Switching from Conventional to Organic Farming – a Real Options Perspective

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Abstract

The objective of this paper is to explore the potential of the real options approach for analyzing farmers' choice to switch from conventional to organic farming. Understanding the determinants of this decision is relevant in particular for agricultural policy makers when predicting the response of farmers to supporting programs. An econometric model is applied to aggregated data of conventional and organic farms in Germany and Austria. The empirical analysis confirms the reluctance to adopt organic farming due to option-like effects. We conclude that the incentives for an adoption of organic farming have to be increased if a higher share of this production type is desired.

Keywords: organic farming, real options, switching regression, hysteresis.

1. Background and Objectives

Organic Farming is frequently regarded as a solution to environmental problems that are related to agriculture as well as to food safety problems. For that reason agricultural policy makers try to promote the change from conventional to organic farming in many countries. For example, the German government has announced the target to increase the share of organic farming from 2 to 20% in the time period from 2002 until 2012. Accordingly, several programs have been implemented providing considerable financial support for the adoption of organic farming. However, the share of organic farms is currently hovering at the 4% mark and the far majority of farmers seem to be reluctant to switch. This reluctance cannot be easily understood by simple economic arguments. Comparing the profits of farms of similar size and structure

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shows that organic farms in Germany frequently outperform conventional farms. Lampkin (1997) reports similar findings for farms in Great Britain.

A lot of research has been conducted to understand the motivation of farmers to adopt organic farming (cf. Pietola and Oude Lansink, 2001). According to Schneeberger et al. (2002) technical challenges and additional labour requirements are important barriers to adoption. Latacz-Lohmann (2002) emphasize that path dependencies play a role for the diffusion of organic farming and Padel (2001) stresses the meaning of tradition and other non monetary effects. An alternative explanation for the reluctance to switch from conventional to organic farming is provided by the real options theory (Dixit and Pindyck, 1994). In that view the adoption of organic farming compares to an investment. The returns to this investment are the difference of gross margins between organic and conventional production. It is well known that real options can cause economic hysteresis if the following conditions hold: first, the investment costs are (partially) sunk, second, the investment returns are uncertain, and third, the investor has flexibility to defer the investment. All three assumptions apply here. Apart from specific investments in animal friendly barns or other assets farmers have to gain considerable knowledge about the practice of organic farming and the marketing of such products. This investment in human capital is very specific and cannot be used elsewhere. Furthermore, the returns for this investment are uncertain due to price and yield fluctuations. Finally, farmers can choose the time of the adoption. However, the question remains how important the investment reluctance is that can be attributed to these characteristics and whether it is relevant for actual decision making of farmers.

The objective of this paper is to explore the potential of the real options theory for analyzing farmers' choice to switch from conventional to organic farming or not. Understanding the determinants of this decision seems to be relevant in particular for agricultural policy makers when predicting the response of farmers to supporting programs or designing such programs. The empirical part of the analysis focuses on the situation in Germany and Austria.

This paper is organised as follows: Section 2 briefly describes the theoretical model, which allowed simultaneous consideration of uncertainty, irreversibility, and flexibility. In section 3 the econometric model is presented followed by a description of the data in section 4. Section 5 provides the estimation results. Furthermore, results of a normative real options model are presented. The paper ends with conclusions (cf. section 6).

2. Theoretical Model

The decision problem considered here is similar to the entry and exit model developed by Dixit (1989) and our exposition closely follows his seminal paper. Consider a representative farmer who has the opportunity to switch from conventional to organic farming and vice versa. Such a change of technology causes switching costs s^o and s^c, respectively, which are sunk costs. The profits that can be earned in organic and conventional farming are p^o and p^c, respectively. The farmer's objective is to maximize the (appropriately discounted) net present value of his profits over an infinite time horizon. The optimal switching decision depends on the profit differential $p = p^o - p^c$. We assume that the profit differential follows a geometric Brownian motion:

$$dp = \mu p dt + \sigma p dz \tag{1}$$

μ and σ denote the drift and the volatility of the stochastic process, dz is a Wiener process. In a deterministic setting a change from conventional to organic farming is profitable, if p exceeds the annualized switching costs $r \cdot s^o$, where r is a discount rate. Quite analogue, $r \cdot s^c$ defines the classical trigger for a change in the opposite direction. While these thresholds consider the switching costs they do not take into account the uncertainty of the returns. Dixit (1989) shows that the conditions for switching between the two technologies in a dynamic stochastic context assuming equation (1) are given by:

