Agent-Based Modeling of Farming Behavior: A Dutch Case Study on Milk Quota Abolishment and Sustainable Dairying

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Abstract
Gaining insight on the effect of policies upon the agricultural domain is essential for policy makers, famers and the agribusiness sector. A variety of models have therefore been developed that enable a prediction of agricultural development under different policies. Most models do however not make predictions on a fine grained level and are weak in accounting for specific factor market and resource constraints farmers (agents) face at farm level. The paper presents an agent-based model where each farm is modeled by means of an agent and studies the effect of milk quota abolishment. Two simulations policy simulations are made: 1) abolition of the milk quota; and 2) land-tied sustainable dairy scenario. Outcomes are analyzed and compared with the predictions of sector models.

Keywords: agent based modelling, dairy, milk quota

1 Introduction

Traditionally EU agricultural policy had a strong focus on measures influencing prices (e.g. support price, intervention price, import tariff, export subsidy), with production quota (milk, sugar beets) and set-aside (cereals) as main exceptions. Since MacSharry (1992) there has been a shift from price support to direct payments and with the introduction of pillar 2 (Agenda 2000) a host of measures aimed to influence rural development have been introduced. Together with the increasing restrictiveness of environmental policy measures (e.g. Nitrate Directive, Water Framework Directive) these policy developments implied an increasing emphasis on regulation relative to incentives. With this changing policy landscape it becomes more important that the analytical tools used for policy analysis are well able to capture restrictions on land use, intensity of production, input use (manure, water) and zoning (High Nature Valued areas, Natura 2000). In order to decide on policy changes in an adequate manner, the policy makers should be able to judge the consequences of these changes in advance. Hence, a need for predictive models exists that enables informed decisions with respect to policy changes.

As a consequence of this need, a variety of predictive models have been developed and published (see e.g. INRA-Wageningen (2002), Lips and Rieder, 2005, Bouamra et al, 2009, Tonini et al, 2011). These models usually take the form of partial or general equilibrium models that tend to focus strongly on product market impacts (prices, supply, demand, trade) but they usually have a limited representation of the factor markets, or in case if they do, usually a lot of the crucial heterogeneity characterizing these markets is ignored. However, adjustments in farm structure, may lead to economies of scale and by that adjust the competitiveness of the farm sector. Therefor these longer term and indirect impacts of policy changes should not be ignored. There are a number of studies which try to analyze the changes in the farm size distribution, for example by modeling farm size evolution by means of a stationary or non-stationary Markov chain process (see e.g. Tonini and Jongeneel, 2009, Huettel and Jongeneel, 2011 and Zimmermann and Heckelei, 2012) A problem with these studies is however that they do not take the inherently spatial nature of agriculture into account. Also the land market is often not properly taken into account, let alone the heterogeneity and competing claims on land and land use. Farms might for instance not be able to expand because they are positioned next to an urban area, or environmental regulations that hold for certain regions could influence the behavior of a farmer. Furthermore, individual farmers might behave quite different with respect to policy changes; some might be more risk taking because they are still relatively young whereas older farmers might more frequently take a more conservative approach.

To enable a detailed insight into the effect of policy changes, agent-based simulations can be a promising paradigm as they enable simulations on an individual level. Hereby, the individual farmer behavior can be modeled as well as the spatial aspects that were mentioned before. Some models exist that take an agent-based approach for simulating farming behavior (see e.g. Happe et al, 2006) however they do not have the detailed spatial level that fully utilizes the advantages an agent-based approach can have.

In this paper, an agent-based model is described which is able to simulate the behavior of individual dairy farmers given certain policy changes. More in specific, the model has been developed to evaluate the impact of the abolishment of the milk quota which is planned for 2015 by the European Union. The behavior of the individual agents is based on detailed behavior analysis from the agricultural domain as well as real geographic data about the current land owned by farmers and other relevant data (e.g. nature areas). A rigorous evaluation of the model has been performed by simulating the prospected changes in the Netherlands after the abolishment of the milk quota. A comparison is made between the model and other predictive models which do not simulate on an individual farm level, showing some similarities as well as differences in the prediction.

