ACTA SCIENTIARUM POLONORUM *Oeconomia 10 (2) 2011, 107–120*

ASSESSMENT OF ECONOMIC EFFECTS OF INNOVATIONS IN AUTOMATIC MILKING SYSTEMS IN PODLASKIE REGION (POLAND) WITH THE USE OF REAL OPTION APPROACH[1]

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Abstract. In the dairy sector of the Podlaskie region, the leader in milk production and processing in Poland, strong concentration processes are observed. Enlargement of herds of dairy cows in a number of farms increases farmers' interest in adoption of innovative, automatic milking systems (AMS). In this paper, the profitability of different timing of investment implementation in milking robots was assessed, focusing on the dairy farm types dominating in the region. The implemented model is based on a real option approach that includes investment irreversibility and stochasticity in direct payments rate, milk and labour prices. Additionally several investment support rates from Rural Development Plan has been considered. The analysis shows that delaying investment in AMS under conditions of the reformed CAP would be a better strategy as compared to investments in the first year of modelling period. However, the benefit form postponing decision on investment is diminishing with increasing farm size and input of hired labour.

Key words: real options, milking robots, dairy farms, uncertainty

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[1] The analysis presented in the paper is based largely on the study that has been conducted in the framework of the 7th EU Framework Programme project CAP-IRE ('Assessing the multiple Impacts of the Common Agricultural Policies (CAP) on Rural Economies') and does not reflect any EU Commission opinion.

Podlaskie region is located in the North-Eastern part of Poland. Agriculture is one of the main industries in the region. Due to favourable natural conditions, milk production is the key activity for about 45% of farms from over 109 thousand in total. In the farming sector of the region, a continuous trend of concentration of land and livestock is observed. It results in the enlargement of herds of dairy cows in farms specialized in milk production and increased needs of investments in land, stands for livestock as well as for labour saving equipment. Automatic milking systems offer a new, labour extensive technology of milking cows that attracts attention of a large number of farmers.

New technology adoption and innovation diffusion represent two central elements for the enterprise and industry development process in all sectors of the economy. Innovation is one of the main drivers of economic growth and an important instrument for improving efficiency and achieving a higher level of farm-business sustainability. Adoption of innovations and re-organization of agri-food chains are two of the Common Agricultural Policy (CAP) Health Check priorities that aim at improving competitiveness of agri-food sectors in the European Union. Competitiveness is one of the axes of the EU Rural Development Programs (RDP). RDP as a whole, and the first axis in particular, are expected to be strengthened in the next years.

However, the effectiveness of even stronger investment support policy is not ensured, as farmers are operating in an increasingly uncertain environment. Such uncertainty is often a cause of delays in the process of farm innovations. Uncertainties can derive primarily from the markets, but are also related to institutional risk created by the upcoming CAP reform process. [Was, Malak 2008; Majewski et al. 2008]. Rodrik [1991], for example, has shown that even a low level of uncertainty regarding a policy reform may withhold farmers from investing.

The objective of the paper is to provide an ex-ante assessment of the effectiveness of delaying decision on investments in milking robots (AMS – automatic milking systems) in selected types of dairy farms.

SELECTION OF FARM TYPES FOR MODELING

Within the CAP-IRE project 250 farmers from Podlaskie region have been interviewed in a farm-households survey conducted in the year 2009 [Majewski et al. 2011]. The farms in the sample represent a range of farm size clusters and different production types. Only commercial farms (approximately larger than 10 hectares of agricultural land) have been selected for the survey.

