Analysing Profits and Economic Behaviour of Organic and Conventional Dutch Arable Farms

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Abstract

This paper uses a micro-econometric model to analyse differences in variable profits and economic behaviour between organic and conventional arable farms. Insight in factors underlying these differences is essential in designing policy measures that aim at encouraging the transition to a more sustainable farming practice. The framework is applied to a rotating panel of Dutch conventional and organic arable farms over the period 1990-1999.

The results show that the, on average larger variable profit of organic farms is mainly associated with the use of land and technological changes. The shadow price of labour suggests over-use of labour on organic arable farms. Demand for pesticides and supply of output are generally more elastic on organic farms. Furthermore, organic farmers that increase the size of their farm are found to become more dependent on the use of pesticides and are found to increase the intensity of the use of land.

Keywords: *The Netherlands, arable farming, organic, conventional, profit, normalized quadratic profit functions*

Introduction

Increased consumer awareness of food safety issues and environmental concerns have contributed to the growth of organic farming over the last few years. Dutch organic farming represented around 1.3% of the total Dutch utilised agricultural area in 1999 (Ministerie van LNV, 2000). Objective of the Dutch government is 10% organic agriculture in 2010. Organic agriculture grew by about 16% a year between 1993 and 1998. However, to accomplish the objective of a share of organic farming of 10% by the year 2010, the growth rate of organic agriculture has to increase to approximately 25% (Ministerie van LNV, 2000).

Creation of demand for organic products, a strong organic production chain, but also a good profitability for the primary producer are factors, which support the objective of the Dutch government (LEI, 2002). The expected decline in income in the transition period to organic agriculture is the greatest bottleneck for the farmers. Having insight in factors determining profit of organic farming is therefore important.

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Although organic farms are usually smaller, they realize higher profits. Yields per hectare are lower for organic farms in comparison to traditional arable farms. According to Geven (1999) the on average 25% higher profits for organic farms are caused by a higher area of vegetables grown at those farms and higher prices for the organic products at general. Besides those higher profits per crop, the other profits are on average 51.000 guilders higher for the organic arable farms. Those higher profits are mainly caused by profits from cattle and supports from the Dutch government. However labour and costs for customs workers are higher on organic arable farms (LEI, 2002).

Currently, the stock of literature on the performance of organic vis-à-vis conventional farming is still small, mainly because there have not been sufficient data on organic farms. Offerman and Nieberg (2000) provide a comparison of the economic performance of organic and conventional farms in different countries and conclude that organic farms have lower yields, higher output prices and slightly lower costs. Also, they find that deviations of average profitability of organic farms from average profitability of conventional farms range between plus and minus 20 per cent of profit of conventional farms. For the Netherlands, Offerman and Nieberg find that organic arable farms are much more profitable than conventional arable farms. The existing studies on comparison of the performance of organic and conventional farms provide contradictory results on how efficient organic farming technology is in using natural resources. Stolze et al. (2000) conclude "organic farming can be defined as a farming system which comprises fewer detrimental effects to the environment and to resource use than conventional farming systems and therefore currently, represents the state-of-the-art of an environmentally sensitive farming system". Oude Lansink et al. (2002) used data envelopment analysis to compare the efficiency and productivity of organic and conventional farms. Their results suggest that specialised organic livestock and arable farms are more efficient than their conventional counterparts; however, conventional farms use a more productive technology. Overall, the performance of organic farms does not differ significantly from the performance of conventional farms, implying that conventional farms use a smaller fraction of the available production capacity than organic farms.

Pietola and Oude Lansink (2001) find that policies promoting organic farming may suffer from adverse selection problems since they find that subsidised organic farming is more attractive to farmers with lower productivity in conventional systems. Farmer switches towards organic technologies may have been encouraged by premium subsidies granted to organic farms rather than by higher productivity and input use efficiency of the organic technology. The results of Pietola and Oude Lansink suggest that organic farms are more likely less productive farms.

The purpose of this paper is to analyse differences in profit and economic behaviour between organic and conventional farms. Profit function models are a useful tool in the analysis of farm specific production behaviour. Profit function models are defined as a set of behavioural relationships that are based on micro economic production theory and estimated on farm data using econometric techniques. The empirical focus is on specialised conventional and organic arable farms in Netherlands were selected, covering the period 1990-1999.

