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Farmers' Adoption of Extensive Wheat Production - Determinants and Implications

Abstract

Using farm-level panel 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 in particular farms with a small area under wheat, low levels of input use and low wheat yields adopted extensive wheat production in the first phase of the programme. If later adoption phases are included in a duration analysis, the difference in wheat area between adopters and non-adopters vanish. However, the level of wheat yields and input use still tend to be lower for adopters. Hence, less intensive producing farms (with lower yield levels) are much more likely to adopt extensive wheat production, which indicates free-riding effects. 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 not reach its full potential and the effectiveness of voluntary participation in agri-environmental programmes should be re-considered. Moreover, we find that changes in wheat prices and the ecological direct payment significantly influenced adoption decisions.

Keywords: agri-environmental programme, adoption analysis, duration analysis, logistic regression, Switzerland

1. Introduction

Reducing the environmental impacts of intensive crop production is a policy goal in many countries (e.g. Wu and Babcock, 1999). Therefore, 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 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 is the reduction of harmful impacts of agriculture on the environment (Finger, 2010a). 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 permitted in this programme and fertilizer use is not directly regulated. This ecological direct payment is available for all Swiss farmers without any 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. These cross-compliance obligations are currently fulfilled by almost all Swiss farms, and consist of ecological compensation areas, even nutrient balances, targeted applications of agro-chemicals, soil protection and regulated crop rotations (BLW, 2008, 2010). In contrast to organic farming, no adjustment of other farm activities is necessarily required if extensive production is adopted for a specific crop.

The here presented analysis is focused on wheat, the most grown crop in Swiss agriculture in general and within this agri-environmental programme in particular (SBV, 2010). Current adoption rates for this programme in Swiss wheat production are above 50% (Finger, 2010a). Thus, the programme on extensive production of wheat and other crops represents a core element of agricultural land use policy in Switzerland. The environmental impacts of this large-scale adoption of extensive cereal production have been rated positive (BAFU, 2006, Nemecek et al., 2011).

According to the Swiss agricultural profit margin calculations (AGRIDEA and FiBL, 2010), extensive wheat producers (i.e. adopters) have, in general, substantially lower costs than non-adopters, in particular due to lower pesticide and fertilizer expenditures. However, because of

reduced input use, adopters face lower yield levels (i.e. face forgone revenues). Due to these opportunity costs, extensive wheat production (i.e. adoption) is – on average – (slightly) more profitable than its intensive counterpart if and only if the ecological direct payments are taken into account (AGRIDEA and FiBL, 2010)¹.

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), and characteristics of the agri-environmental programme (e.g. the level of the environmental payment, programme requirements and transaction costs) (see Table 1 for hypotheses associated with these variables). Moreover, risk attitudes, farmers' environmental preferences as well as attitudes and behavioural norms have been indicated as potentially important.

In this paper, we investigate determinants and implications of adoption decisions towards extensive wheat production in Switzerland. More specifically, our goal 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). We combine logistic regression with duration analysis in order to identify adopters' characteristics. This combination expands earlier work and 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 furthermore 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). Thus, the advantage of our approach is that explanatory variables can vary over time for each farm.

The here presented analysis comprises two time horizons: Firstly, the adoption in the first year of the programmes' availability (1992) is analysed using a binary logistic regression. Secondly,

¹ Note that this represents average calculations and we are aware that this calculation is more heterogeneous across farms. Potential costs and benefits from adoption for the current non-adopters cannot be calculated because potential yield levels and input costs are not known (e.g. due to a lack of pest pressures and yield potentials). Site-specific biophysical analyses could contribute to overcome this lack of data in future research.

the 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 analysis does not consider adoption patterns beyond this period because the uptake of extensive wheat production was relatively stable since then (Finger, 2010a).

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 in order to reduce harmful environmental impacts of crop production (cp. e.g. Herzog, 2005). More specifically, the here indicated (partial) free-riding effects in voluntary programmes based on incentive schemes that are uniform across all farms in a country may point directions to avoid these effects by adjusting programme designs accordingly.

2. Methodology

In the first step of the analysis we focus on the adoption in the first year of the programmes availability in 1992, i.e. early adoption. To investigate adoption determinants, adopters and non-adopters are compared according to their farm and farmers characteristics in the years 1990 and 1991 (i.e. before the adoption took place) using the Mann-Whitney test. To reveal changes in input use and production levels due to the adoption of extensive wheat production, we also compare wheat yields as well as expenditures on pesticides and fertilizer for all farms before and after the adoption decision took place.

