The dynamics of dairy land use change with respect to the milk quota regime

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Abstract
This paper analyses the sequence of changes in land used for milk production on dairy farms in the period before, during, and towards the abolishment of milk quotas. Using a unique dataset comprising farm level data of the Netherlands between 1971 and 2011 we estimate two duration models, analysing the time period between changes in case of increases and decreases in dairy land use. The impact of milk quota, socio-economic and production variables on the likelihood of a farm changing his land use are assessed. Results show that quota abolishment will lead to a more dynamic dairy sector.

Keywords: Duration models, Panel data, Milk quota, Land use change, CAP reform

1. Introduction

Milk quota abolition, taking place in 2015 as part of the Common Agricultural Policy (CAP) reform, is expected to change the dynamics of (dairy) land use. Before milk quota implementation, EU dairy policy consisted of price and income support provided through import levies, export refunds, intervention buying and subsidies on domestic demand (e.g. school milk). Partly due to this price and income support overproduction in milk occurred, which led to the introduction of milk quotas in 1984. The total quota amount in the EU was secured at the 1981 level (+1%), while the distribution was country-specific. In the Netherlands, milk quotas were tied to land, hampering quota trade and farmer's ability to change milk production. To improve the mobility of quota rights, leasing of quota was introduced in 1989-1990 in the Netherlands, allowing quotas to be permanently transferred via temporary lease of land (Boots *et al.*, 1997). During the 2003 Fishler reform it was decided that milk quotas were to be increased as of 2006-2007 in three yearly steps of 1.5% in total. An extra quota increase of 2% was introduced in the Health Check of 2008. Between 2009 and 2014, quotas have been increased yearly by 1%. Complete abolishment in 2015 was affirmed by the EU's agreement of June 2013 (European Commission, 2013).

Land is generally seen as the most scarce production factor besides milk quotas in dairy farming in the Netherlands. In the absence of quota, land is an important factor determining the level of dairy production. Moreover, dairy farming in the Netherlands is bound to environmental regulations expressed per hectare of land, making changes in land use relevant for both farms and policy makers. The presence and abolishment of milk quotas is expected to have an effect on the magnitude and pace of changes in land use that take place at a dairy farm.

The impact of milk quotas on the farm level is complex (Huettel and Jongeneel, 2011), but milk quotas are likely to hamper changes on dairy farms (Piet *et al.*, 2012). Existing research on the influence of milk quotas includes the impact on changes in farm size (Breustedt and Glauben, 2007; Huettel and Jongeneel, 2011; Zimmermann and Heckelei, 2012), production (Ooms and Peerlings, 2005; Breustedt and Glauben, 2007; Huettel and Jongeneel, 2011), farm characteristics (Gale, 2003; Ooms and Peerlings, 2005; Huettel and Jongeneel, 2011), market conditions, land mobility (Harrington, 1995) or a combination of them (Zimmermann and Heckelei, 2012). However, all these studies focus on the impact of milk quotas, but not on the time at which they occur. In the context of policy changes that induce transitions it is important to take time and the length of time periods between changes into account.

The purpose of this paper is to analyse the time period between two changes in land used for milk production on dairy farms and the direction of change before, during and towards the abolishment of milk quota. We hypothesize that quota abolishment will lead to more dynamics in the dairy sector, implying shorter time periods between land use changes.

We define change as a decrease or increase of at least 10% in land used for milk production on a dairy farm. This limits changes to more substantial ones excluding small adjustments due to for example crop rotation. We define change relative to the size of the farm because we assume it to be easier for a large farm than for a small farm to change a fixed number of hectares, both because of economies of scale and because the large farm simply has more land available. We are interested in both positive and negative growth, and the speed with which adjustments over time take place. Both may serve as an indicator for the dynamics of dairy farms.