The structure of remainder of this paper is as follows. The theoretical and empirical models are discussed in section 2 and 3, respectively. Section 4 describes the estimation procedure and the data used for this research. The estimation results are presented in section 5 and the paper concludes with comments on this research.

Theoretical model

Neoclassical production theory forms the framework for our analysis at the differences in profits of organic and traditional Dutch arable farms. The theory is more widely discussed in Chambers (1988) and will only briefly be surveyed here. This section will concentrate on the theory underlying the determination of price elasticities and shadow prices of organic and traditional farms.

To begin, it is assumed that all variable inputs and outputs, or more compactly "netputs", are freely disposable (variable). Profit maximisation conditional on a convex production possibility set or technology T for farm h can be denoted as:

$$\pi_h(w, z_h, t) = \max_{y_h, x_h} \{ y_h - w' \cdot x_h \mid z_h, t \in T \} \tag{1}$$

Where w is a vector of normalised input prices (profit and all prices of inputs have been divided by the price of output to ensure linear homogeneity in prices); y_h is a scalar denoting output and x_h is a vector of quantities of variable inputs; z_h is a vector of fixed input quantities and t denotes technological progress. The maximisation problem in (1) assumes that the producer aims at maximising profit, given prices of outputs and variable inputs and quantities of fixed inputs. The profit function is assumed to be linear homogenous, convex and twice differentiable in input and output prices, monotonically increasing in output prices and fixed inputs and decreasing in input prices.

Applying Hotelling's lemma yields a system of derived input demand equations:

$$\frac{\partial \pi_h(w, z_h, t)}{\partial w} = -x_h(w, z_h, t) \tag{2}$$

Whereas the (numeraire) output supply equation is derived using the definition of normalised profit:

$$y_h(w, z_h, t) = \pi_h(w, z_h, t) - x_h(w, z_h, t) \tag{3}$$

Empirical Model

This section starts by specifying the profit function that is used to determine price elasticities, elasticities of intensity and shadow prices of fixed inputs for conventional and organic arable farms. The normalised quadratic (see e.g. Shumway (1983), Moschini (1988), Oude Lansink and Peerling (1996)), is used here because it is a flexible and self-dual functional form. Also, it has a hessian of constants implying that convexity in prices can be tested and/or imposed globally. A further advantage of the normalised quadratic that is relevant in this study is its empirical simplicity. The normalised quadratic profit function for firm h takes the form:

$$\pi_h = \alpha_h + \sum_{i=1}^{4} \alpha_{hi} w_i + \sum_{j=1}^{5} \beta_j z_{hj} + \frac{1}{2} \sum_{i=1}^{4} \sum_{j=1}^{4} \alpha_{ij} w_i w_j + \frac{1}{2} \sum_{i=1}^{5} \sum_{j=1}^{5} \beta_{ij} z_{hi} z_{hj} + \sum_{i=1}^{4} \sum_{j=1}^{5} \gamma_{ij} w_i z_j \tag{4}$$

Where π and w_i are normalised profit and normalised input prices, with $i = 1$ (output), 2 (pesticides), 3 (fertilizer) and 4 (other variable inputs), using the price of output as numeraire. z_{hj} are quantities of fixed inputs and technological change, with $j = 1$ (labour), 2 (buildings), 3 (machinery), 4 (land) and 5 (trend). All α, β and γ are parameters to be estimated. Note that α_h and α_{hi} are firm-specific parameters.

Netput equations can be derived by applying Hotellings Lemma:

$$-x_{hi} = \alpha_{hi} + \sum_{j=1}^{4} \alpha_{ij} w_j + \sum_{j=1}^{5} \gamma_{ij} z_j \tag{5}$$

The (numeraire) output supply equation is obtained by using the definition of normalised profit:

$$\pi_h = y_h + \sum_{i=1}^{4} w_i x_{hi} \tag{6}$$

$$y_h = \alpha_h + \sum_{i=1}^{5} \beta_i z_i - \frac{1}{2} \sum_{i=1}^{4} \sum_{j=1}^{4} \alpha_{ij} w_i w_j + \frac{1}{2} \sum_{i=1}^{5} \sum_{j=1}^{5} \beta_{ij} z_i z_j \tag{7}$$

