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The Effects of Different Political Schemes on the Willingness to Invest, Firm Profitability and Economic Efficiency in the Dairy Sector – An Agent-Based Real Options Approach –

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Abstract

In recent years, the dairy sector has been exposed to strong changes in general conditions and extreme fluctuations in milk prices. Farmers and lobbyists have therefore asked politicians for additional market regulation. In this paper an agent-based real options market model is developed, which allows the analysis of the effects of different political schemes on the willingness to invest, firm profitability and economic efficiency in the dairy sector. The model results show that political schemes generally increase the willingness to invest in competitive markets under consideration of real options effects. However, they do not offer any substantial financial benefits to the producers and can cause a significant reduction in welfare. Furthermore, the results suggest that investment subsidies are preferable to lower price limits because the welfare is less reduced under the same stimulation of the willingness to invest.

Keywords: Real Options, Competition, Policy Impact Analysis, Dairy Sector

JEL classification: D81, Q12, Q18

1. INTRODUCTION

The dairy sector is of great significance for agriculture in the European Union (EU). In 2009, about 13% of agricultural production valued with respective prices was generated with milk in the 27 EU Member States. Furthermore, in 2007 about 9% of all farms were either classified as specialized dairy farms, or as dairying, rearing and fattening combined farms (EUROSTAT, 2010). These are currently affected by strong changes in general conditions: During the Health Check of the Common Agricultural Policy (CAP) in 2008, a gradual increase of the milk quota was agreed, resulting in its final abolishment in April 2015. In this context, the expected profitability of milk production will change resulting in an increase of competition. Furthermore, volatility of success will (further) increase, as the sector has to cope more and more with competitors on international markets. Finally, entrepreneurial flexibility will rise, as farmers are no longer restricted by the quota when making decisions on investment and production.

Because of extreme fluctuations in milk prices in 2007, 2008 and 2009, farmers and lobbyists have recently called on the government to provide additional market regulation in the EU. The discussed political schemes are price stabilization through continuation of the quota system, politically introduced (higher) minimum prices for milk products, price supports through an increased purchase of excess supply through the European Community, subsidies, etc. (cf. e.g. European Milk Board, 2009). On a microeconomic scale these requests are indeed understandable, because in milk production a considerable share of production costs cannot be varied in short and medium term by a variation of production output. For dairy farms in the EU these non-operating costs consisting of depreciation, rent, interest, own capital unpaid costs, wages and family labour costs accounted for about 46% of the total costs in 2007 (European Commission, 2010). However, there is theoretical evidence in literature that e.g. price stabilizing policies create welfare losses because entrepreneurial risks are socialized and inefficiencies arise as such interventions lead to overinvestment (e.g. Dixit and Pindyck, 1994: ch. 9).

In consequence of the aforementioned aspects, adjustments in the dairy sector can be expected, which usually go hand in hand with investment and disinvestment decisions. During the past one and a half decades, agricultural economists started to realize in result of empirical investigations, that the Real Options Approach is more advantageous for analyzing investments in the dairy sector than traditional investment models (cf. e.g. Purvis et al., 1995; Hyde et al., 2003). Yet, there is not any real options model which allows the analysis of investment decisions under simultaneous consideration of competition and different political schemes. This is mainly due to the analytical complexity of solving equilibriums in competitive markets, that is additionally intensified e.g. by price stabilization policies, which affect the price dynamics exogenously (cf. e.g. Leahy, 1993).

Hence, the objective of this paper is to close this research gap by developing a real options market model, which is capable of analyzing the firms' investment behavior, taking explicitly into account competition as well as political schemes. On that basis, the effects of the implementation respectively the abolishment of political schemes in general on investment trigger, firm profitability and economic efficiency are analysed. Furthermore, a comparative analysis of the welfare effects of a lower price limit maintained by governmental purchases of excess supply as well as investment subsidies is carried out exemplarily. It should be noted that this investigation provides the conceptual basis for analyzing the investment behavior in competitive markets under real options effects in general and (yet) does not refer to empirical data of real firms and prices in a specific market, like e.g. the dairy sector. Accordingly, there are not considered any milk quota effects.

The paper has the following structure: Section 2 firstly explains the fundamentals of the Real Options Approach as well as what difficulties arise from applying real options models to competitive markets. Afterwards the real options market model is designed and combined with a heuristic optimization technique, namely Genetic Algorithms (GA) (section 3). In section 4 the results are discussed. The paper ends with conclusions concerning the usefulness of political schemes in competitive markets and an evaluation of the model's application potential (section 5).

