Short- and long-run policy evaluation: support for grassland-based milk production in Switzerland

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Short- and long-run policy evaluation: support for grassland-based milk production in Switzerland *

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Abstract

In recent years, concentrate supplementation in milk production has increased worldwide with negative effects on the environment and food security. To counteract this trend, Switzerland introduced an agri-environmental program to support grassland-based milk production in 2014. This paper combines ex-post and ex-ante methods to evaluate short- and long-run effects of this policy on environmental and economic outcomes and to evaluate the policy's contribution to food security. We find that the policy has no effect on environmental outcomes like ecological area and N surplus but substantial effects on economic outcomes like milk yield per cow and farm income. Furthermore, the program affects food security positively.

Keywords: policy evaluation, agent-based sector model, difference-in-difference, grassland-based milk production, agri-environmental program

JEL Classification: Q12, Q18, Q58

1 Introduction

After the deregulation of milk production in Switzerland, milk producers have strongly increased the proportion of concentrates they feed in order to raise productivity (Erdin and Giuliani 2011) and stay competitive in markets. This has unintended negative effects on the environment and on the supply and distribution of food (i.e., food security).

Milk markets fail to internalize negative externalities on the environment. The increase in concentrate feed use has led a growing number of farmers worldwide to intensify, abandon or convert grassland to arable land (Huyghe et al. 2010). This has negative effects on the value of grassland for society as a whole (Peeters 2009, Huyghe et al. 2010), as well as on the ecosystem functions of grassland (e.g., carbon sequestration and soil protection), in particular biodiversity (Dahms et al. 2008). Several papers argue that environmental sustainability of milk production deteriorates if high milk performance goes hand in hand with high concentrate supplementation (Cederberg and Mattsson 2000, Soder and Rotz 2001, Thomassen et al. 2008, Arsenault et al. 2011, Mack et al. 2009, Stott and Gourley 2016).

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Providing a growing (world) population with food of sufficient quantity and quality while simultaneously safeguarding the world's natural ecosystems includes a reduction in the use of food-competing feed components in livestock rations (Schader et al. 2015, Erb et al. 2012). The increased use of concentrate feed requires resources, like cereals and maize, that could otherwise be used for human consumption. Such an allocation, while possibly efficient from an economic perspective, raises moral and ethical issues regarding (global) food security in the face of a growing (world) population.

Against the backdrop of unintended negative effects on the environment and ethical issues regarding food security, Switzerland has introduced the first voluntary grassland-based milk and meat (GMF) program in Europe.[1] Introduced in 2014, the GMF program discourages the use of concentrate supplementation in milk production through feeding restrictions for grass, maize, and concentrates. Farmers participating in the program receive a payment of CHF 200 per ha of grassland in compensation for lower milk yields.

In this paper, we combine ex-post and ex-ante analysis to evaluate short- and long-run effects of the GMF program on the economic and environmental performance of Swiss dairy farms. Because the program was introduced recently, in 2014, ex-post analysis can only yield insights into its short-run effects. We estimate the causal short-run effects using a difference-in-differences (DiD) model based on FADN panel data from 2011 to 2015. To assess the long-run effects, we use ex-ante analysis based on the agent-based sector model SWISSland (Möhring et al. 2016).

The main contribution of this paper is to combine ex-post with ex-ante analysis to assess short- and long-run effects of policy measures. On the one hand, there is a literature on ex-post policy evaluation using empirical methods like DiD, fixed-effects models or instrumental variables (e.g., Petrick and Zier 2010, Sielawa and Helfand 2015, Liu and Henningsen 2016). On the other hand, there is a literature on ex-ante policy evaluation using (computational) simulation models (e.g., Deppermann et al. 2014, Cortignani and Severini 2012). However, the two strands of literature are usually independent. Our paper complements a small literature combining ex-ante and ex-post analysis in policy evaluation. For example, Finger et al. (2017) combine econometric time-series models with the static partial equilibrium model CAPRI to analyze the effects of reducing the processing aid for cheese in Switzerland. In contrast, we use causal inference (i.e., DiD) combined with the recursive-dynamic agent-based sector model SWISSland to evaluate economic and environmental effects of an agri-environmental program. Furthermore, this study closes a gap in the evaluation of different policy instruments supporting grassland-based milk production. Thus, we can also discuss the effects of direct payments for grassland conditional on environmental regulations compared to the effects of market-based policy measures like concentrate taxes (Hecht et al. 2014), or (unconditional) area payments (Deppermann et al. 2014, Hecht et al. 2015). Finally, our analysis could be of special interest to policy makers in the European Union since the recent abolishment of milk quotas may have similar effects on concentrate supplementation in EU dairy production. Since the GMF program is the first of its kind in Europe, conclusions drawn from our study are potentially interesting for policy makers in the EU but also other countries.