From the whole sample a subsample of dairy farms was created. With the use of Cluster Analysis[2] three dominating types of dairy farms were identified for modelling. Variables used for cluster analysis were: number of milking cows, milk yield per cow (litres), farm area (ha), share of rented land, farmer's age, number of members of the household, indicator of soil quality, cost of chemical protection per 1 ha, quantity of

[2] A non-hierarchical k-means cluster analysis was applied. In order to avoid arbitrary decision on the number of clusters hierarchical agglomeration method (Ward method, Manhattan distances) was applied in the first phase.

artificial fertilizers in kg per 1 ha, number of family members working full time and part time on the farm, share of income from agricultural activity, value of sales per ha, number of persons in the household younger than 18 years, number of person in the household older than 65 years, value of income from social transfers and off-farm work per household, average age of tractors, average age of buildings, participation in farmers organizations, participation in agro-environmental programs, use of the advisory services. The characteristics of the farms selected for modelling are presented in Table 1.

Table 1. Characteristics of modelled farms
Tabela 1. Charakterystyka gospodarstw modelowych

Specification	Farm cluster		
	C1 – small	C2 – medium	C3 – large
Area [ha agricultural land]	20,20	35,10	90,50
– owned	16,77	24,22	59,73
– leased	3,43	10,88	30,77
Share of permanent grassland [%]	55%	55%	50%
Average cereals yield [t/ha]	3,22	3,96	3,55
Number of dairy cows	15	24	69
Milk yield [kg/head/year]	5634	6708	7112

Source: Own research.
Źródło: Badania własne.

Farms differ in terms of number of cows and area of agricultural land. In the smallest farm (C1) milk yield is noticeably lower than in farms with a larger scale of milk production.

SCENARIOS FOR MODELING

The main investment activity included in the model is installation of Automatic Milking System (AMS). Additional investments in stands for cows allowing to increase the scale of production as well as land lease (up to 1,5 times of currently leased area) were also allowed. Technical and economic coefficients for the innovation in AMS have been collected as secondary data mainly coming from technical papers and interviews with experts.

Different scenarios regarding the level of policy support, labour costs and milk prices were considered in the models.

Policy variable was the RDP support through the on-farm investment measure that intends to provide incentives for innovations adoption. In the models four levels of support have been tested (no support, 25%, 50%, 75% of investment cost). The model covers also uncertainty regarding the rate of direct payments that takes into account potential changes of the CAP to be introduced after 2013 (which are under discussion when writing this paper). Other factors differentiating modelling scenarios were levels of milk prices and hired labour costs (four levels for each variable).

The key milk policy assumption is the abandonment of milk quota in the year 2016. Due to this, after 2016 models are not constrained on the amount of milk produced and in case of increase of quantity of milk there is no cost of milk quota lease, as it could have been calculated for the period 2010–2015.

REAL OPTION MODELING[3]

This paper addresses the decision to adopt an innovation using the Real Options (RO) approach. Such a model typology is able to describe in a better way than capital budgeting tools the investment choice when the decision to adopt an innovation is affected by irreversibility and uncertainty [Dixit and Pindyck 1994; Schwartz and Trigeorgis 2004]. In fact, with the RO approach it is possible to consider in the investment choice the increase of its value as a result of the greater information obtained by the decision maker over time, concerning future decision variables [Mcdonald and Siegel 1986]. Such an increase is the result of the option to delay investment decisions until further information about the state of nature (as well as market and other prices) has been collected [Trigeorgis 1988].

Several authors have developed methodologies based on the RO approach in order to simulate the decision to invest in specific new technologies when are characterised by uncertainty and irreversibility. Some examples in livestock farms are Tauer [2006] concerning the entry/exit and the livestock expansion and Hyde et al. [2003], Engel and Hyde [2003], [Floridi et al. 2010] and Sauer and Zilberman [2010] for an application to the adoption of automatic milking system (AMS).

Under conditions of uncertainty and investment irreversibility, the RO approach enables the quantification of the Net Present Value (NPV) increment due to the option to delay the investment until a following period, when the farmer will have access to more information about the exogenous uncertain variables determining investment profitability [Sauer and Zilberman 2010].