2. THEORETICAL BACKGROUND

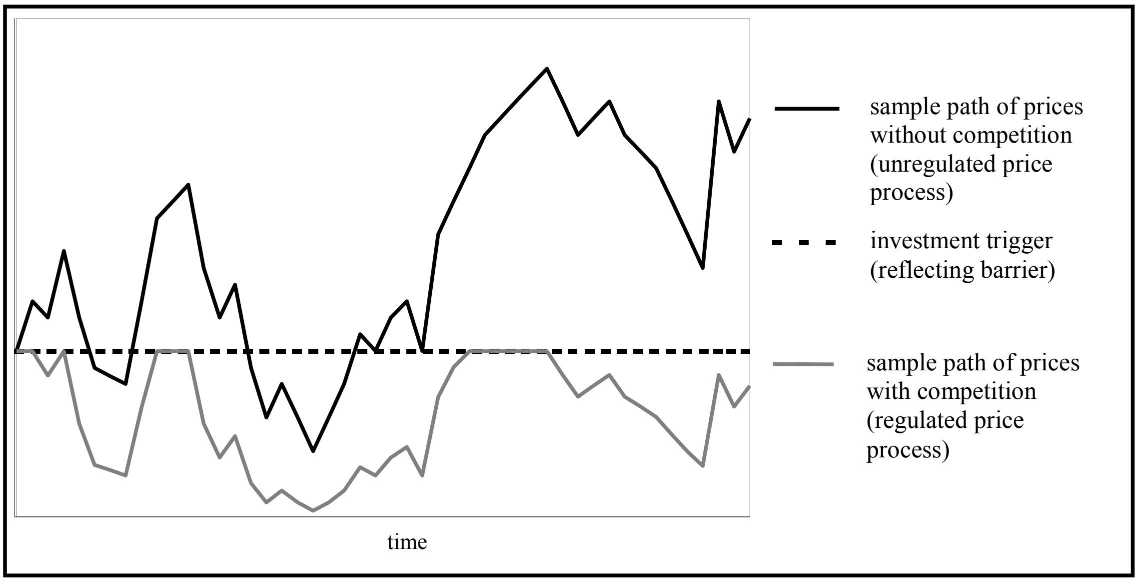
The foundation of traditional investment models is the net present value (NPV) rule saying that investments should be made if the present value of the investment cash flows exceeds the investment costs. This rule assumes implicitly that either the investment is reversible meaning its expenditures can be recovered in case market conditions turn out to be worse than initially anticipated, or, if the investment is irreversible, it constitutes a "now or never" decision. These assumptions are problematic when applying traditional investment models to reality. Particularly in agriculture, several empirical applications have shown that real options models, in contrast, are more precise in analyzing the observable inertia of investments (cf. e.g. Carey and Zilberman, 2002; Odening et al., 2005; Pietola and Wang, 2000; Richards and Patterson, 1998).

Real options models exploit the analogy between a financial option and an investment project (cf. e.g. Abel and Eberly, 1994; Dixit and Pindyck, 1994; McDonald and Siegel, 1986; Trigerorgis, 1996). With an opportunity to invest a firm is holding an "option" analogues to a financial call option – it has the right but not the obligation to buy an asset at any time of the future. If this firm makes the respective irreversible investment expenditure, it exercises the option to invest by giving up the opportunity of waiting for new information to arrive, which might have a positive effect on the profitability of the investment. This lost option value is an opportunity cost or lost "profit" that must be included as part of the investment cost. Furthermore, it is highly sensitive to the uncertainty of the future cash flows. In conclusion, an irreversible investment under uncertainty should only be made, if the present value of its expected returns exceeds the investment costs by an amount equal to the value of the option to invest at a later point in time and possibly generating more profit. In comparison to the NPV rule, this means that the investment trigger price is shifted upwards because the cash flows do not only have to compensate the investment costs but also the lost "profits" from deferring the investment.

The direct transferability of financial option pricing methods to real investment problems, however, is problematic. Financial options constitute exclusive rights for their owners, whereas real investment opportunities are also open to other market participants in competitive markets. Thus, exceeding the investment trigger price will also cause similar reactions of competitors which, taken as a whole, will change sectoral supply and, with this, equilibrium prices. In consequence, the price process cannot any longer be considered as exogenous. As the price process determines again the value of the investment and the optimal trigger price, the direct determination of these values is considerably complicated. Leahy (1993), however, demonstrates that under perfect competition, an investor who decides myopically and ignores potential market entries of competitors finds the same trigger price as a competitive investor. The background of the optimality principle of myopic planning is briefly explained in the following.

The myopic investor plans on the basis of a stochastic price process, which is similar to the stochastic price process under perfect competition with regard to its trend. Yet, in contrast to a competitive investor he/she acts on the assumption that future prices are neither affected by production decisions of competitors nor by his own production decisions. The following difference from both approaches arises: As soon as the market price climbs to the investment trigger price in case of perfect competition, new firms invest and immediately bring it back to a slightly lower level (under the condition of infinitesimal small time periods). Thus, the trigger price constitutes an upper *reflecting barrier* for the price process (Dixit and Pindyck, 1994: 254). Figure 1 illustrates the respective difference between the unregulated exogenous price process as anticipated by the myopic planner, and the regulated endogenous price process under perfect competition. Both simulations assume a Geometric Brownian Motion (GBM), where parameters refer to relative price changes. Although in both cases identical parameters are used, the sample paths look different. Surprisingly, the competitive investor and the myopic planner find identical optimal trigger prices representing the competitive equilibrium. The reason is that the myopic planner commits two errors which completely offset each other: Firstly, he ignores the truncation of the price process and therefore overestimates the investment's profitability. Secondly, he wrongly assumes to have an exclusive option to postpone the investment. The value of waiting in this respect makes it less attractive to invest immediately. In other words, the myopic planner is right for the wrong reasons. The implication of Leahy's result is that the burdensome and iterative determination of an endogenous equilibrium price process can be avoided, when dealing with competitive markets. The complicated optimization problem of a competitive investor can be replaced by the simpler problem of a myopic planner without a loss of precision.

Figure1: Price dynamics with and without competition



Source: own elaboration, following Leahy 1993, p. 1118

Nevertheless, an analytical solution for the optimization problem of a myopic investor can only be found if very restrictive and unrealistic assumptions are fulfilled (McDonald and

Siegel, 1986). Accordingly, the stochastic demand process has to follow a GBM. This, however, e.g. is not the case in the presence of a politically induced lower price limit, which again is one of the research objects. Amongst others, further limitations are the presence of an isoelastic demand function, infinitely divisible investment projects and infinite useful lifetimes. If one of these conditions is not met, a direct determination of equilibriums in competitive markets would be necessary. And this is commonly assessed in the literature as not practicable (cf. e.g. Leahy 1993: 1107). In the next section, an agent-based real options market model will be developed, which allows the numerical endogenous determination of exactly this equilibrium and thus relaxes the assumptions of the optimality principle of myopic planning.

