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Farmers' Adoption of Extensive Wheat Production - Determinants and Implications

Finger, R.[1] and El Benni, N.[1]

1 Agri-Food and Agri-Environmental Economics Group, ETH Zürich, Switzerland

rofinger@ethz.ch

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Finger R. and El Benni N.

Abstract

Using FADN data, we analyse farmers' adoption decisions with respect to extensive wheat production, which is supported in Switzerland since 1992 with an ecological direct payment scheme. It shows that first year adoption was mainly characterized by free-riding effects. In particular small farms with low levels of input use and wheat yields adopted extensive wheat production. If later adoption phases are included, these differences in farm size between adopters and non-adopters vanish. However, the level of wheat yields is still an important adoption determinant. Less intensive producing farms (with lower yield levels) are much more likely to adopt extensive wheat production. In contrast, more intensively producing farms, i.e. those farms that may actually harm the environment, usually not adopt extensive wheat production. Thus, aggregated environmental effects of this programme may be limited and the effectiveness of voluntary participation in agricultural environmental protection programmes should be re-considered.

Keywords: extensive wheat production, agri-environmental programme, adoption analysis, Switzerland

JEL classification: Q1, Q5

1. INTRODUCTION

Reducing the environmental impacts of intensive crop production is a policy goal in many countries (e.g. Wu and Babcock, 1999). Thus, agri-environmental programmes towards the reduction of production intensities in crop farming are a key agricultural policy instrument (e.g. Serra et al., 2008). If participation is voluntary, farmers' responses to the offered incentive schemes determine the success of these programmes. An ex-post analysis of adopters' profiles can thus reveal if the programme has reached the targeted groups and if the agri-environmental programme has reduced environmental harmful input use. Thus, such analysis provides useful insights for policy makers and facilitates the improvement of future policy design.

In Switzerland, a voluntary ecological direct payment programme for extensive cereal and canola production was introduced in 1992 (El Benni and Lehmann, 2010). The primary goal of this ecological direct payment was the reduction of harmful impacts of agriculture on the environment (Finger, 2010a)[1]. For adopters of this ancillary payment scheme, no applications of fungicides, plant growth regulators, insecticides and chemical-synthetic stimulators of natural resistance are allowed (BLW, 2008). The use of herbicides, however, is still allowed in this programme. This ecological direct payment is available for all Swiss farmers without any

[1] One of the initial goals of this programme was also the reduction of overproduction in Swiss agriculture.

regional restrictions, but the extensive production programme and its obligations are on the top of cross-compliance obligations that farmers have to fulfil to receive general direct payments. The here presented analysis is focused on wheat, the most important crop in Switzerland and within this agri-environmental programme.

Current adoption rates for this programme in Swiss wheat production are above 50% (Finger, 2010b) and the environmental impacts of this large-scale adoption of extensive cereal production have been rated positive (BAFU, 2006, Nemecek et al., 2010). An analysis of the farm-level profitability of this programme (Finger, 2010b) has shown that adopters have substantially lower costs than non-adopters (e.g. due to lower pesticide and fertilizer expenditures). However, because of reduced input use, adopters face lower yield levels. Due to these opportunity costs, extensive wheat production (i.e. adoption) is only profitable if the ecological direct payments are taken into account. Besides the identification of profitability as a main driver for such adoption decisions, studies on the adoption of agri-environmental schemes (e.g. Walford, 2002, Ahnström et al., 2009, Siebert et al., 2006, Espinosa-Goded et al., 2010, Jongeneel et al., 2008, Vanslembrouck et al., 2002, Serra et al., 2008, Gardebroek, 2006, Barreiro-Hurlé et al., 2008, and Knowler and Bradshaw, 2007) have pointed out the influence of the following factors for the adoption decision: farmers' characteristics and occupation (such as age, education, wealth and off-farm employment), farm characteristics (such as farm size and land tenure), characteristics of the agri-environmental programme (e.g. the level of the environmental payment, programme requirements and transaction costs). Moreover, risk attitudes, farmers' environmental preferences and attitudes or behavioural norms have been indicated as potentially important.

In this paper, we investigate determinants and implications of adoption decisions towards extensive wheat production. More specifically, the goal of this paper is to identify the factors affecting the adoption decision as well as the influence of the adoption of extensive wheat production on food supply (i.e. yield levels) and potential environmental loads (i.e. pesticide and fertilizer use). Based on the background of the existing literature summarized above, we analyse the influence of several farm and farmers' characteristics on the adoption of extensive wheat production in Switzerland. The here presented analysis comprises two time horizons: Firstly, the adoption in the first year of the programme (1992) is analysed using a binary logistic regression. Secondly, also characteristics of adopters' in subsequent years are analysed using a duration analysis. The duration analysis takes the time span (i.e. the duration) till the programme is adopted by a farmer into account, and comprises the period 1992-2000. The here presented Swiss case study on extensification of wheat production provides insights that are relevant also for other countries that aim to establish voluntary agri-environmental programmes to reduce harmful environmental impacts of crop production (cp. e.g. Osterburg, 2005).