New investment can imply high costs, changes in related farming activities and more complex production management compared to previous farm conditions. In fact, adoption of a new technology implies a reorganisation of the entire farm production system. Therefore, in order to study the investment it is necessary to take into account not only the production operation of a farm, but also the household decisions, given that both play a key role in investment decisions. The decision to invest is also strongly influenced by the uncertainty about many of the decision variables, given the uncertain outcomes. Such variables can be classified with those connected to the farm structure such as household labour availability on-farm, and those connected to market conditions such as shadow prices of household labour allocated off-farm, the prices of the agricultural outputs, and

[3] The chapter is based on Bartolini et al. [2010] section "Conceptual framework".

the cost of the hired labour. Furthermore, they can be associated with variables related to the investment financial management rate of the loan, loan accessibility, and the amount and certainty of obtaining SFP/SAPS and RDP payments.

This approach is presented in Figure 1, with an example in which the choice to invest can be undertaken during two distinct periods.

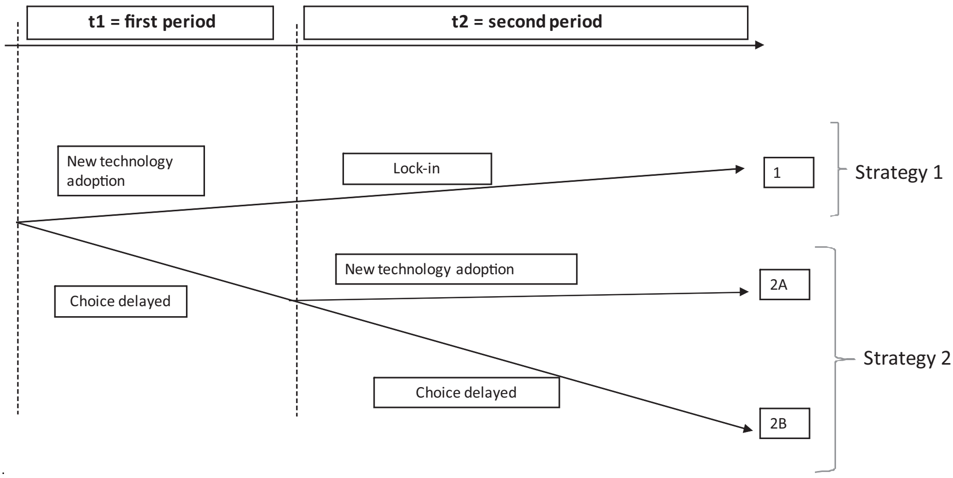

Fig. 1. Process of investment decision in the model in two periods
Rys. 1. Proces podejmowania decyzji inwestycyjnych w modelu w dwóch okresach

Source: Bartolini F., Floridi M. et. al. [2010].
Źródło: Bartolini F., Floridi M. et. al. [2010].

For example, assuming that a decision to adopt an innovation can be undertaken in two separate periods (t1 and t2), the decision process can be interpreted as a discrete choice, which the farmer can carry out in either the first (strategy 1) or the second period (strategy 2). The decision to invest during the first period locks-in the farm with the investment during the second period (strategy 1). Lock-in is determined by high investment and sunk costs and by the irreversibility of the investment [Carruth et al. 2000]. However, the farmer can also delay the investment until he/she obtains more information about the uncertain decision variables, and will then choose to invest or not during the second period. The delay allows the farmer to observe the value of such variables (which were assumed to be stochastic in the first period) and, if such variables are favourable to the adoption of the considered innovation, then the farmer will undertake the investment in period t2 (strategy 2A). Otherwise, if the value of the uncertain variables is not favourable to the profitability of the innovation investment, then the farmer will neither choose to invest in the second period (strategy 2B).