$$\frac{1}{2}\sigma^2 p^2 \frac{d^2V^c}{dp^2} + \mu p \frac{dV^c}{dp} - rV^c = p \tag{2}$$

for a change from conventional to organic farming and

$$\frac{1}{2}\sigma^2 p^2 \frac{d^2V^o}{dp^2} + \mu p \frac{dV^o}{dp} - rV^o = -p \tag{3}$$

for a change in the opposite direction. V^o and V^c denote the present value of the profits from organic or conventional production, respectively. The conditions (2) and (3) follow from an application of stochastic dynamic programming. From the differential equation (2) and (3) in conjunction with standard boundary conditions one can derive triggers for the profit differential which determine the optimal strategy of switching between conventional and organic farming. It can be shown that the following relations hold:

$$p^{o*} > rs^o \equiv c^o \tag{4}$$

$$p^{c*} < -rs^c \equiv c^c \tag{5}$$

Whenever the profit differential exceeds p^{o*} it would be profitable for a conventional farmer to adopt organic farming. If p falls below p^{c*}, the best strategy is to turn back to conventional farming practice. (4) and (5) indicate that the real options triggers p^{o*} and p^{c*} deviate from the classical triggers and the range of inaction, i.e. the region between the p^{o*} and p^{c*}, increases. It has been emphasized in the literature that the wedge between the classical trigger and the real options trigger causes economic hysteresis and reinforces the inertia of the current production system. Under some regularity conditions (cf. Dixit, 1989: 629) explicit solutions for the two thresholds can be derived:

$$p^{o*} = \frac{r-\mu}{r}\frac{\beta}{\beta-1}c^{o} \tag{6}$$

$$p^{c*} = \frac{r-\mu}{r}\frac{\alpha}{\alpha+1}c^{c} \tag{7}$$

β and $-\alpha$ are the roots of the characteristic equation of the differential equations (3) and (4).

$$\beta = \frac{1-\frac{2\mu}{\sigma^2}+\left(\left(1-\frac{2\mu}{\sigma^2}\right)^2+\frac{8r}{\sigma^2}\right)^{\frac{1}{2}}}{2} > 1 \tag{8}$$

$$-\alpha = \frac{1-\frac{2\mu}{\sigma^2}-\left(\left(1-\frac{2\mu}{\sigma^2}\right)^2+\frac{8r}{\sigma^2}\right)^{\frac{1}{2}}}{2} < 0 \tag{9}$$

The terms $\beta/(\beta-1)$ and $\alpha/(\alpha+1)$ in (6) and (7) are the so called option multiples. Investigation of (6)-(9) reveals the determinants of the trigger values. In particular, comparative static shows that higher uncertainty increases the wedge between the classical and the real option triggers and thereby increases the optimal range of inaction. This result is taken up to formulate testable hypotheses in the empirical model that is described in the next section.

3. Empirical Model

Though an increasing number of articles adopt the real options theory to solve dynamic investment problems under uncertainty empirical applications of this theory are still rare. The empirical validation of real options models is hampered by several factors. First, the statements of the real options theory refer to unobservable triggers rather than to actual decision variables (e.g. investments), second economic hysteresis and investment reluctance cannot be uniquely related to option-like effects but may also be explained by other factors as for example risk aversion. Moreover, nonlinearities between endogenous and exogenous variables complicate the estimation. Nevertheless there are some attempts in the literature to test the empirical relevance of the real options theory. Here we adopt a model that has been proposed by Richards and Patterson (1998). Formally this approach is based on a switching regression model that has been introduced by Spiller and Huang (1986) to test for market efficiency. Richards and Patterson (1998) extend this model and incorporate a component that reflects an option-like effect. The model is than used to explain (seemingly) disequilibria on agricultural labour markets. An-other application of this model is carried out by Wossink (2000), who analyzes the investment behaviour of Dutch farmers when buying phosphate quota.