3. THE AGENT-BASED REAL OPTIONS MARKET MODEL

The model described below will derive the price dynamics endogenously from the investment and supply behavior of the competing firms. An exogenous stochastic demand process and rational investment decisions of the firms are taken as a basis for this. Simultaneously, the firms are optimizing their investment behavior and thus their supply behavior by finding the optimal trigger price. In subsection 3.1., the agent-based real options market model is described. Afterwards, the numerical determination of the optimal investment trigger prices of the firms is explained, for which Genetic Algorithms (GA) will be used (subsection 3.2.). In subsection 3.3., it is shown how the economic efficiency of the optimal investment strategy is quantified by means of the concept of consumer and producer surplus.

3.1. Description of the Model

Consider a number of *N* homogenous and risk-neutral firms, each having repeatedly the opportunity to undertake an investment with an exogenously given maximum production capacity ${}_nX^{MAX}$ either now or at a later point in time. The asset of investment is divisible and, thus, a step-by-step investment is possible as well. Size, investment outlay and production are proportional, i.e., there are no economies of scale. The period under review is T years. The production capacity of a firm n in *t*, resulting in a production output ${}_nX_t$, can be adjusted via investments just once in a year, resulting in an additional production output ${}_nx_{t+\Delta t}$ in the next year. Due to the fact that the investment costs are sunk in total there are no possibilities to disinvest, that is, the investment is irreversible. Furthermore, the investment project has an unlimited useful lifetime, so invested firms need to continue producing, regardless of market conditions, and there is not assumed any depreciation, that is, production output stays constant. For the production output in $t + \Delta t$ follows hence:

$$ {}_nX_{t+\Delta t} = {}_nX_t + {}_nx_{t+\Delta t} \tag{1} $$

The stochastic demand process and the price elasticity are assumed to be known. Prices result from the reactions of *all* market participants on the exogenous stochastic demand process and, hence, need to be determined endogenously within the model. Without loss of generality, the respective relationship between demand and price is defined by the following isoelastic demand function (cf. Dixit, 1991: 543):

$$P_t = \left(\frac{\mu_t}{X_t}\right)^{-\frac{1}{\zeta}} \tag{2}$$

P_t denotes the market price per unit, μ_t a stochastic demand parameter and ζ the price elasticity of demand. For μ_t any stochastic process can be applied flexibly in the model, e.g. based on estimated planning data of the real price dynamics in the respective market. However, to validate the model's numerical results for the standard case of the absence of a political scheme with the analytical result according to the optimality principle of myopic planning, μ_t follows a GBM for competitive markets in this investigation (cf. section 2). Assuming discrete time this can be modeled as (cf. Dixit and Pindyck, 1994: ch. 3):

$$\mu_t = \mu_{t-1} \cdot e^{\left[\left(\alpha - \frac{\sigma^2}{2}\right)\cdot\Delta t + \sigma\cdot\varepsilon_t\cdot\sqrt{\Delta t}\right]} \tag{3}$$

with a volatility σ and a drift rate α as constant process parameters, as well as a standard normally distributed random number ε_t and a time step length Δt.

Within the model, perfect competition is assumed. Accordingly, the firms have rational expectations and complete information regarding the development of demand and the investment behavior of all competitors. It is also assumed that firms with lower trigger prices ${}_nP^*$ have a stronger tendency to invest. Thus, all firms are sorted according to their trigger prices, starting with the lowest, i.e., ${}_nP^* \leq {}_{n+1}P^*$. Consequently, firm $n+1$ does not invest if firm n is not already completely invested. Moreover, in every period t, a marginal (or last) firm exists which invests to the extent that its trigger price is equal to the expected product price of the next year. For the size of investment of each firm n' in t, corresponding to the additional production output in the next year, follows:

$$ {}_{n'}x_{t+\Delta t}\left({}_{n'}P^*\right) = \max\left[0, \min\left(\begin{array}{c} {}_{n'}X^{MAX} - {}_{n'}X_t \;, \\ \dfrac{\hat{\mathrm{E}}(\mu_{t+\Delta t})}{\left({}_{n'}P^*\right)} - \left\{\sum_{n=1}^{\mathrm{N}} {}_nX_t + \sum_{n=1}^{n'=-1} {}_nx_{t+\Delta t}\left({}_nP^*\right)\right\} \end{array}\right)\right] \tag{4}$$

Equation (4) implies the following:

1. The "max-query" ensures the irreversibility of investments. Therefore, no disinvestments are possible in the case of a fall in demand ($\rightarrow {}_{n'}x_{t+\Delta t} \geq 0$).
2. The "min-query" ensures that a firm n' cannot build up more production capacity via investments than it needs to produce its maximum production capacity ${}_{n'}X^{MAX}$.
3. The "min-query" also ensures that the total quantity of supply is just expanded so far as the trigger price of the "last" invested firm is equal to the expected product price of the next period.