Price elasticities of netput i to the price of netput j (ε_{ij}), elasticities of intensity of netput i to fixed input z_j (ε_{iz_j}) and shadow prices of fixed inputs (w^s_{zi}) are given by:

$$\varepsilon_{ij} = \alpha_{ij} \cdot \frac{w_j}{\gamma_i} \qquad i,j = 2, \ldots, 4 \tag{8}$$

$$\varepsilon_{iz_j} = \rho_{ij} \cdot \frac{z_j}{\gamma_i} \qquad i = 2,..,4 \text{ and } j = 1,2, \ldots, 5 \tag{9}$$

$$v^s_{zj} = \beta_j + \sum_{k=1}^{5} \beta_{jk} z_k + \sum_{i=2}^{4} \gamma_{ij} v_i \qquad j = 1, 2, \ldots, 5 \tag{10}$$

The price elasticity of netput i to the price of netput j (ε_{ij}) gives the percentage change in netput i to a one percent change in the price of netput j. Similarly, the elasticity of intensity of netput i to fixed input z_j (ε_{iz_j}) gives the percentage change of netput I to a one percent change in fixed input z_j. The elasticities are calculated from the parameters of a short-term profit function (assuming the presence of some fixed inputs). Therefore, all elasticities reflect short-term responses of outputs and variable inputs to changes in prices and fixed inputs. The shadow price of fixed input z_j (w^s_{zi}) gives the change in profit following a marginal change in the quantity of fixed input z_j.

Data and estimation

The Agricultural Economics Research Institute (LEI-DLO) provided the data used in this study. Data of specialised arable farms (farms with more than 50% of total output consisting of marketable crops) were selected, covering the period 1990-1999. The farms usually remain in the panel for a period of two to about five to seven years, so the panel is incomplete. In total there are 29 organic arable farms and 571 traditional arable farms in the sample. Table 1 reports mean values and standard errors of the variables used in the empirical model.

Table 1. Mean values and standard error for organic farm characteristics averaged over farms and years

	Mean value	*Standard error*
Organic Farms (127 observations and 29 farms)		
Output (1990 guilders)	516713.50	299257.00
Fertilizer (1990 guilders)	–8316.74[a]	5980.55
Pesticides (1990 guilders)	–2303.34[a]	4096.30
Other inputs (1990 guilders)	–121341.00[a]	69463.55
Land (hectare)	36.76	15.65
Labour (quality corrected man years)	2.69	1.18
Machinery (1990 guilders)	273197.90	143751.40
Buildings (1990 guilders)	345163.10	200896.20
Trend (years)	4.73	2.83
Conventional Farms (2581 observations and 571 farms)		
Output (1990 guilders)	453259.22	368959.57
Fertilizer (1990 guilders)	–19927.61[a]	15021.70
Pesticides (1990 guilders)	–33878.52[a]	25955.02
Other inputs (1990 guilders)	–85212.62[a]	71778.64
Land (hectare)	61.81	42.37
Labour (quality corrected man years)	1.66	0.96
Machinery (1990 guilders)	311051.99	253832.37
Buildings (1990 guilders)	285390.13	282460.85
Trend (years)	4.65	2.51

a) Variable inputs have negative quantities as they are treated as netputs.

One output, three variable inputs (pesticides, fertilizer and other inputs) are distinguished. Output mainly consists of potatoes, sugar beets, cereals, vegetables[i] and livestock output. Other inputs consist of storage and delivery services, energy (fuels), seed and planting materials, certification, purchased feed input and custom farming costs (excluding fertilizers). Land represents the total area under crops and is measured in hectares; labour is measured in quality-corrected man-years and includes family as well as hired labour; capital includes capital invested in machinery and is measured at constant 1990 prices. The quality correction of labour is performed by the LEI and is necessary to aggregate labour from able-bodied adults with labour from young people or partly disabled workers.

Tornqvist price indices were calculated for outputs and other inputs (prices were obtained from the LEI-DLO, CBS). The price indices vary over the years but not over the farms, implying that relative price changes are the same for all farms in the sample. Implicit quantity indices[ii] were obtained for output, N-fertiliser, other variable inputs and all pesticides as the ratio of value to the price index. Using price indices that are the same for all farms in the sample for calculating implicit quantities implies that differences in the composition of inputs/output and quality differences are reflected in the quantity (Cox and Wohlgenant, 1986). The price premium that organic farms obtain for their products is accounted for by a higher implicit output quantity. A time trend is included to allow for technical change.

