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Effect of yield and price risk on conversion from conventional to organic farming*

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Although the benefits of organic farming are already well known, the conversion to organic farming does not proceed as the Dutch government expected. In order to investigate the conversion decisions of Dutch arable farms, a discrete stochastic dynamic utility-efficient programming (DUEP) model is developed with special attention for yield and price risk of conventional, conversion and organic crops. The model maximizes the expected utility of the farmer depending on the farmer's risk attitude. The DUEP model is an extension of a dynamic linear programming model that maximized the labour income of conversion from conventional to organic farming over a 10 year planning horizon. The DUEP model was used to model a typical farm for the central clay region in the Netherlands. The results show that for a risk-neutral farmer it is optimal to convert to organic farming. However, for a more risk-averse farmer it is only optimal to fully convert if policy incentives are applied such as taxes on pesticides or subsidies on conversion, or if the market for the organic products becomes more stable.

Key words: arable farming, conversion process, dynamic utility-efficient programming model, organic farming, risk aversion.

1. Introduction

Increased consumer awareness of food safety issues and environmental concerns in Europe has contributed to the growth of organic farming over the last few decades. However, the overall significance of organic farming in the European context is still quite small in terms of land area used. In 2002 it represented slightly more than 3 per cent of the total EU utilised agricultural area (Lampkin 2002). Other major agricultural producers like the US and Australia reached percentages of 0.23 and 2.3 respectively (Yussefi 2003). In some EU-member states, such as in the Netherlands, the rapid growth in the nineties has slowed down after the end of the century. The desired target of 5 per cent organic area of the utilised agricultural area in 2005, set by the Dutch government in 2000, was not reached. It was only 2.47 per cent (Eurostat 2006). However, the target of 10 per cent by 2010 still remains (MINLNV

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2005). In order to reach the target, more insight is needed into factors which hamper and stimulate the conversion of farms.

Previous studies showed that organic arable farms can achieve very similar or even higher income levels than comparable conventional farms (Langley *et al.* 1983; Offermann and Nieberg 2000; Morris *et al.* 2001; Acs *et al.* 2007a,b). These results cannot explain the stagnation of conversion over the last years. An aspect that needs more attention in the models is the variability concerning yields and prices, which poses a risk to farmers. Furthermore, it has been common to assume, often implicitly, that decision makers are indifferent to risk. However, assuming absence of risk aversion seems not suitable as it is well known that risk aversion is widespread (Hardaker *et al.* 2004).

Some studies suggest that the main sources of risk for both conventional and organic farmers are output prices and production risks (Martin 1996; Harwood *et al.* 1999; Meuwissen *et al.* 2001). In arable farming in the Netherlands there is a large variation between the years in crops' gross margin of conventional, conversion and organic crops (LEI 2004). This is mainly caused by large revenue (yield and output price) variation across the years. Differences in variation between conventional, conversion and organic crops are caused mainly by different management practices (i.e. restrictions on pesticide use and fertilizer) and by different market opportunities and prices for the products (Lampkin and Padel 1994). This suggests that it is important to take into account the variation of revenue while analysing the conversion to organic farming.

There is quite some literature on inclusion of risk in agricultural farm models (Hardaker *et al.* 2004). To incorporate risk in a mathematical programming model, two frequently used modelling practices can be taken into account. One is quadratic risk programming (QRP) and the other is utility-efficient programming (UEP) model. They both maximise expected income or utility of a risk averse decision maker subject to a set of resource and other constraints (Freund 1956; Lambert and McCarl 1985; Patten *et al.* 1988). The advantage of QRP is that it requires only a vector of means and the variance-covariance matrix of the revenues per unit of possible cropping activities. However, the assumptions necessary to validate the use of QRP for farm planning under risk, which are that the farmer's utility function is quadratic or the distribution of total net revenue is normal (Hardaker *et al.* 2004), are not necessarily met. In contrast, UEP, as a non-parametric method, uses the discrete empirical distribution, and includes the joint distribution of yield and prices by means of so-called 'states of nature' (specific combinations and probabilities of possible outcomes). In contrast to QRP, in UEP a number of types of utility function can be incorporated. Utility-efficient programming was applied by Flaten and Lien (2007) on organic dairy farms but the model was used to optimise decisions for only 1 year. Cocks (1968) and Rae (1971) were the first to introduce the dynamic aspect in risk programming for agriculture in the form of discrete stochastic programming. Any empirical multi-period UEP model analysis in agriculture we did not find in the literature. In this paper the previously developed dynamic linear programming (DLP) model (Acs *et al.* 2007a) is extended with price and yield risk and a utility maximizing objective function (i.e. dynamic utility-efficient programming model, DUEP).

The objective of this paper is to describe the developed model and to apply it to the conversion process from conventional to organic farming, taking into account the risk of yield and price variation before, during and after the conversion years.

The paper starts with the description of the model. Here the inclusion of risk in the mathematical programming model, the general structure of the model, and the activities and constraints are described. Next, the data and the set up of the calculations are presented. Then, the results of the model for a basic situation are presented and analysed followed by a sensitivity analysis for different factors. The paper ends with a discussion on the method and the results obtained.

2. Method

2.1 Inclusion of risk in a mathematical programming model

In order to include risk in a mathematical programming model, two issues have to be taken into account: (i) the uncertainty of the risky events, which can occur in the future; (ii) the attitude of the farmer towards these risky events. The risk in the model is represented by the probabilities of occurrence of different events. Each event represents a state of nature. The attitude towards risk is expressed by an assumed utility function of the farmer.

The arable farmer has the choice to stay conventional, to convert part of the land or convert all the land to organic production. The conversion period takes 2 years. The farmer can also choose to convert the land at once or stepwise (converting in parts). In the model only one-way conversion is permitted. It is assumed that if once the farmer decides to convert (a certain area), no backward conversion can take place.