2. DATA AND METHODOLOGY

We use FADN data from wheat producing farms that are located in the major crop producing areas in Switzerland (Agroscope FAT Tänikon, 2005)[2]. In our dataset, 1312 farms have wheat production records in the year 1992, among those 390 adopted extensive wheat production. Thus, the adoption rate in the first year of the programme was 30%. Table 1 shows the geographical distribution of these observations. Note that some cantons have not been considered in the here used database due to limited data availability and particular due to their location outside of the Swiss Plateau (see Lehmann, 2010, for a description of the dataset). The observations are skewed towards the canton of Bern, which covers the largest area of the considered Swiss Plateau region. It also shows that adoption rates differ over space. In particular, the cantons Fribourg and Vaud located in Western Switzerland show low adoption rates in 1992. This fact is directly connected to some variables that are used later to explain adoption, e.g. farms of our sample located in the canton of Vaud are significantly larger and have a larger area under wheat. Due to these correlations, the farms location is not considered directly in the subsequently introduced regression models.

Table 1: Geographical distribution of observations

Cantons	**ZH/SG/TH**	**BE**	**LU/AR**	**FR/VD**	**SO/BL/SH**	**Sum**
Adopter	86 (22)	123 (67)	131 (11)	12 (9)	38 (12)	390(121)
Non-Adopter	167 (61)	368 (268)	168 (14)	155 (99)	64 (33)	922 (475)
Sum	253 (83)	491 (335)	299 (25)	167 (108)	102 (45)	1312 (596)

Numbers in the Table are frequencies in the full dataset, while numbers in parentheses are the frequencies in the reduced dataset. Abbreviations for Swiss Cantons: ZH-Zurich, BE-Bern, LU-Luzern, SO-Solothurn, BL-Basel Land, SH-Schaffhausen, SG-St.Gallen, AR-Aargau, TH-Thurgau, FR-Fribourg, VD-Vaud.

To allow for comparability of farm and farmers' characteristics before and after the adoption took place, only those farms from the initial set of 1312 farms were selected that have wheat production records in the FADN data for the years 1992 and 1990 and/or 1991. This final dataset includes 596 farms including 121 adopters of extensive wheat production, i.e. an early adoption frequency of 25%. The geographical distribution of the observations in this reduced dataset is also shown in Table 1.

2.1. Binary Logistic Regression

The first analysis is focused on the adoption in the first year of the programme 1992. In a first step, adopters and non-adopters are compared according to their farm and farmers characteristics of the years 1990 and 1991 (i.e. before the adoption took place) using the Mann-Whitney test. Based on the existing literature on the adoption of agri-environmental schemes presented above, we focus on the variables described in Table 2 to explain adoption of extensive wheat production.

[2] Note that the representativeness of the Swiss FADN (Farm Accountancy Data Network) data is limited due to the sampling methods applied (Meier, 2005).

Table 2: Definition of employed variables

Variable Name	Variable Definition for Mann-Whitney Test and the Logit Analysis	Variable Definition for the Duration Analysis
Dependent Variable:		
Adoption of Extensive Wheat Production	A=1 if farm i adopted extensive wheat production in 1992, else A=0	Length of time spell *t* till the farmer adopted extensive wheat production.
Explanatory Variables:	*Average values 1990 and 1991 are taken for explanatory variables*	*Lagged (one year) variables are used in the duration analysis. Thus, the adoption observation in year t is analysed based on explanatory variables from year t-1*
Wheat Area	Area under wheat in ha	
Arable Land	Size of the arable land in ha	
Age	Age of farm-head, 1991 value is used	
Land Tenure	Share of rented to total farm land	
Specialization on Crop Production	Share of revenue from crop production to total farm revenue	
Off-farm income	Share of off-farm income to total farm revenue	
Education	Is only reported in FADN data since 2003. If available for farm *i*, the average in the period 2003-2008 is taken. Levels range from 1 (no agricultural education) to 7 (university degree).	Education is not used in the logistic and the duration analysis due to the lack of observations
Yield	Wheat yield in dt/ha	
Pesticide Use	Expenditures on pesticides in wheat production in CHF/ha	
Fertilizer Use	Expenditures on fertilizer in wheat production in CHF/ha	
Wheat Price/Ecological Direct Payment	---	Ratio of Wheat Price and Level of the Ecological Direct Payment (see section 2.2)

To identify the most important factors explaining early adoption in the first year of the programme, a binary logistic regression model is used. Let A be the binary response variable, i.e. $A_i \in \{0,1\}$, i=1,…,n (farms), with π being the expectation that A=1 given X. In binary logistic regression this response probability is modelled as follows:

$$\log\left(\frac{\pi}{1-\pi}\right) = \alpha + X\beta + \varepsilon \qquad (1)$$

