



AgEcon SEARCH
RESEARCH IN AGRICULTURAL & APPLIED ECONOMICS

The World's Largest Open Access Agricultural & Applied Economics Digital Library

This document is discoverable and free to researchers across the globe due to the work of AgEcon Search.

Help ensure our sustainability.

Give to AgEcon Search

AgEcon Search
<http://ageconsearch.umn.edu>
aesearch@umn.edu

*Papers downloaded from **AgEcon Search** may be used for non-commercial purposes and personal study only. No other use, including posting to another Internet site, is permitted without permission from the copyright owner (not AgEcon Search), or as allowed under the provisions of Fair Use, U.S. Copyright Act, Title 17 U.S.C.*

Paper prepared for the 123rd EAAE Seminar

PRICE VOLATILITY AND FARM INCOME STABILISATION

Modelling Outcomes and Assessing Market and Policy Based Responses

Dublin, February 23-24, 2012



Effects of volatile output prices on agricultural land-use change

Boere, Esther^{1,2}, Peerlings, Jack¹, Reinhard, Stijn^{1,2}, Kuhlman, Tom² and Heijman, Wim¹

1 Agricultural Economics and Rural Policy Group, Wageningen UR, Wageningen, the
Netherlands

2 LEI, Wageningen UR, Wageningen, the Netherlands

Esther.Boere@wur.nl

Effects of volatile output prices on agricultural land-use change

Boere, Esther, Peerlings, Jack, Reinhard, Stijn, Kuhlman, Tom and Heijman, Wim

Abstract

Volatile output prices lead to a fluctuating shadow price (profitability) of agricultural land, and therefore may impact land use decisions in case of risk-averse behaviour. In this paper we assess the effect of volatile agricultural output prices on agricultural land-use change over the past decade in the Netherlands. Using regional data from 2000 through 2009, the number of hectares of land for 10 land uses was calculated. To determine the joint distribution of agricultural activities, hectares of land for each land use were converted to land share equations. Land share equations were estimated to determine the contribution of increased price volatility to land use change. Results show that larger volatility affects land shares negatively. Producer's output responses, therefore, were consistently affected by risk-averse behaviour.

Keywords: land-use, risk, price volatility

JEL classification: Q1, D8

1. INTRODUCTION

Over the past decade in the Netherlands, volatile output prices have led to a fluctuating shadow price (profitability) of agricultural land and may have impacted land use decisions. For a producer, the shadow price of land is the marginal contribution of land to profit. The maximum profit, assuming no constraints on land use, is where shadow price is equal among alternative land uses. Equal shadow prices among land uses only account for risk-neutral producers and for expected output prices because the producer does not know the price for the product at the time the production decision is made. Production decisions with a high expected output price and low profit variability, therefore, are preferred by a risk-averse producer. A risk-averse producer, faced with increased volatility in output price, is likely to switch either to less volatile production activities or to stop producing.

There is an extensive literature on estimation of models that analyse multiple-output supply and land allocation decisions. Broadly, two lines of thinking can be distinguished: estimating a system of output supply, input demand and land-use equations (Coyle, 1992; Oude Lansink, 1999) and estimating land response equations (Moore and Negri, 1992; Wu and Segerson 1995). The first approach has been applied by Coyle (1990; 1992; 1999), who combines the effect of risk aversion, price uncertainty and yield uncertainty on crop production decisions in a duality model of production. Oude Lansink (1999) elaborates on Coyle's work by using a Linear Mean-Variance (LMV) utility function that incorporates risk to determine input demand, output supply and area allocation simultaneously across crops. More recently, Sckokai and Moro (2006) adapted Coyle's framework to account for the increased output price volatility caused by CAP reforms in studying arable crop production.

Estimating land response equations has been applied by Moore and Negri (1992), who develop land and water allocation equations based on a flexible functional form for a multicrop production function. Wu and Segerson (1995) elaborate on this model by adjusting for land heterogeneity. The two approaches are integrated by Chambers and Just (1989) who use a two-step modelling framework: allocating land to different production activities after optimal levels of output and input supply have been determined. Arnade and Kelch (2007) extend this framework by deriving shadow price equations for crop area equations.

