revenue per hectare to justify further land development. That means that the larger the size of original land, the later is the time at which a farmer exercises the option to invest in new land. The positive relation between land size and the threshold value was explained by the fact that a larger size of farmland is associated with decreasing returns to scale and an increasing uncertainty. We expect that the larger the farm size of a farmer, the later he or she will invest.
- The variable "farm type" is a binary variable for farm specialization. The farm type variable has a value of 1 for crop producing farms and 0 for farms specializing in animal husbandry, fodder production, processing of agricultural products and other types of agricultural activity. O'Brien et al. (2003) stated that the entry into some target industries requires more irreversible investments compared to other industries. Subsequently, they argue that as the level of irreversibility of investments required to enter an industry increases, uncertainty will have a stronger negative effect on the entry. We consider that crop producing farms own less assets with irreversible costs than other types of farms. Therefore, we expect that crop producing farms will invest earlier than non-crop producing farms.
- A study by Gardebroek and Oude Lansink (2004) found that increasing age reduces the willingness of farmers to invest. In the present study, we therefore expect that older farmers will invest later than younger farmers because they are more reluctant to invest.

- The dummy variable “gender” is used as an independent variable because prior research on gender revealed that women make more conservative investment decisions (Bajtelsmit and VanDerhei, 1997; Jianakoplos and Bernasek, 1998; Coleman, 2003). Based on this, we expect that female farmers are more reluctant to invest and, therefore, will invest later than male farmers.
- Concerning the education of farmers, we distinguish between the variables “years of education” and “economic education”. The first variable indicates the total number of years of education of a farmer. The second variable “economic education” indicates whether or not a farmer holds a degree in an economy-related subject. Managers with higher education and with a degree in an economy-related subject estimate the value of a real option, and, therefore, the value of waiting higher than other managers (Howell and Jägle, 1997). Therefore, we expect that farmers with more years of education and with an economy-related education will invest later than other farmers.
- The variable “family size” indicates the number of family members of a farmer. Lewellen et al. (1977) found that investors with many dependents make conservative investment decisions. Based on this study, we expect that the larger the family of a farmer, the later he or she will invest.
- The variable “farmer’s income type” is a dummy variable that measures whether or not farming is a principal income for a farmer. Adesina et al. (2000) suggested that an additional non-agricultural income may allow farmers to meet capital costs for technology implementation, which increases the likelihood to adopt new technology. Therefore, we expect that farmers with a principal income from farming are more reluctant to invest due to financial restrictions, which will lead to later investments.
- The variable “HLL value” is a person-specific measure of the risk preferences and is equal to the number of safe choices made by farmers during the HLL experiment. Higher values of HLL correspond to a more risk-averse decision maker. Kroll and Viscusi (2011) argue that risk-averse respondents realize fewer investments. This could also be considered as the manifestation of investment reluctance. We expect that the higher level of individual risk-aversion will lead to later investment decisions.

The investment behavior of farmers during the experiment might be biased by the design of the experiment. In order to control these biases, we derive two hypotheses. First, we pay attention to a framing effect based on the findings of other studies. These studies experimentally demonstrated that participants are more “attached” to a project, which is described in terms that are more familiar to them (Bettman and Sujan, 1987; Cronk and Wasielewski, 2008). In our study, we assume that a treatment describing farmland investment will be closer to the perception of farmers than a treatment describing a non-agricultural option to invest. Subsequently, we expect that farmers will show different investment behavior depending on the framing of a treatment. Thus, our sixth hypothesis is:

Hypothesis H6 "framing effect": Farmers demonstrate different investment behavior if they are confronted with an agricultural or a non-agricultural investment treatment.

Second, responses given in a series of questions and treatments often depend on the order in which these questions and treatments are presented to a respondent (Perreault, 1975–6; Macfie et al., 1989; Legrenzi et al., 1993). With respect to our study that means that the order in which farmers are confronted with both treatments might influence their investment behavior. Therefore, we formulate our last hypothesis as follows:

Hypothesis H7 "order effect": Farmers demonstrate different investment behavior depending on the order how they are confronted with an agricultural and a non-agricultural investment treatment.

3 Experimental setting

The experiment consisted of three parts. The first part described two treatments stylizing an agricultural and a non-agricultural option to invest. In the second part, the HLL experiment was conducted in order to elicit the risk attitudes of farmers. The final part was a questionnaire gathering data about the socio-demographic characteristics of participants and their decision making rules according to which they made decisions. There was no time constrain for participants in the experiment. Participants spent on average about 25 minutes for the investment experiment, 10 minutes for the HLL experiment and 10 minutes for the questionnaire.

The first part included two treatments differing in the framing. In an agricultural treatment, participants had the hypothetical possibility to invest in farmland. In a non-agricultural treatment, participants had the hypothetical possibility to purchase the right to participate in a coin tossing game. Apart from the different wording of the investment treatments, the parameters (initial outlay, interest rate, standard deviation of returns etc.) were the same. In each treatment, each participant was confronted with ten repetitions, i.e., ten (individual) randomly determined paths of the binomial tree. The design of the investment experiment employed the model outlined in the previous section. Within each repetition, respondents could decide to take part in an ongoing investment opportunity in one of ten periods. In every repetition, participants started the experiment with a deposit of 100,000 points. The initial investment outlay was also 100,000 points. According to a binomial approximation of an arithmetic Brownian motion in discrete time, the returns evolved stochastically over ten periods with no drift and with a standard deviation of 20,000 points. The probability that the returns increase or decrease for 20,000 points equaled 50%. The return in period 0 was always 100,000 points. The risk-free interest rate was fixed at 10%. Participants had three possibilities: First, participants could pay the initial outlay of 100,000 points in period 0 and receive the return of period 1. Second, they could postpone the investment decision in period 0 and instead, decide to invest once in periods 1 to 9. Third, participants could invest in none of the 10 periods and save the initial outlay of 100,000 points.

In the HLL experiment, participants could choose from two alternatives: The first alternative provided the opportunity to win 4,000 tenge [3] or 3,200 tenge with probabilities of 10% and 90%, respectively. The second alternative provided the opportunity to win 7,700 tenge or 200 tenge with the same probabilities as in the first alternative. The probabilities varied systematically creating 10 possible combinations: In the first combination, participants could win 4,000 tenge or 7,700 tenge with a probability of 10% and 3,200 tenge and 200 tenge with a probability of 90%. In the second combination, the probabilities rose to 20% and 80%. Until the fourth combination, the expected value of the less risky alternative 1 was higher. When achieving the fifth combination, the expected value of the second alternative exceeded the expected value of the first alternative.

Participants were asked to choose between two alternatives in each of the ten combinations. The observation of the choices of participants regarding the question when 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. Therefore, the decision maker would prefer alternative 1 four times before switching to alternative 2. A HLL value (=number of safe choices) of 4 implied risk neutrality, a HLL value between 0 and 3 expressed risk-preference, whereas a HLL value between 5 and 9 expressed risk aversion of a decision maker [4].

The experiments were conducted in Kazakhstan and in Germany between the end of 2010 and the beginning of 2011. Farmers were recruited through alumni networks of Kazakhstani and German universities. The alumni provided us with addresses of active farmers who were invited to participate in the computer-based experiment. Farmers were also asked to suggest other farmers who might be willing to participate in the experiment. In both countries, farmers received a fixed amount for their participation in the experiment (2,000 tenge in Kazakhstan and €10 in Germany). The target was to recruit about 100 farmers in each country with an acceptable deviation of 10% in both directions. We are not able to indicate an exact figure regarding the amount of farmers who were asked to take part in the experiment, because apart from the farmers we contacted, there is an unknown number of farmers who were invited to participate by other farmers (pyramid scheme). We estimate that approximately 500 farmers were asked to participate in our experiment. In total, 100 Kazakhstani and 106 German farmers participated in the computer-based experiment. That means, 4,120 (2 treatments × 10 repetitions for each of 206 farmers) investment decisions and 206 HLL values were given by participants.