The system of equations to be estimated consists of the netput supply and demand equations (5) and (7). The profit function (4) is not included in order to avoid linear dependence across equations; note that all parameters of the profit function are identified in (5) and (7). Disturbance terms are added to the system of equations to take account of stochastic events (e.g. weather conditions), misspecification, measurement errors in dependent variables and optimisation errors. Every farm is assumed to have a different intercept reflecting differences in farm characteristics. Additionally it is assumed that all slope parameters of the estimated equations are equal across firms. This assumption is made since panel data estimation methods based on Least Squares or Maximum Likelihood estimation allow for estimating firm-specific intercepts in panel data with a large number of firms. The fixed-effects model is the appropriate estimation technique (Judge et al. (1982), but requires farms to be in the panel for at least two years. Because the disturbance terms may be correlated across equations, Seemingly Unrelated Regression is the appropriate estimation technique (Judge et al., 1982).

Estimation results

The parameter estimates and t-ratios for organic and conventional arable farms can be found in Appendix A: Tables A.1. The first set of results for organic farms showed that the condition of convexity in prices was violated. However, the violation was not significant at the critical 5% level and, consequently it was imposed using the Wiley, Schmidt and Bramble (1973) technique (see e.g. Dupont (1991) for an application of this technique). For organic arable farms 24.0% of the parameters is significant at the 5% critical level and 29% of the parameters is significant at the 10% critical level (Appendix A: Table A1). For conventional arable farms 63% of all parameters is significant at the 5% critical level and 73% of the parameters is significant at the 10% critical level (Appendix A: Table A1). For conventional farms, the R^2 of the equations for output, fertilizer, pesticides and other inputs are 0.91, 0. 93, 0.96 and 0.94; for organic farms these values are slightly lower, i.e. they are 0.75, 0.62, 0.79 and 0.83, respectively.

Shadow prices, price elasticities and elasticities of intensity for organic and traditional farms are successively discussed. The percentage of all parameters that are significant at the 5% critical level, within the organic sector, is extremely low, especially for estimates of price elasticities. This means that less weight can be given to these results.

Analysis of profits of organic and conventional arable farms shows that variable profit consistent with (1) and (4) of organic farms (369,406) exceeds that on conventional farms (292,308) by 77,098 guilders (26%). Variable profit represents the reward for the fixed inputs and shadow prices consistent with determine the value for individual fixed inputs. In economic terms, shadow prices are defined as the value that each additional unit of a fixed input represents to the farmer. The shadow prices of quasi-fixed inputs are presented in Table 1.

The shadow price of labour should be compared with the average annual costs of an employee who works 40 hours a week. In 1990 (i.e. the base year of the monetary items in the model), these costs were 47,600 guilders (KWIN, 1991), which is close to the shadow price of labour in conventional arable farming. The shadow price of machinery and buildings should be sufficient to pay interest, maintenance and insurance. Therefore values of about 0.12 and 0.10 are expected for machinery and buildings, respectively (KWIN, 1990). These values are somewhat higher than our finding of 0.10, respectively 0.07 for conventional farms. However the values are not significantly different from the expected levels at 5%. The shadow prices of labour, machinery and buildings for organic farms are not in line with those expectations. The negative value of labour suggests that the organic sector is too labour-intensive, i.e. labour is in the downward sloping part of the production function. Less labour in the organic sector would raise profit.

The shadow price of land for organic farms is not significantly different from the average gross margin (8887[iii]) for all crops at the critical level of 10%. Also the shadow price of land for traditional farms is not significantly different from the average gross margin (3937[iv]) for all crops, at the critical level of 10%. However, it can be seen that the shadow price of land for organic farms is clearly higher than the shadow price for conventional farms.

A further comparison of the shadow prices of quasi-fixed inputs for organic and conventional farms shows that shadow prices for land and trend are higher for organic farms then for conventional farms. The higher shadow price for time trend in organic farming, i.e. an annual increase in profit could represent learning effects and the time required for adaptation of agro-ecosystem and especially soil conditions to the new methods of production. This result seems in line with the Offermann and Nieberg (2000) who argue that profit in organic farming will only be lower in the conversion period and rise afterwards.