The remainder of this paper is organized as follows. Section 2 gives a brief overview of the dairy sector in Switzerland, and describes the GMF program in detail. Section 3 describes the ex-post and ex-ante methods. In Section 4, we discuss and compare the results for the short- and long-run analysis at farm and sector level. Section 5 concludes.

2 The Swiss dairy sector and the GMF program

Dairy production represents the most important production branch in Swiss agriculture. In 2015, approximately 583,000 dairy cows on 28,600 small-sized family farms produced more than 4 million tons of milk. Because of the climatic and topographic conditions, about two thirds of the agricultural area in Switzerland can only be used for grassland, not to mention the almost 500,000 ha of alpine summering pastures. In particular, the areas north of the Swiss Alps are ideal grassland areas with adequate temperature and rainfall which result in a high per-hectare pasture productivity (Thomet et al. 2011). Even though the level of concentrate supplementation in Swiss dairy production is less than half of that in Germany, France or the Netherlands (Schweizer Bauer 2014), trends are similar. From 1990 to 2009, concentrate supplementation increased on average by 23 kg per cow per year whereas milk yield increased

[1] GMF is short for "graslandbasierte Milch- und Fleischproduktion" in German.

on average by 100 kg per cow per year (Erdin and Giuliani 2011). In the last 15 years, tariffs on concentrate feed imports fell, which led to higher imports of concentrate feed for ruminants and to a decline in fodder crop area in Switzerland, having negative impacts on the environmental performance of Swiss dairy production (Agrofutura 2011, Sutter et al. 2013).

Against this background, the Swiss government introduced the grassland-based milk and meat (GMF) program in 2014. The program's goal is to promote animal production systems based on grassland that are characterized by low concentrate and maize supplementation (Bundesrat 2012). The program pays annually CHF 200 per ha of grassland to farmers if the proportions of concentrates and maize they use in total feed for all ruminants are lower than 10 percent and 25 percent respectively throughout the year. More precisely, the proportion of maize in total feed for ruminants must not exceed 25 percent for farms located in the lowlands, and 15 percent for farms located in the mountains. To receive payments, farms must fulfill all feeding restrictions. It does not matter where grass feed is produced, e.g., on the farmer's own farm, on any farm in Switzerland, or abroad. To be eligible for the program, farmers must declare their dry matter intake regarding concentrates, grass and maize for all ruminants. Each year, farmers enter the number and type of livestock, the quantity of concentrates and roughage purchased, and the amount of land and its use into an application form provided by the Swiss Federal Extension Centre (Agridea 2015). Based on these figures, proportions of concentrate, grass and maize in total feed are calculated.

3 Methods

This section describes in detail the methods used to assess both short- and long-run effects of the GMF program.

3.1 Short-run analysis: empirical methods

The goal of the empirical part is to estimate the causal short-run effect of the GMF program on various outcomes described below.

Data

We use FADN data of 736 Swiss dairy farms observed over the period 2011 to 2015 (Hoop and Schmid 2014). The Farm Accountancy Data Network (FADN) is the institution responsible for summarizing and analyzing data from farm accountancy departments and supplementary surveys of various data processors for research, education, consultation, determination of the economic status of agriculture, agricultural-policy decision-making and evaluation, as well as agricultural valuation, including valuation for tax purposes. Our panel contains farm-level data on concentrate feed (percent), maize feed (percent), grass feed (percent), milk yield per cow (kg), ecological area (percent), and farm income (CHF), as well as area (ha), number of ruminants (livestock units), milk price (CHF/kg), direct payments without GMF payments (CHF), location (valley, hill, mountain), farm type (crop, animal, combined), age and education of farmers. Proportions of concentrate, maize, and grass feed in total feed are computed based on FADN data and the specifications provided in the application form collected by the Swiss Federal Extension Centre (Agridea 2015). Quantities for concentrates and roughage are not available in the FADN data and were estimated by dividing concentrate costs for ruminants and roughage costs by average prices (Schmid and Lanz 2013). However, the data on concentrate costs in FADN also include expenses for the use of concentrates produced on-farm, which provides a sound basis for estimating the quantities of concentrate supplementation. Data on N surpluses are only available for a subsample of 62 dairy farms for the four-year period from 2011 to 2014. For those farms, data on N surpluses have been collected by the Central Evaluation of Agri-Environmental Indicators CEAEI (2017). Table 5 in Appendix A.1 shows summary statistics for the observation period 2011 to 2015.