The model formulation starts from the intuition that the profit differential p may fall into three distinct regions. First, a region where p is so small in absolute value that it is not profitable to change the current production technology due to the sunk switching costs, second a region where p is so large that an adoption of organic farming is profitable and third a region where p is largely negative and induces a switch back to conventional farming. As mentioned above classical investment theory and real options theory differ in the determination of the thresholds that separate these three regions. According to classical arbitrage arguments the profit differential should not exceed the annualized switching costs. If deviations from the classical entry and exit barriers occur, this could be attributed to market imperfections but also to (quasi) options effects. The existence of options-like hysteresis seems plausible if the magnitude of the wedge between the classical trigger and the observable profit differential depends on variables that should have an impact on the option multiple, in particular the volatility and the drift rate of the stochastic process. This logic suggests defining the following three regimes for a discrete observation of the profit differential:

$$p_t = \begin{cases} c_t & \text{with probability } 1-\lambda_1-\lambda_2 \quad (10) \\ c_t^o\left(s^o\right)+o^o\left(\sigma_t,\mu_t\right) & \text{with probability } \lambda_1 \quad (11) \\ c_t^c\left(s^c\right)-o^c\left(\sigma_t,\mu_t\right) & \text{with probability } \lambda_2 \quad (12) \end{cases}$$

with $c_t = c + v_t$, $c_t^o\left(s^o\right) = c^o + v_t + u_t$, $c_t^c\left(s^c\right) = c^c + v_t - u_t$

(10) describes a situation where p varies around a constant c_t. v_t is normally distributed with mean zero and variance σ_v. This regime is compatible with the classical investment theory as opposed to the two other regimes. Equation (11) and (12) represent situations where p exceeds (falls below) the traditional triggers. p is now explained by c^o (c^c) plus (minus) a term o^o (o^c) that captures the options effect. These two deterministic components are interfered by an error term v_t and a half normal random variable u_t that has variance σ_u and is not correlated with v_t. The random term u_t may stand for market imperfections, time lags of realizing the change of the production technology or other factors that may cause hysteresis. Note that (11) and (12) show a formal analogy with a stochastic frontier model. The three regimes (10) to (12) are represented graphically in Figure 1.

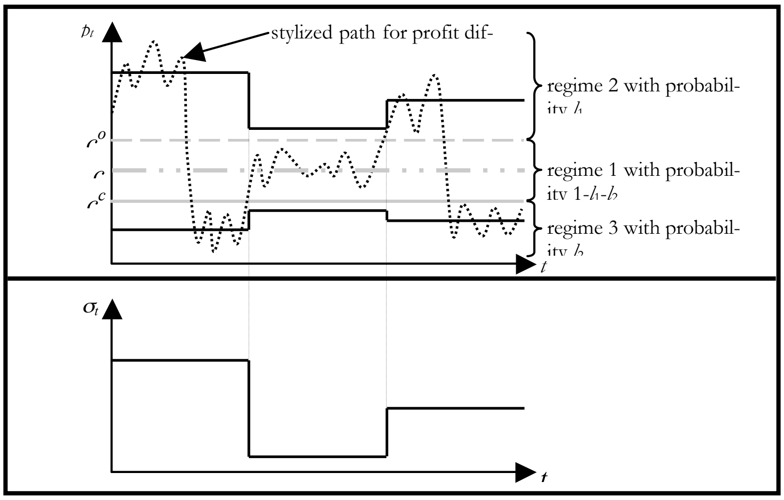

Figure 1. Regimes for the Profit Differential

The three regimes defined in equations (10) to (12) constitute a switching regression model with unknown separator variable (Greene, 1998). The likelihood function of this model has the form (Richards and Patterson, 1998; Sexton et al., 1991):

$$L = \prod_{t=1}^{T} \left(\lambda_1 \cdot f_t^1 + \lambda_2 \cdot f_t^2 + (1 - \lambda_1 - \lambda_2) \cdot f_t^3 \right) \tag{13}$$

The densities f_t^1, f_t^2 and f_t^3 are defined as follows:

$$f_t^1 = \frac{2}{S} \cdot \phi\left(\frac{Z_t^1}{S}\right) \cdot \left(1 - \Phi\left(\frac{-Z_t^1 \cdot \frac{\sigma_u}{\sigma_v}}{S}\right)\right) \tag{14}$$

$$f_t^2 = \frac{2}{S} \cdot \phi\left(\frac{Z_t^2}{S}\right) \cdot \left(1 - \Phi\left(\frac{Z_t^2 \cdot \frac{\sigma_u}{\sigma_v}}{S}\right)\right) \tag{15}$$

$$f_t^3 = \frac{2}{\sigma_v} \cdot \phi\left(\frac{Z_t^3}{\sigma_v}\right) \tag{16}$$

$$
\begin{aligned}
\text{with } Z_t^1 &= p_t - \left(c^o + o_1^o \cdot \sigma_t^2 + o_2^o \cdot \mu_t\right) \\
Z_t^2 &= p_t - \left(c^c - o_1^c \cdot \sigma_t^2 - o_2^c \cdot \mu_t\right) \\
Z_t^3 &= p_t - c \\
S &= \left(\sigma_u^2 + \sigma_v^2\right)^{0,5}
\end{aligned}
$$