This paper is organized as follows. In Section 2 related work with respect to predictive models in the agricultural domain is sketched. Thereafter, the agent-based model is presented in Section 3. The experimental setup concerning the milk quota abolishment is presented in Section 4 whereas Section 5 presents the results. Finally, Section 6 closes with a discussion of the results.

2 Literature review

A variety of economic modelling approaches have been used to analyze and simulate the behavior of farmers. The most relevant ones that focus on abolishment of the milk quota are briefly described here. For some, actual simulations are shown in Section 5 where a comparison is made with the output of the model presented in this paper. There are a number of models that focus on a country level and take the Netherlands into account (which is the country studied in this paper): Helming and van Berkum (2008) use a partial equilibrium model, which allows different dairy farm types. Lips and Reader (2005) make predictions for a large selection of European countries (16) and use a computable general equilibrium modelling approach (GTAP). A European study (IPTS, 2009) uses the CAPRI agricultural sector model to analyze the consequences of milk quota abolition. The INRA-Wageningen consortium (2002)] and Bouamra et al (2009) performed assessments for European alternative dairy policies (including quota abolition) combining a dairy processing and milk supply models.

Next to the sector- and general economy-oriented approaches, an agent-based model called AgriPoliS (for Agricultural Policy Simulator, (Happe et al, 2006)) was found. The main purpose of the approach is to study the effect of policies upon agricultural structure and the model is very extensive. Farms are also represented by means of agents. They use a detailed spatial model for the land of farms to be able to simulate the land market. As a result the model is very extensive and on to this moment only applied in local/regional studies.

3 Agent-Based Model[1]

In this section the agent-based model which has been developed to simulate dairy farm behavior is explained. The model has been developed within the scope of the Dutch dairy sector as ample information is available to develop appropriate models (including a spatial model). Essentially, each dairy farm is represented by an agent who has (1) a land mass at a specific location and a number of dairy cows; (2) certain characteristics related to the owner of the farm (e.g. the age). Based on these characteristics and the land mass the behavior of the agents is expressed. This behavior mainly deals with expansion in terms of buying or selling land from/to other agents and increasing the number of cows. The behavior is based on the economic principle to maximize profit. More details are provided below. Note that this is a simplified specification of the model; the full model is explained in Oudendag (2013).

3.1 Agent goals, revenue and costs

As explained before, the behavior of the agents (i.e. farms) used in the agent-based model is targeted towards profit maximization. As is known from microeconomic theory, as long as there are increasing returns to scale, the firm size structure in an industry is still not at its long run equilibrium. In that case further scale increase is still attractive since it will enable to further reduce the costs per unit of production and by that, at given product and factor prices, to increase profits. In economic textbooks (e.g. Mansfield, 1988) usually a U-shaped average total cost curve drawn, suggesting an optimal firm size at the point where this curve reaches it minimum. Figure 1 shows the empirical cost function for Dutch dairy farms for 2006, as it has been estimated by Tonini et al (2011) using FADN-data which suggest that the optimal farm size would be a herd size of approximately 130 dairy cows, since after that per unit production costs hardly decline any more.

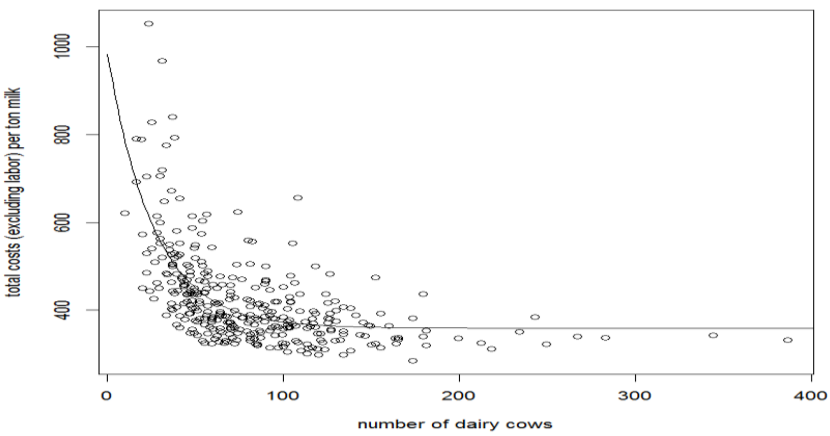

Figure 1 Costs of production and herd size for Dutch dairy farms

[1] Sections 3 and 4 are partially based on Oudendag et al, (2014).