Empirical model

We identify the causal short-run effects of the GMF program in a difference-in-differences (DiD) model, which compares participating and non-participating farms before (2011-2013) and after (2014-2015) the introduction of the program. Our baseline model is a regression formulation of the DiD model, and specified as follows:

$$Outcome_{it} = \alpha + \delta GMF_i + \sum_k \beta_k FARM_{ki} + \sum_j \gamma_j YEAR_{jt} + x'_{it}\eta + \varepsilon_{it}, \tag{1}$$

where $Outcome$ on farm i in year t stands for one of the following outcomes: concentrate feed (percent), maize feed (percent), grass feed (percent), milk yield per cow (kg), ecological area (percent), income (CHF), and N surplus (kg/ha). The dummy variable GMF takes the value 1 if farm i participated in the GMF program starting in 2014. The expressions $\sum \beta_k FARM_{ki}$ and $\sum \gamma_j YEAR_{jt}$ are full sets of dummy variables capturing unobserved farm-specific factors that are constant over time (e.g., location), and year-specific events that are common to all farms (e.g., weather conditions, concentrate costs). The vector x_{it} includes the following farm-year varying covariates: education (dummy variables for no education, vocational training, vocational training completed, further education, and tertiary education), age, farm type (dummy variables for arable crops, special crops, dairy, suckling cows, other cattle, horses/sheep/goats, pigs/poultry, combined dairy/arable crops, combined suckling cows, combined pigs/poultry, combined others), total area (ha), number of ruminants (livestock unit), milk prices (CHF/kg), and total direct payments w/o GMF payments (CHF).

We are interested in the coefficient δ on the variable GMF, which identifies the average treatment effect on the treated (ATT) of participating in the GMF program (see Blundell and Costa Dias 2009, Lechner 2010).

3.2 Long-run analysis: simulation model

We use the agent-based sector model SWISSland (Möhring et al. 2016) to project the long-run effects of the GMF program on the same outcomes discussed in the previous section: concentrate feed (percent), maize feed (percent), grass feed (percent), milk yield per cow (kg), ecological area (percent), income (CHF), and N surplus (kg/ha). SWISSland allows us to analyze the long-run effects of the GMF program at both farm and sector level.

The agent population of the model is based on 3,300 farms in the Swiss FADN database from 2011 to 2013. SWISSland projects farm and sector outcomes from 2014 to 2025. Agents' production decisions are determined by recursive-dynamic PMP-based farm-level optimization models (Möhring et al. 2016). After solving the optimization models of all agents, we aggregate farm supply to aggregate supply at the sector level (Möhring et al. 2016). Then we link aggregate supply with a partial equilibrium demand model to compute market prices for each product. Product prices in the first projection year provide agents' price expectations for the subsequent year (i.e., agents have adaptive expectations), which in turn determine their production decisions.

N surpluses are computed based on nitrogen farm gate balances implemented in the farm optimization models (Oenema et al. 2003). The farm gate balance accounts for nitrogen input and output, which are both estimated based on the results of the optimization model (Möhring et al. 2016). The N surplus measures the overall difference between input and output. Nitrogen input on farm scale originates from purchased nitrogen, i.e., fertilizer, feed or animals, as well as from nitrogen fixation and deposition. Nitrogen output accounts for the amount of nitrogen leaving the farm through sold agricultural products.

Predicting participation in the GMF program for a heterogeneous farm sample in the long run represents a challenge for an agent-based model like SWISSland. We estimate an agent's probability of participating in the GMF program based on a linear probability model (see Appendix A.2 for a detailed discussion). We assume that agents join the GMF program if the predicted probability is higher than 0.5. For those agents joining the GMF program and for whom the concentrate and maize limits are binding, we assume no further increase in milk yields. This assumption is based on the positive correlation of concentrate supplementation and milk yields observed in the data (Erdin and Giuliani 2011). For those agents not participating in the GMF program, we assume an annual increase in the milk yield that reflects the average growth trend over the last 15 years in Switzerland (Möhring et al. 2016). As observed in the data, the increase in milk yield in the model goes hand in hand with an increase in concentrate feed, which is calculated based on farm planning data. We further assume an increase in crop yields along with higher mineral fertilizer input, and a decrease in labor demand due to (labor-saving) technological progress (Möhring et al. 2016).

