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

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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 those 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:** 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% (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% (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; HÜTTEL 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, 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 those 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 organi-

zations. 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 KazAgroFinance, 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, 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 1. 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 ENGELN, 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: 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 1.

### 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  $I$ :

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

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: 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):

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

where  $F(x, t)$  denotes the value of the investment option,  $E(\cdot)$  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: 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.

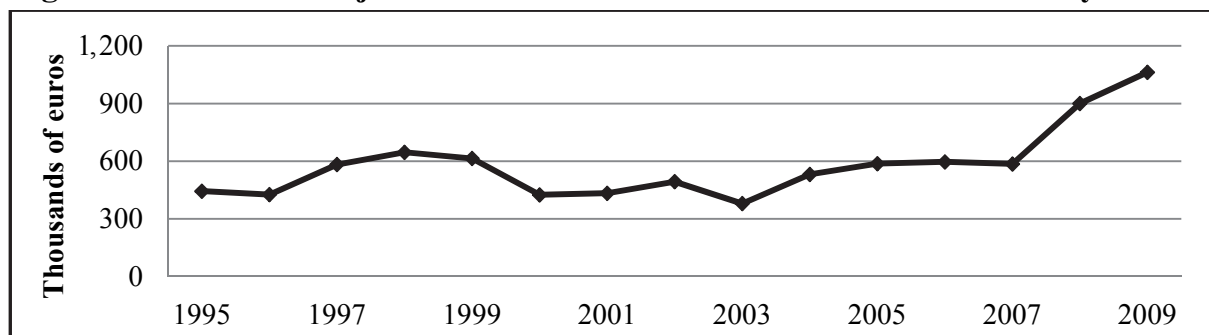
Wheat yields, prices for wheat, milk, and mixed fodder are taken for the years from 1995 to 2009 in order to create an inflation-adjusted time series of the incremental cash flow of the modern dairy farm. In particular, the national average prices for milk for the years from 1995 to 2008 are derived from FAO (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 2.

**Table 2. Averages of disaggregated variables of the inflation-adjusted incremental cash flows of the modern dairy farm (per herd and year)**

Description	Value (€)	%
<b>Revenues</b>	<b>1,612,722</b>	<b>100.00</b>
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
<b>Costs</b>	<b>1,032,229</b>	<b>100.00</b>
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
<b>Incremental cash flow</b>	<b>580,493</b>	<b>-</b>

Source: own calculations

The incremental cash flows shown in figure 1 are taken as an input for an augmented Dickey-Fuller test (ENDERS, 2003: 76-79) as well as for a variance ratio test (CAMPBELL et al., 1997: 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: 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: 310):

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

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

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

Based on a t-test, the drift parameter of an ABM  $\alpha$  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: 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:

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



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

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

Based on a t-test, the drift parameter of a GBM  $\alpha$  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:

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

where  $a_1$  is the weighting factor of the process estimated on the basis of the last observed values  $x_{t-1}$ ,  $\chi_t$  is an error term, and  $\sigma$  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:

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

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 3.

**Table 3. Estimated parameters of the stochastic processes**

Parameter	Arithmetic Brownian motion	Geometric Brownian motion	Autoregressive process of order one
Drift rate $\alpha$	€0 p.a.	0% p.a.	-
Standard deviation $\sigma$	€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, 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