The goal of the model is to identify the investment trigger prices of the firms. For this, an objective function needs to be established which determines the investment behavior of the agents in the model. Each firm's investment decisions aim to maximize the expected NPV of the future cash flows ${}_nF_0$, in the real options terminology also called option value, by choosing its firm specific trigger price. Without loss of generality, variable product costs are excluded and it is assumed that the cash outflow is equal to the yearly capital cost of investment k per output unit, which are the same for every firm. The risk-free yearly interest rate is r. Hence, the aim of firm n can be formulated as:

$$\max_{{}_nP^*}\{{}_nF_0({}_nP^*)\} = \max_{{}_nP^*}\left\{\sum_{t=0}^{T}(-k + P_t) \cdot {}_nX_t({}_nP^*) \cdot e^{-r \cdot t}\right\} \tag{5}$$

To implement a politically induced lower price limit P^{MIN} into the model, the determination of the producer's price has to be modified. Considering the market price P_t according to the demand function (2), the following applies to the producer's price P'_t:

$$P'_t = \max\{P^{MIN}, P_t\} = \max\left\{P^{MIN}, \left(\frac{\mu_t}{X_t}\right)^{-\frac{1}{\zeta}}\right\} \tag{6}$$

Consequently, in equation (5) P_t is replaced by P'_t. As a reference point P^{MIN} will be exogenously fixed as a percentage of the capital cost per output unit and year k.

For an investment subsidy s it is assumed that it will be paid by the state to any firm undertaking investments in the way, that it reduces the capital cost by a fixed percentage. Thus, k in (5) needs to be replaced by the effective producer's capital cost k':

$$k' = k \cdot (1 - s) \tag{7}$$

As explained in section 2, the analytical deviation of equilibriums in competitive markets is problematic due to its complexity, especially in the event of policy interventions. Hence, the remaining question is how the optimal investment triggers can be determined within the above described model? To solve the optimization problem, the multi-firm market model is combined with a genetic algorithm.

3.2. Determination of the Optimal Investment Strategy via Genetic Algorithms

GA are a heuristic optimization technique, which apply the evolutionary concepts of selection, crossover and mutation on a population of behavioral strategies. Even though they normally vary from each other in detail, there is a basic structure common to all GA (cf. Holland, 1975; Goldberg, 1989; Forrest, 1993; Mitchell, 1996; Balmann and Happe, 2001). The first task of a GA always is to define a way of representing each possible strategy as genomes. Since in this case each strategy just consists of a single value, i.e. a trigger price, this trigger price is taken as a real value itself for representing the investment strategy of a specific firm.

The second task is to define a population of N genomes to which the GA operators, i.e., selection, crossover and mutation, will be applied. The population size chosen here is $N = 50$

genomes. As this at the same time corresponds with the number of firms in the model, the set of genomes can be mapped directly to the firm's strategies, that is, every firm's trigger price is represented by one genome. Vice versa every genome can be understood as the strategy of a specific firm. Each application of the GA operators to the population of N genomes creates a new, modified generation of genomes, whereupon a generation is marked with a subscript index $g, g = 1,2, \dots, G$ on the left side. Through this procedure the optimal investment strategy shall be determined, which delivers the highest option value according to (5). Programming of the GA can directly be done in MS EXCEL. The GA passes through the following steps:

Step 1: Initialization

The first generation of genomes is initialized by drawing random values for the trigger prices of the firms out of a pragmatically defined range. These genomes are subsequently sorted according to the price level, starting with the lowest. Following the model assumptions in the previous section, the firm with the lowest trigger price invests to the extent of its maximum output capacity, followed by the firm with the second lowest trigger price, etc., until a last firm invests whose trigger price is equal to the expected price of the next period. The model ensures that there always is one last firm out of the 50 firms which invests last.

Step 2: Determination of the option value for each strategy

To calculate the expected NPV or option value, the stochastic simulation is applied for $S = 50{,}000$ simulation runs. The demand process according to (2) is simulated S times over the period under review of $T = 100$ years. On the basis of this, the option value per firm according to (5) is calculated for each simulation run, marked with a superscript index s, $s = 1, 2, \dots, S$ on the left side. The determination of the option value per firm for the respective generation is carried out as an arithmetic mean:

$$_{n,g}F_0 = \sum_{s=1}^{S} {}_{n,g}^{\;s}F_0 \tag{8}$$

Step 3: Application of the GA Operators

On the basis of the genomes of the current generation and their option values, now the operators of the GA are applied to define the genomes of the next generation. It should be noted that the following specification only represents one of many possibilities.

Step 3.1: Fitness Evaluation

The option values determined in step 2 give information about the "quality" of the respective genome strategy to solve the problem at hand: The higher the option value of a genome, the higher the fitness of its represented investment strategy. Thus, the genomes are sorted according to their option values, starting with the highest.

Step 3.2: Selection and Replication

Selection identifies the genomes to be reproduced in the next generation. The higher the fitness of a genome, that is, the more it is adapted to solving the problem at hand, the more likely it is to be selected for reproduction. There are many different ways to implement a selection rule. In this model the five most successful strategies are quadruplicated, the next five are triplicated, the next five are doubled, and the next five survive but are not multiplied. Hence, the other 30 genomes of the current generation are not replicated in the next generation.

In order to consider the possibility to develop better strategies than the ones already represented by the current genomes, in every generation completely new strategies are to be generated. This happens in the next two steps of Crossover and Mutation.

Step 3.3: Crossover

In general, every genome from *Selection and Replication* is coupled with another genome via a specific mathematic operation with a minor likelihood. In this case, for every genome, starting with the ninth fittest, the arithmetic mean from itself and its foregoing neighbour is calculated to produce an offspring with a likelihood of 5%.