The optimal strategy will be the one that determines a higher net present value (NPV) of the cash flow over both periods: $NPV = \max(NPV_1, NPV_2)$; where NPV_1, referring to Figure 1, is the net present value of the cash flow in strategy1 and NPV_2 is the net present value of the cash flow in strategy2. Expressions of NPV_1 and NPV_2 are given in equations 1 and 2.

$$NPV_1 = -k + \sum_{0}^{t1} \frac{cf_{inn}^{t1}}{(1+i)^t} + \sum_{t1+1}^{t2} \frac{\gamma\, \overline{cf_{inn}^{t2}} + (1-\gamma)\, \underline{cf_{inn}^{t2}}}{(1+i)^{t1+t}} \tag{1}$$

$$\begin{aligned} NPV_2 = {} & \sum_{0}^{t1} \frac{cf^{t1}}{(1+i)^t} + \\ & + \left(\gamma \left(\frac{-k}{(1+i)^{t1+t}} + \sum_{t1+1}^{t2} \frac{\overline{cf_{inn}^{t2}}}{(1+i)^{t1+t}} \right) + (1-\gamma) \left(\frac{-k}{(1+i)^{t1+t}} + \sum_{t1+1}^{t2} \frac{\underline{cf^{t2}}}{(1+i)^{t1+t}} \right) \right) \end{aligned} \tag{2}$$

Where:
cf^t = cash flows of a generic year t, with $t = t1$ if years belong to the first period and $t = t2$ if years belong to the second period; k = cost of investments; i = discount rate; γ = probability of having a state of the nature favourable to innovation adoption; $\overline{cf_{inn}^{t2}}, \overline{cf^{t2}}$ = cash flow of a generic year t when $t = t2$ and stochastic variable values are favourable to innovation adoption; $\underline{cf_{inn}^{t2}}, \underline{cf^{t2}}$ = cash flow of a generic year t when $t = t2$ and stochastic variable values are unfavourable to innovation adoption; inn = subscript, means new technology adoption.

The innovation adoption is subject to uncertainty in the second period. This assumption implies stochastic cash flow values during this period. Following Dixit and Pyndick [1994] we assumed that the annual cash flows follow a Brownian Motion with drift, so that $dcf^t = \mu cf^t\, dt + \sigma cf^t\, dz$, where dcf^t is the instantaneous value of the cash flow; $\mu^t cf^t\, dt$ is the expected cash flow value; μ is drift (percentage); σ is the volatility (percentage); and dz is a Wiener process with a mean of zero and independent increments. Under such approach it is possible to differentiate two values of cash flows: one favourable to the new technology investment $\left(\overline{cf^t}\right)$, and the other unfavourable $\left(\underline{cf^t}\right)$. These two values are generated assuming that the random variable generated from the Wiener process can have positive or negative values in order to allow for adding or removing the same amount from the expected value at any time in the period $t2$. This approach enables to maintain a constant expected value, and to change only the amount of uncertainty in the second period.

CONSTRUCTION OF THE HOUSEHOLD MODEL

The empirical analysis was conducted with the use of the Dynamic Farm Household Model with the objective to maximise the NPV of the cash flow over the next 20 years. The model was hypothesised to be structured in two time periods; the first period ($t1$) includes the years 2010–2013, and the second ($t2$) includes the years 2014–2030, coherently with the actual policy framework. Farm household models enable the maximisation of the utility function generated by the household income, the household leisure time and the household consumption [Taylor and Adelman 2003].

The investment has been simulated considering the connections between the various activities of the farm: livestock activity, crop cultivation and labour allocations among such activities. Number of cows in the model solution is linked with the land available for production of fodder. The model allows to increase area of agricultural land. Cropping structure is determined by availability of land, requirements of animal sector and rotational constraints reflecting crop management systems in model farms. Milk production has been linked with crop production through the fodder balance, taking into account requirement of cows for assumed yield of milk.

The household has been assumed to maximise the whole household NPV, subject to consumption and leisure constraints.

MODELING UNCERTAINTY IN EXOGENOUS VARIABLES

The model has three stochastic parameters: the amount of direct payments received by the farm, milk and labour prices. Formally, uncertainty can be expressed by: $S^t = S^e dt \pm \sigma dz$, where S^t is the expected value for a generic year of each stochastic parameter; S^e is the forecasted or known value during the first period; σ is the oscillation (known during the first period) and dz is a random variable uniformly distributed with a minimum value of 0 and a maximum value of 1. Through a Monte Carlo Approach, dz has been simulated as an $N \times M$ matrix of random values, where M represents the times at which each stochastic parameter changes during the second period (years for prices, EU programming period for payments), and N represents the number of samples generated by the Monte Carlo simulation.