There are only few studies within agricultural economics using a duration model (see e.g. Towe *et al*., 2008; Goncharova *et al*., 2008; Wynn *et al*., 2001; and Väre, 2006). However, none of these allow for both multiple episodes, where events are allowed to occur multiple times (e.g. different occasions of growth), and multiple states, where different kinds of events are allowed to occur (e.g. both growth and decline). A notable exception is Francksen *et al*. (2012) who analyses time between expansions of milk quota, allowing for different growth rates. However, they do not allow for negative growth and are not able to analyse the period before and towards abolishment of milk quota.

We further contribute to the existing literature by using a unique dataset comprising farm structure survey data of the Netherlands covering the period between 1971 and 2011.This allows us to analyse dairy farming before, during and towards the abolishment of the milk quota regime. We analyse the sequence of increases and decreases in land used for milk production with and without the milk quota regime which has to our knowledge not been done before. This is relevant in order to assess the impacts of milk quota abolition on the dynamics of dairy farms.

We begin in the next section by developing a theoretical model for land use change. In section 3, we describe the data and descriptive statistics explain how our sample is split into changes towards a decrease and changes towards an increase in land use. This is followed by the empirical model in section 4 with the duration specification. An analysis of the results is given in section 5. Our conclusions ensue.

2. Theoretical model

Farmers base their decision to change their land used in dairy farming on the relative profitability of an additional unit of land for milk production (shadow price of dairy land) and the adaptation costs related to changing land use. To explain why farms are not continuously adjusting their land used for milk production we present a simple static model with two outputs, milk and other output.

Suppose we have a farmer *h* who can allocate his land between either milk production or other production, given shadow prices $p_h^i(q_h)$ for land used for milk production and shadow price $p_h^e(q_h)$ for other production. Both shadow prices depend on a vector of farm-specific explanatory variables q_h. Depending on the difference between the two shadow prices, the amount of land used for milk production can be adjusted on farm. Moreover, the total amount of farm land can also be adjusted by means of buying (renting) and selling (renting-out). In the profit maximizing optimum and without adaptation costs, the shadow price for milk production equals the shadow price for other production. This implies that the farmer will continue to increase (decrease) land for milk production if the shadow price of dairy land is larger (smaller) than the shadow price of other land. However, with adaptation costs there is a range within which the shadow price of land for milk production can vary due to the adaptation cost:

$$p_h^e(q_h) - t_h(r_h) \leq p_h^i(q_h) \leq p_h^e(q_h) \quad \textbf{(1)}$$

where t_h are adaptation costs for land per farm household and r_h is a vector of explanatory variables of 'variable' adaptation costs for farm household *h*.

Notice that in case of milk quotas, milk production in equation (1) cannot be adjusted without buying quota rights. Without milk quota, milk production can be freely adjusted. Because of the abolishment of milk quotas milk production in the Netherlands, and therefore the shadow price of dairy land, is likely to increase. Due to the nitrate regulations, the amount of milk production per unit of land cannot be freely adjusted. It therefore becomes more profitable to use more land for dairy farming as the farmer wants to increase land for milk production. When $p_h^i(q_h)$ becomes larger than $p_h^e(q_h)$ land will be transferred to milk production. If the use of land for milk production becomes less attractive, e.g. because of a decrease in milk prices, the shadow price of dairy land and thereby the relative shadow price of milk compared to other production falls. This makes it more likely that dairy land will be used for other production. However, given the adaptation costs linked to land mobility, adjustments are not expected to take place for every change in the shadow price of dairy land. Only a change in shadow prices of dairy land or other land large enough to cover adaptation costs can lead to land use change.