This paper uses the approach of estimating land response equations to build a framework where production levels per hectare are fixed, when the optimal allocation of land can be determined. This article contributes to the literature by developing land allocation equations, but adds by adjusting them to take risk aversion and output price uncertainty into account. This has so far only been done in the output supply framework. The advantage of using land response equations lies in being able to account for the interdependence between yearly land allocation decisions and expectations of output prices (Arnade and Kelch, 2007). The objective of this research is to assess the effect of volatile agricultural output prices on change in agricultural land-use over the past decade in the Netherlands. The analysis uses data over 66 Dutch agricultural regions over the period 2000 through 2009 to determine producers' hectare decisions.

The article is organised as follows. The following section establishes a theoretical framework of conditional land share equations that take risk faced by increased price volatility into account. Next, we establish a normalised quadratic functional form according to which the producer optimises his allocation of land use. A description of the study area and data follows in section 4. The land share equations are econometrically estimated and results are discussed in section 5. The final section summarizes the main results and provides some recommendations for further research.

2. THEORETICAL FRAMEWORK

2.1. Profit-maximizing producer

We assume a profit maximizing producer; i.e. a producer who maximises profit given a technological and market constraint. The producer takes the prices of inputs and outputs as exogenous and finds no quantitative restriction on outputs. We define a profit function with multiple outputs that treats total land as fixed, allocable input (Wu and Segerson, 1995). All other inputs, including labour and capital, are treated as variable.

$$\pi_{ht}(p_t, w_t, N_{ht}) \equiv \max_{n_{hit}} \sum_i \pi_{hit}(p_{it}, w_t, n_{hit}) \quad h = 1, \dots, H \quad i = 1, \dots, I, t = 1, \dots, T \quad (1)$$

Subject to:

$$\sum_i n_{hit} = N_{ht} \quad (2)$$

Where:

- $\pi_{ht}(p_t, w_t, N_{ht})$: restricted profit function for producer h and time period t
 $\pi_{hit}(p_{it}, w_t, n_{hit})$: restricted profit function for producer h , land use i and time period t
 p_t : vector of exogenous output prices per hectare land
 p_{it} : output price of land use i at time period t
 w_t : vector of exogenous variable input prices per hectare of land
 n_{hit} : number of hectares for producer h allocated to land use i at time period t
 N_{ht} : total number of hectares to be allocated to different land uses

Producer h , in the empirical framework equal to a region, must decide how to allocate N_{ht} hectares across different land uses i in order to maximize total profits. Exogenous output prices p_{it} differ across land use and time period, whereas exogenous input prices w_t are the same across land use and time period. The quantity and selection of inputs differs across land uses. We will in the empirical part assume that for one producer (region) homogeneity in soil type exists, but that between producers (regions), heterogeneity of soil type may exist. The total amount of hectares of all producers is $N_t = \sum_h \sum_i n_{hit}$, which must be equal to the total amount of agricultural land in a specific year.

In his decision to allocate land to different uses, the producer maximizes profit per hectare of land and total profits over the total number of hectares in a region. We can therefore reformulate the profit function of a single producer as:

$$\pi_{ht}(p_t, w_t, N_{ht}) \equiv \max_{n_{hit}} \sum_i \{p_{it} \cdot n_{hit} - w_t \cdot n_{hit}\} \quad (3)$$

$$\sum_i n_{hit} = N_{ht} \quad (4)$$

Moore and Negri (1992) specify three assumptions regarding the restricted profit function for each land use i : 1) Inputs are allocated to specific land uses, 2) Production is technically separated between production activities so that the allocation of inputs uniquely determines crop-specific output levels and 3) Land is a fixed, allocable input. This allows to establish separate restricted profit functions for each land use i . The profit function $\pi_{ht}(p_t, w_t, N_{ht})$ has the following properties:

- Positively linearly homogeneous in (p_t, w_t)
- Increasing in p_t and N_{ht}
- Decreasing in w_t
- Convex and continuous.

A Lagrangian function for the restricted profit function, denoted L_{ht}^n , states the constrained maximization problem as:

$$L_{ht}^n = \sum_i \pi_{hit}(p_{it}, w_t, n_{hit}) + \lambda_{ht}(N_{ht} - \sum_i n_{hit}) \quad (5)$$

Where λ_{ht} is the shadow price on land constraint. The necessary conditions for an interior solution are:

$$\frac{\partial L_{ht}^n}{\partial n_{hit}} = \frac{\partial \pi_{hit}}{\partial n_{hit}} - \lambda_{ht} = 0 \quad (6)$$

$$N_{ht} - \sum_i n_{hit} = 0 \quad (7)$$

Equation (6) allocates land among land uses to equate marginal profit from each land use. The input constraint in (7) is binding, assuming an interior solution. Solving (6) and (7) gives the optimal allocation of land

$$n_{hit}^\pi = n_{hit}^*(p_t, w_t, N_{ht}) \quad (8)$$

This represents the producer's multi-output equilibrium in land allocation.