Step 3.4: Mutation

Mutation also generates new genetic varieties. Furthermore, it serves as a reminder or insurance operator against an early fixation on an inferior genome, as it allows lost genetic material from previous generations to be recovered into the current generation. Here, every genome from *Crossover*, starting with the ninth fittest, is either increased or decreased via a random number within a range of 0.1 and 2% with a likelihood of 20%.

Step 4: Next Generation

Result is a new population of genomes, on which the steps 2 and 3 are repeatedly applied, until the optimal action strategy is determined. The GA can be stopped, when the obtained strategies are homogenous, that is, ${}_{1,G}P^* \approx {}_{2,G}P^* \approx \cdots \approx {}_{N,G}P^*$, and stable, that is, ${}_{n,G-2}P^* \approx {}_{n,G-1}P^* \approx {}_{n,G}P^*$.

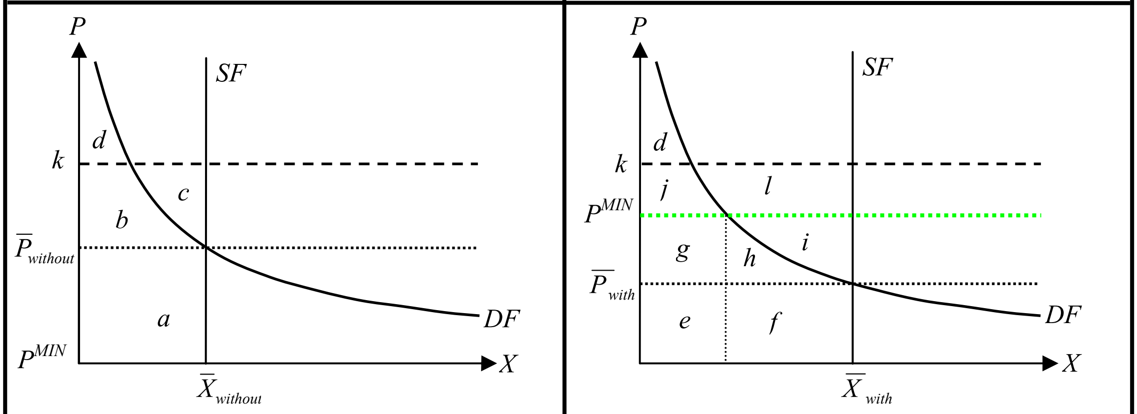
3.3. Determination of the Economic Efficiency of Political Schemes

To quantify the welfare effects of different political schemes, the concept of consumer and producer surplus is applied (cf. e.g. Pindyck and Rubinfeld, 2005: ch. 9; Just et al., 2004: ch. 8). Accordingly, figure 2 shows the welfare in a random production period without (left half) and with (right half) political schemes, using the example of a lower price limit maintained by governmental purchases of excess supply. For the sake of illustration, in the figure a static view is taken and it is assumed that in each case the equilibrium market price $\bar{P}$ is below the yearly capital costs k. Furthermore, there exists a fully price-inelastic supply function based on the model assumption of an unlimited useful lifetime (cf. subsection 3.1.).

It should be noted that international trade is not considered in the present study. Thus, e.g. it is not possible for the state or the firms to export any excess supply to world market prices. This simplification does not influence the basic outcome of the model regarding the willingness to invest and the firm profitability. However, for a more realistic analysis of the welfare effects of specific political schemes, the model needs to be extended in future research work to consider international trade as well.

Figure 2: Welfare without and with political schemes, with a lower price limit as example [a]

Welfare without political schemes ($\overline{P} > P^{MIN}$)	**Welfare with political schemes ($\overline{P} < P^{MIN}$)**



Welfare without political schemes	Welfare with political schemes
CS = Willingness to Pay - Expenditure	CS = Willingness to Pay - Expenditure
= $a+b+d$ - a	= $e+g+j+d$ - $(e+g)$
PS = Revenues - Costs	PS = Revenues - Costs
= a - $(a+b+c)$	= $e+f+g+h+i$ - $(e+f+g+h+i+j+l)$
BG = 0	BG = $-(f+h+i)$
WF = CS + PR + BG	WF = CS + PR + BG
= $b+d$ + $(-b-c)$ + 0	= $j+d$ + $(-j-l)$ + $(-f-h-i)$
= $d-c$	= $d-l-f-h-i$

CS Consumer Surplus	PS Producer Surplus	BG Budget	WF Welfare
DF Demand Function	SF Supply Function		

[a] Determination of the welfare calculation is shown for a specific point in time (statical view). For better clarification, the use of time indices is intentionally avoided.

Source: own elaboration

The welfare is composed of three components (cf. figure 2): The consumer surplus *CS*, the producer surplus *PS* and the state budget *BG*. The latter must be paid for by taxes, and so is ultimately a cost to consumers. Analytically, the consumer surplus corresponds with the integral below the demand function up to the quantity demanded, less the expenditures. As the demand function according to (2) tends to infinity for $X \rightarrow 0$ and a negative elasticity of demand, the willingness to pay would be also infinite. To avoid this, the minimum quantity demanded is assumed to be 1, resulting in a problem of scaling and thus the results for the below efficiency measures can just be interpreted as ordinal numbers. Alternatively the welfare calculation was carried out for a positive elasticity of demand. The basic conclusions are the same. The three welfare components for the basis scenario of the absence of political schemes, for lower price limits maintained by governmental purchases of excess supply and for investment subsidies are determined according to table 1.