Profit maximization implies that farms will strive to achieve this number of cows. The revenues per farm can be expressed by means of the following equation:

$$revenues = milk\_production \cdot milk\_price + number\_of\_cows \cdot non\_milk\_revenue\_per\_cow + fixed\_premiums \quad (1)$$

Here, the *milk production* of the farm is clearly dependent on the number of cows but also depends on a number of other parameters, the *milk price* results from the supply and demand and is assumed to be fixed during simulations. *Fixed premiums* is an external factor, namely the premiums (e.g. Single Farm Payment) provided by the EU. The *nonmilk revenue per cow* represents factors such as the growth and replacement of cattle (which can be sold) as well as other income (e.g. tourism). Costs have a fixed part, related to quasi-fixed factors and a variable part, related to output (e.g. milk supply) or inputs (e.g. number dairy cows, hectares of land) and are expressed as follows:

$$costs = fixed\_costs + variable\ costs\ (milk\ output,\ \#\ dairy\ cows,\ hectares\ of\ land) \quad (2)$$

Here, a certain fixed cost is expressed (also depending on whether the farm is fully specialized as a dairy farm or not) whereas a variable cost per cow is specified as well as another variable cost depending on farm characteristics[2].

3.2 Agent Behavior

The behavior of the agents (i.e. farms) is expressed in the form of an activity diagram in Figure 2. Each of the activities is explained in more detail below.

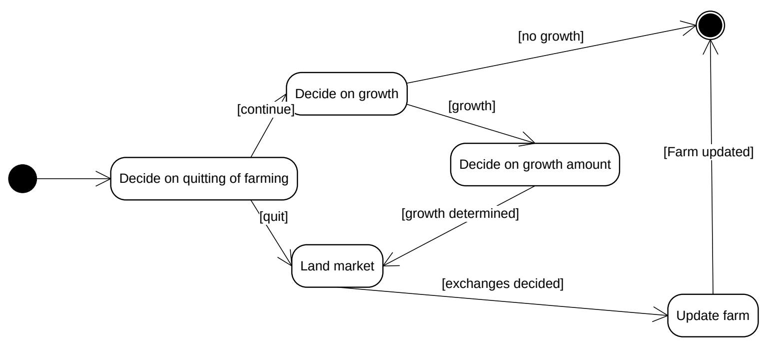

Figure 1. High level specification of agent behavior

Decide on quitting of farming. The first step the agent needs to take is to decide whether or not to quit farming. This decision is made with a certain probability. An agent can decide to quit based on economic reasons as well as non-economic reasons[3]. These probabilities are

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[2] Although the cost function is assumed to be quadratic, a quadratic term of dairy cows in the regression is not significant contributing.

[3] In the standard literature these non-economic reasons are often ignored, or treated as variation that has to be fully explained by economic factors. According to some anecdotal evidence non-economic incidental factors such as

highly dependent on the age of the owner of the farm as well as the size of the farm (cf. Oudendag, 2013) The older the owner is, the higher the probability of quitting. Furthermore, the smaller the size of the farm, the higher the probability as well. Finally, the probability clearly depends on whether profit is being made. Overall, different groups are identified based on real data to judge these probabilities (e.g. older farm owners with a less than 20 cows and no profit have a probability of 0.287 to quit farming). Once the owner has decided to quit he tries to sell his land on the land exchange. If the farm does not quit, the probability to grow is assessed.