ϕ denotes the density of a standard normal random variable and Φ is the corresponding cumulative distribution function. The unknown parameters c, c^o, c^c, o_1^o, o_2^o, o_1^c, o_2^c, σ_v, σ_u as well as λ_1 and λ_2 can be determined by maximizing the likelihood function (13). Significant positive values of λ_1 and λ_2 indicate that at least in some periods the profit differential is so large that it contradicts the traditional investment theory. Significance of the parameters included in o^o and o^c support the hypothesis that real options play a role for the adoption of organic farming.

The specification of the options effects o^o and o^c deserves some attention. In contrast to equations (6) and (7) the options effect enters the empirical model as an additive term and not as a multiple of the switching costs. Moreover, it is difficult to model the nonlinear relationship between the option multiple and its determinants according to equation (8) and (9). Following Richards and Patterson (1998), we approximate the option multiple by a linear function of the volatility and the drift rate, i.e. $o^o(\sigma_t, \mu_t) = o_1^o \cdot \sigma_t + o_2^o \cdot \mu_t$ and $o^c(\sigma_t, \mu_t) = o_1^c \cdot \sigma_t + o_2^c \cdot \mu_t$. Note that an estimation of the unknown parameters o_1^o, o_2^o, o_1^c and o_2^c requires some variability in the control variables σ und μ. It should be mentioned, that no assumptions about the stochastic process of the profit differential have to be made. In section 2 it was convenient to use the geometric Brownian motion, because we strived for a closed form solution. However, the assumption of a geometric Brownian motion (cf. equation (1)) is not very plausible for profit differences since it does not allow a change of the sign.

4. Data

The empirical analysis utilizes aggregated data from the German and Austrian farm accountancy network. Since 1982 (Germany) and 1986 (Austria), respectively, the economic performance of organic farms is compared with conventional farms of similar size and natural conditions. The comparison is based on samples of varying size. The number of farms varies about 150 (organic) and 240 (conventional) in Germany and 30 in Austria. Several financial indicators are displayed for the two farm types. For our analysis we use the total gross margins (TGM) of the two farm types to calculate the variable p. We refrain from using the farm profits since profits include the unknown switching costs. Furthermore, profits shown in the financial statements contain nonoperating expenses and revenues that cannot be attributed to the choice between organic and conventional farming. However, using the incremental TGM to approximate the returns of a changing the production technology is also not without problems. Organic farming frequently requires more labour input and less capital compared to conventional farming, but the total gross margin does not take into account the differences in these costs. Lacking the information to correct the TGM for these positions we have to assume that the higher labour costs and lower capital costs compensate each other roughly. The development of the incremental TGM in Germany and Austria is depicted in figure 2.

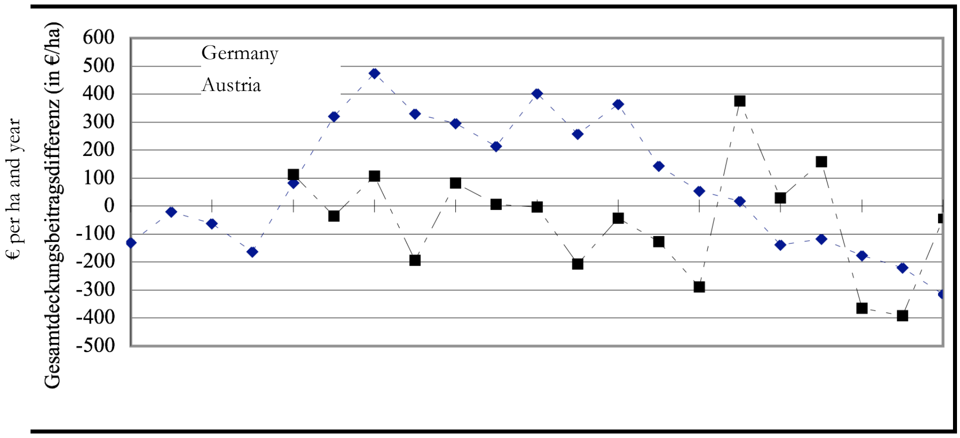

Figure 2. Difference of Total Gross Margin Between Organic and Conventional Production in Germany and Austria