For every sample value generated by Monte Carlo simulation the model has been solved in iterative way. The final results is set of outcome values for N iterations. It was assumed, coherently with the current policy framework that during time $t1$ (first period) the farmer knows the average amount of direct payments (SAPS – single area payment scheme) received by the farm, the average level of agricultural prices, the average cost of labour and the oscillation for each of the stochastic parameters. Following this way the uncertainty in milk and labour process has been calculated, assuming that prices are known for the year 2010, while for remaining years are stochastic. Expected values and oscillation for milk price and labour has been estimated based on Scenar 2020 Study [ECNC, LEI, ZALF 2009].

RESULTS

The number of cows and occurrence of investments in Automatic Milking Systems are the basic outcomes of the model (Table 2). Results presented in Table 2 were achieved for different levels of RDP support (expressed as a percentage of investment costs covered, within the range 0–75%) and for parameters derived as stochastic values – direct payments (SAPS), milk and labour prices. Three investment strategies were considered in the model:

1 – investing in AMS in the year 2010;

2 – postponing decision till 2014 when more information will be available and then:

2A – investing in AMS in 2014,

2B – continuation of farming without investing in AMS.

For the strategy 1 the period 2010–2030 has been divided into two sub-periods: 2010–2017 and 2018–2030. It is assumed that in the strategy 1 the model invests in AMS in the year 2010, regardless of herd's size or conditions for milk production. At the beginning of the second period (2018) the model chooses to continue with investment or not to invest. In case of investment, based on the assumption that milking robot is depreciated in 8 years, continuation requires replacing the existing AMS with a new one.

For strategies 2A and 2 B, investments are allowed in the entire 2014–2030 period.

The number of cows in each farm is increasing in the period 2010–2030 in almost all situations considered, however the scale of growth is different. In the smallest farm (C1) the model adds about 2 cows to the initial herd of 16 cows. In the farm C2 number of cows is increased by about 50% (initially 31 cows) and in the largest farm (C3) the number of cows is doubled in the most progressive solutions.

The milk price was the main factor influencing the scale of production in the model solutions. The greatest differences are observed between strategies 2A and 2B in case of uncertainty of milk price. In unfavourable conditions, the model for the smallest farm cluster shows a slight decrease in the animal number. The medium size cluster (C2) seems to be the least vulnerable to uncertainties considered, and maintain the tendency to grow irrespective of milk price and labour costs. In the C3 cluster, under the most pessimistic assumptions (low milk price, low RDP support), the number of cows remains on the base year level, while in favourable conditions (high milk price, high RDP support) it is more than doubled.

The adoption of AMS in the smallest farm (C1) is not an option in any scenario.

In farms with a larger herd of cows investment decisions are strongly influenced by two factors mainly: rate of RDP support for farm investments and milk prices.

In medium size farms (C2) in case of favourable milk prices and 50% of investment support AMS is adopted in 92% of iterations (strategy 2A). In case of uncertainty in SAPS or labour prices (less favourite conditions) and RDP support below 50% the adoption rate is negligible. At the highest investment support rate (75%) the adoption rate reaches over 90% in case of investment delayed until 2014 (strategy 2A, 2B: 2014–2030) or 2018 (strategy 1: 2018–2030).

A similar pattern is observed in the largest farm (C3). However, differently than in the C2, even at the 25% investment support rate the model adopts the new technology in case of high milk price. In general – the higher support rate is, the stronger is the model encouraged to invest in AMS.

Over 90% of farms are investing in AMS in the second period after delaying the decision (strategy 2), while all farms that installed one AMS in 2010 are increasing the number of units[4] after 2014 to cover the whole herd.