The hypothetical decisions were related to real rewards of participants to ensure the incentive compatibility of the experiment. After all experiments had been carried out, two winners were randomly selected in each experiment conducted with Kazakhstani and German farmers. The chance to be the winner in the investment experiment or the HLL experiment amounted to approximately 1% for Kazakhstani and German farmers, respectively. The reward of the winner in the investment experiment was based on his or her individual scores reached in a randomly chosen repetition of the treatments. The Kazakhstani winner received 2,000 tenge for each 25,000 points, i.e., the potential rewards varied between 4,000 tenge and 36,000 tenge. In the HLL experiment, the winner received a payoff dependent on his or her expressed preference for or aversion against different alternatives. The potential rewards of the winner varied between 200 tenge and 7,700 tenge. The rewards in the experiment intended for German farmers were ten times higher than those in the experiment with Kazakhstani farmers. This adjustment was done on the basis of the ratio of the average salaries in the agricultural sector in both countries, which is ten times higher in Germany than in Kazakhstan (Agency of Statistics of the Republic of Kazakhstan (ASRK), 2011a; Federal Statistical Office (FSO), 2011).

Financial incentives in experiments have been subject to controversial discussions. Although psychologists believe that intrinsic motivation of experimental subjects is high enough to produce steady effort, we presume that experimental subjects will work harder and more effectively if they earn more money for better performance (Camerer and Hograth, 1999). If the budgets of experimenters are limited, many experimenters offer small amounts of financial incentives to each participant. An alternative is a random pay mechanism introduced by Bolle (1990). Although researchers involved in economic experiments have not come to a general agreement regarding payment mechanisms [5], random pay with high stakes is often considered to evoke a more realistic emotional state of participants. Participants become aware that potential outcomes will be substantial if they consider being the one playing for real money (for a recent application of the random pay mechanism in a relatively extreme form and for this line of argument please refer to Schade et al., 2011). In our experiments, we paid a sufficient amount of reward only to two randomly selected participants from each country. Depending on the scores, the expected value of the reward in the investment experiment varied between 40 tenge and 360 tenge. The expected reward of 200 tenge is higher than the wage amount of about 80 tenge for 25 minutes of work in the agricultural sector of Kazakhstan (ASRK, 2011a). In accordance with Holt and Laury (2002), the randomly chosen winner of the HLL experiment received a reward dependent on his or her expressed risk preference. The expected value of the reward in the HLL experiment varied between 2 tenge and 77 tenge. The expected reward of 39.5 tenge is higher than the wage amount of about 32 tenge for 10 minutes of work in the agricultural sector of Kazakhstan (ASRK, 2011a). In the German sample, the expected rewards in both experiments are also higher than the wage amounts for the respective duration of work in the agricultural sector of Germany. Davis and Holt (1993, p. 25) argue that average rewards in experiments should be set enough to compensate the opportunity cost of time for all participants. Therefore, we think that the provided incentive scheme is valid for maintaining the incentive compatibility of the experiment.

4 Normative benchmark

We have to derive normative benchmarks, which reflect the NPV approach and the RO approach for valuing the investment behavior observed in the experiments and for testing our hypotheses. For this purpose, equations (2) and (4) can be used; in view of the experimental design, however, an extension is necessary. Especially, the equation (4) needs to be adapted to the number of potential investment times of ten instead of two. In addition, the risk-adjusted discount rate r^* must be calculated on the basis of the results of the HLL. The solutions of these two tasks are explained in this section.

Calculation of the risk-adjusted discount rate

The risk-adjusted discount rate is calculated using the results of the HLL. In accordance with Holt and Laury (2002), we assume a power risk utility function, which implies declining absolute risk aversion and constant relative risk aversion:

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

where U is utility and θ denotes a relative risk aversion coefficient. Based on equation (6), we can match θ for each farmer based on their choices given in the HLL. On the basis of this information the certainty equivalent CE of a risky prospect is formulated as:

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

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

$$CE_0 = CE_T \cdot (1+r)^{-T} = (E(V_T) - RP_T) \cdot (1+r)^{-T}, \tag{8}$$

where r is a risk-free interest rate. An equivalent risk-adjusted discount rate $r^* = r + v$ can be derived from equation (8) using the following equation:

$$(E(V_T) - RP_T) \cdot (1+r)^{-T} = E(V_T) \cdot (1+r+v)^{-T} \tag{9}$$

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

Obviously, a risk loading v and, thus, a risk-adjusted discount rate $r + v$ depend on a risk premium RP, the length of a discounting period T and the level of an uncertain payment V_T at time T.

Calculation of the exercise frontiers

The calculation of the exercise frontier according to the NPV approach is presented in equation (2). As it can be seen in Figure 1, the exercise frontier for a risk-neutral decision maker according to the NPV approach amounts to a value of 110,000 points and does not change over the periods. That is explained by the fact that the NPV approach does not consider the value of entrepreneurial flexibility to postpone an investment.

The exercise frontier according to the RO approach is determined by a numerical approximation procedure, which is based on dynamic programming (Trigeorgis, 1996, p. 324). As the problem of non-recombining binomial tree for the expected net present value of the project may arise, it however is problematic to apply dynamic programming to a binomial tree by using the risk-adjusted discount rates following equation (9). That means, the amount of potential states increases exponentially as the number of time periods rises (Longstaff and Schwartz, 2001). Therefore, we made a simplification regarding the calculation of the risk-adjusted discount rate in equation (9). First, we fix the level of returns V_T at its initial value.

Second, we fix T in one period. Finally, we derive nine discount rates representing different risk attitudes. The risk-adjusted discount rate varies in the range from 6.8% (HLL value = 0–1) to 13.1% (HLL value = 9–10). Figure 1 depicts the normative benchmarks obtained for the NPV approach and the RO approach for a risk-neutral decision maker.

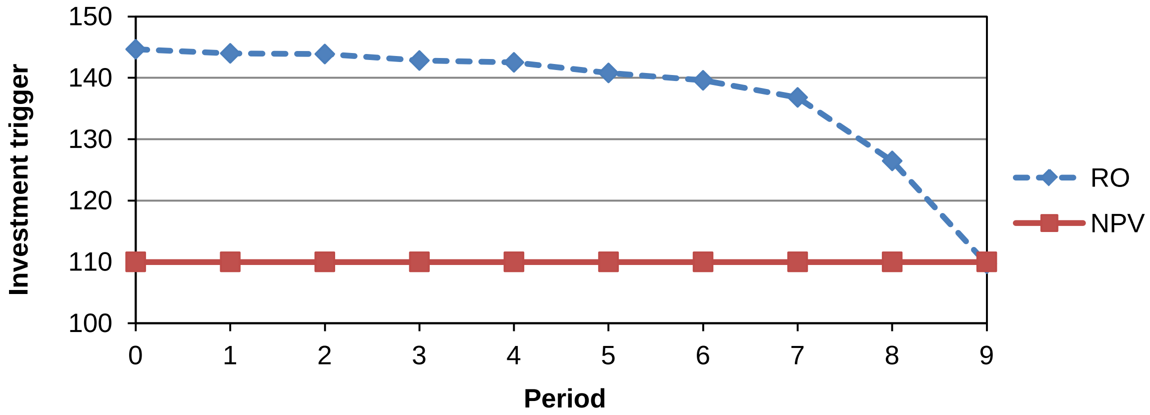

Figure 1. Investment trigger for a risk neutral decision maker
Note: The investment triggers are given in thousand points.

The exercise frontiers of the RO approach decrease exponentially reflecting the diminishing time value of the investment option. The trigger value starts at 144,000 in period 0. The curves coincide with the NPV approach at 110,000 points in period 9 because there is no more time to wait with the investment decision in period 9. The investment trigger in period 8 corresponds to the trigger derived in equation (4) of Section 2. The curve shape of the NPV approach and the RO approach would change slightly according to different risk attitudes of participants, whereas the basic structure is maintained.