Now, let us assume that $n_{hit}^\pi = n_{hit}^*(p_t, w_t, N_{ht})$ is homogeneous of degree 1 in N_{ht} .

$$n_{hit}^*(p_t, w_t, N_{ht}) = n_{hit}^*(p_t, w_t, 1)N_{ht} \quad (9)$$

This means that if total amount of land decreases with the factor q, land allocated to land use i also decreases with the factor q. This can be written in the following share function that represents the share of land for one producer, for one land use, in one time period.

$$s_{hit}^* = s_{hit}(p_t, w_t, N_{ht}) = \frac{n_{hit}^\pi}{N_{ht}} \quad (10)$$

Hence, the shares depend on all output and input prices.

2.2. Utility-maximizing producer

We now assume a risk-averse producer instead of risk neutral one; the producer becomes a utility maximizer instead of a profit maximizer. The preferences of a producer and his expected utility are determined by expected profit ($E\pi$) and variance of profit ($V\pi$), based on expected output prices and actual input prices. For any value of $\alpha > 0$ the producer is risk-averse (Chavas & Pope, 1982). In general, the utility function can be denoted by (Coyle, 1992):

$$U(\hat{p}, w, N) = E\pi(\hat{p}, w, N) - \left(\frac{\alpha}{2}\right)V\pi \quad (11)$$

Where:

$U(\hat{p}, w, N)$: indirect utility function

$E\pi(\hat{p}, w, N)$: expected profits

\hat{p} : vector of expected output prices

$V\pi$: variance of profit

α : measure of absolute risk aversion measured at the expected value of outcomes, $0 \geq \alpha \leq 1$

In case of a risk-neutral producer, the term that captures the risky environment, the risk-coefficient multiplied by the profit variance ($\left(\frac{\alpha}{2}\right)V\pi$), cancels because $\alpha=0$.

If the producer of section 2.1 is risk neutral, the profit function is equal to expected profit, based on expected prices with the variance cancelled:

$$U_{ht}(\hat{p}_t, w_t, N_{ht}) = \max_{n_{hit}} \sum_i E\pi_{hit}(\hat{p}_{it}, w_t, n_{hit}) \quad (12)$$

The expected value and variance of profits per land use, conditional on n_{hit} is

$$E\pi_{hit}(n_{hit}) = \hat{p}_{it} \cdot n_{hit} - w_t \cdot n_{hit} \quad (13)$$

$$V\pi_{ht}(n_{hit}) = n_{hit}^T \cdot Vp \cdot n_{hit} \quad (14)$$

Total expected profits now become:

$$E\pi_{ht}(\hat{p}_t, w_t, N_{ht}) \equiv \max_{n_{hit}} \sum_i \{\hat{p}_{it} \cdot n_{hit} - w_t \cdot n_{hit}\} \quad (15)$$

Where:

\hat{p}_{it} expected output price of land use i at period t

Vp Symmetric, positive definite covariance matrix of output prices

T Transpose

Revenues and costs are calculated per hectare of land, so that they are only a function of amount of land. The covariance matrix can be denoted by:

$$Vp = A'A/T = \begin{bmatrix} \sigma_i^2/T & \sigma_{ik}/T & \cdots & \sigma_{il}/T \\ \sigma_{ki}/T & \sigma_k^2/T & \cdots & \sigma_{kl}/T \\ \vdots & \vdots & \ddots & \vdots \\ \sigma_{li}/T & \sigma_{lk}/T & \cdots & \sigma_l^2/T \end{bmatrix} \quad i = 1, \dots, I \quad k = 1, \dots, I \quad i \neq k \quad (16)$$

The diagonal elements represent the variance of prices for each land use and the off-diagonal elements the covariance of prices for each land use.

Where:

T Number of years over which land use is measured

σ_i^2/T variance of prices belonging to land use i

σ_{ik}/T covariance of prices belonging to land use i and k .