The average values of NPV and the Option Value due to the choice to delay the decision in the second period are presented in Table 3.

[4] It is assumed that maximum capacity of one AMS is 50 dairy cows. In case of farms with herds above 50 dairy cows investment in two or more AMS might be considered.

Table 2. Changes of herd size and AMS adoption rate in the farm clusters considered
Tabela 2. Zmiany w wielkości stada krów i stopa adopcji inwestycji w AMS w modelowych gospodarstwach

Farm cluster	Uncertainty	RDP investment support [%]	Number of cows [heads./farm]				Share of AMS [%]			
			Strategy				Strategy			
			1	1	2A	2B	1	1	2A	2B
	Period		2010–17	2018–30	2014–30	2014–30	2010–17	2018–30	2014–30	2014–30
C1	labour	0	16,3	18,0	18,0	18,0	100	–	–	–
		25	16,3	18,0	18,0	18,0	100	–	–	–
		50	16,3	18,0	18,0	18,0	100	–	–	–
		75	16,3	18,0	18,0	18,0	100	–	–	–
	milk	0	16,3	18,0	18,0	13,1	100	–	–	–
		25	16,3	18,0	18,0	13,2	100	–	–	–
		50	16,3	18,0	18,0	13,2	100	–	–	–
		75	16,3	18,0	18,0	13,2	100	–	–	–
	saps	0	16,3	18,0	18,0	18,0	100	–	–	–
		25	16,3	18,0	18,0	18,0	100	–	–	–
		50	16,3	18,0	18,0	18,0	100	–	–	–
		75	16,3	18,0	18,0	18,0	100	–	–	–
C2	labour	0	31,4	41,1	39,8	39,8	100	–	–	–
		25	31,4	41,1	39,8	39,8	100	–	–	–
		50	31,5	41,4	40,2	40,1	100	–	6	4
		75	31,6	45,5	44,3	44,3	100	100	92	92
	milk	0	31,4	41,1	43,0	37,8	100	–	–	–
		25	31,4	41,1	42,9	37,8	100	–	–	–
		50	31,5	41,3	46,7	38,0	100	–	92	–
		75	31,6	45,5	46,8	39,8	100	100	93	89
	saps	0	31,4	41,1	39,9	39,9	100	–	–	–
		25	31,4	41,1	39,8	39,8	100	–	–	–
		50	31,5	41,4	40,2	40,0	100	–	6	2
		75	31,6	45,5	44,3	44,2	100	100	92	93
C3	Labour	0	77,5	93,5	93,9	86,0	64	–	–	–
		25	77,4	93,5	93,8	86,1	65	–	–	–
		50	77,4	100,0	140,5	96,5	81	100	94	91
		75	89,9	149,3	140,5	97,8	83	100	94	92
	milk	0	77,4	93,5	96,9	69,6	65	–	–	–
		25	77,4	93,5	141,0	69,6	65	–	94	–
		50	77,4	100,0	141,0	78,1	81	100	94	32
		75	90,0	149,3	141,1	96,1	83	100	94	91
	saps	0	77,4	93,5	94,5	87,0	65	–	–	–
		25	77,4	93,5	94,5	87,0	65	–	–	–
		50	77,4	100,0	140,5	96,5	81	100	94	91
		75	89,9	149,3	140,5	96,5	83	100	94	91

Source: Own research.
Źródło: Badanie własne.