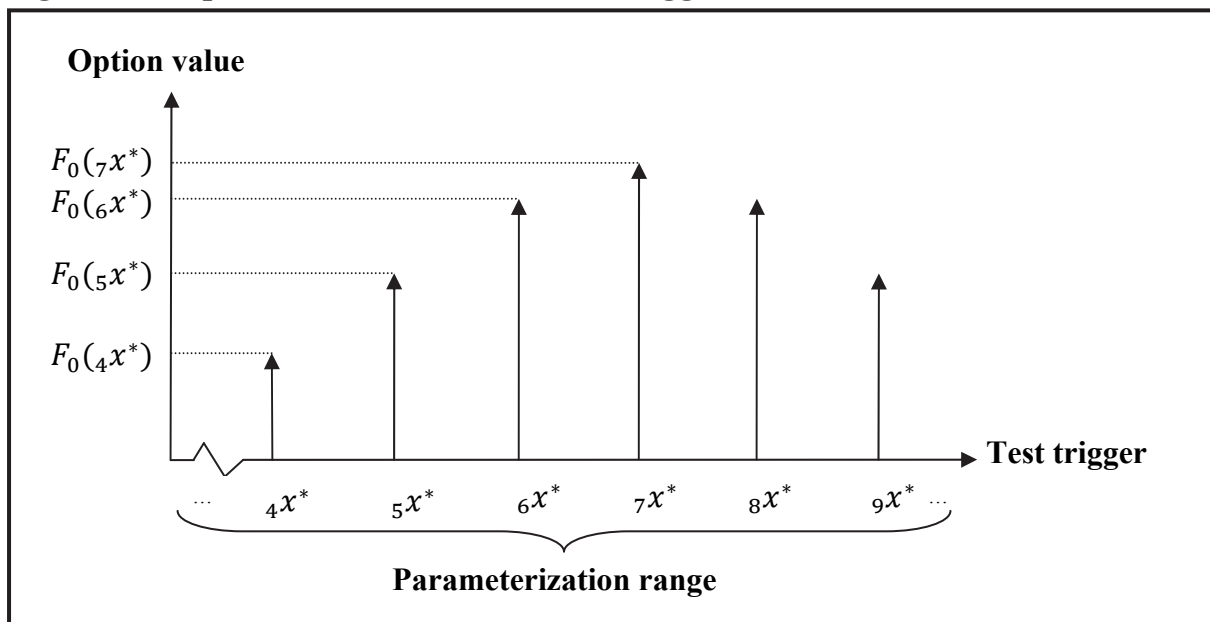
Given the model assumptions described in the previous section, we can interpret the investment decision in dairy farming as the real option with an infinite exercising period during which the investment trigger remains constant at each discrete exercise date. The valuation of this type of option is not 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: 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: 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 value 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  $x_1^* \dots x_N^*$  (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 option 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:

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

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

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 4 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 2). 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: 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 4:

- 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 4. 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
	Stochastic process	Interest rate (% p.a.)	Without consideration of time flexibility			With consideration of time flexibility			Investment-multiple
			Critical cash flow (€)	Critical present value (€)	NPV (€)	Critical cash flow (€)	Critical present value (€)	Option value (€)	
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

Notes: 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 4 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 the location conditions.

## References

- ABDISHUKURULI, O. (2011): The Problems of Revival of the Domestic Husbandry. In: *AgroAlem* 9 (14): 16-19.
- ASRK (Agency of Statistics of the Republic of Kazakhstan) (2007-2011): Series № 3 “Agriculture, Forestry, and Fishery Bulletin: About the Activity of Agricultural Companies in the Republic of Kazakhstan. Main Indicators of the Development of Husbandry in the Republic of Kazakhstan, 2006–2010”. Agency of Statistics of the Republic of Kazakhstan, Astana.
- (2010a): Series №3 “Agriculture, Forestry, and Fishery Bulletin: About the Activity of Agricultural Companies in the Republic of Kazakhstan”, volume № 1 “About the State of Plant Growing in Agricultural Companies in 2009”. Agency of Statistics of the Republic of Kazakhstan, Astana.
- (2010b): Series №3 “Agriculture, Forestry, and Fishery Bulletin: About the Activity of Agricultural Companies in the Republic of Kazakhstan”, volume № 2 “About the State of Animal Husbandry in Agricultural Companies in 2009”. Agency of Statistics of the Republic of Kazakhstan, Astana.
- (2010c): Price Indexes by Sectors of Economy, 1992-1994. In: [http://www.stat.kz/digital/ceni\\_tarifi/Pages/default.aspx](http://www.stat.kz/digital/ceni_tarifi/Pages/default.aspx).
- (2010d): Prices for Agricultural Products Sold through Various Channels in the Republic of Kazakhstan. In: [http://www.eng.stat.kz/publishing/DocLib/Kaz\\_2008\\_eng.pdf](http://www.eng.stat.kz/publishing/DocLib/Kaz_2008_eng.pdf).
- BALMANN, A., M. ODENING, H.-P. WEIKARD and W. BRANDES (1996): Path-dependence without Increasing Returns to Scale and Network Externalities. In: *Journal of Economic Behavior and Organization* 29 (1): 159-172.
- BARLETT, P.F. (1986): Part-time Farming: Saving the Farm or Saving the Life-style? In: *Rural Sociology* 51 (3): 289-313.
- BISHOP, C.P., C.R. SHUMWAY and P.W. WANDSCHNEIDER (2010): Agent Heterogeneity in Adoption of Anaerobic Digestion Technology: Integrating Economic, Diffusion, and Behavioral Innovation Theories. In: *Land Economics* 86 (3): 585-608.
- BOKUSHEVA, R., V. VALENTINOV and V. ANPILOGOVA (2007): The Investment Behaviour of Russian Farms. In: *Post-Communist Economies* 19 (1): 53-71.