Decide on growth. If a farm decides to stay in business the probability to grow (measured in terms of the number of dairy cows) is assessed, which is then used to decide whether the farm will actually grow or not. The probability to grow depends on the age of the farm owner (farms with older owners tend to have a lower probability to grow) and also depends on the area in which the farm is located. If the farm is located near or within a nature conservation area the probability of growth will be lower due to the limited opportunity for growth. For the model we propose to use age of the farmer and proximity of a farm to nature conservation areas to determine the probability on farm growth. We distinguish three age classes (< 50 yrs, 50- <65 yrs, >= 65 yrs) and nine location classes. These locations are a product of three proximity types (within, in the radius of 500 m, further then 500 m from) and two types of nature conservation areas: Nature2000 and Ecological Main Structure. If we define A as a random variable representing if a farm will grow or not (sample space {grow, no grow}) and B and C as the random variables representing location and age class, using Bayes rule we can write:

$$p(A|BC)=(p(ABC))/(p(BC)) = (p(AB))/(p(B)) * (p(AC))/(p(C)) = p(A|B)*p(A|C) \quad (3)$$[4]

As (at this stage) there is not enough proper data for estimating both age and location effect at the same time we only use in our model the proximity of a farm to nature conservation areas to determine the probability on farm (nine location classes). growth. When a farm decides to grow, it decides how much it wants to grow. Otherwise, the farm stays as it is and is not considered until the next iteration.

Decide on growth amount. As explained before, the farms strive towards a certain optimal amount of dairy cows; if the farm already has more cows than this optimal amount it will not have growth potential. In order to reach this amount, a certain amount of land is required. The relationship between the number of cows and the required amount of land is of course crucial. This is however not a trivial matter as it highly depends upon the intensity of the farm (the number of dairy cows per utilizable agricultural area) as well as the type of farm (specialized dairy farm or not). First, it is acknowledged that a farm might have a potential to use its land in a more intensive way. This has been taken into account by allowing a certain autonomous increase in farm intensity. After this has been calculated, the required increase of land is calculated given the desired number of cows. If the required growth is more than a

disease, disability, divorce might be responsible for about one fourth of the number of farmers which annually exit dairying.

[4] Standard rule is p(BC) = p(B|C) * p(C). As B and C are independent (tested for the period 2001-2006), p(B|C) can be written as p(B) and therefore p(BC) = p(B) * p(C).

certain maximum percentage of the current land this maximum percentage is taken as farmers typically expand in a relatively limited way. Once an expansion has been decided upon, a land exchange can take place.

Land exchange. Once the aforementioned processes have ended, a number of quitting farms and a number of farms that expand will be present. These will try to exchange land on a land market. The market is setup in a relatively simple way: the seller simply sells only to the farm which are sufficiently nearby and selects the one which has the lowest cost-revenue ratio (having the highest shadow value of land).

Update farms. After all actions have been performed, the farms are updated.

4 Data and calibration

4.1 Characteristics and parameters

Based on the specification above, the agents have the characteristics as shown in Table 1. In the third column the source of selection of the initial values of the parameters is shown (which will be explained in Section 4). Furthermore, the parameters as shown in Table 2 can be distinguished within the model.

Table 1. Agent Characteristics

Characteristic	Explanation	Source for simulation
Age	The age of the farm owner.	Annual Census
Location	The location of the farm (X,Y coordinates).	Annual Census
Utilizable agricultural area (UAA)	The amount of land the farm owns that can be used for farming.	Annual Census
Land base	The amount of grass land owned by the farm.	Annual Census
Number of cows	The number of cows the farm owns.	Annual Census
Farm intensity	The intensity of the farm (cows per utilizable agricultural area).	Derived based on autonomous increase (see 3.2). Increases more significant without milk quota system.
Farm type	Dairy farm of non-specialized farm.	Annual Census
Costs	The costs a farm currently has.	Derived (see 3.2)
Revenue	The current revenue of a farm.	Derived (see 3.2)
Nature area	Indicates whether a farm lies in a nature area or not.	Nature 2000 (see EC, 1992)
Premium	The premium the farm receives.	Annual Census
Milk production	The overall milk production of a farm.	Derived (see Table 2 and 3.2)
Fixed costs	The fixed costs for a farm.	Report (see LEI, 2013)