Where $\frac{\pi}{1-\pi}$ represents the odds of response A=1 given X, α denotes the model intercept, β is the vector of regression coefficients and ε the vector of error terms. The coefficient estimate β_i for variable x_i, is presented as log-odds: The exponential of the ith ($i = 1,\ldots p$) coefficient estimate is the odds ratio, i.e. the multiplicative change in the odds, (for A=1) when the ith variable increases by one unit and holding all other variables constant: $\exp(\beta_i) = \frac{\pi(x_1,\ldots,x_i+1,\ldots x_p)}{1-\pi(x_1,\ldots,x_i+1,\ldots x_p)}$.

2.2. Duration Analysis

In the second part of our analysis, we investigate determinants of adoption over the first 9 years of the programme, i.e. also including later stages of the extensive crop production

programme. Because FADN dataset is an unbalanced panel, we focus our empirical application of the duration analysis on 129 farms that have continuous production records in the 1991-2000 period[3]. The selection of farms from the sample starts from 1991 because (one year) lagged variables enter the duration model (cp. Table 2). The restriction of the analysed period to the year 2000 is motivated by the fact that adoption rates have been stable thereafter (Finger, 2010b).

In contrast to the logistic regression model, the duration analysis takes the length of time (duration) until extensive crop production is adopted by the farmer into account. Due the annual nature of cropping system decisions, time steps are defined in years (D`Emden et al., 2006). The launch year of the environmental programme for extensive crop production in 1992 defines the start of the analysed time spell. The end of this time spell is defined as the year of adoption (i.e. where the farmer has enrolled to this programme[4]), while observations for farmers that were not enrolled in the programme until 2000 are censored using a dummy variable[5].

In the duration analysis, the probability that the time spell T (time till adoption) is equal or larger than t is defined by the survival function. Thus, this function describes the probability of surviving (i.e. not adopting) in time t:

$$S(t) = 1 - F(t) = Prob\,(T \geq t) \qquad (2)$$

F(t) is the cumulative distribution function of T, where t is a realization of T and is the length of the time spell. Thus, F(t) describes the cumulative distribution of adoption events. The resulting survival function S(t) equals 1 at t=0 (i.e. the probability of adoption is zero before the programme has started) and the survival function strictly decreases towards 0 for $t \to \infty$. In our analysis, the hazard rate Θ(t) is of particular interest. It represents the probability that a farmer adopts extensive crop production in the next time interval f(t), given that the spell has lasted up to t:

$$\Theta(t) = \frac{f(t)}{1 - F(t)} = \frac{f(t)}{S(t)} \qquad (3)$$

In this paper we will use the proportional hazard model to estimate the effect of different covariates on the hazard:

$$\lambda(t, X) = \lambda_0(t)\exp(\beta' X) = \lambda_0(t)\lambda \qquad (4)$$

The explanatory variables are represented by X for which the parameters β have to be estimated. $\Theta_0(t)$ is the baseline hazard function which depends on t but not on the covariates X. The baseline hazard function describes the hazard when all covariates are equal zero and captures the way the hazard rate varies along duration. In contrast, λ=exp(β' X) summarize the differences due to farm and farmers' characteristics, i.e. λ is a farm-specific non-negative

[3] These 129 farms have the following locations (cp. Table 1 for descriptions): ZH/TG/SG: 11, BE: 76, LU/AR: 4 FR/VD: 27, SO/BL/SH: 9.

[4] We assume that the enrolment to extensive crop production happens just once for each subject and thus leave out repeated events, i.e. the possibility that individual farmers may alternate between adoption and abandonment. This assumption was first of all necessary because of limited data availability.

[5] This right-censoring of data is necessary because even if the farmer has not adopted the new technology until the year 2000, he might adopt in the future (i.e. the date of adoption is unknown).

function of covariates X. By using the proportional hazard model, we assume that the baseline hazard is common to all farmers. This means that the conditional probability of a change of state in a given short interval does not depend on the duration that has elapsed (De Souza Filho et al., 1999).