When assuming certainty, one average state can be included in the model, as was done in the previous DLP model (Acs *et al.* 2007a). While including risky outcomes, more states should be taken into account. Each alternative – conventional, conversion and organic – has its own risk. In the DUEP model, the states of nature are represented by the revenues of crops for a number of individual years depending on crop yield and price for the particular year. Each of the alternative states of nature occurs with a certain probability.

Most people are risk averse when faced with significantly risky incomes or wealth outcomes (Hardaker *et al.* 2004). A person who is risk averse is willing to forgo some expected income for a reduction in risk, the range of acceptable trade-off depending on how risk averse that individual is. This trade-off can be included by converting expected income to the utility of the individual, which means that the individuals' attitude towards risk has to be included. Conversion of income to utility is done by using a utility function.

In utility-efficient programming, any convenient form of utility function, with the exception of risk seeking functions, can be used to represent the farmers' preferences (Patten *et al.* 1988). Preferences vary between farmers; therefore, different assumptions can be used on their risk attitude in the range from risk neutral to extremely risk averse. The assumption of risk aversion implies a concave utility function. In our analysis the common negative exponential function is used (Hardaker *et al.* 2004): $U = 1 - \exp^{-\mathrm{Ra}^*\mathrm{z}}$, where U is the utility of a certain person, Ra is the absolute risk aversion coefficient of that particular person and z is discounted labour income over a period of 10 years. Concavity of this function is ensured, as, $U'(z) > 0$, and $U''(z) < 0$. This function exhibits constant absolute risk aversion. This means that preferences between payoffs (labour income) are unchanged if a constant amount is added to or subtracted from all payoffs. Labour income, which is used in this paper as the income measure z, is defined as revenues minus all costs, excluding the costs of family labour. It is therefore the remuneration for labour and management of the farmer and his family.

According to Anderson and Dillon (1992), the degree of risk aversion of any individual with respect to wealth (w) may be characterized in terms of the relative risk aversion coefficient. The coefficient of relative risk aversion can be calculated as $Rr(w) = -wU''(w)/U'(w)$, where $U''(w)$ and $U'(w)$ represent the second and first derivatives, respectively, of the utility function of a person with respect to wealth ($U(w)$) (Mas-Colell *et al.* 1995). This means that the risk aversion is reflected by the curvature of the individual's utility function. The relative risk aversion can be grouped as follows (Anderson and Dillon 1992):

$Rr(w) =$ 0, risk neutral;
$Rr(w) =$ 0.5, hardly risk averse at all;
$Rr(w) =$ 1.0, somewhat risk averse (typical);
$Rr(w) =$ 2.0, rather risk averse;
$Rr(w) =$ 3.0, very risk averse;
$Rr(w) =$ 4.0, extremely risk averse.

As the utility function used includes the absolute risk aversion coefficient Ra, a relationship is required between $Ra(w)$ and $Rr(w)$. Arrow (1965) and Pratt (1964) showed that $Ra(w) = \mathrm{Rr}(w)/\mathrm{w}$ in which w is the wealth measure. In this paper the wealth measure w is measured at the initial wealth level (Gollier 2001) which is approximated by the farm equity.

2.2 General structure of the model

The general structure of the DUEP model is formulated as follows:

$$MaxE[U] = \sum_{S_{comb}} p_{S_{comb}} U_{S_{comb}}(REV_{Sy}, C_y, Ra), Ra \text{ varied} \tag{1}$$

subject to:

$$\mathrm{A}_y x_y \leqslant b_y \tag{2}$$

$$-\mathrm{B}_y x_y + \mathrm{A}_{y+1} x_{y+1} \leqslant 0 \tag{2a}$$

$$x_y \geqslant 0 \tag{3}$$

Table 1 gives an overview of all the variables and symbols used in the model. The expected utility of the farmer over the 10 year planning horizon is maximized, which is a function of different crop revenues (determined by the states of nature), their variable costs, fixed costs and the risk aversion coefficient of the farmer (Equation 1). The 10 year planning horizon is long enough not to influence the results of conversion – usually conversion is completed after 3–6 years (MacRae *et al.* 1990). Maximization is subject to several activity constraints (Equations 2 and 3). The model each year chooses between the activities (x), which together with the states of nature will determine the final outcome.

Activities and constraints are included in each period (year) for all the relevant decisions and many of them are duplicated from 1 year to the next (e.g. annual crop activities). The link between the years is provided by the rotation requirements and the conversion of the land area (Equation 2a) and the objective function. For a more extensive description of the dynamic aspects of the model see Acs *et al.* (2007a).

Following Von Neumann and Morgenstern (1947) the expected utility value is calculated from the utility values weighted by the corresponding probabilities (Equation 4).

Table 1 Variables and symbols used in the model

$E[U]$	Expected utility
S_{comb}	States of nature for combination of the stages [*Sc1St1So1*, *Sc2St1So1*,…, *Sc15St2So15*]
S_y	States of nature of different stages for each year [*Sc*, *St*, *So*]
Sc	States of nature of conventional stage [*Sc1*, *Sc2*, …, *Sc15*]
St	States of nature of conversion (transition) stage [*St1*, *St2*]
So	States of nature of organic stage [*So1*, *So2*, …., *So15*]
p_{Scomb}	Probability of states of nature for combinations of stages
p_s	Probability of each state of nature
U_{Scomb}	Expected utility of states of nature concerning crop revenues for combination of stages
U_s	Expected utility per state of nature of different crop revenues
REV_{Sy}	Revenues per year per state of nature
Ra	Risk aversion coefficient, $Ra > 0$
y	Year [y = 1,2,…,10]
C_y	Total costs per year (variable and fixed) for activities of x_y
x_y	Vector of activities per year
A_y	Matrix of technical coefficients per year
B_y	Matrix linking activities of year (y) to the following year
b_y	Vector of right hand side value per year