5 Descriptive statistics and approach to data analysis

Descriptive statistics

As it is shown in Table I, the average agricultural land size of Kazakhstani participants is much larger than that of German participants. This is not surprising because according to statistical data from the ASRK (2011b) and the Federal Ministry of Food, Agriculture and Consumer Protection (FMFACP, 2011), an average Kazakhstani farmer owns more agricultural land than an average German farmer. Furthermore, the proportion of Kazakhstani farmers engaged in crop production reaches 52% and exceeds an analogous parameter of German farmers (32%). This is explained by the prevalence of the number of grain producing farms in the Kazakhstani agricultural sector. More than half of Kazakhstani farmers are female, while only 19.8% of the German farmers are female. This difference results from the different structural features of farms in the two countries. The Kazakhstani farms consist of several divisions lead by managers who were also involved in the experiment together with the head of the farm. Most of these managers were female in our experiment. In Germany, family farms without several divisions, are prevailing in the agricultural sector. The average number of years of education (school and university years) is the same for Kazakhstani and for German farmers and amounts to 13.8 years. Despite this identity the proportion of Kazakhstani farmers with higher education (70.0%) exceeds the proportion of German farmers with higher education (37.7%). That might be explained by a difference in the educational systems of the two countries. Admission to any course of study at universities and equivalent higher education institutions in Germany requires the general qualification for university entrance or the subject-related higher education entrance qualification. The former enables school-leavers to study at any institution of higher education in any subject or field, while the later only allows the entry into specified study courses (Lohmar and Eckhardt, 2011, p. 146). German pupils have to study from two to three years at a general or a vocational upper level of secondary education in order to obtain the higher education entrance qualification. It is possible to study at a higher level of secondary education only after a successful completion of a lower level of secondary education with the duration of ten years. Kazakhstani pupils have to complete the unified national testing at the end of eleven years of secondary school education successfully. The unified national testing is a form of the final evaluation of pupils in the institutions of secondary education, combined with the entrance examinations in postsecondary or higher education institutions (Education Act of the Republic of Kazakhstan, 2007, s.1(1)).

According to the characteristics of farmers, the sample is unrepresentative for Kazakhstani as well as for German farmers. If the experiment's purpose is to test theory, as it is the case in our study, the use of an unrepresentative sample is acceptable. This is explained by the fact that statistical generalization of the findings from a sample to a larger population is not the purpose of the experimental study aimed at testing theories (Mook, 1983; Lucas, 2003). In these kinds of experimental studies, it is of primary importance to provide internal validity (Falk and Fehr, 2003; Schram, 2005; Sugden, 2005). Internal validity refers to the validity which determines the causality of relationships (Cook and Campbell, 1979, p. 37).

In the following, we would like to compare the investment periods of farmers and the investment periods according to the normative benchmarks. The average period of investment of Kazakhstani farmers is about 0.4 periods longer than the period of investment of German farmers. However, compared to Kazakhstani farmers, German farmers have a higher percentage of non-investment decisions. That means that German farmers decided not to invest in any of the 10 periods provided by the design of the experiment more often than Kazakhstani farmers. Normative benchmarks derived for the NPV approach and the RO approach were applied to 2,000 (Kazakhstan) and 2,120 (Germany) random realizations of the present value of the investment returns generated during the experiment. If the present value of the investment returns observed by the participant in a certain period is higher or equal to the "optimal" investment trigger according to the normative benchmark, the investment should be realized at that period. As it can be seen in Table I, the average periods of investment according to the RO benchmark are considerably later than suggested by the NPV benchmark. In addition, the RO benchmark has a higher percentage of non-investment decisions than the NPV benchmark. Kazakhstani and German farmers invest later than suggested by the NPV benchmark and earlier than suggested by the RO benchmark.

Table I.
Descriptive statistics [a]

	Kazakhstan		Germany	
	Agricultural treatment with 1,000 decisions	Non-agricultural treatment with 1,000 decisions	Agricultural treatment with 1,060 decisions	Non-agricultural treatment with 1,060 decisions
Average farm size	11,685 ha (12,956 ha)		304 ha (570 ha)	
Crop producers	52.0%		32.0%	
Average age of farmers	37.5 years (11.1 years)		30.1 years (10.3 years)	
Average number of years of education	13.8 years (2.1 years)		13.8 years (3.4 years)	
Female farmers	53.0%		19.8%	
Farmers with higher education	70.0%		37.7%	
Farmers with economic education	55.0%		34.9%	
Principal income farmers	88.0%		81.7%	
Average risk attitude of farmers (HLL value)	5.3 (2.6)		4.8 (2.4)	
Average period of investment of farmers without non-investment periods [b]	3.5 (2.8)	3.4 (2.8)	3.0 (3.0)	3.2 (3.0)
Percentage of non-investment of farmers [c]	8.5%	7.4%	12.1%	9.5%
Average period of investment according to NPV without non-investment periods [b]	2.2 (2.1)	2.3 (2.0)	2.3 (2.1)	2.4 (2.1)
Normative percentage of non-investment according to NPV [d]	27.3%	26.8%	27.8%	27.8%
Average period of investment according to RO without non-investment periods [b]	6.0 (2.2)	6.3 (2.1)	6.1 (2.2)	6.0 (2.1)
Normative percentage of non-investment according to RO [d]	46.6%	47.1%	48.3%	46.7%

Note: [a]Standard deviations are indicated in parentheses
[b]The average periods of investment do not take into account the cases of non-investment
[c]Percentage of non-investment of farmers is the percentage of the cases when the participant decided not to invest in any of the ten periods
[d]Normative percentage of non-investment is the percentage of the cases when the normative benchmark predicted no investment

Approach to data analysis

In order to test the hypotheses *H1* and *H2*, we have to define whether there is interdependence between the periods of investment of farmers and the periods of investment according to the forecast following the NPV approach or the RO approach. For this purpose, it is necessary to regress the periods of investment of farmers against the periods of investment according to the NPV approach or the RO approach. The regression is complicated by the fact that, both the dependent variable (the periods of investment of farmers) and the independent variable (the periods of investment according to the NPV approach or the RO approach) have observations which are censored. Censoring takes place because both the dependent variable and the independent variable are interval-censored and measures the time of investment between 0 and 9. Therefore, investment decisions made after these investment periods provided by the experimental design are not observable. Given that the dependent variable and the independent variable are subject to censoring, an appropriate way to estimate the dependence parameter between them is a modified Theil-Sen estimator (Akritas et al., 1995). A modified Theil-Sen estimator is a non-parametric regression based on the Kendall's tau correlation coefficient. We now describe the application of a modified Theil-Sen estimator in the context of our two hypotheses.

X_i^t and Y_i^t, $i = 1, \dots N$, are the investment periods according to the normative benchmarks and the investment periods of farmers, correspondingly. Both variables are not censored, while the variables X_i^c and Y_i^c are censoring variables. The observed values X_i and Y_i are defined as the minimum of the non-censored variables and the censoring variables $X_i = \min(X_i^t, X_i^c)$ and $Y_i = \min(Y_i^t, Y_i^c)$. Censoring indicators, $\delta_i^x = I\,(X_i = X_i^t)$ and $\delta_i^y = I\,(Y_i = Y_i^t)$ are observed. I is an indicator function for an event. We need to estimate an unknown dependence parameter β in the following regression model:

$$Y_i^t = \beta X_i^t + u_i^t, \qquad (10)$$

where β measures the change in Y_i^t associated with a one-period change in X_i^t.

In the uncensored case, the Theil-Sen estimator of the parameter β (Theil, 1950; Sen, 1968) is obtained as the value of b that makes the Kendall's τ statistics between the residuals $y_i - bx_i$ and x_i (approximately) equal to zero. But if both the dependent variable and the independent variable are subject to censoring, the residuals can be right censored, left censored, or both. Akritas et al. (1995) proposed a modification of the Theil-Sen estimator for doubly censored data, which is defined as the solution of b of the equation:

$$T_n(b) = \sum_{i<j} \delta_i^x \delta_j^x \left(I\{X_i < X_j\} - I\{X_j < X_i\}\right) \cdot \left(\delta_i^y I\{r_i(b) < r_j(b)\} - \delta_j^y I\{r_j(b) < r_i(b)\}\right), \quad (11)$$

where $r_i(b)$ is the (possibly) censored analog of $r_i(b)^t = Y_i^t - bX_i^t$.

The modified Theil-Sen estimator of the slope (dependence) parameter with doubly censored data is:

$$\hat{\beta} = \frac{\left(\hat{b}_1 + \hat{b}_2\right)}{2}, \quad (12)$$

where $\hat{b}_1$=$\sup\{b: T_n(b) > 0\}$ and $\hat{b}_2$=$\inf\{b: T_n(b) < 0\}$.

Furthermore, a tobit model (Tobin, 1958) is used in order to test *H3* to *H7*, i.e., to analyze the impact of different independent variables on the investment behavior of farmers. Independent variables are not censored, whereas the dependent variable, i.e., the time of investment of farmers, is subject to censoring. It could be observed only when it falls between 0 and 9. For values below 0, we observe 0; for values above 9, we observe 9. Denoting the time of investment of farmers as Y_i,

$$Y_i = \beta X_i + u_i, \text{ with } i = 1,2, \ldots, N, \quad (13)$$

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

$$Y_i = \begin{cases} 0 & \beta X_i + u_i < 0, \\ 9 & \beta X_i + u_i > 9, \\ \beta X_i + u_i & \text{otherwise,} \end{cases} \quad (14)$$

where 0 and 9 are the censoring interval endpoints. The equation (14) represents a tobit model with double censoring (Maddala, 2006, pp. 150–151).