The use of aggregated data has some obvious drawbacks. The depicted values of the TGM are the result of a mixture of various production activities that does not occur in individual farms. Moreover, the aggregation of individual data does not allow distinguishing the switching behaviour of different farm types. The switching costs are in general higher in livestock farms than in cash crop farms due to prescribed investments in animal friendly facilities. At the same time price premiums of organic milk and meat are in general low. Thus it can be expected that the willingness to adopt organic farming is smaller in intensive livestock farms. It has also been reported that farms operating under favourable natural conditions are more reluctant to convert to organic farming practices (cf. Pietola and Oude Lansink, 2001).

Pooling the data from Germany and Austria gives a time series with totally 38 observations. The number of parameters that have to be estimated reduces considerably compared to two separate estimations. However, differences in the adoption decision between both countries are likely to exist. For example, the interdependence between organic farming and other farm activities not included in the incremental TGM can be different. In this context Freyer et al. (2001) point out that the relationship between organic farming and on-farm-tourism is of particular importance in Austria, while this aspect is not so relevant in Germany. Moreover, the empirical switching behaviour may appear unequal due to the fact that the aggregated (synthetic) farms, on which the comparison between organic and conventional farming is based, are composed in a different manner. As a consequence a dummy variable, that takes country specific effects into account, is introduced.

As mentioned above the empirical model requires variability of the factors that potentially impact the option value of changing the production technology, namely the volatility and the drift of the incremental TGM. The sole variation of these factors between the two countries is not sufficient, since the influence of drift and volatility on the option multiple could not be separated from the country specific dummy variable. On the other hand, estimation of a time varying volatility model, e.g. a GARCH model, is neither an alternative regarding the shortness of the available time series. As a way out we separate the time series for the two countries at distinct points, where a structural break seems plausible and estimate different drift rates and volatilities for the four resulting periods. Thereafter this guess is tested for statistical significance. For Germany a structural change was assumed in 1992 since the McSharry reform was introduced at that date, which meant a renunciation of price support and the implementation of direct payments to farmers. A structural change can also be conjectured when Austria entered the European Union in 1995. Apart from the adaptation to the common agricultural policy the so called ÖPUL program has been launched. This program targets at fostering extensive and environmentally friendly farming systems. F-tests and t-tests, respectively, confirm the assumption of unequal variances (Germany and Austria) and of an unequal drift (Germany) before and after these periods on a 5 and 10 % significance level.

The solution of a switching-regression models combined with a stochastic-frontier model is not offered by standard econometric software packages. Therefore we maximize the likelihood function (13) directly by means of a genetic algorithm. The empirical t-values are calculated from the information matrix (cf. Greene, 2000: 131).

5. Results

Before we turn to the results of the econometric model we carry out some calculations with the normative model that was introduced in section 2. These calculations shall demonstrate the *potential* magnitude of option-like hysteresis in the context of the adoption of organic farming. The objective function of the farmer consists of maximizing the present value of the cumulated TGM difference from conventional or organic farming. The maximization is carried out with respect to the critical difference of total gross margins that triggers off the adoption of organic farming. We assume switching costs of €1500 per hectare and an interest rate of 6.75 %. Uncertainty enters the model through the difference of gross margins per ha of organic and conventional production. Statistical tests indicate that the differences of the gross margins follow an arithmetic Brownian motion for Germany and an integrated moving average process of the first order (IMA(1,1)-process) for Austria. Since no closed form solution exists for these stochastic processes, we determine the optimal entry and exit trigger for organic farming by stochastic simulation. The results are depicted in Table 1. According to the classical investment theory a gross margin difference of $c^o = €1500 \cdot 0{,}0675$ = €101 per hectare triggers a change from conventional to organic farming. If uncertainty and flexibility to defer the adoption decision are taken into account, the critical value increases considerably for Germany. Farmers should wait until the gross margin difference exceeds p^{o*} = €402 per ha and year before they convert to organic farming. In other words, farmers require an additional option premium of €301. Note that the difference between the classical trigger and the real options trigger can be neglected for Austria. The reason is that the total gross margin differences in Germany and Austria follow different stochastic process.