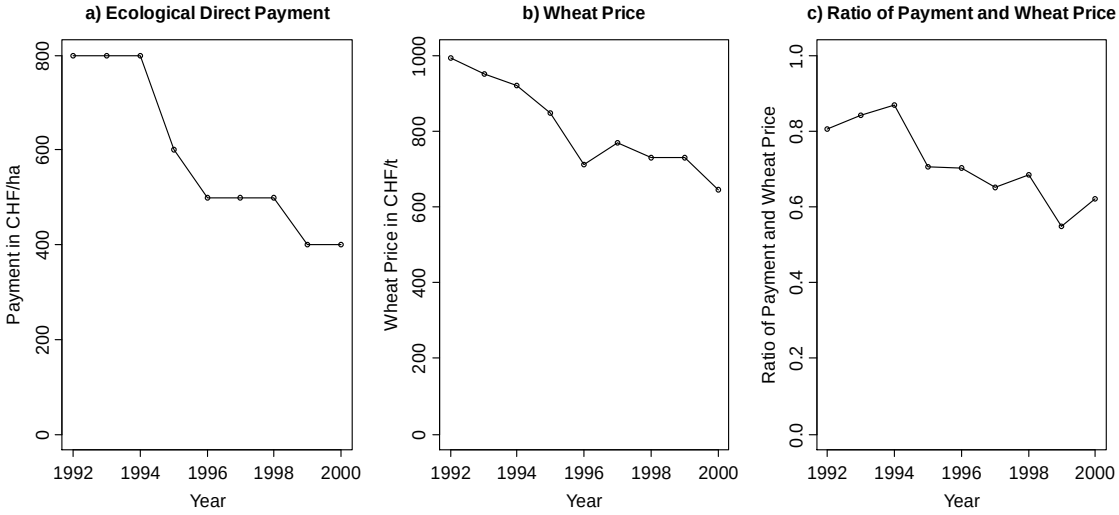
The duration model allows the explanatory variables to be fix and time-variant. To include time-dependent variables we re-organized the data set as proposed by Fox (2002). Each parameter summarizes the proportionate response of the hazard to a small change in the relevant covariate holding all other influencing factors constant. Negative (positive) parameters indicate that the explanatory variables have a negative (positive) effect on the conditional probability of adoption[6]. By taking the logarithm of the explanatory variables, the elasticity of the hazard rate with respect to changes in a given covariate is derived (Jenkins, 2005). Maximum likelihood procedures are used to estimate the parameters in the exponential model using the survival package in R (R Development Core Team, 2010).

The explanatory variables, i.e. the covariates, used in the duration analysis are identical to those used for the logistic regression (cp. Table 2). This allows us to compare if the same factors do explain early adoption as well as later adoption, or if certain factors that explain early adoption become less important over time. All variables enter the duration analysis model as time dependent and lagged (one year) values. Thus, the adoption observation in year t is analysed based on explanatory variables from year t-1[7]. In addition to the set of explanatory variables consisting of farm and farmers' characteristics (Table 2), we expect wheat prices as well as the level of the ecological direct payment to be very important for the adoption decision. Figure 1 shows that wheat prices and ecological direct payments for adopters of the extensive wheat production have decreased simultaneously in the considered 1992-2000 period. Due to the high correlation of both variables, we include the ratio of wheat prices and ecological direct payments in our analysis, which is displayed in the right panel of Figure 1. An increasing ratio, e.g. due to increasing wheat prices or decreasing ecological direct payments, decreases the adoption incentives because opportunity costs of yield level reductions due to extensive production increase. Thus, we expect that an increasing ratio of wheat price and ecological direct payment decreases the adoption probability and vice versa.

Figure 1: Development of the ecological direct payment, wheat price and the price/payment ratio from 1992 till 2000

[6] Another common specification for the hazard function is (among others) the Weibull probability distribution. As other parametrical distribution, the Weibull function makes assumptions on the effect of duration on the hazard function (see e.g. Jenkins, 2005) and are therefore suitable for modelling adoption where the hazard is duration dependent (D`Emden et al., 2006). However, we assume that the adoption of extensive crop production is not dependent on duration but solely on the explanatory variables specified.

[7] Lagged values are employed because mainly winter wheat is used in Switzerland, and the adoption decision observed in t thus already took place in t-1.



Source: BLW (2008) and FAO (2010)

3. RESULTS

Table 3 shows the comparison of farm and farmers' characteristics in 1990-1991 (i.e. before the adoption took place) of farms that adopted (non-adopted) extensive wheat production in 1992. It shows that adopters (i.e. participants of the extensive production programme) are characterized by a significantly smaller area under wheat (3.09 vs. 4.61 ha) and a smaller size of arable land. Moreover, adopters tend (significant at the 10% level) to rely stronger on off-farm income than non-adopters. No significant differences between adopters and non-adopters are indicated for land tenure, specialization on crop production and education. Most importantly, we find that adopters of extensive wheat production had a less intensive production before the adoption took place: Adopters' wheat production was characterized by a significant lower use of pesticides and fertilizer as well as lower wheat yield levels. This underlines the expectation that early adoption took place particularly at less productive soils, because such environmental payment offers incentives to reduce the production intensities at sites with low yield potential, i.e. lower opportunity costs (Zgraggen, 2005). Thus, the introduction of this programme for extensive wheat production has induced free-riding effects, which lowers the effectiveness of this programme at least in the early years of its launch.