Those agents participating in the GMF program but not fulfilling the program's feeding constraints must expand the quantity of grass at the expense of concentrate or maize supplementation. We include the most relevant farm strategy options in the optimization models: (i) reduction in concentrate supplementation in dairy production which needs to be substituted equally with high-quality grass, (ii) reduction in the number of ruminants per ha of grassland, (iii) increase in grassland area at the expense of arable land, (iv) intensification of grassland from one to more additional cuts per year, (v) purchase of grass or hay. However, substituting concentrates with grass cannot fully compensate the nutrient loss. We therefore assume a decrease in milk yield per cow. The milk yield reductions are calculated based on feed recommendations for Swiss farmers from Agroscope (2016), taking into account the level of milk yield and the amount of concentrate reduction.

If land use or livestock numbers change as a consequence of participating in the program, labor demand is also affected. In this case, non-family labor is adjusted in the optimization process. Family labor and land capacities, however, remain at their initial levels. All ecological obligations which Swiss farmers have to fulfil in order to receive direct payments (nitrogen balance, requirement for 7 percent of ecological compensation areas and an upper limit on livestock densities per ha) are also taken into account.

4 Results and discussion

This section presents and discusses the results from the short- and long-run analysis.

4.1 Short-run analysis

First, we provide summary statistics showing in what respects farms participating in the GMF program differed prior to its introduction in 2014. Table 1 compares the mean values for a number of available characteristics on which we have data for farms participating and not participating in the GMF program. The participation rate is about 77 percent (see Table 5 in Appendix A.1). We see that farms participating in the GMF program are on average slightly smaller in terms of total farm area but have more grassland area. They have fewer ruminants, each producing less milk. Farms participating in the GMF program receive less direct payments, and are more often located in mountainous regions, and specialized in animal production. Farmers participating in the GMF program are more likely to have completed vocational education, and less likely to have further education. This shows that participating and non-participating farms were already different before entering the GMF program. This hints at selection issues.

[Table 1 about here.]

To check if the two groups followed a common trend before the program's introduction, we look at the evolution of all outcomes over time for both groups. Figure 1 shows that, prior to introduction, all outcomes for participating and non-participating farms followed a common trend. Until 2013, all outcomes evolved very similarly for both groups. After 2013, most outcomes of farms participating in the program start to deviate from those of non-participating farms. We conclude that, although there are observable differences in farm characteristics, all outcomes follow a similar trend for farms in both groups before the introduction of the program. This strengthens our confidence in the assumption that there are no important differences in unobserved factors between the two groups correlated with the decision to participate in the GMF program.

[Figure 1 about here.]

Third, we discuss the results from estimating model (1) by OLS. Model (1) identifies the ATT of the GMF program on a particular outcome. Columns in Table 2 show the results of model (1) for the following outcomes: concentrate feed (percent), maize feed (percent), grass feed (percent), milk yield per cow (kg), ecological area (percent), and income (CHF). We argue that, since both groups follow a common trend before the introduction of the program, there are no unobservable factors correlated with a farmer's decision to participate in the program. In other words, once we control for observable differences, we have taken care of selection issues. To estimate the unbiased effect of the program, there should be no interaction between farms participating and not participating in the program (called the stable unit treatment value assumption or SUTVA). However, there may be spillovers through market interactions. Since our ex-ante analysis explicitly models such interactions, comparing the results of the ex-post with ex-ante analysis offers a way of assessing potential biases.

[Table 2 about here.]