6 Experimental results

In this section, we test the aforementioned hypotheses.

Hypotheses H1 “NPV conformity” and H2 “RO conformity”

In order to test *H1* and *H2*, we compare the investment behavior of farmers with the benchmark prediction given by the NPV approach and the RO approach in an agricultural and a non-agricultural treatment. Table II shows the hit ratio of the comparison; that is, in how many cases do farmers invest earlier than the NPV approach, in accordance with the NPV approach, in periods between the NPV approach and the RO approach, in accordance with the RO approach and later than the RO approach. In around 45% of the cases, both Kazakhstani and German farmers invest earlier than suggested by the NPV approach in both treatments. Kazakhstani farmers decide in accordance with the NPV approach and invest in the optimal period of this approach in 13.2% of the cases in an agricultural treatment and 12.3% of the cases in a non-agricultural treatment. They invest in accordance with the RO approach in 13.1% of the cases in an agricultural treatment and 11.6% of the cases in a non-agricultural treatment. German farmers invest slightly more often in accordance with the NPV approach and the RO approach in both treatments compared to Kazakhstani farmers. Kazakhstani farmers invest later than predicted by the NPV approach but earlier than predicted by the RO approach in 23.9% of the cases in an agricultural treatment and 22.1% of the cases in a non-agricultural treatment. The percentages of the cases when German farmers time their investment decisions between the periods predicted by the two normative benchmarks are 18.3% and 19.3% in an agricultural treatment and in a non-agricultural treatment, respectively. Kazakhstani farmers invest later than the RO approach in 10.4% of the cases in an agricultural treatment and 10.9% of the cases in a non-agricultural treatment. In about 10% of the cases, German farmers invest later than suggested by the RO approach in both treatments.

Table II.
Hit ratio of the investment behavior of farmers and investment behavior according to the normative benchmarks

	Kazakhstan		Germany	
	Agricultural treatment with 1,000 decisions	Non-agricultural treatment with 1,000 decisions	Agricultural treatment with 1,060 decisions	Non-agricultural treatment with 1,060 decisions
Earlier investment than predicted by the NPV	44.2%	46.8%	49.3%	47.2%
Optimal investment as predicted by the NPV	13.2%	12.3%	13.3%	16.0%
Investment made between the periods predicted by the NPV and the RO	23.9%	22.1%	18.3%	19.3%
Optimal investment as predicted by the RO	13.1%	11.6%	15.1%	13.5%
Later investment than predicted by the RO	10.4%	10.9%	10.1%	9.8%

Note: The sum of the percentages of cases in each column is not equal to 100%. This is explained by the fact that in some cases both normative benchmarks give identical predictions regarding the investment periods of farmers.

Table III illustrates the p-values of dependence parameters $\hat{\beta}$ between the investment timing of farmers and the optimal investment timing according to the NPV approach or the RO approach for Kazakhstan and Germany. The value of a dependence parameter $\hat{\beta}$ equals -6.7055e-08, which is identical for both benchmarks and both countries. The p-values of the dependence parameter are not significant. That means that there is no dependence between the investment timing of farmers and the investment timing according to the normative benchmarks for both countries. Consequently, neither the NPV approach nor the RO approach is able to predict the investment timing of farmers. Thus, the hypotheses *H1 "NPV conformity"* and *H2 "RO conformity"* are rejected.

Table III.
p-values of dependence parameters $\hat{\beta}$ between the investment timing of farmers and the optimal timing

Approach	Kazakhstan	Germany
NPV	0.700	0.294
RO	0.680	0.792

For testing the hypotheses *H3* to *H7*, we run a tobit model in which we regress the investment timing of farmers in an agricultural as well as in a non-agricultural treatment on different independent variables. The results of the tobit regression are presented in Table IV.

Hypothesis H3 "country differences"

The results of the tobit model show that the estimated coefficient of the variable "country" is highly significant and has a positive sign (p-value < 0.001), i.e., on average, German farmers invest 0.737 periods later than Kazakhstani farmers. That means that compared to Kazakhstani farmers, German farmers time their investment decisions closer to the optimal investment periods predicted by the RO approach. Hence, we fail to reject *H3 "country differences"*. At the same time, this might imply that German farmers are more likely to consider the value of flexibility than Kazakhstani farmers when making investment decisions.

Hypothesis H4 "learning effect"

Figure 2 illustrates the average investment period of the 206 farmers from both countries for each of the 20 repetitions (2 treatments × 10 repetitions). It is important to note that this figure does not include the censored data, where farmers do not invest in any of the ten periods.

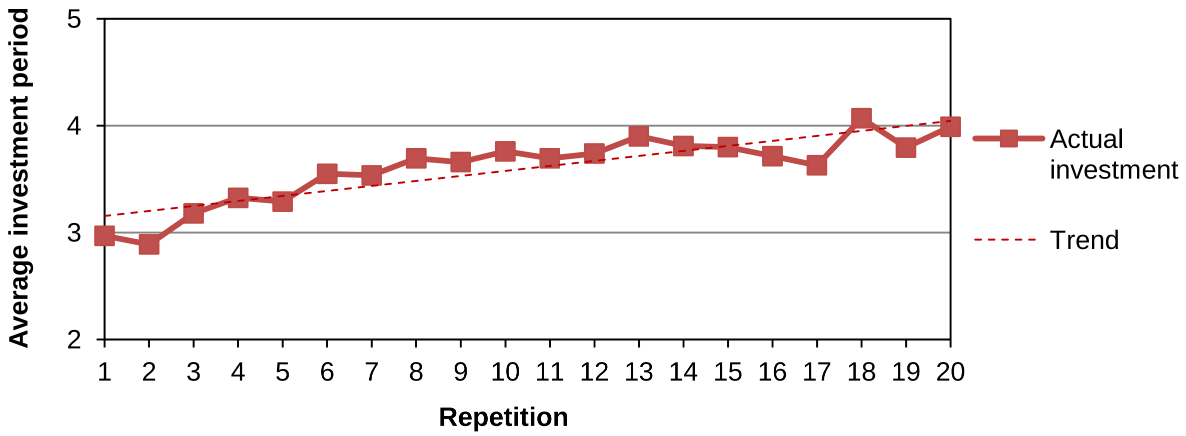

Figure 2. Average investment period of farmers depending on repetition

The trend of the curve is positive, i.e., the greater the repetition, the later farmers invest. The difference of the investment periods between the first (period 3.0) and the last (period 4.0) repetition amounts to 1.0 periods on average.

For further testing of *H4 "learning effect"*, we insert the variable "repetition" in the tobit model. The variable "repetition" corresponds to the number of paths of the binomial tree discussed in Section 3. The estimated coefficient of the variable "repetition" is highly significant and has a positive sign (p-value < 0.001), i.e., with each repetition of an investment treatment, Kazakhstani and German farmers invested 0.066 periods later.

Table IV.
Tobit regression of the individual investment period of farmers (N=4,120)

	Coefficient	Robust standard error	p-value	
Constant	-1.258	0.549	0.022	**
Country (1: Germany, 0:Kazakhstan)	0.737	0.167	<0.001	***
Repetition (from 1 to 20 repetitions)	0.066	0.010	<0.001	***
Farm size	4.56469e-05	7.44387e-06	<0.001	***
Farm type (1: crop producer, 0: other)	0.310	0.126	0.014	**
Age	0.019	0.006	0.002	***
Gender (1: male, 0: female)	0.866	0.133	<0.001	***
Years of education	0.131	0.024	<0.001	***

Table continues on next page

Table IV (continued)

	Coefficient	Robust standard error	p-value	
Economic education (1: economic, 0: other)	-0.244	0.134	0.068	*
Family size	0.068	0.035	0.054	*
Farmer`s income type (1: principal income, 0: sideline)	1.190	0.182	<0.001	***
HLL value (from 0 to 10)	-0.024	0.025	0.343	
Framing (1: non-agricultural, 0: agricultural)	-0.056	0.120	0.641	
Order (1: first agricultural; second non-agricultural, 0: first non-agricultural; second agricultural)	-0.555	0.123	<0.001	***
Wald test for joint significance of farmer-specific variables			<0.001	***

Note: Chi2 = 252.72, Log-Likelihood = -9311.09. Asterisk (*), double asterisk (**) and triple asterisk (***) denote variables significant at 10%, 5% and 1%, respectively.