$$MaxE[U] = \sum_{S_{comb}} U_{S_{comb}} * p_{S_{comb}} \tag{4}$$

where

$$\sum_{S_{comb}} p_{S_{comb}} = 1 \tag{5}$$

The utility values are calculated by transferring the discounted labour income into utility values using the negative exponential utility function: $U_{S_{comb}} = 1 - \exp^{-Ra*z_{S_{comb}}}$, where $z_{S_{comb}} = \sum_y (GM_{Sy} - C_{Fy})$. The discounted labour income over 10 years per state (z_{Scomb}) is the sum over 10 years of the discounted gross margin per state of nature per year (GM_{Sy}) minus the discounted fixed costs (C_{Fy}) per year (costs of land, machinery and buildings). The discounted annual gross margin is calculated as follows:

$$GM_{Sy} = \frac{\sum_L (REV_{SLy} - C_{Ly}) * LUS_{Ly}}{(1+i)^y}; \quad S_y \in [Sc, St, So] \tag{6}$$

where REV_{SLy} is the revenue per state of nature per crop per year, C_{Ly} is the variable costs per crop per year, LUS_{Ly} is the land use system (cropping pattern) in hectare of each crop per year, L is the crop type and i is the discount rate (4 per cent). The choice of activities determines the revenues and the costs of farming. The revenues represent the discrete stochastic element in the model, which depends on the chosen crops and the states of nature of each crop. Variable costs include crop production costs (including costs of variable operations, pesticide use, energy use, contract work, marketing costs and other remaining costs), costs of purchased nutrients (manure and fertilisers), hired labour costs and nutrient taxes. The final production plan maximizes the probability-weighted average of the utilities of the discounted labour income of the cropping patterns over the 10 years.

The matrix developed comprised 9845 activities and 11 031 constraints. The model was solved using GAMS programming language and SBB solver (Brooke *et al.* 1988).

2.3 Activities and constraints

The main groups of activities (x) in the model are:

1. Crop activities:

Conventional: winter wheat, spring barley, ware potatoes, seed potatoes, sugar beet, onion, and carrot;

Organic: winter wheat, spring barley, ware potatoes, seed potatoes, sugar beet, onion, carrot, spring wheat, kidney bean, green pea, alfalfa celeriac, grass-clover;

Conversion: the same as organic crop activities with only difference that organic yields and conventional prices are used.

2. Hired labour. There is an opportunity to hire unlimited amount of skilled and unskilled labour at any time of the year for 18 Euro/h and 9 Euro/h, respectively (CAO 2002).
3. Manure and fertiliser purchase.
4. Activities for calculating nutrient surplus, organic matter input and pesticides use.

The main groups of constraints are:

1. Land availability. A 48 hectare farm size is assumed, which is an average farm size in the central clay region in the Netherlands.
2. Rotation restrictions. All the individual crops and groups of crops have their own rotation constraints which are mainly based on agronomic reasons. For conventional production 3 year crop rotation is used for the whole land area, which is characterising the region. For conversion and organic production 6 year crop rotation is used. This more diverse crop rotation is a requirement for organic farming. More detailed information concerning crop rotations can be found in Acs *et al.* (2007b).
3. Conversion restrictions. Technical constraints concerning the dynamic aspect of the model. The first year the model is restricted to produce only in conventional way. This restriction was imposed in order to be able to compare the conventional production with the conversion and organic production plan. From the second year onwards the model can convert to organic production. In case land goes into conversion, it will be in conversion for 2 years to become organic land area. The model decides how much land goes from conventional into conversion. In the model the conversion is restricted to one-way direction, so the model excludes the possibility to convert back.
4. Household labour constraint. The available amount of family labour is assumed to be 1.1 full-time labour (2255 h/year), which is an average labour supply in this region for 48 ha land area (De Wolf & De Wolf, pers. comm., 2004). Family labour supply per period is assumed to be constant over the year.
5. Nutrient balance calculation for Dutch Mineral Accounting System (MINAS) regulation. MINAS calculates a nutrient balance at farm level per hectare. Above the acceptable level (100 kg N and 25 kg P_2O_5 per hectare in year 2002) the farmer has to pay a levy in Euro/kg of unacceptable surplus, which is 2.3 Euro/kg in the case of nitrogen and 9 Euro/kg in the case of phosphate (MANMF 2004).
6. Maximum manure input restriction for Manure Transfer Agreement System (MTAS) regulation. MTAS sets a limit to the amount of manure that can be used on the farm. This limit is based on nitrogen (N) content which is 170 kg N from manure per hectare.

7. Several counting rows for pesticides use and organic matter input to the farm.

2.4 Data

Regarding crop revenues, yearly average data for different crops were available from the Farm Accountancy Data Network (FADN) from the Agricultural Economics Research Institute (LEI) in the Netherlands (LEI, 2004). FADN is a unique panel dataset, which includes crop-level information for a representative sample of farms. The number of conventional, conversion, and organic farms in the sample was 400, 80, and 32 respectively. As farm level data were not available, the data used in this paper consists of average yields and product prices per crop per year. For conventional crops data were available from 10 years, for conversion crops data were available from only 2 years, and for organic crops data were available from 3 years. Because prices and yields tend to change over time in a more or less consistent and predictable way, they were de-trended to account for inflation and technical progress (Barry *et al.* 2000), with 2002 as the base year. Prices were corrected for inflation by using the inflation index of prices (CBS 2005). Crop yields were corrected for technical progress by regressing yield on time as an explanatory variable. Consequently, inflation and technical progress are absent in modelling.