Table 1. Critical Differences of Total Gross Margins in Germany and Austria

	c^o	p^{o*}	$p^{o*} - c^o$
Germany	101	402	301
Austria	101	104	3

Table 2 shows the estimates for the switching regression model described in section 3. The estimates of the parameters λ_1 and λ_2 are significantly different from zero at a significance level of 5 % (critical t-value = 1.7). That means all three regimes are temporarily active, implying that market constellations occurred, which cannot be explained by the classical investment theory. The classical switching costs from conventional to organic farming are c^o = €169 per ha and year. For a change in the other direction the annualized switching costs are estimated at c^c = €70. This relation is not implausible, because changing back to the familiar production technology causes less transaction costs. The coefficients o_1^o and o_1^c, which are related to options effects, are also significant. That is, the higher the uncertainty of the relative profitability is, the higher is the reluctance to change the production system. The magnitude of this effect is remarkable: the incremental TGM that triggers a switch from conventional to organic farming increases by 0.888 times the standard deviation. The premium for German farmers equals 70 % of the classical trigger for an average standard deviation of €137 per ha and year. This dimension is not uncommon and coincides with the results of the normative calculations. The coefficients o_2^o and o_2^c of the drift are not significant. On the other hand, country specific effects are very pronounced. Obviously, Austrian farms are more willing to switch production technology. However, the magnitude of the dummy variable is implausible: subtracting this value from the classical switching costs for Germany, results in negative conversion costs for Austria (€169 - €295 = €-126). One possible explanation are synergy effects of organic land use with other farm production areas, which are very distinct in Austria as we mentioned above. Furthermore, the dummy variable may compensate an overestimation of the options effect for Austria. This overestimation could occur since the same parameters are estimated for both countries although the incremental TGMs follow different stochastic processes.

Table 2. Parameter Estimates of the Switching Regression Model

	parameter	estimated value	t-value
regime 1	$1-\lambda_1-\lambda_2$	0,259	–
	c	11,991	0,360
regime 2	λ_1	0,387	5,350
	c^o	168,637	7,526
	o_1^o	0,888	9,485
	o_2^o	0,397	0,810
regime 3	λ_2	0,354	4,599
	c^c	-70,499	-2,088
	o_1^c	0,676	4,633
	o_2^c	-1,037	-1,453
	σ_v	83,100	4,708
	σ_u	10,047	0,416
	d	-294,925	-2,486

6. Conclusions

For Germany, a normative and an empirical analysis show that the critical difference in total gross margins, that triggers an adoption of organic farming, is considerably higher than the annualized switching costs if uncertainty and the option to defer exist. Interestingly, this trigger is significantly smaller for Austria than for Germany. The analysis confirms the reluctance to adopt organic farming due to option-like effects for Germany. The results are also compatible with the fact that organic farming is more widespread in Austria.

From a policy maker's view, we conclude that the incentives for an adoption of organic farming have to be increased if a higher share of this production type is desired. There are three strategies to accomplish this: (1) a relative increase of the average gross margins of organic farming, (2) a reduction or compensation of the switching costs and (3) a decrease of the uncertainty of the gross margin differential between organic and conventional farming. The first two strategies have already been implemented in policy measures by granting acreage premiums and temporal adoption aid to organic farms. However, this financial support was obviously to low to compensate the inertia of conventional farming that is due to the joint impact of uncertainty, irreversibility and flexibility.

The empirical results are consistent with the hypotheses derived from the real options approach. However, one should be careful to interpret the results as a validation for the empirical relevance of the new investment theory. Caution is required for the following reasons: first of all, the proposed model is a crude simplification of reality. For example, fundamental changes of the farm organisation, as the adoption of organic farming, are time consuming. Hence the implicit model assumption that superprofits are immediately eroded is unrealistic and "disequilibria" may simply be explained by the time lag between the observed incremental TGM and the realization of the conversion. Furthermore, the estimation equations were not directly derived from the normative approach. Thus there is no rigorous connection between the empirical switching-regression model and the real options model. Finally, the significant impact of uncertainty that we found cannot be uniquely attributed to the existence of real options. Alternatively, the reluctance to adopt organic farming could be caused by risk aversion. Our model does not allow distinguishing both factors. However, this distinction may be not so important when it comes to practical conclusions, because both mechanisms result in the same effect, i.e. an increasing range of inaction. All in all the suggested model can be regarded as a first step for an empirical validation of real options models. The development of more sophisticated structural models is a challenging task and a promising direction for further research.

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