We see that the ATT of the GMF program on the proportion of concentrate feed is about 1 percentage point. The effect is statistically significant at the 1 percent level. It means that in the absence of the program the proportion of concentrate feed would have been almost 1 percentage point higher. We also see that the program has no effect on the proportion of maize feed, the proportion of ecological area, or the N surplus (kg/ha). All three coefficients are very small (both in absolute terms and relative to their pre-treatment means), and statistically not significant. However, the GMF program increases the proportion of grass feed by about 1 percentage point and income by approximately CHF 6,300, and decreases milk yield per cow by about 170 kg. All coefficients are statistically significant. We conclude that the GMF program has either no effect, or only very small effects, in the short run on environmental outcomes like ecological area and N surplus. However, the GMF program has an effect on economic outcomes like farm income (CHF 6,300 increase or almost 10 percentage points), and milk yield (170 kg/cow decrease or almost 3 percentage points) in the short run. Furthermore, the program substitutes grass feed at the expense of concentrate feed, i.e., concentrate feed increases by 0.9 percentage points whereas grass feed increases by 1 percentage point. This suggests a small but positive effect on food security.

4.2 Long-run analysis

In SWISSland, we compare the outcomes at farm and sectoral level in a scenario where the GMF program is in place with a reference scenario without the program (holding everything else constant). In other words, the scenario with the GMF program in place simulates the counterfactual. The difference between the two scenarios identifies the average treatment effects of the program.

Effects at farm level

Table 3 below shows the average treatment effects at farm level on the various outcomes (columns) in 2015, 2020 and 2025 (rows) respectively. The first panel shows the average treatment effect (ATE), the second panel the average treatment effects on the treated (ATT), and the third panel the average treatment effects on the untreated (ATU). The ATE measures the difference in mean (average) outcomes of all farms in a state without the GMF program, and a counterfactual state with the GMF program in place. Similarly, the ATT (ATU) measures the difference in mean outcomes of participating (non-participating) farms in a state without the program, and in a counterfactual state with the program. All simulation results can be found in Table 6 in Appendix A.2.

[Table 3 about here.]

Our discussion of the long-run effects estimated by SWISSland focuses on the average treatment effects (ATE); the discussion for ATT is very similar. In 2015, the GMF program leads on average to a reduction in milk yield of about 60 kg per cow, a 1.7 percent reduction in the proportion of concentrate feed, and an increase in the proportion of grass feed. In the long run, the impact of the GMF program on milk yield and proportions of concentrate and maize feed is increasing: the milk yield in 2025 is approximately 400 kg less per cow, and the proportion of concentrate feed is 2.6 percentage points lower, whereas the proportion of grass feed is 2 percentage points higher, ceteris paribus. The intuition is the following. Because participating farms cannot realize milk yield increases due to concentrate restrictions, the gap in milk yields between participating and non-participating farms grows. The GMF program does not affect the proportion of maize feed either in the short or the long run. However, the GMF program has a positive effect on farm income in the long run, of approx. CHF 8,000. On the one hand, there is a direct effect on farm income through the payment received from the program (compensation for forgone revenue from milk sales due to lower milk yields). On the other hand, there are indirect effects on farm income through lower feed costs, and higher milk prices due to lower milk supply (see discussion below on equilibrium effects at sector level). Here, it is interesting to see that non-participating farms gain even more from higher milk prices as their milk yields continue to grow. The GMF program has a redistributive aspect, in the sense that it redistributes income generated from milk sales from participating to non-participating farms through its effect on milk prices. Finally, the program has a small long-run effect on the ecological area and the N surplus. On average, the ecological area remains almost unchanged whereas the N surplus is about 3 kg per ha lower in 2025. We conclude that the GMF program has no or only a very modest effect on environmental outcomes but more substantial effects on economic outcomes and food security in the long run.

Effects at sector level

One advantage of the analysis with SWISSland over the empirical analysis is that it allows us to assess the effects of the GMF program at sector level (see Table 4 below).

[Table 4 about here.]

First, we see that the GMF program has a negative effect on farm exit. The intuition is that increasing farm incomes due to the GMF program lead to a lower exit rate since farm income is the main determinant of the exit rate (Möhring et al. 2015). Even though the number of dairy cows increases slightly due to the GMF program, it does not offset the effect of lower milk yields on milk sales. This leads to an equilibrium with lower milk supply, and higher milk prices. In fact, milk prices are about 6 cents higher per kg in 2025, leading to higher revenues from milk sales (i.e., the price effect dominates the quantity effect). Finally, the GMF program increases intensively used grassland while having a slightly negative impact on extensively used grassland. The cap on maize in the GMF program has no effect on the maize area. The GMF program has a small positive effect on the N surplus of the Swiss agricultural sector of about 2,000 tons. In the long run, the program's effect on the N surplus is almost constant even though the concentrate use in ruminant production is decreasing. The increase in intensively used grassland at the expense of extensively used grassland, which causes higher N input through fixation and through mineral fertilizer, partially compensates the positive effects of concentrate savings. However, the decrease in N output due to lower milk yields also reduces the positive effects of the savings. Last, we see that the increase in farm income exceeds the budget outlay of the GMF program. This suggests a high transfer efficiency, i.e., change in income due to the program in relation to the change in direct payments.