To avoid shock effects because of lumpiness of data, the corrected data on conventional and organic crops were transformed into 15 states of nature by using the procedure for simulating multivariate empirical probability distributions described by Richardson *et al.* (2000). This procedure takes into account stochastic correlation between crops and produces a smoother distribution of states of nature given the probability distributions encapsulated in the original data. Serial correlation was not taken into account as this correlation appeared to be very low ($R^2 < 0.25$). Latin Hypercube sampling was used to simulate 15 states of nature, which are considered enough to get reliable results (Lien *et al.* 2009). The resulting 15 states of nature for conventional and organic farming are presented in Tables 2 and 3. For conversion crops it was judged that simulation of 15 states was not justified given that there are only 2 years of data. Data from these 2 years were used as two states of nature (see Table 4). Within each stage of cropping (conventional, conversion, and organic) each state has the same probability to occur: $p_{sc} = 0.06667$ for conventional, $p_{st} = 0.5$ for conversion and $p_{so} = 0.06667$ for organic states of nature. Based on this, the joint probability (p_{Scomb}) for all combinations of states of nature is 0.02222 ($p_s = p_{sc} \times \mathrm{p}_{st} \times \mathrm{p}_{so}$), which all together sum up to one.

Regarding variable costs of crops, data was obtained from Quantitative Information Handbook (KWIN 2002). Fixed costs for conventional and organic farms were calculated from the results of real farms (Wijnands and

Table 2 Simulated states of nature for gross revenues of conventional crops (Euro/ha)

State of nature	Winter wheat	Seed potato	Sugar beet	Seed onion	Carrot	Spring barley	Ware potato	*P*-value
Sc1	1842	8778	3244	5919	13 516	1452	6015	0.06667
Sc2	1637	6627	3329	3702	12 990	1559	5744	0.06667
Sc3	1636	7034	3382	5785	11 635	1519	5159	0.06667
Sc4	1757	9623	3728	10 237	14 182	1415	9134	0.06667
Sc5	1857	7450	3230	3857	7832	1499	5507	0.06667
Sc6	1824	7163	3264	3086	9818	1565	4748	0.06667
Sc7	1836	7242	3213	5929	13 479	1509	4999	0.06667
Sc8	1838	7470	3647	3001	13 134	1646	4546	0.06667
Sc9	1843	7117	3376	3091	12 231	1628	3893	0.06667
Sc10	1859	6403	3192	2899	13 119	1620	3640	0.06667
Sc11	1818	9806	3218	10 720	15 393	1453	8479	0.06667
Sc12	1610	9069	3599	10 720	10 837	1417	6005	0.06667
Sc13	1932	7711	3026	3462	12 763	1463	5311	0.06667
Sc14	1858	5839	3258	2699	13 474	1654	3331	0.06667
Sc15	1708	9659	3846	10 240	12 977	1442	8600	0.06667
Mean	1790	7799	3370	5690	12 492	1523	5674	—
SDs	98	1269	230	3183	1852	84	1782	—

Dekking 2002). The direct costs (variable costs without nutrient and labour costs) and the labour and nutrient requirement per crop are summarized in Table 5. Detailed information about these input data and about fixed costs, crop rotation, household labour use and organic matter input can be found in Acs *et al*. (2007a,b).

For the calculation of the absolute risk aversion coefficient (Ra) with respect to wealth, by means of formula: $Ra(w) = \mathrm{Rr}(w)/\mathrm{w}$, an assumption on wealth should be made. For this the average owners equity was used of the same farms from which the yields and product prices were taken. The average ownership equity amounted to 835 000 Euro (LEI, 2004). As shown before the relative risk aversion coefficient (Rr) can take the range between 0 and 4. This means that the corresponding absolute risk aversion coefficient can take values between 0 and 0.0000048.

3. Results

3.1 Basic results of DUEP model

The results in Table 6 show the expected discounted labour income with the accompanying standard deviation and certainty equivalent, the area converted to organic farming and the optimal cropping plan across different risk aversion coefficients. The degree of risk aversion has a strong effect on the optimal decision of a farmer to convert. While it is optimal for the risk neutral farmer to convert the whole area to organic production, for a farmer with a relative risk aversion ranging from 0.5 to 2.0 it is optimal to convert only

Table 3 Simulated states of nature for gross revenues of organic crops (Euro/ha)

State of nature	Ware potato	Seed potato	Sugar beet	Kidney been	Green pea	Spring barley	Alfalfa	Winter wheat	Spring wheat	Seed onion	Carrot	Celeriac	Grass-clover	*P*-value
So1	16 905	19 442	4915	3110	2824	1707	700	1746	2133	18 082	26 263	12 158	721	0.06667
So2	2289	3955	4534	3197	2899	1816	1170	1966	2309	3019	12 573	5047	721	0.06667
So3	2880	3955	3195	2080	2694	1697	1318	2242	2322	5607	10 700	5047	721	0.06667
So4	16 907	19 443	4972	2985	2698	1702	700	1746	2133	18 083	26 264	12 258	721	0.06667
So5	16 887	17 784	3195	2081	2694	1702	981	2033	2225	9142	22 047	9362	721	0.06667
So6	3298	9347	4505	2900	2716	1764	893	1984	2281	5833	19 077	10 775	721	0.06667
So7	11 719	6169	3406	2457	2712	1697	901	1921	2240	12 617	19 058	8107	721	0.06667
So8	2088	8760	3195	2080	2694	1697	1203	2242	2264	5897	10 700	8657	721	0.06667
So9	7395	12 878	5135	3723	3125	1816	700	1775	2210	16 416	26 263	11 719	721	0.06667
So10	16 906	19 442	4708	3487	2742	1720	700	1746	2133	18 083	26 262	12 258	721	0.06667
So11	1833	4025	3272	3438	3082	1712	1318	2208	2322	3329	11 697	5641	721	0.06667
So12	2786	5353	4045	3134	2856	1706	1271	2235	2282	3019	19 049	6880	721	0.06667
So13	4551	14 095	5135	3548	3125	1816	782	1767	2289	8220	25 113	10 264	721	0.06667
So14	1833	3955	4538	2832	3125	1816	1318	2243	2322	3019	10 700	5047	721	0.06667
So15	2062	4644	3847	2709	2712	1709	1318	2242	2311	3019	11 176	6262	721	0.06667
Mean	7356	10 216	4173	2917	2846	1739	1018	2006	2252	8892	18 463	8632	721	—
SDs	6498	6351	760	546	179	51	264	214	71	6109	6633	2835	0	—