Table 3: Mean of Farm and Farmers' Characteristics of Adopter and Non-Adopter in 1991-1992

Variable	**Adopter**	**Non-Adopter**
Characteristics		

Wheat Area***	3.09 ha	4.61 ha
Arable Land***	10.83 ha	13.25 ha
Age (n.s.)	42.94 (N= 108)	42.97 (N=424)
Land Tenure (n.s.)	0.48 (N=110)	0.50 (N=448)
Specialization on Crop Production (n.s.)	0.38	0.40
Off-farm income*	0.07	0.05
Education (n.s.)	3.68 (N=47)	3.58 (N=137)
Yield***	55.83 dt/ha	61.26 dt/ha
Pesticide Use***	204.14 (CHF/ha)	316.92 (CHF/ha)
Fertilizer Use***	345.87 (CHF/ha) (N=118)	406.87 (CHF/ha)
Number of Observations	121	475

*, ** and *** denote significance at the 10%, 5% and 1% level of the Mann-Whitney test. n.s. denotes not significant. See Table 2 for definitions of the variables.

3.1. Results of the logistic regression model for early adoption in 1992

In the logistic regression analysis, the variables arable land and education are not included in the model because area under wheat is significantly positive correlated (cor=0.84) with the size of arable land and the variable education has not enough observations (see Table 3) to conduct a meaningful regression analysis. Because the variables land tenure and age also contain missing values that reduce the degrees of freedom in the regression analysis, these variables are included in the logistic regression in separate models. The area under wheat has a highly skewed distribution and thus the logarithm of this variable is used in the logistic regression. The results of the binary response model are presented in Table 4.

The coefficient estimates are presented as log-odds, which signifies positive (negative) influence of the respective variable on the adoption probability if coefficient estimates are larger (smaller) than one. More specifically, the coefficient estimates can be interpreted as follows: A one dt higher yield in 1990/1991 leads to a 1.06-fold (1/0.947) decrease in the odds that a farmer adopted extensive wheat production in 1992 if all other variables are hold fixed. Due to the logarithm transformation of the variable wheat area, the interpretation of the odds ratio estimate changes as follows: a 1% increase in the 1990/1991 wheat area leads to a 2.28-fold (1/0.439) decrease in the odds that a farmer adopted extensive wheat production in 1992.

As indicated by the Mann-Whitney test presented in Table 3, the logistic regression shows that in particular the area under wheat as well as the production intensity (expressed by pesticide and fertilizer use and wheat yield level) explains the adoption behaviour in 1992. A higher specialization on crop production has a positive effect on the adoption probability, but is only significant at the 10% level in the models 2-3. In contrast, no influence of off-farm income[8], land tenure and age on the adoption decision is indicated by the logistic regression.

Table 4: Results of the logistic regression on factors explaining adoption in 1992

Variable	**Model 1**	**Model 2**	**Model 3**
Intercept	237.917 (5.003)***	283.724 (4.775)***	1260.574 (4.621)***
Log(Are under Wheat)	0.439 (3.782)***	0.431 (3.619)***	0.365 (3.856)***

[8] The difference between the Mann-Whitney test (Table 3) and the logistic regression (Table 4) with regard to the significances of the variables off-farm income and specialization of crop production is due to the significant (positive) correlation between these two variables.

Specialization on Crop Production	3.014 (1.548) (n.s.)	4.340 (1.891)*	3.999 (1.679)*
Off-farm income	1.350 (0.261) (n.s.)	0.858 (0.111) (n.s.)	0.616 (0.326)
Yield	0.947 (3.033)***	0.946 (2.853)***	0.938 (2.892)***
Pesticide Use	0.992 (6.048)***	0.991 (6.057)***	0.990 (6.022)***
Fertilizer Use	0.997 (2.366)**	0.998 (2.109)**	0.998 (1.677)*
Land Tenure	---	0.717 (0.824) (n.s.)	0.492 (1.612) (n.s.)
Age	---	---	0.990 (0.785) (n.s.)
Number of Observations	593	555	507
Pseudo R^2 (AIC)	0.23 (472.37)	0.23 (433.83)	0.26 (390.86)

Coefficient estimates are presented as log-odds. *, ** and *** denote that odds ratios are significantly smaller or larger than 1 at the 10%, 5% and 1% level, respectively. n.s. denotes not significant. The Pseudo R^2 is calculated as the quotient of residual and null deviance. AIC denotes the Akaike information criterion. See Table 2 for definitions of the variables.

Table 5 shows the expenditures on pesticide and fertilizer use as well as wheat yield levels for adopters and non-adopters in 1992 as well as percentage changes from 1990/1991 to 1992. In addition, Figure 2 shows box plots of fertilizer and pesticide use as well as crop yields from adopters and non-adopters for the period before and after the adoption. It shows that the differences in these variables between both groups are even larger after the adoption. More specifically, adopters reduced their expenditures on pesticides by about 31%, because only herbicides can be used in the extensive production scheme and contribute to the remaining pesticide costs. In contrast, no changes in fertilizer and pesticide use for the non-adopters have been observed from 1990/1991 to 1992. Wheat yield levels decreased for all farmers in this period, however, with a stronger decrease by about 15% for adopters. In summary, adopters decreased their pesticide use which also decreased yield levels as expected. However, this reduction is marginalized from an environmental point of view by the fact that pesticide use was already on a low level before the adoption took place.