Price elasticities consistent with (8) are presented in Table 2. The own price elasticity of fertilizer is –1.69, indicating that a one percent increase in the price of fertilizer decreases demand for fertilizer by 1.69 percent. The cross price elasticities for inputs show that, in both sectors, fertilizer and pesticides are gross complements, whereas pesticides and N-fertilizer are gross substitutes with respect to other inputs. The price elasticities that relate to the output are generally small. In organic farming, all price elasticities of pesticides are much higher than in conventional farming: the own-price elasticity of pesticides is –6.84 in organic farming and –1.38 in conventional farming. However, it should be noted that two price elasticities related to pesticides are not significantly different from zero at the critical 5% level. The higher values for pesticides may nevertheless be attributed to the relatively small quantity of pesticides in organic farming.

The price elasticities that relate to the quantity of output are generally small, although output from organic farms reacts more elastically to changes in the price of other inputs and output than output from conventional farms.

Elasticities of intensity of netput quantities to changes in fixed inputs and time trend are found in Table 3. The results for time trend show that output of organic farms is increasing ceteris paribus by 0.41% annually. The result for time trend of output of conventional farms is not significantly different from zero. Therefore, output of conventional farms is not affected by technological change. These results suggest that organic farms are increasing their productivity at a very rapid pace. The increase in productivity may be a reflection of learning effects and a gradual adjustments of e.g. soil conditions to the organic production technology.

Labour is found to be a substitute for fertilizer on organic farms (although the elasticity is not significant at 5%) and a complement on conventional farms. Furthermore, it can be seen that labour increases the use of pesticides and other inputs on organic and conventional farms. The negative though not significant effect of labour on output of organic farms implies that organic farms use labour too intensively.

Table 2. Shadow prices of quasi-fixed inputs for the organic and traditional arable farms. (estimated ‘t-ratio’ in parentheses)

Variable	*Dimension*	*Organic*	*Conventional*
Trend	guilders/year	37621	954
		(3.36)	(0.62)
Land	guilders/hectare	12243	3937
		(1.94)	(6.74)
Labour	guilders/man-year	–41771	33594
		(–0.76)	(2.62)
Machinery	guilders/guilder	–0.06	0.10
		(–0.12)	(1.46)
Buildings	guilders/guilder	0.02	0.07
		(0.07)	(1.51)

Table 3. Price elasticities for organic (O) and Conventional (C) arable farms. (estimated ‘t-ratio’ in parentheses)

Quantity/ price	*Fertilizer*		*Pesticides*		*Other inputs*		*Output*	
	O	*C*	*O*	*C*	*O*	*C*	*O*	*C*
Fertilizer	–1.69	–1.18	–1.18	–1.38	2.90	2.30	–0.03	0.25
	(–1.83)	(–12.28)	(–2.29)	(–11.94)	(3.28)	(15.67)	(–0.02)	(5.70)
Pesticides	–3.41	–0.65	–6.84	–1.38	9.57	1.92	0.69	0.11
	(–2.29)	(–11.94)	(–1.19)	(–6.58)	(1.52)	(8.29)	(1.12)	(4.58)
Other inputs	0.16	0.44	0.18	0.78	–0.93	–1.28	0.59	0.06
	(3.28)	(15.67)	(1.52)	(8.29)	(–1.72)	(–11.91)	(1.00)	(2.33)
Output	0.00	–0.01	0.00	–0.01	–0.16	–0.01	0.17	0.03
	(0.02)	(–5.70)	(1.12)	(–4.58)	(–1.00)	(–2.33)	(1.13)	(0.79)

The elasticities of intensity related to the use of machinery and buildings are not significantly different from zero (at 5%) except for the effect of buildings on other inputs for conventional farms. This suggests that demand for variable inputs and supply of output are largely independent of the level of these quasi-fixed factors. Nevertheless, the relation between machinery and pesticides suggest a different role of machinery on organic vis-a-vis conventional farms. The effect of machinery on demand for pesticides implies that machinery and labour are substitutes on organic farms and complements on conventional farms. The substitutory relationship between machinery and pesticides on organic farms suggests a more important role for mechanical weeding, whereas on conventional farms the machinery acts as a complement for pesticides (e.g. spraying equipment) in activities aimed at crop protection.