Table 1: Calculation of consumer surplus, producer surplus and state budget

	Basis Scenario (No Political Schemes)	**Lower Price Limit**	**Investment Subsidy**
CS	$CS_t = \int_1^{X_t} \frac{\mu_t}{X_t} dX_t - \mu_t$	See basis scenario, replace X_t by X_t': $X_t' = \begin{cases} X_t, & if\ P_t > P^{MIN} \\ \mu_t/(P^{MIN})^{-\zeta}, & otherwise \end{cases}$	See basis scenario
PS	$PS_t = X_t \cdot P_t - X_t \cdot k$	See basis scenario, replace P_t by P_t': $P_t' = \max\{P^{MIN}, P_t\}$	See basis scen., replace k by k': $k' = k \cdot (1 - s)$
BG	0	$BG_t = \max[0, (P^{MIN} - P_t) \cdot (X_t - \mu_t/(P^{MIN})^{-\zeta})]$	$BG_t = \sum_{n=1}^{N} {}_nX_t \cdot k \cdot s$

Source: own elaboration

The total welfare for the whole period under consideration is calculated as present value of the welfare of all T production periods (cf. e.g. Just et al., 2004: ch. 14):

$$WF = \sum_{t=1}^{T} WF_t \cdot e^{-r \cdot t} = \sum_{t=1}^{T} (CS_t + PS_t + BG_t) \cdot e^{-r \cdot t} \tag{9}$$

For the determination of the effects of political interventions on the economic efficiency, finally, the welfare with the respective political scheme WF_{with} is set in relationship to the welfare without political schemes $WF_{without}$, resulting in the economic efficiency measure R:

$$R = \frac{WF_{with}}{WF_{without}} \tag{10}$$

To correctly consider the volume dynamics when determining R, it is essential to use two different sets of genomes. Accordingly, the optimal trigger prices in case of the existence of a political scheme are taken for the calculation of WF_{with}, and the optimal trigger prices in case of the absence of a political scheme are taken for the calculation of $WF_{without}$. In the course of the stochastic simulation, R is calculated S times and, consequently, the expected economic efficiency results from the arithmetic mean of R over all simulation runs S.

4. RESULTS

The illustration and discussion of the model's results below is split into two parts: In subsection 4.1., the general effects of the implementation of political schemes on the trigger price, firm profitability and economic efficiency are analyzed by using the example of a lower price limit. These effects also apply in the opposite direction, that is, the abolishment of political schemes. Subsequently, the effects of a lower price limit and those of an investment subsidy are compared (subsection 4.2.).

4.1. Effects of a Lower Price Limit on Trigger Prices, Option Values and Economic Efficiency

In table 2, the optimal trigger prices, the corresponding option values and economic efficiencies are quoted for a lower price limit maintained by governmental purchases of excess supply. This is implemented for 80%, 90%, 95% and 97.5% of the capital cost k. The calculations are based on a risk-free interest rate $r = 6\%$ p.a. and a demand elasticity $\zeta = -1$. To emphasize the effects of different levels of the demand process parameters, the drift rate α is fixed at -2.5%, 0% and 2.5% and for the volatility σ, 10%, 20% and 40% are chosen.[1]

Table 2: Effects of political schemes on trigger prices, option values and economic efficiency by using the example of a lower price limit [a]

P^{min} [b]	σ	10%			20%			40%		
	α	P^*	F_0	R	P^*	F_0	R	P^*	F_0	R
0%	**-2.5%**	1.5348	-0.0118	100.00%	1.8357	-0.0042	100.00%	2.6372	-0.0170	100.00%
80%		1.3349	-0.0097	85.04%	1.4295	-0.0071	76.20%	1.6169	-0.0033	72.48%
95%		1.1454	-0.0041	70.68%	1.1369	0.0005	60.46%	1.0931	0.0022	57.18%
0%	**0%**	1.2548	-0.0113	100.00%	1.5819	-0.0042	100.00%	2.3934	-0.0413	100.00%
80%		1.1876	-0.0101	93.09%	1.3202	-0.0025	81.07%	1.5359	-0.0020	71.77%
90%		1.1317	-0.0040	88.14%	1.1929	-0.0011	72.82%	1.2619	0.0007	62.86%
95%		1.0786	-0.0021	83.36%	1.0841	0.0004	65.35%	1.0560	0.0018	55.34%
97.5%		1.0291	-0.0021	78.81%	0.9939	0.0000	59.00%	0.9014	0.0050	49.60%
0%	**2.5%**	1.1058	-0.0125	100.00%	1.3809	0.0076	100.00%	2.1724	-0.0060	100.00%
80%		1.0904	-0.0013	98.08%	1.2244	-0.0036	86.96%	1.4460	0.0350	79.41%
95%		1.0266	-0.0022	92.70%	1.0398	0.0027	73.28%	1.0203	0.0538	67.22%

[a] GBP, $r = 6\%$, $T = 100$, $\Delta t = 1$, $k = 1$, $\zeta = -1$.

[b] In relation to the annual cost of capital k.

Source: own elaboration

The above results can be summarized as follows:

1. The increase of a lower price limit induces a decline in trigger prices. This is due to the fact that the lower price limit represents a lower reflecting barrier for the firms, whereby the

[1] In addition, it needs to be clarified whether the results of the numerical model correspond to the analytical result. This is done by use of the respective pricing formulas of Dixit and Pindyck (1994, p. 140ff.), which are again based on the McDonald-Siegel pricing formula. Accordingly, for a drift rate of 0% and a volatility of 20% the resulting trigger price is 1.7676. In the numerical model, in contrast, the respective trigger price is 1.5826, assuming $\Delta t = 1$ (cf. table 2). The reason of this underestimation lies in the temporal discretization, which is an unavoidable assumption of numerical evaluation methods in contrast to (time-continuous) analytical procedures. The longer the time step length, the more likely a (strong) overshooting in prices of the upper reflecting barrier becomes because of the bigger time lag in production. As a result, the expected future price ceteris paribus is higher and, hence, allows a lower trigger price. By way of illustration, a smaller time length step is chosen at 0.1 instead of 1. The resulting trigger price out of the model is 1.7282, which comes already very close to the aforementioned analytical result.

expected future price rises. Consequently, a lower trigger price can already ensure a compensation of the investment cost by the expected present value of the future cash flows.