Besides adaptation costs linked to a unit of change in land use there might be also adaptation costs that are independent on the size of change in land use. A change in land used for milk production only takes place in the case the 'new' (after the change) income is higher than the 'old' (before the change) income plus these 'fixed' adaptation costs that are linked to land mobility:

$$K_h = \begin{cases} 1 \text{ if } I_h^n > I_h^o + T_h^1(q_h^1) & \text{(land mobility)} \\ 0 \text{ if } I_h^n \leq I_h^o + T_h^1(q_h^1) & \text{(no land mobility)} \end{cases} \quad \textbf{(2)}$$

where K_h is the household h's decision whether to change allocation of land, I_h^n is 'new' income of household *h*, I_h^o is 'old' income of household *h*, T_h^1 are the total adaptation costs (both 'fixed' and 'variable') linked to land mobility, q_h^1 is a vector of explanatory variables of adaptation costs linked to land mobility for farm household *h*.

The theoretical model shows that land use change is not something that instantaneously takes place when the relative shadow prices of land change. Only with low adaptation costs and relatively large changes in shadow prices land use change to or from milk production will take place. The length of the time period between two land use changes is an indicator for the dynamics of the dairy sector. It is hypothesized that the abolishment of milk quotas will mark a deviation from the quota regime that implied a less dynamic environment, and therefore less land use changes. The variables explaining the length of the time period between two land use changes, shadow price of land for dairy farming and adaptation costs are divided into quota variables, socio-economic variables of the farm that can be divided into characteristics of the farm operator, and characteristics regarding continuation of the farm, and production variables.

3. Data and descriptive statistics

In this section we describe the data used in this study. The data was obtained from the Farm Structure Survey, covering all farms in the Netherlands that have at least ten dairy cows between 1971 and 2011 (Statistics Netherlands, 2013).

3.1 Study sample

The complete database contains over 2 million observations from 141,779 farms that have at least 10 cows. The definition of a farm with milk production as a farm that owns at least 10 cows is chosen because this excludes farms for which dairy farming is not an economic activity. It does include mixed farms that may expand and specialize in dairy farming during the sample period. The data set includes both farms that enter after 1971 and farms that exit before 2011. We therefore deal with an unbalanced panel. There is a large amount of right truncation; 67% of all farms are first observed in 1971, while only 6.2% of all farms are observed during the whole sample period. This implies a large exit of farms during the sample period, which might either be due to farms specializing in other activities than dairy farming (farms who went from 10 cows or more to anything below 10 cows), or to farms who stop farming altogether. Succession by a family member is treated as farm continuation.

In this research we limit our scope to those farms that increase or decrease their land used for milk production. The event of land use change is defined as the time at which a farm changes its land used for milk production with at least 10% compared to the previous change in land. This may be a change in the use of land already existing on the farm as well as a change in the use of land through the purchase or sale of additional land. The limit of 10% is set to account only for substantial changes in dairy land use and not for small yearly adjustments coming from e.g. crop rotation. Land used for milk production is composed of grassland and fodder land, which mainly includes fodder maize in the Netherlands. Grassland and fodder land is not only used by dairy cows, but also by other livestock such as beef cattle, sheep, goats and equidae. We correct for these using the livestock unit classification (LSU), which is based on feed requirements expressed per hectare of land of other livestock compared with feed requirements of a dairy cow (Eurostat, 2013). Hence, the amount of land used for milk production is measured as the share of dairy herd in the total number of LSU multiplied by the total amount of grassland and fodder land on farm.

For every farm, the years between two changes in land used for milk production of at least 10% of the total are measured. The year of first change in land use is not observed because we do not know the time period with its previous land use change. In order to overcome this partial censoring to the left, the year of entry of the farm in the dataset is the second year for which land use change is observed. We analyse the time period from a change in land use to either an increase or a decrease in dairy land. It therefore does not matter whether the first observation is an increase or a decrease in dairy land. We use this definition for the time period in order to ensure a continuous dataset. Hence, our subsample includes only farms with at least two years in which a change of at least 10 per cent in dairy land is observed. With every subsequent year in the sample it is possible for the time period to increase by one year. This causes the data to be truncated to the left, the farm may be first observed after some time.