Table 3. NPV and Real Option Value for different strategies of investing in AMS
Tabela 3. NPV i wartości Real Option różnych strategii inwestycji w AMS

Farm cluster	Uncertainty	RDP investment support [%]	Financial results			
			Strategy			
			1 Investment in 2010	2 (2A&2B) Decision in 2014	Real Option Value	
			NPV [EUR]	NPV [EUR]	S2-S1 [EUR]	RO/NPV(S2) [%]
C1	labour	0	–72 364	34 761	107125	308%
		25	–48 134	34 778	82912	238%
		50	–23 880	34 772	58652	169%
		75	273	34 778	34505	99%
	milk	0	–72 310	35 187	107496	306%
		25	–48 155	35 185	83341	237%
		50	–23 880	35 187	59067	168%
		75	273	35 187	34915	99%
	saps	0	–72 310	34 776	107086	308%
		25	–48 157	34 773	82930	238%
		50	–23 880	34 768	58648	169%
		75	273	34 778	34505	99%
C2	labour	0	177 833	266 712	88879	33%
		25	202 004	266 752	64749	24%
		50	226 208	266 683	40474	15%
		75	269 861	291 168	21308	7%
	milk	0	177 851	267 810	89959	34%
		25	202 004	267 783	65779	25%
		50	226 202	273 944	47742	17%
		75	269 690	294 064	24375	8%
	saps	0	177 851	266 728	88878	33%
		25	202 004	266 756	64752	24%
		50	226 209	266 750	40541	15%
		75	269 841	291 021	21180	7%
C3	labour	0	1 417 048	1 531 406	114358	7%
		25	1 441 510	1 531 683	90173	6%
		50	1 489 846	1 559 373	69527	4%
		75	1 590 684	1 634 957	44274	3%
	milk	0	1 417 337	1 546 868	129531	8%
		25	1 441 507	1 563 652	122145	8%
		50	1 489 816	1 610 287	120471	7%
		75	1 590 671	1 676 188	85518	5%
	saps	0	1 417 311	1 531 554	114242	7%
		25	1 441 511	1 531 566	90054	6%
		50	1 489 846	1 558 655	68809	4%
		75	1 590 697	1 634 233	43537	3%

Source: Own research.
Źródło: Badanie własne.

The modelling results indicate that the optimal strategy for Podlaskie dairy farmers is to delay investment decision until the second period since the Real Option Value is positive under all types of conditions for milk production considered – delaying investment in AMS gives better financial results.

More information on milk, labour prices and the amount of direct payments to be received after 2014 before making a decision regarding concentration in livestock and the modernisation of milking systems reduces risk of wrong decisions. In farms C2 and specifically C3, however, the Real Option Value is relatively small (the ratio RO/NPV below 10% in a number of cases). This suggests, that individual decisions of large scale farmers to invest in 2010, can be justified.

The number of adoptions increases with higher RDP support. For the largest farms (cluster C3) in case of higher rates of RDP support the real option value in relation to NPV value is relatively low. However, pointing out that models have been designed for an average farm within the cluster, it might be worth to consider investment in 2010 for farms from the C3 group with the largest numbers of cows.

In all model solutions, farm size is increased mainly because an additional land for producing fodder in models enlarging herds of cows is required (Table 4). Because differences in the farm size under different levels in uncertainty of milk prices, labour costs and financial support were insignificant the are of agricultural land is presented as an average for respective model solutions.

Table 4. Changes of agricultural land area in model solutions
Tabela 4. Zmiany w powierzchni użytków rolnych w rozwiązaniach modelowych

Farm cluster	Uncertainty	Agricultural land [ha]			Agricultural land [2009 = 100%]		
		Strategy			Strategy		
		1	2A	2B	1	2A	2B
C1	labour	25,35	25,36	25,36	126%	126%	126%
	milk	25,36	25,36	23,85	126%	126%	118%
	saps	25,35	25,36	25,36	126%	126%	126%
C2	labour	51,42	51,41	51,41	146%	146%	146%
	milk	51,42	51,42	51,41	146%	146%	146%
	saps	51,42	51,41	51,41	146%	146%	146%
C3	labour	136,49	136,17	136,66	151%	150%	151%
	milk	136,49	135,84	136,67	151%	150%	151%
	saps	136,48	136,18	136,66	151%	150%	151%

Source: Own research.
Źródło: Badanie własne.