- BREALEY, R.A., S.C. MYERS and F. ALLEN (2008): *Principles of Corporate Finance*. McGraw Hill, Irwin.
- BROADIE, M. and J. DETEMPLE (1996): American Option Valuation: New Bounds, Approximations, and a Comparison of Existing Methods. In: *The Review of Financial Studies* 9 (4): 1211-1250.
- CAMPBELL, J.Y., W. LO and C. MACLINLAY (1997): *The Econometrics of Financial Markets*. Princeton University Press, Princeton, New Jersey, USA.
- COBB, B.R. and J.M. CHARNES (2003): *Simulation Methodology for Collateralized Debt and Real Options: Simulation and Optimization for Real Options Valuation*. Paper presented at the 35th Conference on Winter Simulation: Driving Innovation. December 7-10, 2003, New Orleans, Louisiana, USA.
- DERCON, S. and L. CHRISTIAENSEN (2011): Consumption Risk, Technology Adoption and Poverty Traps: Evidence from Ethiopia. In: *Journal of Development Economics* 96 (2): 159-173.
- DIXIT, A.K. and R.S. PINDYCK (1994): *Investment under Uncertainty*. Princeton University Press, Princeton, New Jersey, USA.
- ENDERS, W. (ed.) (2003): *Applied Econometric Time Series*. Wiley, John & Sons, New Jersey, USA.
- ENGEL, P.D. and J. HYDE (2003): A Real Options Analysis of Automatic Milking Systems. In: *Agricultural and Resource Economics Review* 32 (2): 282-294.
- FAO (Food and Agriculture Organization of the United Nations) (2010): Milk Prices, 1995-2007. In: <http://faostat.fao.org/site/570/DesktopDefault.aspx?PageID=570#ancor>.
- GEBREGZIABHER, G. and S. HOLDEN (2011): Does Irrigation Enhance and Food Deficits Discourage Fertilizer Adoption in a Risky Environment? Evidence from Tigray, Ethiopia. In: *Journal of Development and Agricultural Economics* 3 (10): 514-528.
- GEBREMEDHIN, T.G. and S. GEBRELUL (1992): An Investment Analysis of Meat Goat Enterprises for Small-scale Producers. In: *Review of Agricultural Economics* 14 (1): 45-53.
- HAUG, E.G. (1998): *The Complete Guide to Option Pricing Formulas*. McGraw Hill, New York, USA.
- HU, X. and F. SCHIANTARELLI (1998): Investment and Capital Market Imperfections: A Switching Regression Approach Using U.S. Firm Panel Data. In: *Review of Economics and Statistics* 80 (3): 466-479.
- HUDSON, D., K. COBLE and J. LUSK (2005): Consistency of Risk Premium Measures. In: *Agricultural Economics* 33 (1): 41-49.
- HULL, J.C. (ed.) (2009): *Option, Futures, and Other Derivatives*. Prentice Hall, Toronto, Canada.
- HULT, G.T.M., C.W. CRAIGHEAD and D.J. KETCHEN, Jr. (2010): Risk Uncertainty and Supply Chain Decisions: A Real Options Perspective. In: *Decision Sciences Journal* 41 (3): 435-458.
- HÜTTEL, S., O. MUSSHOFF and M. ODENING (2010): Investment Reluctance: Irreversibility or Imperfect Capital Markets? In: *European Review of Agricultural Economics* 37 (1): 51-76.