The variance of profits, conditional upon n_{hit} can then be denoted by:

$$V\pi_{ht} = \sum_i n_{hit}^2 \sigma_i^2 + \sum_i \sum_k 2n_{hit} n_{hkt} \sigma_{ik} \quad (17)$$

If we substitute the expected value of profits (13) and the expected variance of profits (14) into the expected profit function (15), we get the following indirect utility function (Oude Lansink, 1999):

$$U_{ht}(\hat{p}_t, w_t, Vp, N_{ht}) = \max_{n_{hit}} U_{ht} \left(\sum_i \{ \hat{p}_{it} \cdot n_{hit} - w_t \cdot n_{hit} \} - \left(\frac{\alpha_{hit}}{2} \right) n_{hit}^T \cdot Vp \cdot n_{hit} \right) \quad n_i \in T \quad (18)$$

The indirect utility function represents the relation between the maximum attainable utility U and exogenous variables $\hat{p}_t, w_t, Vp, N_{ht}$. This utility function $U_{ht}(\hat{p}_t, w_t, Vp, N_{ht})$ has the following properties (Coyle, 1990):

- Increasing in \hat{p}_t , decreasing in w_t , decreasing in Vp .
- Linearly homogeneous in $(\hat{p}_t, w_t, Vp, N_{ht})$
- Convex in $(\hat{p}_t, w_t, Vp, N_{ht})$
- Differentiable.

The Lagrangian function for the indirect utility function in equation (18), denoted L_{ht}^U , states the constraint utility maximization problem as:

$$L_{ht}^U = \sum_i \{ \hat{p}_{it} \cdot n_{hit} - w_t \cdot n_{hit} \} - \left(\frac{\alpha_{hit}}{2} \right) n_{hit}^T \cdot Vp \cdot n_{hit} + \lambda_{ht} \left(N_{ht} - \sum_i n_{hit} \right) \quad (19)$$

This function has the following first order conditions:

$$\frac{\partial L_{ht}^U}{\partial n_{hit}} = \hat{p}_{it} - w_t = \alpha_{hit} Vp n_{hit} - \lambda_{ht} \quad (20)$$

$$N_{ht} - \sum_i n_{hit} = 0 \quad (21)$$

The optimal allocation of land use i for region h at year t is defined by $n_{hit}^U = n_{hit}'(\hat{p}_t, w_t, Vp, N_{ht})$. This represents the producer's multi-output equilibrium in land allocation when risk and expected output prices are taken into account. Assuming $n_{hit}^U = n_{hit}'(\hat{p}_t, w_t, Vp, N_{ht})$ is homogeneous of degree 1 in N_{ht} , $n_{hit}^U(\hat{p}_t, w_t, Vp, N_{ht}) = n_{hit}^U(\hat{p}_t, w_t, Vp, 1)N_{ht}$. This can be written in the following share form:

$$s_{hit}^U = s_{hit}(\hat{p}_t, w_t, Vp, N_{ht}) = \frac{n_{hit}^U}{N_{ht}} \quad (22)$$

The shares depend on all output and input prices, the output-price variance and the degree of risk-averseness. In case α_{hit} is equal to zero (risk neutrality) or the price variance is equal to zero, price equalizes marginal costs.

3. EMPIRICAL FRAMEWORK

In the empirical model, we continue with the specification of a short term cost function. For this we use the Normalised Quadratic functional form. This because it proved to be more suitable for Dutch agricultural census data (Oude Lansink & Thijssen, 1998), is easier to compute than other functional forms and has zero observations for outputs and inputs.

Let us assume for the moment a producer where the cost function is a function of output allocated to land n_{hit} , variable input prices w_{mt} , and levels of quasi-fixed inputs and regional characteristics (including soil type) z_{hqt} . This results in the following quadratic short-run cost function of a multi-output, multi-input producer

$$\begin{aligned}
 C_{ht}(w_t, z_{ht}, N_{ht}) = & \alpha_0 + \sum_i^I \beta_i n_{hit} + \sum_m^M \gamma_m w_{mt} + \sum_q^Q \lambda_q z_{hqt} \\
 & + \frac{1}{2} \sum_i^I \beta_{ii} n_{hit}^2 + \frac{1}{2} \sum_m^M \gamma_{mm} w_{mt}^2 + \frac{1}{2} \sum_q^Q \lambda_{qq} z_{hqt}^2 & i=1, \dots, I \\
 & & m=1, \dots, M \\
 & + \sum_i^I \sum_k^K \beta_{ik} n_{hit} n_{hkt} + \sum_m^M \sum_k^K \gamma_{mk} w_{mt} w_{kt} + \sum_q^Q \sum_k^K \lambda_{qk} z_{hqt} z_{hkt} & q=1, \dots, Q \\
 & & i \neq k, m \neq k, q \neq k \\
 & + \sum_i^I \sum_m^M \mu_{im} n_{hit} w_{mt} + \sum_i^I \sum_q^Q \varphi_{iq} n_{hit} z_{hqt} + \sum_m^M \sum_q^Q \eta_{mq} w_{mt} z_{hqt}
 \end{aligned} \tag{23}$$