Existing ex-ante impact evaluations of direct payments for grassland without concentrate feed restrictions also show an extension of grassland area and dairy cows in Switzerland (Hecht et al. 2014, Hecht et al. 2015). However, these studies show that direct payments for grassland lead to an increase in milk supply with negative effects on milk prices, whereas no effect on the amount of concentrates used in ruminant production was found.

4.3 Discussion of short- vs. long-run results

For a better understanding and interpretation of our results, we compare ex-post and ex-ante results in detail. Remember, Table 2 shows the average treatment effects on the treated (ATT) for various outcomes. In Table 3, the second panel shows the ATT for all considered outcomes. We compare the first line labeled GMF 15 of the middle panel in Table 3 with GMF in Table 2. Overall, the empirical and the simulation model draw very similar conclusions about the effect of the GMF program on the farms participating in the program.

Taking a closer look, we see that simulation results show larger effects on the proportion of concentrate feed and grass feed (twice the size of the effect in the empirical analysis), whereas they show a somewhat smaller effect on milk yield (80 kg per cow less) and larger effect on income (CHF 1,000 more). Both models essentially find no short-run effect of the GMF program on ecological area (while they agree about the negligible size of the effect, they disagree on the sign). However, the effects on maize feed and N surplus are very similar.

Differences are explained by different assumptions of ex-ante and ex-post models. For example, the difference in the effects on concentrate feed can be explained by assumptions in SWISSland about non-compliance on the one hand, and milk yield increase on the other hand. First, in SWISSland, all farms participating in the program are assumed to always comply with all feeding restrictions. However, we know that, in reality, non-compliance occurs if farmers suspect that monitoring of a program is difficult for the government (Ferraro 2008). From interviews with program inspectors, we know that inspections of concentrate use for ruminants are difficult to conduct, such that non-compliance might occur. These assumptions imply that SWISSland may tend to overestimate the effects on concentrate use in the long run. Second, milk yields per cow are assumed to increase at a constant rate in SWISSland (based on long-run milk yield trends) whereas, in reality, milk yields fluctuate from year to year.

Both models find that the GMF program has very small effects on environmental outcomes in the short and long run. In both the short and long run, the changes in ecological area and the N surplus are negligible (and not statistically significant). Since there is no effect on the proportion of ecological area, we do not expect positive effects on biodiversity. However, because the GMF program reduces concentrate use in ruminant production (not only total concentrate use but also concentrate use per kg of milk), as well as concentrate imports, it potentially contributes to food security. Furthermore, since there is a small positive effect on the proportion of grassland area, there might be positive effects on ecosystem services such as carbon sequestration and soil protection.

However, both models find significant effects on economic outcomes like farm income and milk yield per cow. Lower milk yields per cow imply better animal health in the long run (Rauw et al. 1998, Oltenacu and Broom 2010). Several studies show a negative correlation between high milk performance per cow and health risks, e.g., lameness, mastitis, metritis, or fertility dysfunctions (Ingvartsen et al. 2003, Lopez et al. 2004, Archer et al. 2010, de Vries et al. 2014). Incomes of both participating and non-participating farms increase through effects of milk prices due to a lower milk supply (i.e., lower milk yields) in equilibrium. However, spillover effects of the GMF program on non-participating farms (control group) through market interactions (i.e., through milk prices) are a potential problem for the DiD analysis. If spillover effects are present in reality, the DiD model might yield biased estimates. Since SWISSland accounts for such interactions, our ex-ante analysis offers a way to gauge potential bias. We note that the DiD model may underestimate the effect of the GMF program on farm income. However, our analysis suggests that if there are any biases, they are rather small.

In sum, both approaches, although very different in terms of methodology, give very similar results in terms of sign and order of magnitude of the short-run effects. In other words, both empirical and simulation models yield short-run effects that are in the same ballpark. Furthermore, the discussion above on spillover effects highlights an important contribution of our paper. By combining ex-ante and ex-post analysis, we are able to shed more light on potential violations of our models' assumptions. Altogether, this makes us more confident in our results.