A binary logistic regression model is applied to identify the most important farm and farmers characteristics that determined early adoption in 1992 and to estimate its marginal effects on the adoption decision. In the logistic regression model, A is the binary response variable, i.e. $A_j \in \{0,1\}$, $j=1,\dots,n$ (farms), with π being the expectation that $A=1$ given the explanatory variables X which is modelled as follows:

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

In equation 1, $\frac{\pi}{1-\pi}$ 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 i th (

$i = 1, \dots, p$) coefficient estimate is the odds ratio, i.e. the multiplicative change in the odds (for $A=1$), when the i th variable increases by one unit and all other variables are hold constant:

$$\exp(\beta_i) = \frac{\pi(x_1, \dots, x_i + 1, \dots, x_p)}{1 - \pi(x_1, \dots, x_i + 1, \dots, x_p)} \quad (2)$$

In order to assess the goodness of fit of the logistic regression model, we conduct a cross-validation. To this end, a training dataset consisting of 50% of the observations is selected randomly, and the remaining observations are used as validation dataset. The training dataset is used to conduct a logistic regression and its estimates are subsequently used to predict the adoption decisions for the observations in the validation dataset. This cross validation procedure was repeated 1000 times for each model and the average percentage of correct predictions is presented.

In the second step, we use a duration analysis to investigate the adoption determinants over the entire first 9 years of the extensive crop production programme. In contrast to the logistic regression model, the duration analysis accounts for the duration until extensive crop production is adopted by the farmer. 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 is defined as the start of the analysed time spell. The end of this time spell is the year of adoption of each farm (i.e. where the farmer has enrolled to this programme²), while observations for farmers that were not enrolled in the programme until 2000 are censored using a dummy variable³.

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 $S(t)$. Thus, this function describes the probability of surviving (i.e. not adopting) in time t :

$$S(t) = 1 - F(t) = \text{Prob}(T \geq t) \quad (3)$$

$F(t)$ is the cumulative distribution function of T , the length of the time spell, where t is a realization of T . Thus, $F(t)$ describes the cumulative distribution of adoption events. The resulting survival function 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 $t \rightarrow \infty$. In

² 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. Thus, farms that adopted are not considered further.

³ 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).

our analysis, the hazard rate $\Theta(t)$ 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 :

$$\Theta(t) = \frac{f(t)}{1 - F(t)} = \frac{f(t)}{S(t)} \quad (4)$$

In this paper, we will use the proportional hazard model to estimate the effect of different covariates (i.e. explanatory variables) on this hazard rate:

$$\Theta(t, X) = \Theta_0(t) \exp(\beta' X) = \Theta_0(t) \lambda \quad (5)$$

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 , i.e. it describes the hazard when all covariates are equal zero. 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)⁴. In contrast, $\lambda = \exp(\beta' X)$ summarize the differences due to farm and farmers' characteristics, i.e. λ is a farm-specific non-negative function of the covariates X . 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). The estimated parameters summarize the proportionate response of the hazard to a small change in the relevant covariate holding all other influencing factors constant. By taking the logarithm of specific 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).

3. Data

We use Farm Accountancy Data Network (FADN) data from wheat producing farms that are located in the major crop producing areas in Switzerland (Agroscope FAT Tänikon, 2005, Lehmann, 2010). In our dataset, 1312 farms had wheat production records in the year 1992,

⁴ 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.

among those 390 adopted the environmental programme of extensive crop production. Thus, the adoption rate in the first year of the programme was 30%⁵. Note that organic producers are not considered in our analysis and thus were removed from the dataset (see e.g. Finger and Lehmann, 2012, for an analysis on the adoption of organic crop production). We find that early adoption differed across space, with lower adoption rates in Western Switzerland (cantons of Vaud and Fribourg). This observation is directly connected to some explanatory variables of our analysis, e.g. farms of our sample located in the canton of Vaud are significantly larger and have a larger area under wheat. Thus, regional differences are indirectly considered in our regression analyses. 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 comprising 121 adopters of extensive wheat production, i.e. an early adoption frequency of 25%. Table 1 presents the employed explanatory variables as well as the hypotheses associated with these variables which are derived from the literature. The variables on farm and farmers' characteristics are taken from the FADN data while wheat prices are taken from the FAO database (FAO, 2010). We have chosen to use national wheat prices to represent general developments in price levels. In contrast, farm-level price data can substantially differ from year to year due to different quality levels met, which potentially does not allow isolating the general price developments. The influence of price and quality variability on adoption of agri-environmental programmes, however, should be addressed in future research.