Table 4 Gross revenues of conversion crops per state of nature de-trended and adjusted for inflation to 2002 (Euro/ha)

Year	State of nature	Ware potato	Weed potato	Sugar beet	Kidney been	Green pea	Spring barley	Alfalfa	Winter wheat	Spring wheat	Seed onion	Carrot	Celeriac	Grass-clover	*P*-value
1995	St1	3291	5781	2602	1490	1002	1134	780	1227	1256	4654	7610	2275	423	0.5
1996	St2	2209	4619	2514	1520	1124	1348	900	1265	1396	1646	9990	2625	717	0.5
Mean	—	2750	5200	2558	1505	1063	1241	840	1246	1326	3150	8800	2450	570	—
SDs	—	766	822	62	21	86	151	85	26	99	2126	1682	247	208	—

Source: LEI 2004; own calculations.

Table 5 Costs, labour and nutrient requirement of conventional, conversion and organic crops

Crops	Costs (Euro)*		Labour requirement (h)		Nutrient requirement (kg)			
	Conventional	Conversion/ organic	Conventional	Conversion/ organic	Conventional		Conversion/ organic	
					N	P_2O_5	N	P_2O_5
Ware potato	1681	2255	26.4	20.6	255	120	150	48
Seed potato	3245	2226	95.3	77.1	125	120	50	47
Sugar beet	1008	884	19.2	86.1	150	80	80	160
Seed onion	1975	1284	37.7	316.5	110	120	50	43
Carrot	9450	12 450	29.3	185.7	80	120	40	57
Winter wheat	484	439	10.4	13	210	20	125	62
Spring barley	312	393	9.6	12.1	65	20	25	60
Winter barley	—	339	—	12.1	—	—	75	53
Spring wheat	—	415	—	13.5	—	—	75	62
Kidney bean	—	624	—	25.6	—	—	50	20
Green pea	—	658	—	22.5	—	—	10	25
Alfalfa	—	169	—	2.2	—	—	0	133
Celeriac	—	2666	—	134.9	—	—	140	74
Grass-clover	—	141	—	5.5	—	—	0	105

*Direct production costs do not include the costs of nutrients and labour.

part of the area. In the case the farmer is even more risk averse ($3.0 \leq Rr \leq 4.0$) conversion is not optimal.

Up to a relative risk aversion of 1.0 the type of crops included in the conventional and organic cropping plan remain the same. The only change is that the area of organic farming decreases. When going from somewhat risk averse to rather risk averse, the organic area increases, which might seem contrary to what would be expected. However, the replacement of the risky organic crop seed onion by organic sugar beet (see Table 3 for revenues and SD of revenues of organic crops) makes organic farming as a whole less risky, causing the increase of the organic area. At high risk aversion ($3.0 \geq Rr \geq 4.0$) organic farming is not interesting. Moreover, less risky conventional crops like seed potato and sugar beet take the place of more risky crops like ware potato, seed onion and carrot (see Table 2 for revenues and SD of revenues of conventional crops).

3.2 Sensitivity analysis

The basic outcome of the DUEP model shows that partial conversion takes place when relative risk aversion ranges between 0.5 and 2.0 while no conversion takes place when relative risk aversion is 3.0 or higher. In the sensitivity analysis, different policy incentives (i.e. taxes on pesticides and subsidies

Table 6 Optimal farm plan over time for different risk aversion coefficients

Risk attitude	Risk aversion					
	Risk neutral	Hardly risk averse	Somewhat risk averse	Rather risk averse	Very risk averse	Extremely risk averse
Ra	0	0.0000006	0.0000012	0.0000024	0.0000036	0.000048
Rr	0	0.5	1.0	2.0	3.0	4.0
Expected discounted						
Labour income (Euro)	296 653	262 867	252 885	212 025	145 482	138 899
Standard Deviation (SD)	607 593	423 544	398 310	320 711	209 501	206 642
Certainty Equivalent (CE)	296 653	213 062	152 916	109 719	89 686	71 308
Conventional (ha)	0.0	19.6	25.2	22.6	48	48
Converted to organic (ha)	48.0	28.4	22.8	25.4	0	0
Total area (ha)	48.0	48.0	48.0	48.0	48.0	48.0
Optimal cropping plan (ha)						
Conventional (t = 1)						
Winter wheat	16.0	16.0	16.0	16.0	16.0	16.0
Seed potato	6.9	6.9	6.9	6.9	11.4	11.5
Ware potato	9.1	9.1	9.1	9.1	4.6	4.5
Seed onion	9.6	9.6	9.6	9.6	—	—
Carrot	6.4	6.4	6.4	6.4	4.0	4.0
Sugar beat	—	—	—	—	12.0	12.0
Conventional (t = 2–10)						
Winter wheat	—	6.5	8.4	7.5	16.0	16.0
Seed potato	—	—	—	—	11.4	11.5
Ware potato	—	6.5	8.4	7.5	4.6	4.5
Seed onion	—	3.9	5.0	4.5	—	—
Carrot	—	2.6	3.4	3.0	4.0	4.0
Sugar beat	—	—	—	—	12.0	12.0
Conversion (t = 2–3)					No conversion	No conversion
Spring wheat	16.0	9.5	7.6	8.5		
Seed potato	8.0	4.7	3.8	4.2		
Seed onion	4.0	2.4	1.9	2.1		
Sugar beet	12.0	7.1	5.7	6.3		
Alfalfa	8.0	4.7	3.8	4.2		
Organic (t = 4–10)						
Spring wheat	8.0	4.7	3.8	4.2		
Seed potato	8.0	4.7	3.8	4.2		
Seed onion	8.0	4.7	3.8	—		
Celeriac	8.0	4.7	3.8	4.2		
Kidney bean	8.0	4.7	3.8	4.2		
Green pea	8.0	4.7	3.8	4.2		
Sugar beet	—	—	—	4.2		

for organic production), the effect of market stabilization, and the effect of learning are examined for a somewhat risk averse (Rr = 1) and a extremely risk averse farmer (Rr = 4.0).