2. The firms do not make any profits despite of a lower price limit, that is, the zero-profit-condition is still met. To the extent that the expected future price increases through implementation of the lower price limit (cf. 1.), the firms cause a decline of the reflecting barrier by investing earlier. Therefore, though price stabilization policies induce less risk for the producers, they do not offer any sustainable financial benefits.
3. The economic efficiency decreases with implementation of a lower price limit. By static view, this follows directly from figure 2. In addition, the higher the lower price limit, the higher the reduction in economic efficiency. The reason is that the government needs to intervene more often through purchases of excess supply with an increasing lower price limit.
4. The trigger price can even fall below the annual capital cost of investment amounting to 1. This is especially obvious in the scenario $\alpha = 0\%, \sigma = 40\%$ and $P^{MIN} = 97.5\%$, where the trigger price is merely 0.9014. The reason is the discrete time assumed in the model, which causes a time lag in production. Through this, it becomes more likely that prices (strongly) overshoot the upper reflecting barrier in the short term, even in case of a very fine temporal discretization, while they can never fall below the lower price limit. In other words, the firms invest at a trigger price below the cost of capital, because they hope for sporadic upward "outliers".
5. An increasing drift rate induces decreasing trigger prices as expected, because with the drift rate the expected price rises as well. What is remarkable is that the economic efficiency increases likewise in the case of a lower price limit. The reason is that with a higher drift rate the lower price limit ceteris paribus is hit less often. Therefore, the government needs to intervene less frequently, even though the upper reflecting barrier is lower and thus the market price level is lower as well.
6. A classical statement of option pricing theory is that the investment trigger increases with a higher risk of the future cash flows (cf. section 2). In contrast, the model results show that if the lower price limit is sufficiently high, a higher volatility can ceteris paribus even lead to lower trigger prices. This is e.g. the case in the scenario $\alpha = 0\%$ and $P^{MIN} = 97.5$: At $\sigma = 20\%$ the trigger price amounts to $P^* = 0.9939$ while at $\sigma = 40\%$ it amounts to $P^* = 0.9014$. The effect can be explained by a higher fluctuation margin of prices coming along with an increasing volatility: A (strong) overshooting of the upper reflecting barrier becomes more likely while prices are buffered downwards at the same time by means of the higher lower price limit. As a result, the expected future price is higher and, hence, allows for a lower trigger price.
7. The higher the volatility, the stronger the reduction in trigger prices and economic efficiencies by increasing the lower price limit (cf. 1. and 3.). The trigger price decreases stronger because an overshooting of the upper reflecting barrier becomes more likely in combination with a downward buffering at the same time. The economic efficiency is

stronger reduced, as with a higher volatility the lower price limit ceteris paribus is more often and stronger hit.

4.2. Comparison of the Effects of a Lower Price Limit vs. an Investment Subsidy

By implementing an investment subsidy at different levels into the model, the same general effects can be observed as in the case of a lower price limit (cf. subsection 4.1.). It is yet to clarify, which of both political schemes is preferable concerning its economic efficiency for a given reduction of the trigger price. For this purpose, in table 3 the effects of a lower price limit and an investment subsidy on the trigger price, the consumer surplus, the producer surplus, the state budget and the economic efficiency are compared for a drift rate of 0% and a volatility of 20%. By iterative searching, the investment subsidy is fixed such that the resulting trigger prices nearly equal the trigger prices of the lower price limits at 80%, 90%, 95% and 97.5%.

Table 3: Comparison of the effects of a lower price limit and an investment subsidy [a]

Lower Price Limit						**Investment Subsidy**					
***P^{MIN}* [b]**	***P****	***CS***	***PS***	***BG***	***R***	***s* [b]**	***P****	***CS***	***PS***	***BG***	***R***
80%	1,3202	295,13	-0,02	-32,76	81,07%	**16%**	1,3210	311,56	-0,08	-31,90	93,48%
90%	1,1929	295,36	0,09	-53,85	72,82%	**24,5%**	1,1915	329,29	-0,09	-54,18	89,35%
95%	1,0841	302,61	0,09	-76,16	65,35%	**31,5%**	1,0865	340,26	0,16	-76,07	84,90%
97,5%	0,9939	300,73	0,06	-97,74	59,00%	**37%**	0,9948	360,07	0,02	-98,20	80,80%

[a] GBP with $\alpha = 0\%$ and $\sigma = 20\%$, $r = 6\%$, $T = 100$, $\Delta t = 1$, $k = 1$, $\zeta = -1$.
[b] In relation to the cost of capital k.
Source: own elaboration

The results can be summarized as follows:

1. The consumer surplus is higher in case of an investment subsidy than in case of a lower price limit. This can be illustrated by the following: As the trigger prices for both political schemes are the same, the total quantities offered by the firms are hence the same as well. Therefore, the consumer surplus resulting from an investment subsidy is higher to the extent of the areas g and h on the right side of figure 2, compared to the consumer surplus resulting from a lower price limit.
2. The producer surplus amounts to zero for both political schemes. This follows directly from the aforementioned validity of the zero-profit-condition, that is, the competing firms do not make any profit despite of political support.
3. The burden of the state budget is the same for both political schemes. This is due to the fact that both measures reduce the trigger price to the same level by paying the farmers a financial compensation for investing correspondingly earlier. As the stochastic demand process is the same in both cases, this compensation has to be the same as well.
4. The economic efficiency of an investment subsidy is higher than the economic efficiency of a lower price limit. As the producer surplus and the state budget are the same for both measures (cf. 2. and 3.), this follows directly from the higher consumer surplus in case of an investment subsidy (cf. 1.).