Table 1: Definition of employed variables

<p>Dependent Variable for the Mann-Whitney Test and Logit Analysis: A=1 if farm <i>i</i> adopted extensive wheat production in 1992, else A=0.</p> <p>Dependent Variable for the Duration Analysis: Length of time spell <i>t</i> till the farmer adopted extensive wheat production.</p>		
Explanatory Variables ^{a)}		Hypothesis associated with the explanatory variable
Wheat Area	Area under wheat in ha	Larger farms (with larger area under wheat) tend to have higher adoption probabilities (e.g. Siebert et al., 2006, Knowler and Bradshaw, 2007)
Arable Land	Size of the arable land in ha	

⁵ It also shows that early adoption rates differed across space, with lower adoption rates in Western Switzerland (cantons of Vaud and Fribourg). This observation 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, and thus indirectly considered in our regression analyses.

Age	Age of farm-head in 1991	Younger and better educated farmers are expected to have higher adoption probabilities (e.g. Barreiro-Hurlé et al., 2008, Jongeneel et al., 2008, Knowler and Bradshaw, 2007)
Education ^{b)}	Is only reported in FADN data since 2003. If available for farm <i>i</i> , the average in the period 2003-2008 is taken. Levels range from 1 (no agricultural education) to 7 (university degree).	
Land Tenure	Share of rented to total farm land	Land owners are expected to have higher adoption probabilities (e.g. Siebert et al., 2006), but ambiguous results have been found in the literature (e.g. Knowler and Bradshaw, 2007)
Specialization on Crop Production	Share of revenue from crop production to total farm revenue	Specialized farms may have higher opportunity costs and thus lower adoption probabilities (e.g. Vanslebrouck et al., 2002). However, ambiguous results with respect to farms' specialization have been indicated (e.g. Siebert et al., 2006)
Off-farm income	Share of off-farm income to total farm revenue	For more extensive production, positive effects of off-farm employment are expected (e.g. Jongeneel et al., 2008), while also ambiguous effects have been found (e.g. Siebert et al., 2006)
Yield	Wheat yield in dt/ha	More productive soils (i.e. higher yields, also implying lower intensities) negatively influence adoption probabilities (e.g. Knowler and Bradshaw, 2007)
Fertilizer Use	Expenditures on fertilizer in wheat production in CHF/ha	
Pesticide Use	Expenditures on pesticides in wheat production in CHF/ha	Lower costs and efforts due to the adoption decision (i.e. lower initial pesticide use) increase adoption probabilities (e.g. Vanslebrouck et al., 2002)
Price/Payment ratio ^{c)}	Wheat prices in CHF/ha divided by the level of ecological direct payments for extensive crop production in CHF/ha	Higher opportunity costs (forgone revenue, i.e. higher wheat prices) or lower levels of payments (i.e. an increasing ratio) decrease adoption probabilities (e.g. Siebert et al., 2006, Knowler and Bradshaw, 2007)

^{a)} For the Logit Analysis average values for the explanatory variables of the year 1990 and 1991 (i.e. lagged values) are taken. Also for the Duration Analysis Lagged (one year) variables are used. Thus, in the duration analysis the adoption observation in year *t* is analysed based on explanatory variables from year *t*-1. 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.

^{b)} The variable education is used for group comparisons with the Mann-Whitney test but not in the logistic and the duration analysis due to the lack of observations.

^{c)} The price/payment ratio is used as explanatory variable in the duration analysis.

Because the 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. The selection period starts in 1991 because (one year) lagged variables enter the

duration model (cp. Table 1). The restriction of the analysed period to the year 2000 is motivated by the fact that adoption rates have been stable thereafter (Finger, 2010a)⁶.

The explanatory variables, i.e. the covariates, used in the duration analysis are identical to those used for the logistic regression (cp. Table 1). This allows us to compare if the same factors do explain early adoption as well as later adoption patterns, or if certain factors that explain early adoption become less important over time. In addition to the set of explanatory variables consisting of farm and farmers' characteristics, we expect wheat prices as well as the level of the ecological direct payment (i.e. the payment for extensive crop production)⁷ 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 their ratio in our analysis, which is displayed in the right panel of Figure 1. An increasing ratio, e.g. due to increased wheat prices or reduced ecological direct payments, is expected to decrease the incentive to adopt extensive wheat production. This is because the opportunity costs of yield level reductions increase the lower (higher) direct payments (prices) become.