- IBANEZ, A. and F. ZAPATERO (2004): Monte Carlo Valuation of American Options through Computation of the Optimal Exercise Frontier. In: *Journal of Financial and Quantitative Analysis* 39 (2): 253-275.
- ISON, R. and D. RUSSEL (ed.) (2000): *Agricultural Extension and Rural Development: Breaking out of Traditions*. Cambridge University Press, Cambridge, UK.
- JOSHI, G.R. and S. PANDEY (2006): Farmers' perceptions and adoption of modern rice varieties in Nepal. In: *Quarterly Journal of International Agriculture* 45 (2): 171-186.
- KAF (KazAgroFinance) (2009): *The Creation of Large Scale Commercial Dairy Farms*. KazAgroFinance, Astana.
- KAHNEMAN, D. (2003): Maps of Bounded Rationality: Psychology for Behavioral Economics. In: *American Economic Review* 93 (5): 1449-1475.
- KALIBA, A.R.M., H. VERKUIJL and W. MWANGI (2000): Factors Affecting Adoption of Improved Maize Seeds and Use of Inorganic Fertilizer for Maize Production in the Intermediate and Lowland Zones of Tanzania. In: *Journal Agricultural and Applied Economics* 32 (1): 35-47.
- KAM (KazAgroMarketing) (2009): *The Development of the Commercial Dairy Farms Network on the Territory of Kostanai and North Kazakhstan Oblasts*. KazAgroMarketing, Astana.
- KAY, A. (2003): Path Dependency and the CAP. In: *Journal of European Public Policy* 10 (3): 405-420.
- LERMAN, Z., Y. KISLEV, D. BITON and A. KRISS (2003): Agricultural Output and Productivity in the Former Soviet Republics. In: *Economic Development and Cultural Change* 51 (4): 999-1018.
- LUENBERGER, D.G. (1998): *Investment Science*. Oxford University Press, New York, USA.
- LUONG, Q.V. and L.W. TAUER (2006): A Real Options Analysis of Coffee Planting in Vietnam. In: *Agricultural Economics* 35 (1): 49-57.
- MAK (Ministry of Agriculture of Kazakhstan) (2009): *Master Plan for the Development of Milk Production and Processing (in Russian)*. In: [http://www.minagri.kz/images/master\\_plan/ms\\_pl\\_moloko.pdf](http://www.minagri.kz/images/master_plan/ms_pl_moloko.pdf).
- MCDONALD, R. and D. SIEGEL (1986): The Value of Waiting to Invest. In: *Quarterly Journal of Economics* 101 (4): 707-728.
- MCGUIRE, S.J. (2008): Path-Dependency in Plant Breeding: Challenges Facing Participatory Reforms in the Ethiopian Sorghum Improvement Program. In: *Agricultural Systems* 96 (1-3): 139-149.
- MILNER-GULLAND, E.J., C. KERVEN, R. BEHNKE, I.A. WRIGHT and A. SMAILOV (2006): A Multi-agent System Model of Pastoralist Behavior in Kazakhstan. In: *Ecological Complexity* 3 (1): 23-36.
- NBRK (National Bank of the Republic of Kazakhstan) (2010): *The Structure of National Currency Denominated Government Securities in Circulation*. In: <http://www.nationalbank.kz/?docid=353>.
- ODENING, M., O. MUSSHOFF and A. BALMANN (2005): Investment Decisions in Hog Production – an Application of the Real Options Approach. In: *Agricultural Economics* 32 (1): 36-47.