3.2 Descriptive statistics

The dependent variable in our model is the time period between two changes of at least 10% in land use. The time period is measured as the number of years between a change, either a decrease or an increase, in dairy land use.

The variables explaining the time period between two land use changes and adaptation costs are divided into quota variables, socio-economic variables, and production variables. The quota variables are a dummy representing whether there is a quota regime, and a trend starting in 2003 when quota abolishment was decided.

Socio-economic characteristics of the farm are grouped to characteristics with respect to the farm operator and a variable regarding the continuation of the farm. In this article we use age and age squared, whether the farm operator works full-time or part-time on the farm and whether the farm operator followed an agricultural education and his level of education, described by a dummy variable indicating whether or not he completed at least post-secondary occupational education. We included both age and age squared because previous studies observed live cycle patterns of farms (Weiss, 1999; Gale, 2003). For variables related to the farmer's education and successor we did not have information on all years of the observation period. For these variables we tried to fill in missing years based on the information on surrounding years. However, there remained missing values, for which the observations are dropped during estimation. A description of all variables used in the analysis can be found in Table 1 below.

We used the presence of a successor as a characteristic measuring continuation of the farm. Having a successor is a binary variable that takes the value 1 if the farm operator is over 50 years old and has a successor. Data limitations restricted us to use the change in total labour (hired and household labour), the total ha available on farm, the share of fodder land on farm, the change in the number of cows on farm and the change in the average milk production per cow as production variables.

Table 2 shows the descriptive statistics for these explanatory variables for the subsample of increasing farms and decreasing farms separately. Except for the change in total labour and the change in the number of cows, which is positive in the case of increases and negative in the case of decreases, descriptive statistics between increases and decreases in land use do not differ much. Correlations between the dependent and independent variables showed that there are no correlations high enough that multicollinearity can be expected.

Table 1: Description of variables

Variable	Explanation
Quota related variables (K_{ht})	
quota	Dummy (1 between 1984-2011, 0 between 1971-1983)
transition	Time trend as of 2003, when the EU started to yearly increase milk quota
Socio-economic characteristics (Z_{ht})	
Farm operator	
age	Age of the farm operator
age_2	Age squared of the farm operator
fulltime operator	Dummy whether the farm operator works full-time
agricultural educated	Dummy whether the farm operator followed an agricultural education
completed occupational education	Dummy whether the farm operator completed at least post-secondary occupational education
Continuity of the farm	
successor	Binary variable that takes the value 1 if the farm operator is over 50 years old and has a successor.
Production variables (Q_{ht})	
productivity growth	Change in 100 kg average milk production per cow with respect to the previous year
share fodder land	Share of grassland and fodder land in total agricultural land

change in total labour	Change in total labour (household + hired) with respect to the previous year measured in FTE
total ha land	Total land on farm in ha
change in cows	Change in the number of cows with respect to the previous year
Dependent variables	
Y	Time period equation: Number of years between a decrease or increase of at least 10% in land used for milk production

Table 2: Descriptive statistics of explanatory variables separated by increases and decreases in land use

	Increases in land use			Decreases in land use		
Variable	Obs	Mean	Std. Dev.	Obs	Mean	Std. Dev.
Quota variables (K_{ht})						
quota	241,102	0.587	0.492	165,305	0.637	0.481
transition	241,102	0.420	1.405	165,305	0.413	1.436
Socio-economic characteristics (Z_{ht})						
age	240,987	49.799	11.348	165,226	51.377	11.401
age^2	240,987	2608.722	1157.705	165,226	2769.630	1179.697
fulltime operator	241,102	0.962	0.190	165,305	0.955	0.208
agricultural educated	183,163	0.755	0.430	120,050	0.695	0.461
completed occupational education	203,571	0.262	0.440	139,412	0.221	0.415
Continuity of the farm						
successor	229,917	0.967	0.178	151,359	0.955	0.207
Production variables (Q_{ht})						
share fodder land	241,100	0.907	0.180	165,305	0.915	0.179
productivity growth	241,102	0.898	1.112	165,305	0.934	1.129
change in total labour	237,399	0.011	0.714	161,881	-0.025	0.734
total ha land	241,102	25.439	18.889	165,305	25.719	20.277
change in cows	241,102	2.049	8.294	165,305	-2.399	9.615

4. Empirical model

In this section we present an empirical model that explains the time period between two changes in land used for milk production and the direction of land use change.