⁶ An adoption analysis of extensive and organic production in Swiss agriculture under in the years 2008 and 2009 is presented by Finger and Lehmann (2012).

⁷ Note that the level of payment includes only ecological direct payments for extensive wheat production (cp. Table 1), i.e. no other direct payments are considered here.

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

Source: BLW (2008) and FAO (2010)

4. Results

4.1. Group comparisons between adopters and non-adopters

In Table 2 early adopters and non-adopters of extensive wheat production are compared with respect to their farm and farmers' characteristics in 1990-1991 (i.e. before the adoption took place). Note that average values of the years 1990 and 1991 are reported throughout the paper. Definitions of variables as well as associated hypotheses are presented in Table 1. It shows that the adopters 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. No significant differences between adopters and non-adopters are indicated for land tenure, off-farm income, specialization on crop production, and education. Most importantly, we find that adopters of the environmental programme already produced less intensively before the adoption took place: adopters' had (compared to non-adopters) significantly lower expenditures on pesticides and fertilizer as well as lower wheat yield levels before the adoption decision took place. This underlines the expectation that early adoption took place particularly at farms with less productive soils and lower levels of input (especially pesticide) use. The introduction of direct payments for extensive wheat production thus offered adoption incentives for farms with low yield potential, i.e. where opportunity costs were lower (Zgraggen, 2005), as well as for farms with potentially lower pest-pressure. Thus, the introduction of the programme for extensive wheat production has, at least partially, induced free-riding effects.

Table 2: Mean of farm and farmers' characteristics of adopter and non-adopter in 1990-1991

Variable	Adopter	Non-Adopter
Characteristics		
Wheat Area***	3.09 (ha)	4.61 (ha)
Arable Land***	10.83 (ha)	13.25 (ha)
Age	42.94 (N= 108)	42.97 (N=424)
Land Tenure	48% (N=110)	50% (N=448)
Specialization on Crop Production	38%	40%
Off-farm income	7%	5%
Education	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)	406.87 (CHF/ha)
	(N=118)	
Number of Observations	121	475

*** denotes significance at the 1% level indicated by the Mann-Whitney test. See Table 1 for definitions of the variables. N denotes the number of observations if missing values reduced the sample size for specific variables.

Table 3 shows the expenditures on pesticide and fertilizer use and wheat yield levels for adopters and non-adopters in 1992. Furthermore, the percentage changes from 1990/1991 to 1992 are shown. Besides mean values, also 5% and 95% quantiles are presented for all variables in order to identify the heterogeneity in the observed effects.

The results show that the differences in pesticide use and yield levels between adopters and non-adopters increased after the introduction of the direct payment programme in 1992. More specifically, adopters significantly reduced their expenditures on pesticides by about 31% (the remaining pesticide costs include herbicides that are still allowed in the extensive production scheme). In contrast, no significant changes in pesticide use for the non-adopters have been observed from 1990/1991 (mean of both years) to 1992. Wheat yield levels decreased for all farmers in this period. However, stronger yield decreases (by about 15%) have been observed for adopters. In summary, adopters decreased their pesticide use which also decreased yield levels as expected. From an environmental point of view, it is important to note that this reduction of pesticide use took place on a low level, i.e. pesticide use was already low before the adoption took place.

Table 3: Input use and yield levels in 1992 as well as changes from 1990/1991 to 1992

Variable	Adopter		Non-Adopter	
	Mean Value in 1992	Mean change from 1990/91 to 1992	Mean value in 1992	Mean change from 1990/91 to 1992
	$[q_{0.05} - q_{0.95}]$	$[q_{0.05} - q_{0.95}]$	$[q_{0.05} - q_{0.95}]$	$[q_{0.05} - q_{0.95}]$
Yield (dt/ha) ^{xxx}	47.7	-15% ***	57.57	-6% ***
	[34.5-60.8]	[-40 - +12]	[42.2 -71.9]	[-13 - +18]
Pesticide Use	140.3	-31% ***	329.63	+4%
(CHF/ha) ^{xxx}	[0-305]	[-100 - +93]	[140-562.8]	[-54 - +83]
Fertilizer Use	340.3	-2%	412.42	+1%
(CHF/ha) ^{xxx}	[125.7 -568.4]	[-61 - +82]	[198 - 632]	[-41 - +57]
Observations	121		475	

$q_{0.05}$ and $q_{0.95}$ are the 5% and 95% quantiles, respectively. ^{xxx} in the left column denote significant differences between adopter and non-adopter with regard to their 1992 values at the 1% level (Mann-Whitney test). *** in the 3rd and 5th column denote significant changes from 1990/1991 to 1992 for adopter and non-adopter, respectively at the 1% level (Mann-Whitney test).