Therefore, we fail to reject *H4 "learning effect".* That means that with an increasing number of repetitions, the average investment period of farmers increases continuously into the direction of the optimal periods predicted by the RO approach, i.e., the difference between actual and optimal investment periods decreases.

Hypothesis H5 "farmer-specific variables"

We computed the Wald statistic in order to test if farmer-specific variables have a collective influence on the investment behavior of farmers. Table IV shows that farmer-specific variables are jointly significant as indicated by the p-value of less than 0.001 on the Wald test for joint significance. As it can be seen in Table IV, the estimated coefficients of the variables "farm size", "age", "years of education", "family size" and "farmers' income type" are significant and have a positive sign. This implies that farmers with a larger size of farmland, older farmers, farmers with more years of education, farmers with a larger family size and farmers earning a principal income from farm business invest later. All these findings meet our expectations described in Section 2. It can be seen in Table IV that crop producing farmers and male farmers invest later, which contradicts our expectations. The variable "economic education" has a negative sign, which implies that farmers with economic education invest earlier. This might be explained by the fact that in both countries, farmers are more familiar with the NPV approach than with the RO approach as the latter is a relatively new theory and, thus, has not found its way yet into the study program of most economic schools. In general, based on these results, we fail to reject *H5 "farmer-specific variables"* [6].

Hypothesis H6 "framing effect"

As it can be seen in Table IV, the coefficient "framing" is not significant. That means that the framing of the investment experiment has no impact on the investment behavior of farmers in an agricultural context as well as in a non-agricultural context. Farmers demonstrate similar investment behavior in an agricultural as well as in a non-agricultural investment treatment. Therefore, a framing effect is not revealed and *H6 "framing effect"* is rejected. However, we have to consider that the opportunities to invest in farmland and to participate in a coin tossing game were only hypothetical in our experiment.

Hypothesis H7 "order effect"

As already mentioned, a framing effect has no influence on the investment behavior of farmers. But for testing the framing effect, we do not take into account that the order of treatments is randomized, i.e., some participants are confronted first and some participants last with an agricultural treatment (a non-agricultural treatment). It is possible that farmers who are first confronted with an agricultural treatment and afterwards with a non-agricultural treatment show different investment behavior than farmers who are faced with the two treatments in reverse order. We test this assumption by means of the variable "order" included in the tobit model. The variable "order" is a dummy variable, which takes the value of 1 if a farmer is at first confronted with an agricultural treatment and then with a non-agricultural treatment and 0 if a farmer is confronted with both treatments in reverse order. The coefficient of the parameter "order" is significant. That means that the investment behavior of farmers regarding the two variations of the order is different. Farmers, who are first confronted with an agricultural treatment, invest 0.555 periods earlier than farmers who are first confronted with a non-agricultural treatment. A possible interpretation of this finding may be that farmers, who are first confronted with an agricultural treatment, make their decisions in the second treatment with the first treatment in mind and in reverse order. That means, the first treatment influences the investment decision in the second treatment. Therefore, we fail to reject *H7 "order effect"*. However, if we exclude the variable "order" from the tobit model, the signs and the significance of the remaining explanatory variables do not change.

7 Discussion and conclusions

The correct analysis of an investment decision requires a special attention because it represents one of the most important decisions for the economy as a whole and for the particular company. In this article, we focus on the analysis of the investment behavior of Kazakhstani and German farmers. We suggest that German farmers are more likely to take into account the value of flexibility than Kazakhstani farmers when making investment decisions. This suggestion is based on the fact that Germany has had a market economy for a longer period of time compared to Kazakhstan. In order to test this suggestion, we experimentally analyzed whether the investment behavior of Kazakhstani or German farmers is more consistent with the NPV approach or with the RO approach.

We could not indicate that the NPV approach or the RO approach can exactly predict the investment behavior of Kazakhstani as well as German farmers. That means, farmers failed to completely recognize the value of flexibility provided by the RO approach. However, we found that the investment behavior of German farmers is closer to the predictions of the RO approach than that of Kazakhstani farmers. This finding might imply that German farmers are more likely to consider the value of flexibility than Kazakhstani farmers when making investment decisions. Moreover, this result shows that it is not acceptable to apply the results of experiments investigating the investment behavior of entrepreneurs in a transforming country to entrepreneurs in a Western industrialized country and vice versa. Based on the findings of other experimental economic researchers, we tested if the investment behavior of farmers improves with an increasing number of repetitions of the investment treatment. We found out that farmers invest later with each repetition. That means, with each repetition, the average investment period of farmers increases continuously into the direction of the optimal investment periods predicted by the RO approach. We also expected that farmers would demonstrate different investment behavior in an agricultural treatment and in a non-agricultural treatment. However, results show that the investment behavior of farmers in the two treatments does not differ significantly. An important aspect is the order in which the two treatments were allocated to farmers. Farmers, who were first confronted with an agricultural treatment, invested earlier than farmers who were first confronted with a non-agricultural treatment.

From a policy-maker’s viewpoint, our results are relevant insofar as they do not only draw attention to the generally known determinants of an investment decision (e.g. the level of the returns and their uncertainty or the level of the conversion costs), but also to the influence of temporal flexibility with regard to the investment timing in the case of uncertainty. An exclusive reliance on the NPV approach generates the risk that both, the speed and the type of behavioral adaptations to changing institutional environments, are misjudged. Since it is not possible to provide an exact prediction of farmers' investment behavior by using RO benchmarks, experimental methods should be included in the tool kit of policy impact analysis. This allows taking into account the bounded rationality of farmers and the fact that real actors normally pursue multiple goals including non-monetary motivations. In addition, the results of this study imply that there is still room for improvement for farmers in order to achieve the RO benchmark. This could be achieved via training (human capacity building). This implication is consistent with the finding of Howell and Jägle (1997), who also suggested training for managers in order to reduce the noise or bias of intuitive option valuations.

There are various possible research avenues that might help to explain the deviation of observed investment behavior from the normative predictions given by the superior RO approach. It would make sense to test whether simple heuristics can predict the investment behavior of farmers better than the RO approach. Start buy rules or rules containing orders, such as "investing in the project if the project returns rise x-times in a row", are possible examples for such heuristics. It would be interesting to measure the impact of loss aversion on premature investments. As it is stated in the literature, gains tend to cause risk-aversion, whereas losses tend to cause risk-seeking behavior (Kühberger et al., 2002; Cullis et al., 2012). In addition, it was found that losses influence preferences of a decision maker stronger than gains (Tversky and Kahneman, 1991; Epley and Gneezy, 2007). Further research should investigate why the variables "farm type" and "gender" resulted in a later investment decision. It would be interesting to observe how the investment decisions of farmers would change if, instead of land investment, another asset was used in the experiment (i.e., investment in cow barn, pig-fattening barn, irrigation technology etc.). Researchers may also compare disinvestment decisions in transforming and Western industrialized countries. Finally, it is worth pursuing if farmers from other transforming countries would show different investment behavior compared to a Western industrialized country.

Notes

1. The irreversibility of an investment decision is caused by investment expenditures that are sunk costs when they are firm or industry-specific (Dixit and Pindyck, 1994, p. 8).
2. In this study, the term "uncertainty" refers to the unpredictability created by environmental change and complexity (Griffin, 2012, p. 72).
3. €1 = 200 tenge.

4. The instructions for the experiments are available from the authors.
5. Laury (2005) conducts an experiment comparing the two alternatives. She finds that the decisions of the participants did not differ significantly under the two payment systems. This finding is also supported by the results of experiments of other scientists (Armantier, 2006; Wakker et al., 2007).
6. At a first glance it seems to be useful to estimate a fixed effects model in order to control for unobservable participant characteristics. However, the explanatory variables included in the tobit model do not fit to the assumptions of a fixed effects model because they do not change over the repetitions for any participant. Time-invariant causes of the dependent variable cannot be analyzed by the fixed effects estimator. Technically, time-invariant characteristics of the individuals have a perfect collinearity with the person dummies. Inherently, fixed effects models analyze the causes of changes within a person. A time-invariant characteristics cannot cause such a change as it is stable for each person (Kohler and Kreuter, 2005, p. 245).