Table 5: Input use and yield levels in 1992 as well as changes from 1990/1991 to 1992

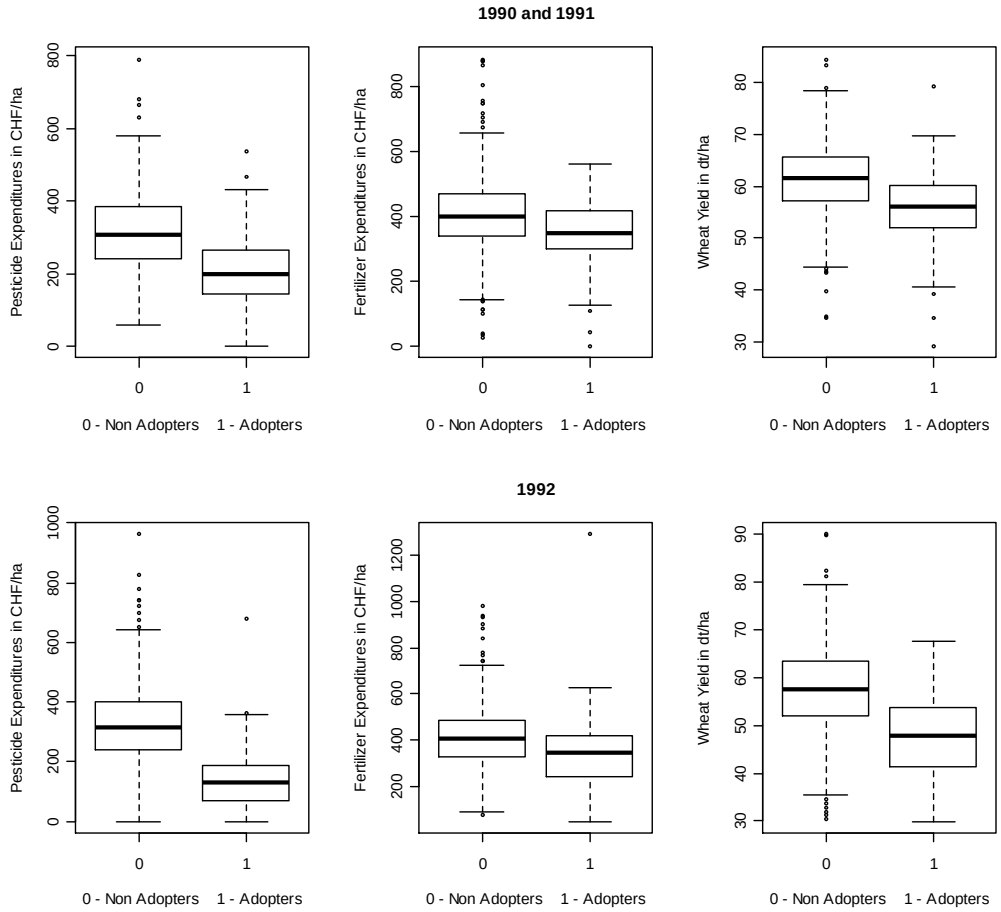
Variable	**Adopter**		**Non-Adopter**	
	Value in 1992	Change from 1990/1991 to 1992	Value in 1992	Change from 1990/1991 to 1992
Yield***	47.70	-15% ***	57.57	-6% ***
Pesticide Use***	140.31	-31% ***	329.63	+4% (n.s.)
Fertilizer Use ***	340.29	-2% (n.s.)	412.42	+1% (n.s.)
Observations	121		475	

*, ** and *** denote significance at the 10%, 5% and 1% level of the Mann-Whitney test. n.s. denotes not significant. See Table 2 for definitions of the variables.

Figure 2 shows that the variables contain some outliers (e.g. extensively producing farms with very high pesticide and fertilizer expenditures). The here used Mann-Whitney test is robust against such outliers. To control for outliers influence in the regression analysis, we used robust (outlier resistant) logistic regression (see Cantoni, 2004, for details). The only change revealed by using this robust logistic regression is that the variable yield is significant at the 5% level in all models. Furthermore, multicollinearity may affect regression results, which is tested using the variance inflation factor. For the here presented regression analysis, these factors range from

1.06 (Age) to 1.32 (Specialization on Crop Production) and are thus clearly below the threshold values reported in the literature (e.g. O'Brien, 2007).