If we substitute the short-run cost function (23) into the indirect utility function (18), we get the following Lagrangian function for constraint utility maximization, denoted L_{ht}^*

$$L_{ht}^* = \sum_i^I \{ \hat{p}_{it} \cdot n_{hit} - C_{ht}(w_t, z_{ht}, N_{ht}) \} - \left(\frac{\alpha_{hit}}{2} \right) n_{hit}^T \cdot Vp \cdot n_{hit} + \lambda_{ht} \left(N_{ht} - \sum_i^I n_{hit} \right) \tag{24}$$

This function has the following first order conditions

$$\frac{\partial L_{ht}^*}{\partial n_{hit}} - \lambda_{ht} = \hat{p}_{it} - \beta_i - \beta_{ii} - \sum_k^K \beta_{ik} n_{hkt} - \sum_m^M \mu_{im} w_{mt} - \sum_q^Q \varphi_{iq} z_{hqt} - \alpha_{hit} \sum_i^I n_{hit} Vp_{ik} = 0 \tag{25}$$

and

$$N_{ht} - \sum_i^I n_{hit} = 0 \tag{26}$$

This can be rewritten to yield the output supply equation of n_{hit} :

$$n_{hit} = \frac{1}{\beta_{ik} + \alpha_{hit} Vp_{ik}} \left(\hat{p}_{it} - \beta_i - \beta_{ii} - \sum_k^K \beta_{ik} n_{hkt} - \sum_m^M \mu_{im} w_{mt} - \sum_q^Q \varphi_{iq} z_{hqt} - \alpha_{hit} \sum_i^I n_{hit} Vp_{ik} \right) \tag{27}$$

Based on this optimisation, the producer decides how much land to allocate to land use n_{hit} .

4. STUDY AREA AND DATA

We divided the Netherlands in 66 agricultural regions, based on Helming (2005). One of the advantages of using this classification in types of agricultural regions is homogeneity of soil within regions. All regions can be classified based on soil types clay, sand or mixed soil. Different soil types generate different yields and therefore attract different production activities. Hence, agricultural production in the Netherlands is likely to be regionally concentrated. Moreover, environmental impacts, such as the intensity of nitrate leaching can also depend on soil type.

Agricultural census data over all farm households in the Netherlands covering the period from 2000 through 2009 were aggregated to the 66 agricultural regions. Nine outputs, grouped to different types of land use were distinguished. More specifically, land uses were grouped to grain, meadows, sugar beet, consumption potatoes, fodder maize, bulb, onions, vegetables, and other land use (table 1).

Table 1: Specification of land use categories

#	Land Use Categories	Land Cover
1	Grain	Winter wheat, Summer wheat Winter barley, Summer barley
2	Meadows	Remaining meadows Temporary meadows
3	Sugar Beet	Sugar beet
4	Consumption Potatoes	Seed-potato, Feeding potato
5	Fodder Maize	Fodder maize
6	Bulb	Bulb
7	Onions	Seed onion, onion
8	Vegetables	Vegetables
9	Other Land Use	Other grain, Legume Cash crop, Arable seed Other tuberous plant/root crop Other fodder crop

For each year and each region, the amount of land measured in hectares for each of nine land uses was calculated, using Dutch agricultural census data. To determine the joint distribution of agricultural activities, the number of hectares of land for each land use was converted to land share equations. We defined price volatility by only taking fluctuations of agricultural output prices into account, while ignoring fluctuations of input prices. Data on output prices come from deflated yearly output price indices, aggregated per cluster of agricultural outputs as found in table 1 (Eurostat, 2011). We consider the price variation to be equal across regions. Expected output prices are measured by taking for each year and each land

*Price Volatility and Farm Income Stabilisation
Modelling Outcomes and Assessing Market and Policy Based Responses*

use the variance of deflated output price indices over the past four years. Only for land use fodder maize there was no data on price indices available before 2000, which led us to use the same variance between 2000 and 2004.