4.2. 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 models. The size of arable land is significantly positive correlated ($\text{cor}=0.84$) with the area under wheat and thus causes multicollinearity problems. The variable education has not enough observations (see Table 2) 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 (see Model 1-3 in Table 4). Because the variable area under wheat has a highly skewed distribution, we used the logarithm of this variable in the logistic regression models. Note that variables and the associated units are presented in Table 1.

The coefficient estimates of the binary response models that are presented in Table 4 are expressed as odds ratio. Positive (negative) influence of the respective variable on the adoption probability is indicated 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 constant). 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.

It shows that in particular the area under wheat and the production intensity (expressed by pesticide and fertilizer use as well as by wheat yield levels) explains the observed uptake of the extensive production programme. Farmers producing less intensively are more likely to adopt extensive wheat production. A higher specialization on crop production tends to have a positive effect on the adoption probability, but is not significant. Furthermore, no significant influence of off-farm income, 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 - without land tenure and age	Model 2 - without age	Model 3 -full model
Intercept	237.917 (5.003)***	283.724 (4.775)***	1260.574 (4.621)***
Log(Wheat Area)	0.439 (3.782)***	0.431 (3.619)***	0.365 (3.856)***
Specialization on Crop Production	1.011 (1.548)	1.015 (1.891)	1.013 (1.679)
Off-farm income	1.003 (0.261)	0.998 (0.111)	0.995 (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	---	0.997 (0.824)	0.993 (1.612)
Age	---	---	0.990 (0.785)
Number of Observations	593	555	507
Pseudo R ² (AIC)	0.23 (472.37)	0.23 (433.83)	0.26 (390.86)
Correct Predictions	81.55%	81.86%	82.19%

Coefficient estimates are presented as log-odds. ** and *** denote that odds ratios are significantly smaller or larger than 1 at the 5% and 1% level, respectively. The Pseudo R² is calculated as the quotient of residual and null deviance. AIC denotes the Akaike information criterion. See Table 1 for definitions of the variables and units used.

To ensure that the presented regression results are not influenced by outliers⁸, we used robust (outlier resistant) logistic regression to validate the results (see Cantoni, 2004, for details). The only change revealed by using this robust logistic regression is that the variable yield is

⁸ The here used Mann-Whitney test is robust against such outliers.

significant at the 5% level (instead the 1% 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). This is also underlined by comparing the three estimated models (Model 1-3, Table 4), where effects and significance levels of explanatory variables do not differ (except for fertilizer use which is not significant if farmers' age is included in Model 3).

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

Figure 2 depicts the survival function which is estimated with the non-parametric Kaplan-Meier estimator that takes censored data into account. The survival function shows the frequency of non-adoption (i.e. survival) over time. It shows that rates of (additional) adoption decreased over time which implies a saturation effect. In total, 76 from the 129 considered farms (59%) adopted extensive wheat production in the period 1992-2000.

Figure 2. 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 5. Parameters reported in this table represent hazard rates. A hazard rate larger (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. All covariates enter the model as lagged variables. 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 higher yield levels in the year t-1 decrease (though only significant at the 5% and 10% levels) the probability that a farmer adopts extensive wheat production in year t. Though the estimated effects of pesticide and fertilizer use still show that low levels of input use are associated with the adoption of extensive production techniques, these effects are no longer significant⁹.

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. Hence, after mostly small farms entered the programme in 1992, adoption of extensive wheat production was not limited to small farms in the subsequent years. As expected, the ratio of wheat price and the amount of the ecological direct payment has a dominating negative effect on the probability that farmers adopt extensive crop production. In line with our hypothesis, high opportunity costs reduce the adoption probabilities. This shows that the diffusion of an environmental programme depends strongly on economic incentives.