4.1 Growth in dairy land and time period

For a farm with multiple changes in land used for milk production we observe the time periods between two changes of at least 10% of land used for milk production. The time period is represented by Y_{ht}^{inc} and Y_{ht}^{dec} and is defined as the number of years between two land changes for farm *h* in year *t*, which can either be an increase (Y_{ht}^{inc}) or a decrease (Y_{ht}^{dec}) in dairy land. We model these periods using the following equations:

$$Y_{ht}^{inc} = \alpha_h^{inc} + \varphi^{inc} K_{ht} + \delta^{inc} Z_{ht} + \rho^{inc} Q_{ht} + u_{ht}^{inc} \quad \text{for an increase in land use, and} \qquad \textbf{(3)}$$

$$\mathrm{Y}_{ht}^{dec} = \alpha_h^{dec} + \varphi^{dec} K_{ht} + \delta^{dec} \mathrm{Z}_{ht} + \rho^{dec} \mathrm{Q}_{ht} + u_{ht}^{dec} \quad \text{for a decrease in land use} \qquad \textbf{(4)}$$

Here the unobserved heterogeneity terms α_h^{inc} and α_h^{dec} capture unobserved time invariant characteristics of farm h influencing the time period in case of an increase and decrease respectively. K_{ht} represents two variables related to the presence of the milk quota system for farm *h* in year *t*: a dummy representing whether there is a quota regime, and a trend starting in 2003 when quota abolishment was decided. φ^{inc} and φ^{dec} represent the vectors of coefficients of these milk-quota related variables. Z_{ht} contains the strictly exogenous explanatory variables on the socio-economic characteristics for farm *h* at year *t*. The socio-economic variables can be divided into characteristics specific to the farm operator: whether he works full-time or part-time on the farm, age and age squared; and a characteristic regarding continuation of the farm: whether there is a successor. δ^{inc} and δ^{dec} represent the vectors of coefficients for the strictly exogenous socio-economic variables for farm *h* at year *t*. Q_{ht} represents the vector of production related variables: change in total labour, change in cow numbers, change in average production per cow and total hectares of land on farm. ρ^{inc} and ρ^{dec} represent the vectors of coefficients for the these variables. u_{ht}^{inc} and u_{ht}^{dec} represent the error terms.

4.2 Estimation method

The two equations representing the time periods are estimated employing a duration model. Duration models analyse the impact of factors that have a significant effect on the length of time between two events (see e.g. Verbeek (2008)). A duration starts at the beginning of a previous change and ends at the beginning of a new change.

A number of decisions have to be made in the specification of a duration model. We estimate a multistate-multi-episode process where each farm has the possibility to either increase or decrease the land used for milk production (multistate) as often as the number of years during which it is under observation (multi-episode) (Blossfeld *et al.*, 1995). We estimate the duration model twice, once for increases and once for decreases in dairy land use. The explanatory variables occur over the time period and the change in land use occurs at the end of the period. The socio-economic characteristics of the farm and quota variables are estimated one year lagged, whereas changes in production variables and the direction of land use change occur at the year of change.

The statistic reason for duration analysis is that it provides a solution to the otherwise violated normality assumption of OLS, meaning that time, conditional on the explanatory variables, is assumed to follow a normal distribution (Cleves *et al.*, 2008). This assumption is unrealistic because the distribution of the equation for the time period is non-symmetric. The time period is always positive and not constant over time. Moreover, OLS does not correct for right censored data. This means that farms may still be in the process of land use change at the end of the observation period (Cleves *et al.*, 2008).