After performing correlation tests on the nine different land uses (table 2), we decided to omit variables ‘bulb’, ‘vegetables’ and ‘other land use’ due to the high correlation. This led us to remain with six land uses, of which the descriptive statistics on the output price indices and the correlation matrix can be found in table 3.

Table 2: Correlation test on land uses.

Land Use	grain	meadows	sugar beet	potatoes	fodder maize	bulb	onions	vegetables	other
Grain	1.0000								
Meadows	0.3311	1.0000							
sugar beet	-0.4307	0.5292	1.0000						
Potatoes	0.3836	-0.5025	-0.5764	1.0000					
Fodder maize	0.5464	0.6027	0.3269	-0.0484	1.0000				
Bulb	0.5493	0.5453	-0.0542	0.2589	0.1561	1.0000			
Onions	0.2234	0.4056	0.3216	0.1831	0.3996	0.3609	1.0000		
Vegetables	0.2356	0.5667	0.2804	0.0732	0.0943	0.8696	0.4589	1.0000	
Other	0.5810	0.7224	0.1655	0.1536	0.4176	0.8962	0.6835	0.8427	1.0000

Table 3: Descriptive statistics and correlation output price indices.

Land Use	Mean	Standard Deviation	Min	Max
Grain	97.88	20.89	74.5	143.4
Meadows	90.30	8.15	78.6	102.1
Sugar beet	87.83	15.87	68.8	116.3
Potatoes	250.89	116.09	100	465.1
Fodder Maize	107.13	11.12	90.6	125.4
Onions	95.27	18.73	71.6	132.4

Land Use	Grain	Meadows	Sugar Beet	Potatoes	Fodder Maize	Onions
Grain	1.0000					
Meadows	0.3311	1.0000				
Sugar beet	-0.4307	0.5292	1.0000			
Potatoes	0.3836	-0.5025	-0.5764	1.0000		
Fodder maize	0.5464	0.6027	0.3269	-0.0484	1.0000	
Onions	0.2234	0.4056	0.3216	0.1831	0.3996	1.0000

5. RESULTS

In the following econometric model, land shares are regressed on share in total land use in the previous year, output price index in the previous year, and relative variance with respect to other land uses. Relative variances are calculated as the variance of expected output price of the alternative land use divided by the variance of expected output price of the land use of interest. Observations on land uses are estimated for the period 2001 through 2009. All data are treated as a cross-section of six land share equations with, in total, 594 observations. Estimation results can be found in table 4.

The estimates in table 4 indicate that when the relative variance of a land use with respect to the particular and use is larger than zero, both land uses are substitutes. When the relative variance is smaller than zero, both land uses are complements. For example, the relative variance of fodder maize with respect to meadows is smaller than zero and significant at the 1%

*Price Volatility and Farm Income Stabilisation
Modelling Outcomes and Assessing Market and Policy Based Responses*

level, which indicates that the land uses are complements. This makes sense because fodder maize is largely used as an input for dairy production, which is represented by land use meadows.

Table 4. Estimates of land share equations

With respec t to	Grain	t	Mea dows	t	Sugar Beet	t	Pota toes	t	Fodder Maize	t	Onions	t
Share prev year	0.999	226.0	0.993	446.5	0.956	308.3	0.977	279.3	0.998	245.1	1.000	183.5
Output price prev year	0.000	2.88	-0.002	-6.36	0.000	1.42	0.000	8.00	0.000	1.78	-0.000	-0.34
Relative variance of alternative land uses												
Grain			-0.000	-0.33	-0.000	-2.35	-0.184	-7.24	0.001	3.50	-0.00	-2.76
Meadows	0.003	0.48			0.004	3.85	0.962	7.98	-0.020	-6.22	-0.002	-0.89
Sugar Beet	0.001	0.33	-0.004	-3.08			-1.216	-8.14	0.012	9.10	0.002	1.79
Potatoes	0.000	0.70	-0.000	-2.50	0.000	4.27			-0.000	-4.03	-0.000	-0.05
Fodder Maize	-0.001	-2.08	0.005	5.05	-0.004	-2.31	1.013	6.75			0.004	0.99
Onions	-0.000	-1.28	0.000	5.69	-0.000	-1.09	0.011	3.71	0.000	0.55		

As expected, the lagged share of land use explains by far the most of the land use in the current year. For land uses grain, potatoes and fodder maize, a 1% increase in the output price in the previous year will lead to a significantly positive effect on land use in the current year. For sugar beet and onions, there is no significant effect. For meadows there is a significant negative effect. A possible explanation for meadows and sugar beet is the quota on milk and sugar beet, which makes it impossible for producers to increase production in the current year if they were already producing at the maximum level in the previous year.