Table 7 Conversion ranges for different factors used in sensitivity analysis for somewhat risk averse ($Rr = 1$) and very risk averse farmers ($Rr = 4$)

	Tax on pesticides (Euro/kg a.i.*)	Yearly subsidy for organic production (Euro/ha)	Reduction of SD due to market stabilization (%)	Reduction of SD due to learning effect* (%)
$Rr = 1$				
Partial conversion	0–12	0–147	0–22	—
Full conversion	≥13	≥148	23–100	0–100
$Rr = 4$				
No conversion	0–6	0–220	0–29	0–8
Partial conversion	7–34	221–440	30–34	9–22
Full conversion	≥35	≥441	35–100	23–100

a.i., active ingredient. *Mean of organic revenues is raised by 5 per cent.

3.2.1 *Taxes on pesticides*

The first policy incentive to convert is a tax on pesticides. Pesticides are used only for conventional crops, as the use of synthetic chemical inputs in organic farming is not allowed. This gives an option to impose a tax on pesticide use in order to stimulate the farmers to convert to organic production. The amount of pesticides used for each crop activity is fixed in the model (i.e. it does not allow to use less pesticide which could have an affect on the output results). Pesticides use is measured in active ingredient (a.i.), which is the weight of the toxic substance in the applied product in kilograms. In this analysis the minimum amount of tax (in Euro/kg a.i.) necessary for conversion is determined.

The sensitivity analysis shows that, taking into account a somewhat risk averse farmer, a tax of at least 13 Euro/kg active ingredient would cause the farm to fully convert (Table 7). The area converted increases by raising taxes up to 13 Euro as this leads to higher costs of farming conventionally. Besides, by raising taxes crops requiring more pesticide are being replaced by crops requiring lower amount of pesticide (i.e. winter wheat is replaced by spring barley, seed potato by ware potato). For a very risk averse farmer full conversion would take place if taxes exceed 35 Euro/kg a.i.

3.2.2 *Subsidies for organic production*

Another option to stimulate conversion to organic farming is using subsidies on organic production. Subsidies can take different forms: (i) subsidy at once, at the beginning of the conversion period; (ii) conversion subsidies, given during the conversion period which would serve as a compensation for switching costs (i.e. costs of investment/disinvestment, learning costs, lower revenues during this period); (iii) subsidies for all organically produced crops starting from conversion years. All of these are hectare-based subsidies for the area converted. The minimum amount of subsidy required to convert is determined by the DUEP-model.

Model calculations show that for a somewhat risk averse farmer at least 148 Euro/ha subsidy would be required for every year of organic farming, starting from conversion, to make the farm fully organic. For extremely risk averse farmer a 221 Euro/ha subsidy would be needed for partial conversion and 441 Euro/ha for full conversion (Table 7). Partial conversion enables the farmer to keep one part of the area with more stable income originating from conventional production while with the other part the riskier organic production would be compensated by the provided subsidies.

In the case if the subsidy would be given at once, at the beginning of the conversion period then somewhat risk averse farmer would need to be paid 1144 Euro/ha/year for full conversion, and extremely risk averse farmer would require 1708 Euro/ha/year for partial and 3410 Euro/ha/year for full conversion. If the subsidy were given during the 2 year conversion period then for somewhat risk averse farmer 584 Euro/ha/year and for extremely risk averse 872 Euro/ha/year (1739 Euro/ha/year for full conversion) would be required, given the 10 year planning horizon.

3.2.3 Market stabilization

In this analysis, we explore how the conversion would take place if the market for organic products were more stable, meaning less variability in organic revenues. The decrease of the organic revenue SD at which it is optimal to convert is determined. This is done by redefining the values in Table 3 (same average, decreased SD) and doing model calculations based on the redefined data. By trial and error the required decrease of SD was determined.

Table 7 shows that the SD of organic revenues has to be reduced by at least 22 per cent of the current SD before the somewhat risk averse farmer would convert fully to organic production. For an extremely risk averse farmer a reduction of SD by 30 per cent would be required to make the farm convert partly while 35 per cent reduction would lead to full conversion.

3.2.4 Learning effect

During the conversion years, the farmer has to learn organic production practices. After a few years of experience, the organic crops might give higher and more stable yield and thus more stable revenues. In this scenario, this effect is investigated by raising the mean and decreasing the SD of organic crop revenues from the fourth year onwards. The mean is assumed to rise by 5 per cent and stay at this higher level the following years, and the percentage reduction in SD that is necessary for conversion is determined.

The results in Table 7 show that assuming 5 per cent rise in organic crop revenues from the fourth year would in itself cause the somewhat risk averse farmer to fully convert. For an extremely risk averse farmer, next to the rise in organic crop revenues the SD of it should be 9 per cent lower than the original SD in order to make the farm convert partly (23 per cent lower for full conversion).

4. Discussion and conclusion

The developed method is suitable to model the conversion from conventional to organic farming including future yield and price risk of conventional and organic crops. The dynamic aspect and the inclusion of stochastic elements into the model is one of the advantages of this modelling approach. This makes farm level analysis of conversion closer to the real situation compared with static and deterministic models. The model can also be used as a tool for policy makers to analyse the effect of certain incentives at farm level conversion. However, the model strongly depends on the data available for use.