Generally all farms tend to increase the area through additional lease of land up to the maximum allowed by the model constraints (150% of currently leased area) despite the relatively high land lease price assumed (400 EUR/ha). Only in case of the smallest farm cluster and low milk prices the maximum area allowed to the model has not been reached. This shows that unfavourable conditions are limiting the growth of small farms to a greater extent.

CONCLUSIONS

Modelling results allow to emphasize that decisions to adopt the new technology for milking cows and the timing of such decisions, depend on the direction of the policy reform and availability of information. In particular, they highlight the importance of "predictability" as a major policy feature and component of policy design facing a strongly uncertain context. This confirms the existing literature pointing out the negative effect of (policy) uncertainty on private investment (e.g. Rodrik 1991, Feng 2001, see also Gallerani et al. 2009), but brings a new light on the consequences of introducing different, possible CAP measures in the specific context of the Podlaskie region.

The main limitation of the model is its simplification compared with reality, as it is the case of all bio-economic models. This applies at least to the timing of investment processes and the way uncertainty is treated in the model for an average farm from a cluster, despite heterogeneity of farms within the cluster. In particular, the fact that some farms in the groups analysed show interest in investment in new technologies even at lower co-funding rates than shown by the simulation, may reveal that the heterogeneity within the cluster would require higher consideration in the model design strategy.

This suggests a number of potential developments in the direction of adding more point in time for investment decisions, of including uncertainty in other decision variables (investment costs, technological development, prices of factors and products) and of allowing for the simulation of uncertainty to use different combinations of uncertainty parameters with an explicit correlation between each other. Another option could be the use of scenarios to model changes in CAP payments following the upcoming proposals for regulations for the post-2013 CAP.

Coming to more detailed findings it could be pointed out that AMS should be recommended only for herds of 50 cows or greater. The greatest positive economic effect is observed in large farms with hired labour. High milk prices and stronger investment support highly increases adoption rate of the new technology, while SAPS payments and labour cost have relatively small effects on the investment decisions.

Removal of milk quotas creates space for growth of dairy farms in Podlaskie region, especially under highly favourable economic and market conditions (greater policy support for investments and high milk price). The modelling results suggest that larger farms may tend to increase size of the herds and area of agricultural land as well as to adopt the new technology for milking cows.

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OSZACOWANIE EKONOMICZNYCH EFEKTÓW INNOWACJI W AUTOMATYCZNE SYSTEMY DOJU W REGIONIE PODLASKIM (POLSKA) Z ZASTOSOWANIEM PODEJŚCIA REAL OPTION

Streszczenie. W sektorze mlecznym w regionie podlaskim, które jest liderem w produkcji i w przetwórstwie mleka w Polsce, obserwuje się silne procesy koncentracji. Powiększanie stad krów mlecznych w wielu gospodarstwach wywołuje wśród rolników zainteresowanie wprowadzeniem innowacyjnych, automatycznych systemów doju krów (AMS). W artykule przedstawiono wyniki oszacowania korzyści finansowych z tytułu zróżnicowania decyzji inwestycyjnych w czasie. Do rozważań wybrano dominujące w regionie typy gospodarstw mlecznych. Zastosowany model gospodarstwa jest oparty na podejściu real option. W modelu przyjęto nieodwracalność inwestycji, stochastyczne kształtowanie się płatności bezpośrednich, cen mleka i kosztów robocizny. W badaniach założono różne poziomy wsparcia inwestycji z Planu Rozwoju Obszarów Wiejskich. Analiza wyników prowadzi do konkluzji, że odłożenie inwestycji w AMS w czasie, w warunkach reformowanej WPR, byłoby korzystniejszą strategią w porównaniu do inwestycji w 1. roku okresu modelowania. Jednakże korzyści z przesunięcia inwestycji na bardziej odległy termin maleją wraz ze wzrostem wielkości gospodarstw i zwiększaniem nakładów pracy najemnej.

Słowa kluczowe: real options, roboty do doju krów, gospodarstwa mleczne, niepewność

Accepted for print – Zaakceptowano do druku 06.04.2011