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Appendix: Experimental Instruction

English version of the Russian and German instructions used in the experiments

Instruction for farmland investment (agricultural treatment)

General Information

[…] The game consists of three parts and would require approximately 40 minutes of your time. Please, read the following instructions carefully as your earnings from the experiment will depend on your decisions. Of course, your data will be treated as confidential and will be analyzed anonymously. […]

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

Beside an expense allowance of 2,000 tenge [1] each participant has two times the chance to receive a bonus if he or she completes the entire game.

- In the first part of the game a player is randomly selected and is given 2,000 tenge cash per 25,000 points achieved in a randomly selected round. The selected player will therefore receive between 4,000 tenge and 36,000 tenge.
- In the second part of the game again a player is selected randomly and is given a cash bonus of between 200 tenge and 7,700 tenge.

In total, up to 100 farmers can participate in the game. They will be informed via e-mail by the 30th of July 2011 if they receive one of the two cash bonuses in addition to the expense allowance. The earnings can be paid out or transferred to an account specified by the selected player.

Good luck!

Please note that submitted decisions cannot be changed.

First Part *(Instruction: Investment Experiment)*

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

Imagine you as a farmer have liquid assets of 100,000 tenge at your disposal and you are offered land for purchase. The land can be used for cultivation and will yield an annual gross margin over an infinite useful lifetime. You can decide within the next 10 years:

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

In the period between 0 and 9 years you can invest in farmland only once. If you decide to invest in farmland you have to pay 100,000 tenge/ha.

The tree chart below shows the possible present values of the returns in thousand tenge, which you can earn in the respective years (year 1 to year 10) when investing in farmland. The present value corresponds to the gross margins in tenge/ha, which can be achieved in case of a risk-free investment, at the respective time of investment assuming an infinite useful lifetime of the farmland and an interest rate of 10%. Moreover, it is assumed that the gross margin observed at the time of investment is guaranteed by an appropriate insurance during the entire useful lifetime. A gross margin of e.g. 10,000 tenge/ha and year then results in a present value of 100,000 tenge/ha, while a gross margin of 12,000 tenge/ha and year would result in a present value of 120,000 tenge/ha etc.

The tree chart starts with a present value of 100,000 tenge/ha in year 0. Starting from this initial value the present value of the following years increases or decreases by 20,000 tenge/ha. The probability of the occurrence of the present value in each year is indicated under the present value.

Year 0	Year 1	Year 2	Year 3	Year 4	Year 5	Year 6	Year 7	Year 8	Year 9	Year 10
										300 (0.1%)
									280 (0.2%)	
								260 (0.39%)		**260** (0.98%)
							240 (0.78%)		**240** (1.76%)	
						220 (1.56%)		**220** (3.13%)		**220** (4.39%)
					200 (3.13%)		**200** (5.47%)		**200** (7.03%)	
				180 (6.25%)		**180** (9.38%)		**180** (10.94%)		**180** (11.72%)
			160 (12.5%)		**160** (15.63%)		**160** (16.41%)		**160** (16.41%)	
		140 (25%)		**140** (25%)		**140** (23.44%)		**140** (21.88%)		**140** (20.51%)
	120 (50%)		**120** (37.5%)		**120** (31.25%)		**120** (27.34%)		**120** (24.61%)	
100		**100** (50%)		**100** (37.5%)		**100** (31.25%)		**100** (27.34%)		**100** (24.61%)
	80 (50%)		**80** (37.5%)		**80** (31.25%)		**80** (27.34%)		**80** (24.61%)	
		60 (25%)		**60** (25%)		**60** (23.44%)		**60** (21.88%)		**60** (20.51%)
			40 (12.5%)		**40** (15.63%)		**40** (16.41%)		**40** (16.41%)	
				20 (6.25%)		**20** (9.38%)		**20** (10.94%)		**20** (11.72%)
					0 (3.13%)		**0** (5.47%)		**0** (7.03%)	
						-20 (1.56%)		**-20** (3.13%)		**-20** (4.39%)
							-40 (0.78%)		**-40** (1.76%)	
								-60 (0.39%)		**-60** (0.98%)
									-80 (0.2%)	
										-100 (0.1%)

Figure A.1 Binomial tree of potential investment returns from investing in farmland
Note: The investment returns are given in thousand tenge.

An investment decision example

Imagine you decide to invest in land in year 5. The present value has developed randomly as shown below and currently amounts to 160,000 tenge/ha. What exactly you will earn from the investment in land depends on the present value development in the next year (year 6):

- you will either earn 180,000 tenge/ha with probability 50%
- or you will earn 140,000 tenge/ha with probability 50%

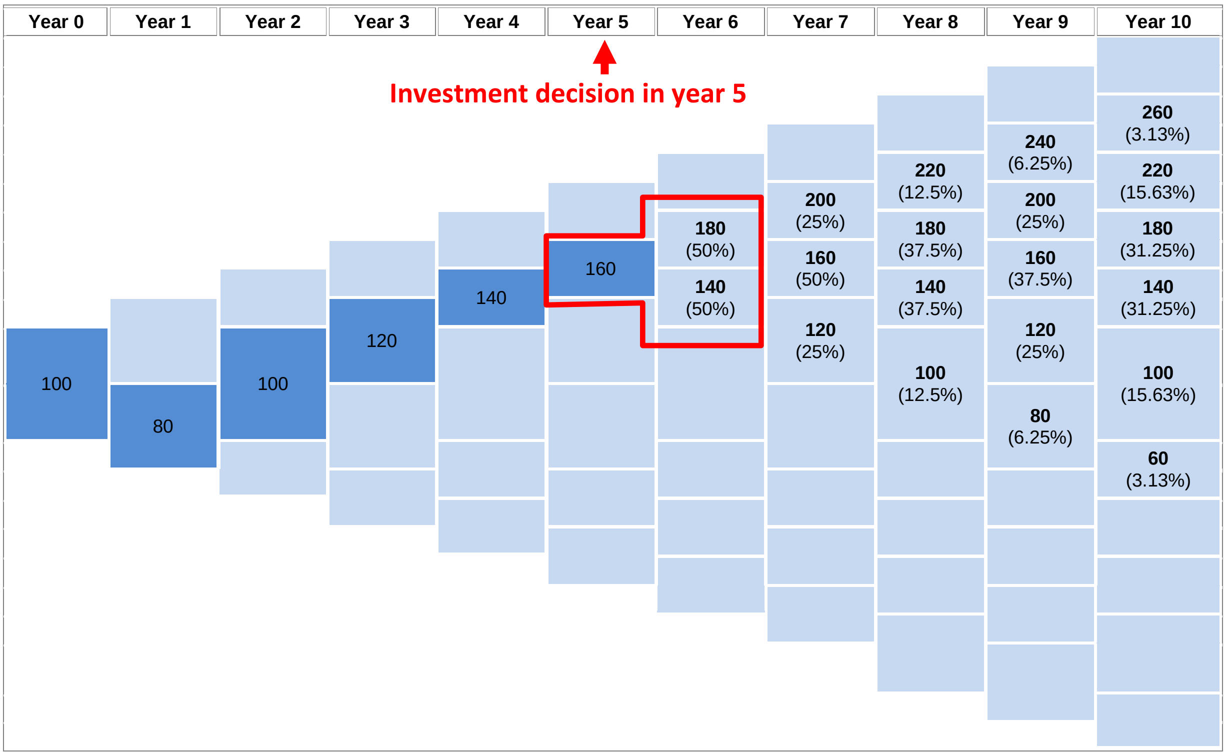

Figure A.2 Binomial tree of potential investment returns from investing in farmland in year 5
Note: The investment returns are given in thousand tenge.

The liquid assets you dispose of in your account in a given year will yield an interest rate of 10% meaning that they will increase by a tenth of their value. For example, if you do not decide to invest in land within the 10 years (between year 0 and year 9), your chance to invest expires and you will leave the game with your starting credit of 100,000 tenge that has increased to 259,374 tenge over the 10 years. In case this game is randomly selected for determining the cash premium, you will receive 20,750 tenge (=259,374/25,000*2,000 tenge).

Example for the calculation of your final account balance in case of an investment in year 10

Imagine the situation of the aforementioned example. In year 5 you decided to invest at a present value of 160,000 tenge/ha. We assume a negative development of the present value from year 5 to year 6 resulting in a decrease of 20,000 tenge/ha. With this investment you would therefore earn 140,000 tenge/ha. In this case your total balance of year 10 would be calculated as follows:

- Your starting credit of 100,000 tenge increases by 10% to 100,000 tenge*1.1^5 = 161,051 tenge.