In this research, survey data were used for assessing risks. For conversion and organic crop yields and prices there were only 2 and 3 year data observations available, respectively. This questions the reliability of the model results. Especially for established organic systems data availability is improving by collection and publication of data from organic farms (FADN data collected by LEI), and from BIOM-projects (Organic Farming: Innovation and Conversion). However, more observations are needed also from in-conversion farms in order to get more realistic model results. The low data-availability prompts for reserve regarding the validity of the conclusion.

The survey data used in this article concerning yield risk and also other evidence (Morris *et al.* 2001; Van Bueren *et al.* 2002) showed that in organic farming the variability of crop yields is higher compared to conventional farming. However, the conclusion that organic yields fluctuate more than in conventional systems is not a 'fact', there is also evidence in the opposite direction (Lampkin and Padel 1994). In the case organic farming would have more stable yields, compared to conventional farming, a risk averse farmer would convert 'more easily' to organic production given its higher expected revenues.

Calculations with the DLP model developed by Acs *et al.* (2007a) showed that one-step conversion of the whole farm area would maximize net present value in 10 years. This result is valid in the case when there is no risk aversion. When including a typical risk aversion level of one in the DUEP model only partial conversion takes place. At a risk aversion level of 3.0 or higher conversion does not take place at all. Moreover, in that case the optimal (conventional) production plan of the farm is affected. Other studies on inclusion of risk aversion into mathematical modelling showed that the cost of ignoring risk aversion may be small in short-run (tactical and operational) decision problems in farming (Pannell *et al.* 2000; Lien and Hardaker 2001; Flaten and Lien 2007). Our results suggest that in considering risk aversion in the decision problems with a longer planning horizon (strategic decisions for several years) the effect of risk aversion can be considerable.

Sensitivity analysis showed that policy incentives such as taxes and subsidies and output price and yield stabilization stimulate the conversion to organic farming. The model results show that for a somewhat (i.e. typical) risk averse farmer in the case of a 13 Euro tax on pesticides it would be optimal to convert the whole area to organic farming (35 Euro tax for an extremely risk averse farmer). A tax of 13 Euro and a *Rr* of 1.0 would mean that in the first conventional year 10 993 Euro tax has to be paid while this amount would be 25 297 Euro if tax per kg a.i. would be 35 Euro and *Rr* would be 4.0.

In case subsidies are implied, the model results show that subsidies required for full conversion of arable farms ($Rr = 1.0$) is almost equal to the actual subsidies paid to farmers between 2000 and 2003 in the Netherlands. The initial conversion subsidy was 1136 Euro/ha (MINLNV, 2000) while the minimum required amount calculated by the model for a somewhat risk averse farmer is 1144 Euro/ha/year. This means that the governmental subsidy level should be higher to persuade somewhat risk averse farmers to fully convert their farm, especially if any non-economic reluctance to change would need to be overcome. For extremely risk averse farmers the required subsidy should be more than three times as high as was paid in reality.

Analysis of the impact of a more stabilised market for organic products and on the learning effect showed that the variation of expected revenue of organic products must be considerably lower than the observed variation. Prices of organic crops might have great variability also in the future, due to the small-scale, immature nature of the organic market (easy substitutability of organic products with the conventional ones) and the lack of government intervention to stabilise prices (Lampkin and Padel 1994). Yields are also subject to weather and other agronomic factors, which mean that the yields stay rather volatile also in the future. This suggests that policy incentives, such as taxes or subsidies, will also in the future be needed to stimulate conversion.

This study provides valuable insight into the farm-specific decision as to whether or not to convert to organic farming. The results show that for a risk-neutral farmer it is optimal to convert to organic farming; however, for a risk-averse farmer it is only optimal to fully convert if policy incentives are applied such as taxes on pesticides or subsidies on conversion, or if the market for the organic products becomes more stable. The more risk averse a farmer is the more incentive is needed to make a farmer convert to organic farming. Although this seems obvious, risk aversion of farmers is often ignored. This model provides the basis to determine such incentives.

References

Acs, S., Berentsen, P.M.B. and Huirne, R.M.B. (2007a). Modelling conversion from conventional to organic arable farming systems in the Netherlands by means of Dynamic Linear Programming, *Agricultural Systems* 94, 405–415.

Acs, S., Berentsen, P.M.B., de Wolf, M. and Huirne, R.M.B. (2007b). Comparison of conventional and organic arable farming systems in the Netherlands by means of bio-economic modelling, *Biological Agriculture and Horticulture* 24, 341–361.

Anderson, J.R. and Dillon, J.L. (1992). *Risk Analysis in Dryland Farming Systems*. Farm Systems Management Series 2, FAO, Rome, pp. 55.

Arrow, K.J. (1965). *Aspects of the Theory of Risk-Bearing*. Yrjö Jahnssonin Säätiö, Academic Bookstore, Helsinki.

Barry, P.J., Ellinger, P.N., Baker, C.B. and Hopkin, J.A. (2000). *Financial Management in Agriculture Danville*, 6th edn. Interstate Publishers, Inc., Illinois.

Brooke, A., Kendrick, D. and Meeraus, A. (1988). *GAMS: A User's Guide*. The Scientific Press, San Francisco, USA, pp. 289.

CAO (2002). *Collectieve Arbeidsovereenkomst Landbouw, 2002*. Ministry of Social Affairs and Employment, The Hague.

CBS (2005). *Agricultural Figures*, 1993–2002 (In Dutch). Agricultural Economic Research Institute and Central Bureau of Statistics, The Hague.

Cocks, K.D. (1968). Discrete stochastic programming, *Management Science* 15, 72–81.

Eurostat (2006). European Commission, Eurostat. Available from URL: http://www.organic-europe.net/europe_eu/statistics.asp [accessed 8 Feb 2006].

Flaten, O. and Lien, G. (2007). Stochastic utility-efficient programming on organic dairy farms, *European Journal of Operational Research* 181, 1574–1583.

Freund, R.L. (1956). The introduction of risk into a programming model, *Econometrica* 24, 253–263.

Gollier, C. (2001). *The Economics of Risk and Time*. The MIT Press, Cambridge, Massachusetss, pp. 445.