5. Conclusive Remarks

The results show that the above developed numerical real options market model allows the analysis of investments under simultaneous consideration of competition and political schemes. To our knowledge, in this respect it is the first model which explicitly relaxes the unrealistic assumptions of the optimality principle of myopic planning. It thus provides the conceptual basis for a detailed policy impact assessment for competitive markets that are evidentially characterized by strong investment inertia, like e.g. the dairy sector. Accordingly, the results show that political interventions in such markets generally increase the willingness to invest, but neither can be justified under welfare aspects nor offer any sustainable financial benefits to the producers. The latter is particularly worth mentioning, as "helping the producers" is the most commonly used argument by farmers and lobbyists when calling for additional political support. At the same time, the aforementioned effects also apply in the opposite direction, i.e., the abolishment of specific political interventions.

Furthermore, by the use of genetic algorithms and stochastic simulation, a vast modelling flexibility is gained, which enhances the scope of the model. In particular, nonstandard stochastic demand processes and complex political schemes can be handled. Through this, the model can be matched to specific industries and specific political schemes as needed. This represents a fundamental advantage compared to analytical procedures, which can just derive solutions for a basis scenario. For example, the above model results suggest that under the given assumptions, investment subsidies are preferable to lower price limits because the welfare is reduced less under the same stimulation of the willingness to invest.

For further investigation, one could map the EU dairy market by using real data for the estimation of the model parameters. In addition, the effects of further relevant policy issues could be investigated, like e.g. the abolishment of the milk quota system. Finally, disinvestment decisions besides investment decisions could be integrated into the model, as disinvestments are equally important for the modelling of structural change in agriculture.

REFERENCES

Abel, A.B. and Eberly, J.C. (1994): A Unified Model of Investment under Uncertainty. *American Economic Review* 84: 1369-1384.

Balmann, A., Happe, K. (2001): Applying parallel genetic algorithms to economic problems: the case of agricultural land markets. *IIFET Conference "Microbehavior and Macroresults". Proceedings*. Corvallis, Oregon.

Carey, J.M., Zilberman, D. (2002): A model of investment under uncertainty: modern irrigation technology and emerging markets in water. *American Journal of Agricultural Economics* 84 (1): 171-183

Dixit, A. (1991): Irreversible imvestments with price ceilings. *Journal of Political Economy* 99 (3): 541-557.

Dixit, A. and Pindyck, R.S. (1994): *Investment under Uncertainty*. Princeton, US: Princeton University Press.

European Commission (2010): http://ec.europa.eu/agriculture/rica/pdf/dairy_report_2010.pdf

European Milk Board (2009): http://www.europeanmilkboard.org/en/special-content/news/news-details/browse/48/article/declaration-of-the-international-congress-of-non-governmental-agricultural-organizations-of-new-eu.html?tx_ttnews%5BbackPid%5D=78&cHash=0bbc4614a7

EUROSTAT (2010): http://epp.eurostat.ec.europa.eu/portal/page/portal/agriculture/data/database

Forrest, S. (1993): Genetic algorithms: principles of natural selection applied to computation. *Science* 261: 872-878.

Goldberg, D.E. (1989): *Genetic Algorithms in Search, Optimization and Machine Learning*. Reading, MA: Addison-Wesley.

Holland, J.H. (1975): *Adaption in Natural and Artifical Systems*. Ann Arbor. MI: University of Michigan Press.

Hyde, J., Stokes, R., Engel, P.D. (2003): An Ex Ante Real Options Analysis of Automatic Milking Systems in Pennsylvania and the Northeast. *Agricultural and Resource Economics Review* Spring 2003: 75-92.

Just, R.E., Hueth, D.L., Schmitz, A. (2004): *The Welfare Economics of Public Policy: A Practical Approach to Project and Policy Evaluation*. Cheltenham, Elgar.

Leahy, J.V. (1993): Investment in Competitive Equilibrium: The Optimality of Myopic Behavior. *Quarterly Journal of Economics 108*: 1105-1133.

McDonald, R., Siegel, D. (1986): The value of waiting to invest. *Quarterly Journal of Economics* 101: 707-728.

Mitchell, M. (1996): *An Introduction to Genetic Algorithms*. Cambridge, MIT Press.

Odening, M., Mußhoff, O., Balmann, A. (2005): Investment Decisions in Hog Finishing: An Application of the Real Options Approach. *Agricultural Economics* 32: 47-60

Pietola, K.S., Wang, H.H. (2000): The Value of Price and Quantity Fixing Contracts. *European Review of Agricultural Economics* 27: 431-447.

Pindyck, R.S., Rubinfeld, D.L. (2005): *Microeconomics*. Upper Saddle River, NJ: Pearson Prentice Hall.

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

Richards, T.J., Patterson, P.M. (1998): Hysteresis and the Shortage of Agricultural Labor. *American Journal of Agricultural Economics* 80(4): 683-695.

Trigeorgis, L. (1996): *Real Options*. Cambridge, MIT Press.