Your account balance in year 5 is therefore 161,051 tenge.

- You will invest 100,000 tenge of these 161,051 tenge to purchase 1 hectare of land.
- The residual amount of 61,051 tenge yields 10% interest by year 10 (another 5 years) meaning that it increases as follows: 161,051 tenge* 1.1^5 = 98,323 tenge.
- In year 6 you receive a present value from the investment in 1 hectare of land of 140,000 tenge, which also will yield 10% interest by year 10 (another 4 years). 140,000 tenge * 1.1^4 =204,974 tenge.

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

98,323 tenge + 204,974 tenge = 303,297 tenge.

In this example your account balance would be 303,297 tenge in year 10. If this game was randomly selected for determining the cash premium, you would receive 24,264 tenge (=303,297 tenge/25,000*2000 tenge).

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

If the present value of the investment in land is 200,000 tenge/ha in one year, which two present values can occur in the next years?

Please indicate the two present values here:

___________tenge/ha

___________tenge/ha

What is the probability (in %) that the present value in the tree chart increases by 20,000 tenge/ha from one year to another?

Please indicate your answer here: ________ %

What is the probability (in %) that the present value in the tree chart decreases by 20,000 tenge/ha from one year to another?

Please indicate your answer here: ________ %

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

Please indicate your answer here: ________ %

How much are the costs of the investment in land?

___________tenge/ha

In the observed year 5 the present value in the tree chart is 120,000 tenge/ha. The possible present values which can be realised in the next years are indicated in bold.

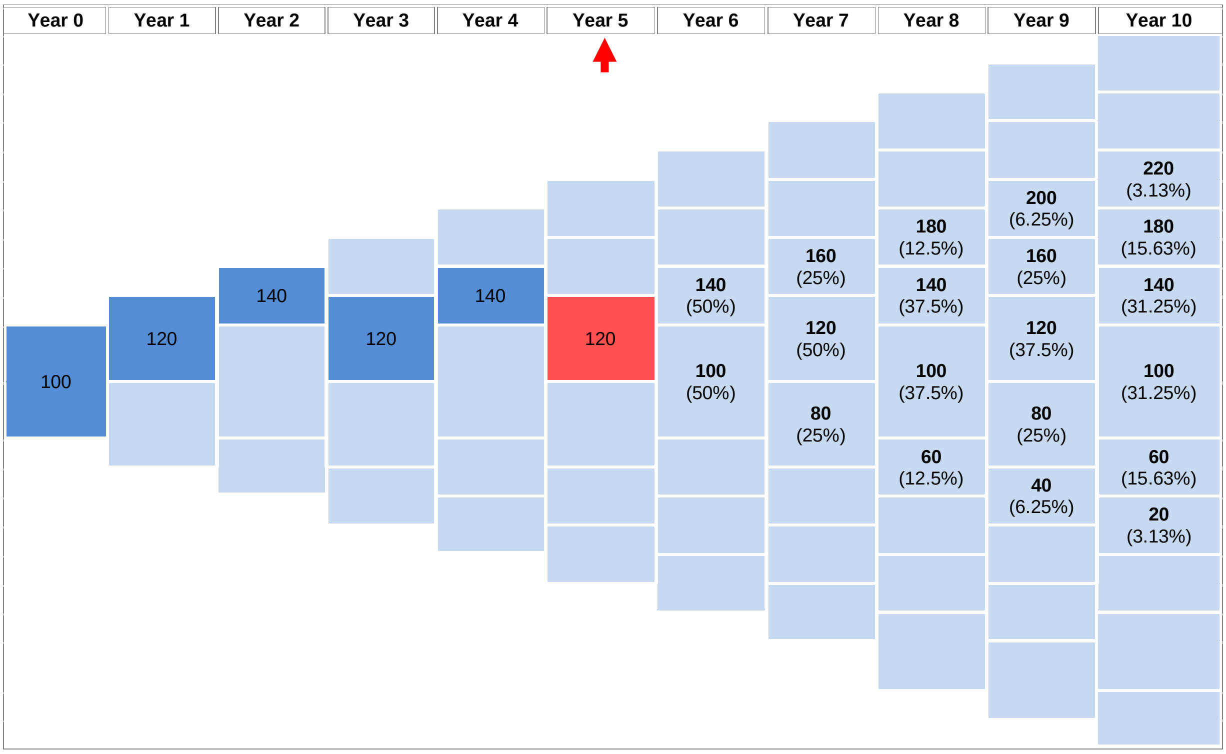

Figure A.3 Randomly chosen fragment of a binomial tree in a control question
Note: The investment returns are given in thousand tenge.

Which of the two present values can potentially be realised in the coming year (year 6)?

Please indicate the two present values here:

___________tenge/ha

___________tenge/ha

You answered all control questions correctly!

Please click “continue” to start the game.

- Here, the experiment starts –

[The investment experiment (first part) consists of two scenarios differing in the framing of the investment situation.

1) *The aforementioned instruction describes an investment situation in an agricultural context. Farmers have the hypothetical possibility to invest in farmland.*

2) *The following scenario would describe an investment situation in a non-agricultural framing. It is possible to purchase the right to participate in a coin tossing game.*

Besides the different wording of the investment situations the parameters in the experiment are exactly the same (e.g. investment cost and discount rate). Therefore, we will not repeat the instruction for the coin tossing game in the appendix. It is randomly determined in which order the individuals were confronted with both investment situations.

Farmers repeated both investment situations (farmland investment and coin tossing game) 10 times.]

Second Part *(Instruction: Holt and Laury lottery)*

Also for the second part of the experiment one participant who receives a cash premium is selected randomly. The cash premium depends exclusively on your own decisions and on chance.

On the next page, you have ten times the option to choose between two lotteries: lottery A and lottery B. With certain probabilities you can win 4,000 tenge or 3,200 tenge in lottery A and 7,700 tenge or 200 tenge in lottery B. The probabilities are varied systematically, so that 10 different starting situations arise. Please decide for one lottery in each of the presented options.

The following figure shows an excerpt of the options between lottery A and B. Option 4 stands out in clear black font. You have to decide between winning 4,000 tenge with 40% probability or 3,200 tenge with 60% probability in lottery A and winning 7,700 tenge with 40% probability or 200 tenge with 60% probability in lottery B.

	Lottery A	Decision for		Lottery B
		A	B	
1	with 10% gain of 4,000 tenge with 90% gain of 3,200 tenge	O	O	with 10% gain of 7,700 tenge with 90% gain of 200 tenge
2	with 20% gain of 4,000 tenge with 80% gain of 3,200 tenge	O	O	with 20% gain of 7,700 tenge with 80% gain of 200 tenge
3	with 30% gain of 4,000 tenge with 70% gain of 3,200 tenge	O	O	with 30% gain of 7,700 tenge with 70% gain of 200 tenge
4	with 40% gain of 4,000 tenge with 60% gain of 3,200 tenge	O	O	with 40% gain of 7,700 tenge with 60% gain of 200 tenge
5	with 50% gain of 4,000 tenge with 50% gain of 3,200 tenge	O	O	with 50% gain of 7,700 tenge with 50% gain of 200 tenge
...	...	O	O	...

Your cash premium emerges as follows: A ten-sided dice determines

1. throw: Which of the ten lottery pairs will finally be decisive for your cash premium. That means that if throwing a 4, the fourth lottery pair will be decisive.

2. throw: Which amount of money from the decisive lottery counts for your cash premium. For example, in the 4th lottery pair you decided for option A (40%: 4,000 tenge; 60%: 3,200 tenge). In case of number of points higher than 4 (=60% probability), you win 3,200 tenge. A thrown number of points of 1 to 4 means that you win 4,000 tenge.

Please decide very carefully since for your cash premium each lottery pair and each amount of money can be drawn by lot.

In the following we ask you to decide in each case for one of the two lotteries A and B. Please make a decision in each of the ten lines. At the end of the game, one of the ten decisions is selected randomly to be relevant for the disbursement of your cash premium.