Table 2. Parameters of the model

Parameter	Explanation	Default values used in simulation
Optimal number of cows	The number of cows at which the cost per cow is lowest.	130 (cf. Oudendag, 2013)
Milk price	The (assumed to be) fixed price for a unit of milk.	300 euro/ton (cf.LEI, 2013)
Milk production per cow	The amount of milk produced per cow given the specific characteristics of a farm.	5000 liter per cow (assumption based on domain expert). Increases 2.4% with milk quota and 6% without.
Non milk revenue per cow	The revenue per cow outside of milk (premium, tourism, etc.)	212 (cf. LEI, 2013)
Costs per cow	The costs per cow for a farm.	See Equation 4

Costs grass land	The costs of maintain an certain grassland area.	See Equation 4
Probability to quit farming	The probability to quit farming given the age, cost/revenue ratio and number of cows of a farm.	See Table 3
Location growth effect	The probability of farm expansion provided the location of the farm (taking nature areas into account).	Tuned value.
Age growth effect	The growth probability of a farm provided the age of the farm owner.	See Table 3
Land expansion required	Calculates the land expansion required for a farm to grow from *x* cows to *y* cows given its intensity and type.	See Section 3.2
Trade radius	The radius within which land trade can take place between farms.	5 kilometers (assumption based on domain expert)

4.2 Model Setup

As shown in Section 3.3 the model has ample parameters that should be set. In this paper, 2006 has been taken as an initial year, and 2011 as the year to predict.

First of all, initial values for all the agents should be set. The total number of farms that have dairy activities in the Netherlands was 21137 in 2006. For each of those farms an agent has been created, and the values of the characteristics of those agents have been set to values registered for each individual farm according to sources such as the Annual Census (Wijsman, 2013). The precise sources for the values are shown in Table 1. For 2011 the actual values were also known as a means of comparison.

Second, the global parameters should be set to an appropriate value. In fact these have also been derived based on historic data and are shown in Table 2 (including their sources). Some are however less trivial to specify. The costs for a farm, for example, were shown to be best described (based on Oudendag (2013)) using the following equation for specialized dairy farms:

$$log(costs) = \text{fixed costs} + 0.90578 \cdot \log(number\ of\ dairy\ cows) - 0.2059 \cdot fraction\ grassland \quad (4)$$

Fixed costs depend on specialization of dairy farming (specialized versus non specialized). Just as in formula 3 variable costs are farm specific.

Table 3. Probability of quitting (CRR stands for Cost-revenue ratio)

	Number of dairy cows < 20		**Number of dairy cows >= 20**	
Age	**CRR >= 1**	**CRR < 1**	**CRR >= 1**	**CRR < 1**
< 50	0.188	0.163	0.093	0.091
50 – 65	0.269	0.229	0.126	0.139
>= 65	0.287	0.406	0.187	0.200

For the probability of quitting data has been taken from the Census of 2001 and 2006 and is based on categories. The probabilities are expressed in Table 3.Another probability is the growth of a farm given its location. In the data that is present there does not seem to be a dependence on the location, however these rules have recently changed, therefore the value is tuned to get realistic behavior according to experts. The growth probability based on age is known (Annual Census 2001-2006): younger than 50 means a growth probability of 0.62, between 50 and 65 0.59 and 65 or older 0.55. Finally, the expansion required to reach a certain number of cows has been made dependent upon the type of farm (specialized dairy farm or not) and the intensity of the farm, this results in a specific equation which specifies the relationship between the number of dairy cows and the required utilizable agricultural area. This relationship has been estimated by means of the Annual Census.

4.3 Performance check

The model has been implemented in NetLogo (see for details Wilensky, 1999). Furthermore, the numbers presented are averages over 3500 runs given the probabilistic nature of the model. The performance of the model has been check in two ways. First the model has been used, starting from 2006 to estimate results for 2011. Table 4 presents the results.