Parametric duration analysis allows us to handle the specific features of our data; time-varying explanatory variables, delayed entry, gaps, and right censoring. Where nonparametric and semi-parametric models compare different farms at times of land use changes, parametric models use probabilities that define the land use changes over the whole time period, given the information of the farm in the explanatory variables. Hence, a parametric model exploits all information on the explanatory variables. Within parametric models, there are 5 common distributions, namely the exponential, weibull, gompertz, log-normal and log-logistic. Estimating our duration model for each of these distributions showed little variation in the signs and significance of different covariates. This means that our model is robust to different distributions. According to our theoretical framework the profit increasing potential achieved by growth of size will decrease the time period. However, the existence of a quota regime undermines this process. Following the introduction of the quota regime, the hazard rate will therefore increase as time passes. In this study, we assume that the model follows a non-monotonic hazard, where the time period decreases before the introduction of the quota, and increases after the introduction of the quota. Only the log-normal and log-logistic model use this distribution for the hazard; we choose the log-logistic model.

The log-logistic model is estimated using the AFT (Accelerated Failure Time) metric, which assumes a linear relationship between the log of *t* and the characteristics of the farms **x**:

$$\ln(t) = \mathbf{x}\boldsymbol{\beta} + \varepsilon \qquad \textbf{(5)}$$

where ε_j is distributed normally with mean 0 and standard deviation $\pi\gamma/\sqrt{3}$ (Cleves *et al.*, 2008). This means that we estimate the time period, depending on its explanatory variables, using maximum likelihood (Blossfeld *et al.*, 1995).

5. Results

In this paper, the time period and the direction of change between two changes in land used for milk production on dairy farms before, during and towards the abolishment of milk quota are analysed. We define change as a decrease or increase of at least 10% in land used for milk production on a dairy farm. Change is measured relative to the size of the farm to rule out the effect of farm size on the pace of change; hence, we hypothesize that it is easier for large than for small farms to adjust a certain number of hectares of land.

5.1 Model results

Table 3 shows the regression results and marginal effects (ME) for increases and decreases in land use separately. The logged time period increases with a positive coefficient and decreases with a negative coefficient. When exponentiated, the coefficients in report the ratio change in the expected time period associated with a one unit increase in the explanatory variable. Our log-logistic models found log-likelihood values of -53469.45 for increases and -71557.59 for decreases in land use. Using the likelihood ratio test, this leads to χ^2 values of 32818.72 and 19850.18 respectively. Hence, the null hypothesis of no significant contribution of at least one of the explanatory variables to the model fit can be rejected at the 1% level. More specifically, significant coefficients were observed in all selected groups (variables related to the presence of a quota regime, socio-economic characteristics and production). The log-logistic models for increases and decreases in land use both show $\gamma<1$, meaning that the log-logistic hazard first increases and then decreases, as we hypothesised in the previous section.

5.2 Regression results

Variables used to analyse the time period equations consist of variables related to the presence of milk quota (K_{ht}), socio-economic characteristics (Z_{ht}), and production variables (Q_{ht}).

Variables related to the presence of milk quota (K_{ht}) consist of a dummy indicating whether there is a quota regime and a trend as of 2003 representing the transition towards quota abolishment. There is a positive effect of the presence of a quota regime and a negative effect of the transition towards quota abolishment on the time period between both increases and decreases in land use. Table 3 shows that the large marginal effects are found for the presence of the quota regime, for increases and decreases in land use this leads to a deceleration of land use change of 3.78 and 4.85 years respectively. Towards quota abolishment, shorter time periods of land use change are observed, with marginal effects of -0.78 years for increases and -0.88 years for decreases. This indicates that quota hamper the pace of change in land used for milk production. This is in line with previous research that indicated that the existence of a quota regime delays the pace of farm structural change (Breustedt and Glauben, 2007; Piet *et al.*, 2012).