Lottery A					Lottery B
with **10%** gain of **4,000 tenge** with **90%** gain of **3,200 tenge**	A	☐	☐	B	with **10%** gain of **7,700 tenge** with **90%** gain of **200 tenge**
with **20%** gain of **4,000 tenge** with **80%** gain of **3,200 tenge**	A	☐	☐	B	with **20%** gain of **7,700 tenge** with **80%** gain of **200 tenge**
with **30%** gain of **4,000 tenge** with **70%** gain of **3,200 tenge**	A	☐	☐	B	with **30%** gain of **7,700 tenge** with **70%** gain of **200 tenge**
with **40%** gain of **4,000 tenge** with **60%** gain of **3,200 tenge**	A	☐	☐	B	with **40%** gain of **7,700 tenge** with **60%** gain of **200 tenge**

Option A			Option B
with **50%** gain of **4,000 tenge** with **50%** gain of **3,200 tenge**	A ☐	☐ B	with **50%** gain of **7,700 tenge** with **50%** gain of **200 tenge**
with **60%** gain of **4,000 tenge** with **40%** gain of **3,200 tenge**	A ☐	☐ B	with **60%** gain of **7,700 tenge** with **40%** gain of **200 tenge**
with **70%** gain of **4,000 tenge** with **30%** gain of **3,200 tenge**	A ☐	☐ B	with **70%** gain of **7,700 tenge** with **30%** gain of **200 tenge**
with **80%** gain of **4,000 tenge** with **20%** gain of **3,200 tenge**	A ☐	☐ B	with **80%** gain of **7,700 tenge** with **20%** gain of **200 tenge**
with **90%** gain of **4,000 tenge** with **10%** gain of **3,200 tenge**	A ☐	☐ B	with **90%** gain of **7,700 tenge** with **10%** gain of **200 tenge**
with **100%** gain of **4,000 tenge** with **0%** gain of **3,200 tenge**	A ☐	☐ B	with **100%** gain of **7,700 tenge** with **0%** gain of **200 tenge**

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

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

Notes

1. It should be noted that in the original German version of this instruction euro (€) is used as the monetary unit instead of tenge.

IV. Summary and Discussion

The objectives of this dissertation are the analysis of the explanatory potential of the RO approach regarding the reluctance of Kazakhstani farmers to invest in modern dairy farming and the experimental examination of the investment behavior of Kazakhstani and German farmers. The research questions mentioned in the introduction are briefly answered in the following:

1. Does the RO approach have an explanatory potential regarding the reluctance of Kazakhstani farmers to invest in modern dairy farming?

The research results demonstrate that farmers should not invest in modern dairy farming until the present value of the investment returns transcend the investment costs by a substantial amount. These results corroborate that the RO approach has an explanatory potential regarding the reluctance of Kazakhstani farmers to invest in modern dairy farming.

2. How do different risk attitudes of decision makers influence the level of investment triggers in Kazakhstani modern dairy farming?

The investment triggers rise whenever the interest rates increase. In other words: a more risk-averse farmer is less willing to invest. This result is valid in the context of the NPV approach as well as for the RO approach. A further result is that it is less beneficial for a farmer to postpone the investment at a higher discounting rate. This can be seen from the value of the investment multiple that decreases in comparison to a situation in which only the temporal flexibility is taken into account and not the risk aversion at the same time.

3. How do different stochastic processes influence the level of investment triggers in Kazakhstani modern dairy farming?

The investment trigger based on the assumption of an arithmetic Brownian motion, which seems most plausible for the current application, is smaller than those based on an autoregressive process of order one and a geometric Brownian motion. This result demonstrates the importance of the correct identification of the stochastic process.

4. Is the investment behavior of farmers consistent with the NPV approach or the RO approach?

The research results show that both approaches do not provide an exact prediction of the investment behavior of Kazakhstani and German farmers.

5. Is the investment behavior of German farmers closer to the optimal investment behavior predicted by the RO approach than that of Kazakhstani farmers?

German farmers invest later than Kazakhstani farmers meaning that the investment behavior of German farmers is closer to the RO approach. This could also mean that German farmers are more likely to consider the value of flexibility when making investment decisions than Kazakhstani farmers.

6. Do farmers learn from their experience during the experiment and time their investment decisions closer to the optimal periods predicted by the RO approach over the repetitions?

With an increasing number of repetitions, the average investment period of farmers increases continuously into the direction of the optimal periods predicted by the RO approach, i.e. the difference between actual and optimal investment periods decreases. That means, farmers learn from their experience during the experiment and time their investment decisions closer to the optimal periods predicted by the RO approach over the repetitions.

The results of this dissertation have different practical relevance. The two articles provide certain policy implications. The results of the study presented in the first article reveal the considerable effect of the flexibility of an investment decision and volatile returns on the investment trigger of farmers and, therefore, emphasize the significance of temporal opportunity costs. Therefore, it is important for policymakers to consider alternative ways of promoting modern dairy farming in Kazakhstan rather than subsidies and other forms of transfer payments. For instance, the impact of transfer payments might rise if the payments were limited in time. Ultimately, the temporal opportunity costs would decrease over time and the decision to invest would be moved closer to a “now-or-never-decision”. For the government, it would be the wrong sign to promise more payments to farmers in order to promote modern dairy farming. This would cause an increase of the intertemporal opportunity costs and would hence result in stronger reluctance to invest. The experimental study presented in the second article found that farmers do not completely recognize the value of flexibility provided by the RO approach when making investment decisions. This implies that there is still room for improvement for farmers in order to achieve the RO approach benchmark. This could be achieved via training (human capacity building). Since the RO benchmark cannot exactly predict the investment behavior of farmers, experimental methods should be included in the tool kit of policy impact analysis. This would allow considering the bounded rationality of farmers and the fact that real actors normally pursue multiple goals including non-monetary motivations.

There is the need for future research in each of the studies presented, which is explained in detail in the conclusion sections of each article. Nevertheless, the following range of subjects is prominent:

The model used in the first article does not consider personal preferences different from profit maximization and risk aversion (Wale et al., 2005), perceptions (Joshi and Pandey, 2006), and other behaviorist characteristics possibly inherent in each decision maker (Sandri et al., 2010). Therefore, an experimental investigation of the investment decision patterns of Kazakhstani farmers aiming at the differentiation of behavioristic factors from option-based factors might be a motivation for further research. Moreover, market and climatic conditions are different across the regions of Kazakhstan. In future studies, it is thus important to analyze the sensitivity of the results with regard to location conditions.

With respect to the study presented in the second article, there are different research directions that might contribute in a better explanation of the deviation of the actual investment behavior of farmers from the normative predictions given by the superior RO approach. It is useful to analyze if simple heuristics can predict the investment behavior of farmers better than the RO approach. Examples for such heuristics are start buy rules or rules containing orders, such as "investing in the project if the project returns increase x-times in a row". It would make sense to estimate the effect of loss aversion on premature investments. Some studies revealed that profits cause risk aversion, whereas losses cause risk-seeking behavior (Kühberger et al., 2002; Cullis et al., 2012). Moreover, it was found that losses have a stronger impact on preferences of a decision maker than profits (Tversky and Kahneman, 1991; Epley and Gneezy, 2007). Finally, it would be interesting to investigate whether farmers from other transforming countries would demonstrate different investment behavior compared to farmers from a Western industrialized country.

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Curriculum vitae

Name	Dulat Tubetov
The date of birth/place	24.04.1986 in Astana (Kazakhstan)
Education	
06/2001	School leaving examination, Secondary school № 37, Astana, Kazakhstan
09/2001–07/2004	Specialization in accountancy, economics and audit, Akmola financial economic college, Astana, Kazakhstan
07/2004	Diploma in Accountancy, economics and audit, Akmola financial economic college, Astana, Kazakhstan
09/2004–07/2007	Specialization in finance, Kazakh humanitarian law university, Astana, Kazakhstan
07/2007	Bachelor in Finance, Kazakh humanitarian law university, Astana, Kazakhstan
06/2009	Master of Science in Management, S.Seifullin Kazakh agricultural technical university, Astana, Kazakhstan
Practical training	
03/2004–06/2004	Professional practice in JSC KazAutoTrans, Astana, Kazakhstan
02/2008–03/2008	Professional practice in LTD KazAgroTrade+, Astana, Kazakhstan
08/2008–11/2008	Professional practice in LTD AgroCenterAstana, Astana, Kazakhstan
Current occupation	
Since 10/09	A scientific assistance at the Georg-August-Universität Göttingen – Working group “Farm Management” of the Department of Agriculture and Rural Development
Language skills	English