Table 5: Results of the generalized and restricted proportional hazard models

Variable	Model 1 - without land tenure and age	Model 2 - without age	Model 3 - full model
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)

⁹ No differences with respect to effects and significance levels of variables are indicated between the three estimated models.

Number of (total)			
Observations	766 ¹	740 ¹	740 ¹
Log-Likelihood	-259.102	-250.783	-250.704
Pseudo R ²	0.19	0.19	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%, 5% and 1% level, respectively. See Table 1 for definitions of the variables and units used.

5. Discussion and Conclusion

In this paper, we investigate characteristics of adopters and non-adopters of an ecological direct payment scheme for extensive crop production in Switzerland. The here presented analysis is based on FADN data and focuses 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. The lower initial levels of input use are in agreement with the hypothesis that more productive soils (i.e. higher yields, also implying higher intensities) negatively influence adoption probabilities (e.g. Knowler and Bradshaw, 2007). Mainly farms that 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 the uptake of a farm programme is particularly determined by the way it fits into the current farm programme. The observation that early adopters had a lower area under wheat (and smaller farms) contrasts the general hypothesis that larger farms are more likely to adopt agri-environmental programmes (e.g. Siebert et al., 2006, Knowler and Bradshaw, 2007). Altogether, these results indicate that adoption was, at least partially, based on free-riding effects.

Specialization on crop production, the relevance of off-farm income, and land tenure had no significant effect on adoption, which is in agreement with the ambiguous effects found in other studies (e.g. Siebert et al., 2006, Knowler and Bradshaw, 2007). We do not find significant differences between adopters and non-adopters with respect to age and education, which

contrasts the hypothesis that younger and better educated farmers are more likely to adopt agri-environmental programmes.

The adoption determinants in the first nine years of the programme, i.e. over the period 1992-2000, have been investigated using a duration analysis. Similar to the analysis of early adoption characteristics, it shows that low levels of wheat yields (and input use) still tend to increase the adoption probability. In contrast to the investigation of early adoption determinants, the area under wheat had no effect on the observed adoption decision during the entire first nine years of the programme. While early adoption was rather limited to small farms, also larger farms applied to the programme thereafter. Similar to the early adoption analysis, land tenure, age, and the importance of off-farm income had no effect on the adoption decision. The duration analysis shows furthermore that the ratio of wheat prices and the level of the ecological direct payment for extensive production influenced the adoption decision significantly. Thus, farmers' do react to economic incentives. Decreasing opportunity costs associated with the adoption decision (e.g. due to decreasing wheat prices) increases the adoption probability, while decreasing ecological direct payments (or increasing wheat prices) reduce adoption incentives. This underlines the expectation that economic incentives are of outmost importance in the uptake of agri-environmental programmes (e.g. Siebert et al., 2006, Knowler and Bradshaw, 2007).

Our results show that farmers reduce their pesticide use significantly after the adoption of extensive wheat production, which is expected to imply positive effects for the environment. However, our comparison for early adopters showed that this reduction of input use starts on a relatively low level. In contrast, farms with high input use, i.e. those farms that might actually harm the environment most, are not primarily reached with such voluntary participation programme. Thus, even though field trials show that extensive production is less environmental harmful than its conventional counterparts (see Nemecek et al., 2011), it is not clear if the reductions of pesticide use are comparable large in practice. This is because the most intensive producers are less likely to really adopt this extensive production technique. Hence, the reduction of environmental harms due to the extensive crop production programme at large may be smaller than it is indicated by field trials.

Our results show that 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. More effective reductions of environmental loads could be possible. 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.

Furthermore, also the use of ecological direct payments that are non-uniform but differ according to certain characteristics (e.g. regions that reflect yield potentials) could be used (Finger and Lehmann, 2012). These results for Swiss wheat production might point a way for other countries if applying large-scale voluntary agri-environmental programmes towards more extensive crop production techniques. The potential drawbacks of voluntary incentive schemes with uniform payment levels should be considered in the design of such programmes.

However, any (politically motivated) reductions of environmental loads from agriculture 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 producers¹⁰. Together with high adoption rates 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 also be evaluated from a societal point of view taking environmental benefits but also its costs (due to the financial compensation of the farmers) and forgone food production into account.

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. The presented approach could also be augmented by explicitly considering site-specific biophysical information on potential yield and pest pressure. This would allow approximating potential costs and benefits from the adoption of extensive wheat production for each farmer.

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¹⁰ 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. The paper Finger (2010b) is available upon request from the authors.

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