Socio-economic characteristics (Z_{ht}) consist of characteristics related to the farm operator and the continuity of the farm. Characteristics related to the farm operator were grouped to age and age squared, whether the farm operator works full-time or part-time on the farm and whether he followed an agricultural education and his level of education.

With respect to the time period between two changes in land use, we observe a positive and significant sign for age and a negative and significant sign for age squared of the farm operator for both the increasing and the decreasing time period equation. More specifically, if the farm operator is one year older this leads to respectively 0.05 and 0.03 years more before a land use change (increase and decrease respectively) is observed.

We find a significant and decelerating effect of full-time labour involvement of the of the farm operator on both increases and decreases in land use. Working full-time on the farm decelerates the time period towards an increase in land use with 0.69 years and the time period towards a decrease in land use with about 1.39 years. This means that the more involved the farm operator is, the less likely he is to change his land use.

Whether the farm operator followed an agricultural education shows a significant and decelerating effect for both increases and decreases in land use. However, the marginal effect is much larger for decreases in land use (2.83 years) than for increases in land use (1.96 years). This may imply a certain locked-in effect; being agriculturally educated may limit the possibilities to work outside, but does not directly lead to acceleration in farm growth. The level of education of the farm operator accelerates increases and decreases in land use by 0.68 and 0.12 years respectively. This implies that the higher the level of education of the farm operator, the more likely he is to expand dairy farming.

The continuity of the farm is measured with a binary variable indicating whether the farm operator is more than 50 years old and has a successor. Having a successor shows an accelerating effect both for increases and decreases in land use, respectively by 1.39 and 1.02 years. This implies a higher pace of change with a successor.

Production variables (Q_{ht}) involve the change in the national average milk production per cow to represent productivity growth, the share of land for milk production already on farm to represent specialization, the change in total labour (both household and hired labour), the total hectares of land (both dairy and non-dairy land) to represent farm size and the change in the number of cows. All changes are calculated with respect to the previous year.

The yearly change in the average production per cow was used as a measure of productivity growth on the farm. An increase of 100 kilograms milk production per cow leads to shorter time periods for both increases and decreases in dairy land (-0.20 and -0.37 respectively). The existing share of fodder land shows a decelerating effect on both increases and decreases in land use (5.41 and 4.60 respectively). This may be because less land that can be easily converted is available on farm, which leads to higher adaptation costs.

The decelerating effects of change in total labour (0.08 for increases and 0.19 for decreases) may be because an increase in labour is not common to occur; farm expansion is achieved using other production factors than labour. For the change in the number of cows, we find that an increase of the dairy herd by one cow leads to an acceleration of 0.15 year for increases in land and a deceleration by 0.21 year for decreases in land use. Due to the nitrogen regulations in the Netherlands, a change in dairy herd demands a corresponding change in land for dairy production.

The total ha on the farm shows a significant and decelerating effect of 0.02 years per hectare for increases in land use and a significant and accelerating effect of 0.02 years per hectare for decreases in land use. This may have to do with our definition of growth as relative to the total land used for dairy farming. Hence, with the same percentage, the absolute number of hectares of change is much smaller for small farms than for large farms.