Table 4. Predicted value for 2011 versus the actual values

Attribute	Base year 2006	Actual value 2011	Simulation 2011
Number of dairy cows (1000)	1409	1465	1475
UAA (1000 ha)	926	886	902
Number of farms	21137	18624	18528
UAA per farm	43.5	47.6	48.7
Dairy cows per farm	66.7	78.8	79.6
Costs per 100 kg milk	49.7	53.4	56
Revenues per 100 kg milk	38.4	49.5	47.8
Milk production (1000 kg)	11052	11738	11707

As Table 4 shows the results obtained using the model are quite accurate, suggesting an adequate model calibration. The largest deviation is found for the costs per 100 kg of milk (which in the simulation is 4.8% higher than the value that is actually observed), whereas all other deviations are substantially less than 4%.

Second sensitivity analysis has been used to see the influence of changing parameters of the model and investigate whether the resulting change in the model is as expected according to the domain knowledge. Nine different parameters have been investigated and the results seen when changing those parameter values were as expected. For the sake of brevity a further elaboration on these results is not possible (see Oudendag, 2013 and Oudendag et al, 2014 for more details).

5 Policy simulation results

The model has been used to assess the impact of milk quota abolition, without considering any further restrictions (see scenario S1). Abolition of the milk quota might lead to additional manure production and associated difficulties for the dairy sector to stay within the environmental constraints (N and P reference levels). This could then even lead to the introduction of a national quota on the number of dairy cows. For that reason, both the Dutch farmers union, LTO, and the branch organization of the dairy industry, NZO, have made a plea for a land-based sustainable dairy sector, including outdoor grazing of cows (“dairy cow in the meadow”). A production intensity of about 12 thousand kg milk per hectare has been suggested in some studies as an amount to release the pressure on the environment and to achieve a dairy sector which production is more closely tied to land (see Rougoor, 2013).

Therefore a second scenario (S2) is analyzed which combines quota abolition with a restriction on the intensity of milk production ($\leq$12 thousand kg/ha).

For the policy simulations the year 2006 (rather than 2015) has been chosen as the base year in which the quota is abolished. Subsequently the model is simulated a period of 5 years ahead (2011) allowing sectoral dynamics and adjustment to take place. Note that after the milk quota are abolished dairy farms are no longer constrained with respect to their milk supply, providing them more and cheaper options to increase the scale of their operation, relative to the current policy regime. However, competition for scarce resources and production factors remain. A summary of the results of scenario's S1 and S2 at sector level are given in Table 5.

Table 5. Model simulation results for 2011: milk quota abolition scenario's without (S1) and with (S2) a restriction on production intensity

Attribute	**Baseline: 2011 with milk quota**	**S1: 2011 without milk quota**	**S2: 2011 without quota, with selective growth**
Number of dairy cows (1000)	1,475	1,525	1,420
UAA (1000 ha)	902	899	865
Number of farms	18,528	18,527	18,528
UAA per farm	48.7	48.5	46.7
Dairy cows per farm	79.6	82.3	76.7
Cow per UAA	1.64	1.70	1.64
Production intensity (kg milk/ha)	12,979	13,938	13,479
Costs per 100 kg milk	56	46	48
Revenues per 100 kg milk	47.8	47.3	48.0
Milk production (1000 kg)	11,707	12,530	11,659