Table 4. Elasticities of intensity for organic (O) and Conventional (C) arable farms (estimated 't-ratio' in parentheses)

Quantity/ price	*Trend*		*Labour*		*Machinery*		*Buildings*		*Land*	
	O	*C*	*O*	*C*	*O*	*C*	*O*	*C*	*O*	*C*
Fertilizer	-0.15 (-0.75)	-0.21 (-10.98)	-0.19 (-0.49)	0.15 (2.97)	0.52 (1.59)	-0.04 (-1.27)	-0.43 (-1.69)	0.04 (1.65)	1.21 (2.53)	0.90 (11.97)
Pesticides	-1.06 (-2.31)	-0.06 (-3.91)	0.56 (0.94)	0.09 (3.23)	-0.65 (-1.32)	0.02 (1.01)	-0.28 (-0.73)	0.01 (0.38)	2.52 (3.52)	0.69 (16.79)
Other inputs	0.27 (3.57)	0.04 (2.63)	0.08 (0.52)	0.17 (4.35)	0.12 (0.91)	0.03 (1.06)	-0.06 (-0.62)	0.07 (3.62)	1.07 (5.48)	0.88 (15.28)
Output	0.41 (6.44)	0.00 (0.00)	-0.19 (-0.40)	0.18 (2.81)	0.01 (0.03)	0.07 (1.35)	-0.01 (-0.04)	0.06 (1.66)	1.19 (1.79)	0.83 (8.42)

Elasticities of intensity related to the use of land are all significant at the critical 5% level or 10% level (output of organic farms). These results show that land is a crucial determinant of variable input demand and output supply. Furthermore, results show that land is playing the same role in organic and conventional farms, i.e. it is a complement for all inputs and it increases output. The large impact of land on demand for pesticides on organic farms shows that the dependence on the use of (organic) chemicals increases with farm size. The explanation for this is that smaller farms more easily use labour and machinery in crop protection than larger farms. Labour and machinery intensive crop protection strategies may not be feasible on larger farms because of insufficient supply of labour in peak seasons (in particular during off-school holiday periods) or insufficient capacity of weeding equipment. Insufficient supply of labour and or insufficient capacity for weeding may also render the labour and machinery-intensive crop protection strategies too risky on large farms. Land is also found to have a relatively strong positive (larger than 1%) impact on the supply of organic output. This effect implies that organic farms increase the intensity of the use of land (change the crop mix) when increasing the size of the farm. This may be caused by the fact that large farms more likely produce crops with a high gross margin such as potatoes and vegetables.

Conclusion

The purpose of this research was to analyse differences in profit and economic behaviour between organic and conventional Dutch arable farms. A profit function approach is adopted and is applied to panel data of Dutch arable farms over the period 1990 – 1999. In total there were 29 organic arable farms and 571 conventional arable farms in the sample. The model accounts for unobserved heterogeneity among the farms in the sample by employing a fixed-effects estimation technique. The small number of observations for organic farms causes a large number of parameters to be not significant at the 5% critical level, so results have to be interpreted with care. Nevertheless, interesting differences between organic and conventional farms are found.

The average annual variable profit for organic farms exceeds profit of conventional farms by 30%. The variable profit reflects the reward for the employment of quasi-fixed factors and technological change. The results of the shadow prices show that the larger variable profit of organic farms is mainly related to the use of land and technological changes. Learning effects and gradual adaptation of e.g. soil conditions to the organic farming technology explain the large contribution of technological change effect. The (negative) shadow price of labour on organic farms suggests over-use of labour. Price elasticities show that fertilizer and pesticides are gross complements in both sectors, whereas pesticides and N-fertilizer are gross substitutes for other inputs. Demand for pesticides and supply of output are generally more elastic on organic farms. Elasticities of intensity show that technological change, labour and particularly land are important factors determining variable input demand and output supply on organic and conventional farms. Results for time trend on organic farms also suggest relatively large pesticides saving and output increasing technological changes. This implies that learning effects and technological innovations have reduced the use of pesticides and increased productivity on organic farms. Furthermore, results show that organic farmers that increase the size of their farm become more dependent on the use of pesticides and increase the intensity of the use of land.

The policy implications of the results of this research can be elaborated along several lines. First, information about the large impact of technological change on profitability of organic farming could provide an incentive to conventional farmers having plans to switch to organic farming. Particularly, the technological change may compensate for the risk for farmers of a drop in income in the transition period. As such, this information could play a role in the extension provided to farmers. Second, results show that output of organic farms reacts more elastically to output price changes than output of conventional farms. Therefore, policies aimed at increasing the premium for organically produced output may provide a further incentive to farmers to switch to organic farming. Third, the result that machinery and pesticides are substitutes on organic farms suggests that policies that enhance the purchase of machinery by organic farms are likely to reduce disadvantage of organic farming resulting from limitations on the use of chemical pesticides.