- PEREZ, C. and L. SOETE (1988): Catching up in Technology: Entry Barriers and Windows of Opportunity. In: Dosi, G. (eds.): In Technical Change and Economic Theory. Printer, London: 458-479.
- PINDYCK, R.S. and D.L. RUBINFELD (ed.) (1998): Econometric Models and Economic Forecasts. Irwin/McGraw Hill, Boston, Massachusetts, USA.
- PRESS CENTER OF KAZAGROFINANCE (2011): Breeding Stock for Kazakh Farms. In: Agro-Dom 8 (21): 3.
- PURVIS, A., W.G. BOGGESE, C.B. MOSS and J. HOLT (1995): Technology Adoption Decisions under Irreversibility and Uncertainty: An Ex Ante Approach. In: American Journal of Agricultural Economics 77 (3): 541-551.
- RICHARDS, T.J., W.E. NGANJE and R.N. ACHARYA (2009): Public Goods, Hysteresis, and Underinvestment in Food Safety. In: Journal of Agricultural and Resource Economy 34 (3): 464-482.
- RODINA LTD. (2008): The Financial Report for the Year 2007. Priozernoe village, Akmolinskaya oblast, Kazakhstan.
- (2010): The Financial Report for the Year 2009. Priozernoe village, Akmolinskaya oblast, Kazakhstan.
- ROGERS, E.M. (ed.) (2003): Diffusion of Innovations. Free Press, New York.
- SANDRI, S., C. SCHADE, O. MUSSHOFF and M. ODENING (2010): Holding on for Too Long? An Experimental Study on Inertia in Entrepreneurs' Disinvestment Choices. In: Journal of Economic Behavior and Organization 76 (1): 30-44.
- SAUER, J. and D. ZILBERMAN (2012): Sequential Technology Implementation, Network Externalities, and Risk: The Case of Automatic Milking Systems. In: Agricultural Economics 43 (3): 233-252.
- SCANDIZZO, P.L. and S. SAVASTANO (2009): Optimal Farm Size under an Uncertain Land Market: The Case of Kyrgyz Republic. Paper presented at the 111th EAAE-IAAE Seminar "Small Farms: Decline or Persistence", June 26-27, 2009. Canterbury, UK.
- SEO, S., E. SEGARRA, P.D. MITCHELL and D.J. LEATHAM (2008): Irrigation Technology Adoption and Its Implication for Water Conservation in the Texas High Plains: A Real Options Approach. In: Agricultural Economics 38 (1): 47-55.
- SIMON, H.A. (1979): Rational Decision Making in Business Organizations. In: The American Economic Review 69 (4): 493-513.
- STOKES, J.R. (2006): Entry, Exit, and Structural Change in Pennsylvania's Dairy Sector. In: Agriculture and Resource Economics Review 35 (2): 357-373.
- SUMNER, D.A. and J.D. LEIBY (1987): Human Capital on Size and Growth among Dairy Farms. In: American Journal of Agricultural Economics 69 (2): 465-470.
- TAUER, L.W. (2006): When to Get in and out of Dairy Farming: A Real Option Analysis. In: Agriculture and Resource Economics Review 35 (2): 339-47.
- TIWANA, A., J. WANG, M. KEIL and P. AHLUWALIA (2007): The Bounded Rationality Bias in Managerial Valuation of Real Options: Theory and Evidence from IT Projects. In: Decision Sciences 38 (1): 157-181.
- VAN ENGELEN, A. (2011): Dairy Development in Kazakhstan. Food and Agriculture Organization of the United Nations, Rome.

- WALE, E., K. HOLM-MUELLER, J. MBURU and M. ZELLER (2005): Economic Analysis of Farmer's Preferences for Coffee Variety Attributes: Lessons for On-farm Conservation and Variety Adoption in Ethiopia. In: *Quarterly Journal of International Agriculture* 44 (2): 121-139.
- WOOLDRIDGE, J.M. (ed.) (2009): *Introductory Econometrics: A Modern Approach*. South-Western, Mason, Ohio, USA.
- ZHUANG, J., M.A. MARCHANT, L.C. SCHARDL and C.M. BUTLER (2005): Economic Analysis of Replacing Endophyte-infected with Endophyte-free Tall Fescue Pastures. In: *Agronomy Journal* 97 (3): 711-716.

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