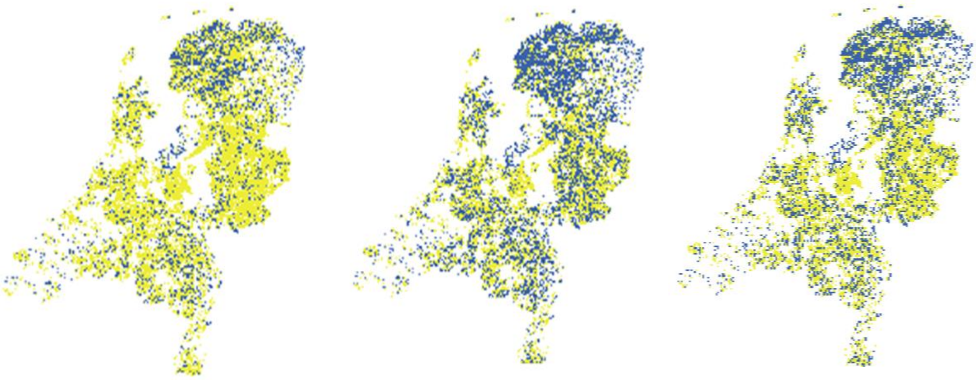

Figure 2. Comparison of predictions. Light gray indicates an average farm size of < 80 cows for an area of 4 km^2; dark gray $\geq$ 80 cows. The left figure concerns 2006 (base year); center: 2011 without milk quota (S1) and right 2011 without milk quota but milk production tied to land (S2).

As Table 5 shows in scenario S1 the number of dairy cows (+3.3%) as well as the number of dairy cows per farm (+3.3%) increases when the milk quota system would be abolished. The overall milk production increases significantly (+7.0%), and the costs per 100 kg of milk are substantially reduced (-17.8%). This suggests that the milk quota system still constraints Dutch dairy farmers and hampers the sector to find its long run equilibrium with respect to the optimal farm size. The quota system clearly creates an inefficiency (milk is not produced at the lowest possible costs), which in the end also affects consumers. Note that milk production per hectare increases by approximately 1000kg to a level of 14 thousand kg milk per hectare. In scenario S2, the intensity of production is controlled and only farmer having a milk production less or equal to 12 thousand kg milk/ha are allowed to grow (selective growth). As can be seen this would curtail a lot of farms in their growth strategy, in particular in the southern part of The Netherlands. The increase in milk supply in this land-tied milk production-scenario is 5.4% (as compared to 2006), which is even less than in the with-quota scenario. This suggests that (under the conditions in the model) connecting milk production to land is more restrictive than continuing the current quota system. With this selective growth scenario the average milk production per hectare is still 13.5 thousand kg.

Figure 3 provides a graphical illustration of the spatial dimension of the quota-abolition result is presented. From close inspection it can be seen that in particular the number of larger farms is certainly projected to increase from 2006 to 2011. Dutch milk productions shows a tendency to further expand and migrate to the north-east part of the country (in S1 as well as S2 the milk supply especially increases in the northern provinces Friesland, Groningen, Drente)[5].

As compared to the base year 2006 the number of farms declines 2.6% per annum. There is no difference between the with quota and S1 scenario in this regard (see Table 5). For scenario S2 the decline of the number of dairy farms is only marginally lower. Figure 3 provides an overview of the dairy farm size distribution. It shows that as compared to the with quota situation, the abolition of quota (S1) will lead to an increase in the farms with herd sizes of 100 and more. In contrast, when milk production will be tied to land, this will favor the relative growth of dairy farms with herd sizes of 100 and less.

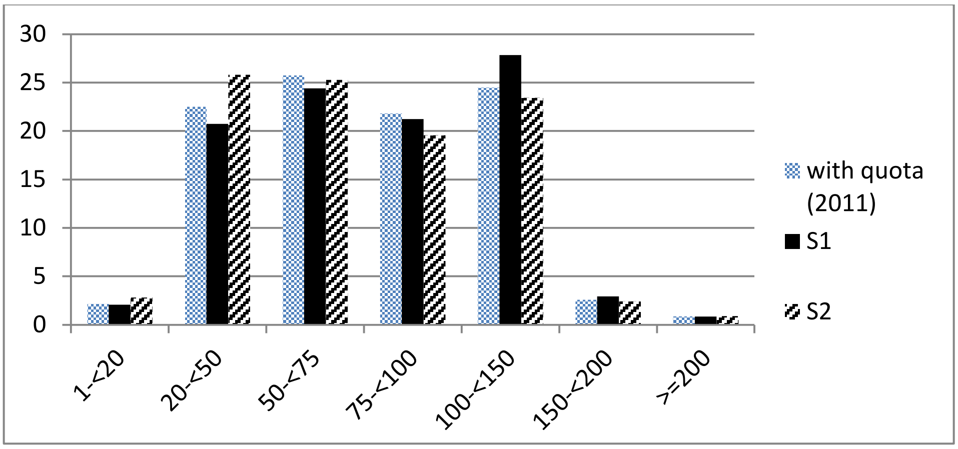

Figure 3 The dairy farm herd size distribution (%) under different quota abolition scenario's