Results of this research fit in the growing body of economic research aimed at comparing the economic performance of organic and conventional farms. This body of literature will continue to grow in the coming years with the increasing availability of farm level data of organic and conventional farms and the present interest of many West-European governments in enhancing the adoption of more (environmentally) sustainable farming technologies. An important issue for future research on comparing conventional and organic farms is the need for addressing the dynamic aspects of the switch from conventional to organic farming. Farmers switching from conventional to organic farming are expected to increase their productivity through learning and the gradual adaptation of the physical environment to the organic farming practice.

Notes

1. Only vegetables grown outdoor are included.
2. Aggregating inputs and outputs using expenditures and revenues, respectively assumes that inputs and outputs are homothetically separable.
3. Average for cereals, potatoes, sugar beet, onions, carrots, cauliflower and red cabbage (KWIN, 1997), in prices of 1990.
4. Average for cereals, potatoes, sugar beet, onions, carrots, cauliflower and red cabbage (KWIN, 1990).

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Appendix

Results of estimation

Table A.1. Estimation results for organic and conventional arable farms

Parameter	*Conventional*		*Organic*	
	Estimate	*t-ratio**	*Estimate*	*t-ratio **
$ß_1$	5517.95	5.96	18081.33	1.05
$ß_2$	68294.69	2.83	118295.50	0.62
$ß_3$	0.19	1.82	1.22	0.79
$ß_4$	–0.02	–0.27	0.05	0.17
$ß_5$	4838.36	0.95	–76637.00	–1.56
α_{22}	25200.51	12.28	10353.64	3.69
α_{23}	23504.23	11.94	13068.95	1.96
α_{24}	–39808.40	–15.67	–23111.40	–4.79
α_{33}	39846.34	6.58	13222.45	1.63
α_{34}	–56172.40	–8.29	–20970.30	–1.07
α_{44}	93771.57	11.91	24706.18	2.29
$ß_{11}$	–18.60	–1.65	179.55	0.42
$ß_{12}$	633.79	2.25	–467.33	–0.15

Parameter	*Conventional*		*Organic*	
	Estimate	*t-ratio**	*Estimate*	*t-ratio **
β_{13}	0.00	3.11	–0.02	–0.65
β_{14}	0.00	–3.46	–0.01	–0.64
β_{15}	136.66	2.62	509.57	0.93
β_{22}	–14321.60	–1.83	–14323.90	–0.32
β_{23}	–0.17	–4.20	–0.63	–1.50
β_{24}	0.14	4.05	–0.17	–0.60
β_{25}	–5866.78	–2.38	27160.14	2.14
β_{33}	0.00	1.97	0.00	1.87
β_{34}	0.00	0.20	0.00	–0.44
β_{35}	–0.01	–1.34	–0.04	–0.63
β_{44}	0.00	0.18	0.00	1.20
β_{45}	0.01	1.28	0.04	0.53
β_{55}	–263.02	–0.31	6158.90	0.70
ρ_{21}	–293.47	–11.97	–275.57	–2.53
ρ_{22}	–1827.20	–2.97	759.54	0.49
ρ_{23}	0.00	1.27	–0.02	–1.59
ρ_{24}	0.00	–1.65	0.01	1.69
ρ_{25}	1022.23	10.98	241.84	0.75
ρ_{31}	–379.70	–16.79	–153.24	–3.52
ρ_{32}	–1827.63	–3.23	–569.77	–0.94
ρ_{33}	0.00	–1.01	0.01	1.32
ρ_{34}	0.00	–0.38	0.00	0.73
ρ_{35}	461.97	3.91	588.59	2.31
ρ_{41}	–1207.59	–15.28	–3580.24	–5.48
ρ_{42}	–8614.70	–4.35	–3075.55	–0.52
ρ_{43}	–0.01	–1.06	–0.06	–0.91
ρ_{44}	–0.02	–3.62	0.02	0.62
ρ_{45}	–765.90	–2.63	–7188.55	–3.57

The t-ratios have been corrected for degrees of freedom after estimation. The correction is required when estimating the Fixed Effects model using the within transformation of the data (see Judge et al. (1982))