Table 3: Regression results and marginal effects at means

	Increases in land use			Decreases in land use		
	coeff	sign	ME	coeff	sign	ME
Quota variables (K_{ht})						
quota	0.706	**	3.782	0.696	**	4.851
transition towards quota abolishment	-0.140	**	-0.780	-0.121	**	-0.876
Socio-economic characteristics (Z_{ht})						
Farm operator						
age	0.034	**	0.048	0.035	**	0.029
age squared	-0.000	**		-0.000	**	
fulltime operator	0.132	**	0.689	0.211	**	1.388
agricultural educated	0.381	**	1.956	0.427	**	2.829
completed occupational education	-0.125	**	-0.681	-0.017	*	-0.120
Continuity of the farm						
has a successor	-0.225	**	-1.390	-0.133	**	-1.019
Production variables (Q_{ht})						
productivity growth	-0.036	**	-0.198	-0.052	**	-0.373
share fodder	0.974	**	5.414	0.637	**	4.605
change in total labour	0.014	**	0.075	0.027	**	0.192
total ha land	0.003	**	0.019	-0.003	**	-0.023
change in cows	-0.026	**	-0.145	0.029	**	0.210
constant	-0.744	**		-0.181	**	
gamma	0.339			0.408		

Note: ** and * denote significance at the 1 and 5 per cent levels respectively.

5.3 Sensitivity analysis

To explore the consequences of our definition of land use change we performed three sensitivity analyses. First, we simulated a change of at least 5%; second, we simulated a change of at least 15%; third, we simulated a change of at least four hectares of land. We chose to use four hectares of land use change as a robustness check because this is on average a 10% change in land used for milk production. All changes are with respect to the previous change (either decrease or increase). Except for the variable successor, none of the variables reports a change in both sign and significance. With a fixed amount of land use change, the total amount of land on the farm shows an accelerating effect for both increases and decreases. This indicates that land use change expressed as a percentage of the size of the farm indeed corrects for the effect of farm size on the pace of change. In general we can see that the marginal effects of the covariates become slightly larger (both positive and negative) when the percentage increase and decrease becomes larger. However, in general we find only very small changes in the size and not in both the significance and sign of the covariates, which indicates that our results are robust.

6. Conclusion and discussion

The purpose of this paper is to analyse the time period between two changes in land used for milk production on dairy farms and the direction of land use change over a period before, during and towards the abolishment of milk quota. We use longitudinal data from the farm structure survey of the Netherlands covering the period between 1971 and 2011. Land use change is defined as an increase or decrease of at least 10% of land used for milk production on dairy farms. This can be accomplished through a change in the use of land already available on farm as well as through the buy or sale of additional land. However, we hypothesize that land use changes involve adaptation costs hampering land dynamics. Employing a dynamic duration model we are able to make specific statements about the pace of change in dairy farming as a result of the abolishment of milk quotas.

Quota variables representing the presence of the quota regime and the transition towards abolishment of the quotas show that quotas hamper the pace of change in land used for milk production. The time period for both increases and decreases in land use is enlarged during the quota regime and shortened towards the abolishment of quota. The accelerating effect on the time period of quota abolishment shows that more farm dynamics can be expected as a result of the possibility to produce more milk. Our results therefore show that quota abolishment will lead to a more dynamic dairy sector. There is however another limiting factor. Under the Dutch nitrate regulations, the amount of nitrogen that can be deposited is set per hectare of agricultural land. When milk quota are abolished and farms can increase milk production without restrictions, the nitrate regulations expressed per hectare of land may become the limiting factor for milk production. Further research is necessary to investigate to what extent the increased dynamics from quota abolishment will be offset by the nitrate regulations.

The farm's decision to increase or decrease land used for milk production is largely determined by characteristics of the farm operator such as age, full-time employment, education and whether he has a successor. We find that older farm operators who are agriculturally educated, work full-time on the farm, have no successor and already spend a large portion of their total land to milk production experience the least dynamics in land use change. It may be that these type of farms face higher adaptation costs for land use change.

A number of possible caveats can however be mentioned. First, our approach only looks at farms operating through time, and is thereby not able to explain farm structural change. Second, as of 2003 it was not only decided to gradually abolish milk quotas, but also to introduce single farm payments. Our model does not account for these, and other, policy measures. The estimates of the effect of quotas on the pace of land use change may therefore be overestimated. Despite these caveats the duration model for the pace of change in land use over a period before, during and towards the end of the milk quota regime shows that quota abolishment leads to more dynamics in the dairy sector.

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