[5] In these provinces about 58% of the dairy farms has still an intensity lower than 1.55 dairy cows/ha (e.g. in the southern province of Brabant this is only 26%; Dutch average is 47%). Table 5 also suggests that the total land use might go down in S2, which might be a consequence of a still too rigid modelling of the functioning of the land market. Further research is planned on improving this aspect in the future.

The model outcomes of S1 have been compared to those from four other studies (INRA-Wageningen, 2002, Helming and Peerlings, 2002; Lips and Rieder, 2005, and IPTS, 2009) running a similar policy experiment. Table 6 shows the differences on milk production and dairy cow numbers (our outcomes are indexed to be 100).

Table 6. Comparison of quota abolishment results with other studies: milk supply and cow numbers

Source	**Absolute values**		**Index (our research = 100)**	
	Milk production (1000 litre)	**Number of dairy cows (in 1000)**	**Milk production**	**Number of dairy cows**
Inra-Wageningen, 2002]	13638	1625	109	106
Helming and Peerlings, 2002	16051	1850	128	121
Lips and Reader, 2005	12573	-	100	
Helming and van Berkum, 2008	13229	1430	106	94
IPTS, 2009	13471	1639	108	108
This research	12530	1525	100	100

A first observation on Table 6 is that the results of the other models are quite diverse even in their own right. One reason for this might be that the research has been conducted in different years, which complicates the comparison. In addition, they also consider different factors. Our results are relatively in line with another model (i.e. the Lips and Reader, 2005 study). Most other studies predict a higher increase in aggregate milk output than our study. The model presented here does explicitly take the spatial aspect into account (including effect of nature areas) which has been ignored in other works. Furthermore, the number generated by the models and presented in this paper are certainly not unrealistic according to domain experts.

6 Discussion

In this paper, an agent-based model of dairy farming has been presented. The approach presented enables a thorough analysis of the effect of policy changes on individual farmers and their farms. The model is shown to be able to come close to actual data from 2011 provided that it is initialized with data from 2006. This performance to track the 5 year history is considered to be remarkably good for a calibrated model and underscores the value of the synthetic calibration procedure chosen (which combines econometric estimation on micro data and micro economic theory to determine the behavioral parameters).

The sectoral and spatial impacts of abolishing the milk quota were analyzed. Our results shows that the total milk supply as well farm scale will increase by about 7 and 3 per cent respectively. Tying milk production to land leads to selective growth (i.e. allows extensive farms, extensive production regions to increase milk production) and a reduced sectoral dynamics (supply increase +5.4%). This turns out to be even more restrictive than continuing the current (soft-landing) milk quota regime.

The projected supply increase is lower than those obtained in a number of other studies. However, as compared to the other studies analyzing the impact of milk quota abolition, it is the strength of our agent based modelling approach, including the behavior of more than 20 thousand individual dairy farms, to take into account resource and factor market constraints.

While these are known to still play a role in limiting the expansion of production and scale increase of farms, it is not surprising that taking these into account leads to a lower projected supply increase relative to those studies ignoring the factor market and land use-constraining zoning aspects. The outcomes of our model are not unrealistic according to domain experts, although in the light of other studies further validation work is recommended.

It should be noted that the quota abolition simulations have be done in a stylized way (e.g. imposing a “virtual” quota abolition in base year 2006 rather than in 2015). More work needs to be done to refine the analysis with respect to the expected growth dynamics. However, the first insights generated with the agent-based modelling approach of the Dutch dairy sector suggests this analysis to be a helpful complement to the existing sectoral modelling approaches.

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