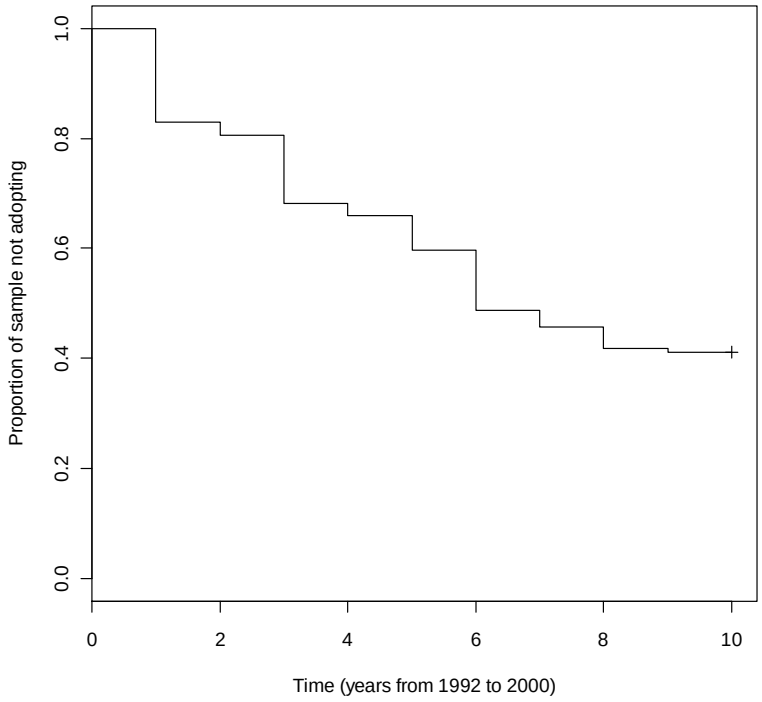
Figure 2. Pesticide and Fertilizer Expenditures and Wheat Yields: 1990-1991 and 1992.



3.2. Results from the Duration Analysis for the adoption within the period 1992-2000

Figure 3 shows the survival function estimated with the non-parametric Kaplan-Meier estimator that takes censored data into account. The function shows the frequency of non-adoption (i.e. survival) over time. Adoption rates decreased over time, i.e. showed a saturation effect. In total, 76 from the 129 considered farms (59%) adopted extensive wheat production in the period 1992-2000.

Figure 3: Survival function based on the duration analysis sample.



The results of the duration analysis (i.e. the conditional proportional hazard models) are shown in Table 6, where the parameters reported are the hazard rates. A hazard rate greater (smaller) than 1 indicates that the covariate has a positive (negative) effect on the likelihood of adoption. The significances of the parameters are reported in parentheses as p-values. Note that in line with the procedure used in the logistic regression, the variables age and land tenure are entered in the model in additional steps. Similar to the results from logistic regression for early adoption, it shows that in particular higher yield levels in the year t-1 decrease the probability that a farmer adopts extensive wheat production in year t. Though the estimated effects of pesticide and fertilizer use still show that especially low levels of input use are associated with the adoption of extensive production techniques, these effects are no longer significant.

Moreover, the significant influence of the area under wheat disappears in the duration analysis. While early adopters in 1992 were characterized by a smaller area under wheat, no differences in this variable are indicated if a longer time horizon is considered. After mostly small farms entered the programme in 1992, adoption of extensive wheat production was not limited to small farms if a longer time horizon is considered. As expected, the ratio of wheat price and the amount of the ecological direct payment (Figure 1) has a negative effect on the probability that farmers adopt extensive crop production. Hence, the higher the opportunity costs are, the lower is the probability of adoption.

Table 6: Results of the generalized and restricted proportional hazard models

Variable	**Model 1**	**Model 2**	**Model 3**
Log(Area under Wheat)	1.173 (0.50)	1.158 (0.54)	1.186 (0.49)

Specialization on Crop Production	2.341 (0.33)	2.340 (0.33)	2.209 (0.37)
Off-farm income	1.389 (0.73)	0.731 (0.80)	0.848 (0.90)
Yield	0.966 (0.04)*	0.969 (0.07)*	0.969 (0.08)*
Pesticide Use	0.999 (0.82)	0.996 (0.71)	0.999 (0.72)
Fertilizer Use	0.984 (0.11)	0.984 (0.13)	0.998 (0.13)
Price/Payment Ratio	0.000 (0.00)***	0.000 (0.00)***	0.000 (0.00)***
Land Tenure	---	1.327 (0.51)	1.360 (0.48)
Age	---	---	1.006 (0.69)
Number of (total) Observations	766[1]	740[1]	740[1]
Log-Likelihood (Pseudo R^2)	-259.102 (0.19)	-250.783 (0.19)	-250.704 (0.19)

[1] The number of (total) observations is based on single observations of 129 farms over 9 years or – if they adopted extensive wheat production – till the year of adoption. Some observations have been removed due to missing values. All coefficients are presented as hazard ratios and significance levels (p-values are reported in parentheses) for the null hypothesis that hazard ratios are equal to one. * and *** denote significance at the 10% and 1% level, respectively.