The estimated results show an overall significant effect of a relative increase in price volatility on land use change. This indicates that, when producers experience a relative larger expected price volatility for a certain land use, they are more likely to lower this type of land use. Therefore, producers seem to display risk averse behaviour. We can assume that risk-averse producers, faced with increased volatility in output price, are likely to switch to less volatile production activities. Production decisions with high expected output price and low profit variability are therefore preferred by a risk-averse producer.

6. CONCLUSIONS AND DISCUSSION

This article analysed the impact of increased output price volatility on agricultural land use change. To accomplish this, we estimated a system of land share equations conditional on land use in the previous year, output price in the previous year and the relative variance of alternative output prices over the previous four years. The estimated results show an overall significant

effect of increased price volatility on land use. Share equations show a larger decrease in number of hectares allocated to land uses that experience more volatility than to land uses that experience less volatility. Producer's output responses can therefore be characterised by risk-averse behaviour.

This research helps to further explain the effect of increased output price volatility and the role of risk on agricultural land use change. However, there is room for extending this research in several ways. The estimated effects of agricultural output prices on land use do not correct for the yield per hectare of land. The research could therefore be extended by including a price per hectare of land use. The influence of risk on production decisions can not only be measured by output price volatility, but also by accounting for the effects of input price volatility. Moreover, a regional distinction in output prices can be made. The share equations have been estimated separately not taking into account that shares add up to one. Use of panel data structure could help further analysis. Furthermore, the effects of risk uncertainty may not be fully visible due to policy limitations, such as production restrictions or environmental regulations, and productions schemes, such as rotation cycles. This analysis can be further adjusted to include these elements in a more empirical satisfactory way.

REFERENCES

- Arnade, C. and Kelch, D. (2007). Estimation of Area Elasticities from a Standard Profit Function. *American Journal of Agricultural Economics* 89(3): 727-737.
- Chambers, R. and Just, R. (1989). Estimating Multioutput Technologies. *American Journal of Agricultural Economics* 71(4): 980-995.
- Chavas, J. and Pope, R. (1982). Hedging and Production Decisions Under a Linear Mean-Variance Preference Function. *Western Journal of Agricultural Economics* 7: 99-110.
- Coyle, B. (1990). A Simple Duality Model of Production Incorporating Risk Aversion and Price Uncertainty. *Canadian Journal of Agricultural Economics* 38(4): 1015-1019.
- Coyle, B. (1992). Risk Aversion and Price Risk in Duality Models of Production: A Linear Mean-Variance Approach. *American Journal of Agricultural Economics* 74(4): 849-859.
- Coyle B. (1999). Risk Aversion and Yield Uncertainty in Duality Models of Production: A Mean-Variance Approach. *American Journal of Agricultural Economics* 81(3): 553-567.
- Eurostat (2011). <http://epp.eurostat.ec.europa.eu/portal/page/portal/agriculture/data/database>.
- Helming, J. (2005). A model of Dutch agriculture based on Positive Mathematical Programming with regional and environmental applications. PhD dissertation. Wageningen: Wageningen University.
- Moore, M. and Negri, D. (1992). A Multicrop Production Model of Irrigated Agriculture, Applied to Water Allocation Policy of the Bureau of Reclamation. *Journal of Agricultural and Resource Economics* 17(1): 29-43.
- Oude Lansink, A. and Thijssen, G. (1998). Testing among functional forms: an extension of the Generalized Box-Cox formulation. *Applied Economics* 30: 1001-1010.
- Oude Lansink, A. (1999). Area Allocation Under Price Uncertainty on Dutch Arable Farms. *Journal of Agricultural Economics* 50(1): 93-105.
- Sckokai, P. and Moro, D. (2006). Modeling the Reforms of the Common Agricultural Policy for Arable Crops under Uncertainty. *American Journal of Agricultural Economics* 88(1): 43-56.
- Wu, J. and Segerson, K. (1995). The Impact of Policies and Land Characteristics on Potential Groundwater Pollution in Wisconsin. *American Journal of Agricultural Economics* 77: 1033-1047.