Hardaker, J.B., Huirne, R.B.M., Anderson, J.R. and Lien, G. (2004). *Coping with Risk in Agriculture*, 2nd edn. CAB International, Wallingford, p. 332.

Harwood, J., Heifner, R., Coble, K., Perry, J. and Somwaru, A. (1999). *Managing Risk in Farming: Concepts, Research, and Analysis*. Economic Research Service, US Department of Agriculture, Washington.

KWIN (2002). *Quantitative Information Handbook (In Dutch) (Kwantitatieve Informatie Akkerbouw en Vollegrondsgroenteteelt)*. Praktijkonderzoek Plant en Omgeving, Lelystad.

Lambert, D.K. and McCarl, B.A. (1985). Risk modelling using direct solution of nonlinear approximations of the utility function, *American Journal of Agricultural Economics* 67, 846–852.

Lampkin, N. (2002). Certified and policy-supported organic and in-conversion land area in Europe, 1985–2002. Available from URL: http://www.organic.aber.ac.uk/statistics/euroarea03.htm [accessed 13 Feb 2006].

Lampkin, N.H. and Padel, S. (1994). *The Economics of Organic Farming. An International Perspective*. CAB International, Wallinford, pp. 454.

Langley, J.A., Heady, E.O. and Olson, K.D. (1983). Macro implications of a complete transformation of U.S. agricultural production to organic farming practices, *Agriculture, Ecosystems & Environment* 10(4), 323–333.

LEI (2004). *FADN-Data for Several Years*. Agricultural Economics Research Institute (LEI), The Hague.

Lien, G. and Hardaker, J.B. (2001). Whole-farm planning under uncertainty: impacts of subsidy scheme and utility function on portfolio choice in Norwegian agriculture, *European Review of Agricultural Economics* 28(1), 17–36.

Lien, G., Hardaker, J.B., Van Asseldonk, M.A.P.M., and Richardson, J.W. (2009). Risk programming and sparse data: how to get more reliable results. *Agricultural Systems* 101, 42–48.

MacRae, R., Hill, S., Mehuys, G. and Henning, J. (1990). Farm-scale agronomic and economic conversion from conventional to sustainable agriculture, *Advances in Agronomy* 43, 155–198.

MANMF (2004) – Ministry of Agriculture, Nature Management and Fisheries, 2004. Wetsvoorstel aanpassing verliesnormen naar Tweede Damer. Available from URL: http://www.minlnv.nl/persberichten/Mestloket [accessed 28 Jan 2004].

Martin, S. (1996). Risk management strategies in New Zealand agriculture and horticulture, *Review Market Agricultural Economy* 64, 31–44.

Mas-Colell, A., Whinston, M.D. and Green, J.R. (1995). *Microeconomic Theory*. Oxford University Press Inc., New York, pp. 981.

Meuwissen, M.P.M., Huirne, R.B.M. and Hardaker, J.B. (2001). Risk and risk management: an empirical analysis of Dutch livestock farmers, *Livestock Production Science* 69, 43–53.

MINLNV (2000). Change of regulation on stimulating organic production methods. (In Dutch) (Wijziging Regeling stimulering biologische productiemethode) 17 september 2000/ Nr.TRCJZ/2000/5181 Directie Juridische Zaken Staatscourant 20 september 2000, nr. 182, p. 26.

MINLNV (2005). Ministry of Agriculture, Nature and Food Quality (In Dutch) (Ministerie van Landbouw, Natuur en Voedselkwaliteit. Persbericht ministerraad). Available from URL: http://www.minlnv.nl/persberichten [accessed 20 Nov 2005].

Morris, C., Hopkins, A. and Winter, M. (2001). *Comparison of the Social, Economic, and Environmental Effects of Organic, ICM and Conventional Framing*. Final report to The Countryside Agency, Institute of Grassland and Environmental Research, UK, pp. 152.

Offermann, F. and Nieberg, H. (2000). Economic performance of organic farms in Europe, *Organic farming in Europe: Economics and Policy* Volume 5, Universitaet Hohenheim, Stuttgart.

Pannell, D.J., Malcolm, B. and Kingwell, R.S. (2000). Are we risking too much? Perspectives on risk in farm modelling, *Agricultural Economics* 23, 69–78.

Patten, L.H., Hardaker, J.B. and Pannell, D.J. (1988). Utility-efficient programming for whole-farm planning, *Australian Journal of Agricultural Economics* 32, 122–136.

Pratt, J.W. (1964). Risk aversion in the small and in the large, *Econometrica* 32, 122–136.

Rae, A.N. (1971). Stochastic programming, utility, and sequential decision problems in farm management, *American Journal of Agricultural Economics* 53, 448–460.

Richardson, J.W., Klose, S.L. and Gray, A.W. (2000). An applied procedure for estimating and simulating multivariate empirical (MVE) probability distributions in farm-level risk assessment and policy analysis, *Journal of Agriculture and Applied Economics* 32, 299–315.

Van Bueren, E.T.L., Struik, P.C. and Jacobsen, E. (2002). Ecological concepts in organic farming and their consequences for an organic crop ideotype, *Netherlands Journal of Agricultural Science* 50, 1–26.

Von Neumann, J. and Morgenstern, O. (1947). *Theory of Games and of Economic Behavior*. Princeton University Press, Princeton.

Wijnands, F.G. and Dekking, A.J. (2002). *Integrated and Organic Farming. Central Clay Region (In Dutch)*. Applied Plant Research (PPO-Bedrijfssystemen) – 2002, no 1. & no 4., PPO, Lelystad.

Yussefi, M. (2003). Development and state of organic agriculture world-wide, in Yussefi, M. and Willer, H. (eds) *The World of Organic Agriculture: Statistics and Future Prospects 2003*. International Federation of Organic Agriculture Movements, Tholey-Theley, Germany.