4. DISCUSSION AND CONCLUSION

In this paper, we investigated characteristics of adopters and non-adopters of an ecological direct payment scheme for extensive crop production in Switzerland. The analysis was based on FADN data and focused on wheat production. For the first year of the programme in 1992, i.e. early adoption, our results show that mostly small farms that already produced with low intensity subscribed to the environmental programme. These farms had a significant smaller area under wheat and used less pesticides and fertilizer (resulting in lower wheat yields) in the years before the programme was established. Using a duration analysis, the adoption determinants over the period 1992-2000, i.e. including late adopters, have been investigated. Similar to the analysis of early adoption characteristics, it showed that in particular low levels of wheat yields (and input use) increase the adoption probability. In contrast, the area under wheat does not affect the adoption decision of farmers that enter the programme after 1992. Land tenure, age and the importance of off-farm income had no effect on the adoption decision.

The here presented results indicate that early adoption was primarily based on free-riding effects. Mainly small farms that already used low levels of fertilizer and pesticides – and thus required only little adjustments in input use – adopted the ecological direct payment scheme on extensive wheat production. This is in line with results of Brotherton (1991) and Wilson (1997) who found that in particular the way an agri-environmental scheme fits into the current farm programme determines its uptake. In contrast, adoption over the entire first 9 years of the programme was not limited to small farms. However, the ratio of wheat prices and the level of the ecological direct payment influenced the adoption decision significantly. It shows that in particular decreasing opportunity costs of the adoption (e.g. due to decreasing wheat prices) increases the adoption probability.

The duration analysis shows that the level of wheat yields (and input use) is an important determinant for adoption of extensive wheat production. Thus, farms with high wheat yields, i.e. potentially large yield decreases (large opportunity costs) due to the adoption of extensive production techniques, are less likely to adopt this agri-environmental programme. Furthermore, the logistic regression (and partially the duration analysis) shows that farms that already use low

levels of pesticides are more likely to adopt extensive wheat production. This might indicate that in particular farms that face low pest pressure and thus use fewer pesticides are typical adopters.

Though farmers reduce their pesticide use after the adoption of extensive wheat production, our comparison for early adopters showed that this reduction starts on a relatively small level of input use. In contrast, farms with high input use (and high wheat yields), i.e. those farms that might actually harm the environment, are not primarily reached with such voluntary participation program. Thus, even though extensive production is less environmental harmful than its conventional counterparts if it is assessed in field trials (see Nemecek et al., 2010), it is not clear if the reductions of pesticide use are comparable large in practice because (very) intensive producers are less likely to really adopt this extensive production technique. This means that the reduction of environmental harms from wheat production at large due to the extensive crop production programme may be smaller than it is indicated by field trials.

Therefore, the effectiveness of voluntary participation in agricultural environmental protection programmes (see e.g. Wu and Babcock, 1999, for discussions) in Switzerland must be re-considered. In contrast to voluntary participation schemes, bans or limitations of specific agro-chemicals as well as taxes on harmful inputs would also reduce input use at intensively producing farms. These results for Swiss wheat production might also point a way for other countries if applying large-scale voluntary agri-environmental programmes towards more extensive crop production techniques.

However, any (politically motivated) reductions of environmental loads from crop production must take into account the associated reduction of food production. Our analysis shows that wheat yield levels reduced after the adoption took place. Moreover, Finger (2010b) found lower increases of wheat yields over time (i.e. technical progress) for extensive wheat producers[9]. Together with high adoption rates (i.e. a large-scale adoption) of extensive wheat production, these effects have contributed to stagnating wheat yield levels in Switzerland since the early 1990s (Finger, 2008, 2010a). Thus, less intensive production should be evaluated from a societal point of view taking its costs (due to the financial compensation of the farmers) and forgone food production into account.

In this paper, we have combined logistic regression with duration analysis in order to identify characteristics of adopters of extensive wheat production in Switzerland. This allows us to distinguish short term effects of an agri-environmental programme (i.e. early adoption) and long-term adoption patterns. The use of farm-level bookkeeping panel data enables a before-after comparison of adopting and non-adopting farms. The use of panel data in the duration analysis contrast other studies on the adoption of environmental friendly production methods, which often had to rely on survey data (e.g. Fuglie and Kascak, 2001, Kallas et al., 2010, Läpple, 2010, Wynn et al., 2001). The advantage of our approach is that explanatory variables

[9] Lower yield increases over time might be explained by the fact that the choice of varieties in extensive production (i.e. with restricted use of pesticides) is rather focused on improved pest tolerances than on high yield levels.

can vary over time for each farm. The next step for future research should consider farmers' attitudes towards the environment and agri-environmental payments in the analysis of adoption factors. To this end, panel data over a long time period should be combined with survey data.

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