5 Conclusion

This paper combines ex-post and ex-ante methods to evaluate an agri-environmental program in Switzerland. It allows us to combine evidence for causal short-run effects with predictions of long-run effects. This has the advantage that policy instruments can be evaluated soon after their introduction, allowing policy makers to adjust policy instruments more promptly.

We find that the GMF program meets most of its political goals, but not all. While the program improves the competitiveness of Swiss dairy farmers and contributes positively to food security, its effects on environmental outcomes like N surplus are modest at best. However, if the main goals of the policy are to support farmers' incomes or to contribute to food security, this is a good way to do so since the policy has no negative effects on the environment. But if the main goal is to improve environmental outcomes, our analysis shows that this is not an effective policy.

For Switzerland, the program might prevent future increases in concentrate supplementation in dairy production if tariffs on fodder concentrates are reduced in upcoming trade liberalizations (Mack et al. 2009). The impact of the program on maize feed should be improved by adjusting maize feeding restrictions in the lowland regions of Switzerland. Because concentrate feeding restrictions have a dampening effect on milk supply due to lower milk yields per cow or reductions in the number of dairy cows even when milk prices are rising, the program may lower milk price volatility. We believe that further research in this direction is promising.

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A Appendix

A.1 Appendix: Empirical analysis

[Table 5 about here.]

A.2 Appendix: Simulation analysis

Table 6 below shows the data in levels from the simulation runs with SWISSland.

[Table 6 about here.]

We estimate the probability of a farm participating in the GMF program based on FADN data (Hoop and Schmid 2014). In particular, we estimate the following linear probability model with OLS

$$Pr\left(GMF_{i,post} = 1 | X_{i,pre} = x_{i,pre}\right) = x'_{i,pre}\beta \tag{2}$$

where the vector $x_{i,pre}$ includes the following covariates (varying at the farm level): concentrate feed (percent), maize feed (percent), milk yield per cow (kg), ruminants (livestock unit), cow density (cows/ha), cows with high concentrate intake (percent), age, crop area (ha), as well as a constant. All independent variables are averages computed for the pre-treatment period 2011 to 2013, whereas the dependent variable $GMF_{i,post}$ refers to whether farm i participates in the GMF program in the post-treatment period 2014 and 2015. Altogether, we have observations for 740 farms.

Here, it is important to see the conceptual difference between the DiD model (1) and the LP model (2). The DiD model (1) estimates the *causal* effect of the GMF on various outcomes by comparing participating and non-participating farms before *and* after the introduction of the program. The LP model (2) predicts whether a particular farm participates in the program *after* its introduction, based on farm characteristics observed *before* the program's introduction. Hence, there is no identification problem (i.e., simultaneity) in the causal model since future participation in the program has no effect on past outcomes (characteristics). However, since participation in the LP model (2) depends on lagged outcomes, we need to control for those outcomes in the DiD model (1), see also the discussion on selection issues in Section 4.1.

The linear probability model represents a simple way to integrate the estimated probability of participation in the GMF program into SWISSland. Of course, we are well aware of the shortcomings of using a linear probability model, like heteroskedasticity of the error term and predictions outside the $(0, 1)$ interval (Winkelmann and Boes 2009). We address the issue of heteroskedastic errors by computing robust standard errors. The issue of predictions outside the $(0, 1)$ interval is a potential problem. However, we only use the information whether the predicted probability is below 50 percent (non-participation) or above 50 percent (participation). Thus, predictions outside the $(0, 1)$ interval are either set to zero for predictions below zero, or to one for predictions above 1. Table 7 below shows the results from the linear probability model (LPM), as well as marginal effects from Probit and Logit models evaluated at the mean. We see that the estimated marginal effects are very similar for the LPM, Probit and Logit models.

[Table 7 about here.]

We are especially worried about cases where the LPM predicts a probability above 0.5 whereas the Probit (and Logit) model predicts a probability below 0.5, and vice versa. Figure 2 depicts predicted probabilities in our sample for both LPM (x-axis) and Probit model (y-axis).

[Figure 2 about here.]

We note that in most cases LPM and Probit model agree (upper right and lower left quadrant), and only in a very few cases (precisely, just 2 percent or 20 out of 740 observations) LPM and Probit disagree (upper left and lower right quadrant). Thus, we are assured that the way we implement the results of the LPM does not introduce a serious bias into our simulation model SWISSland.

Tables and Figures

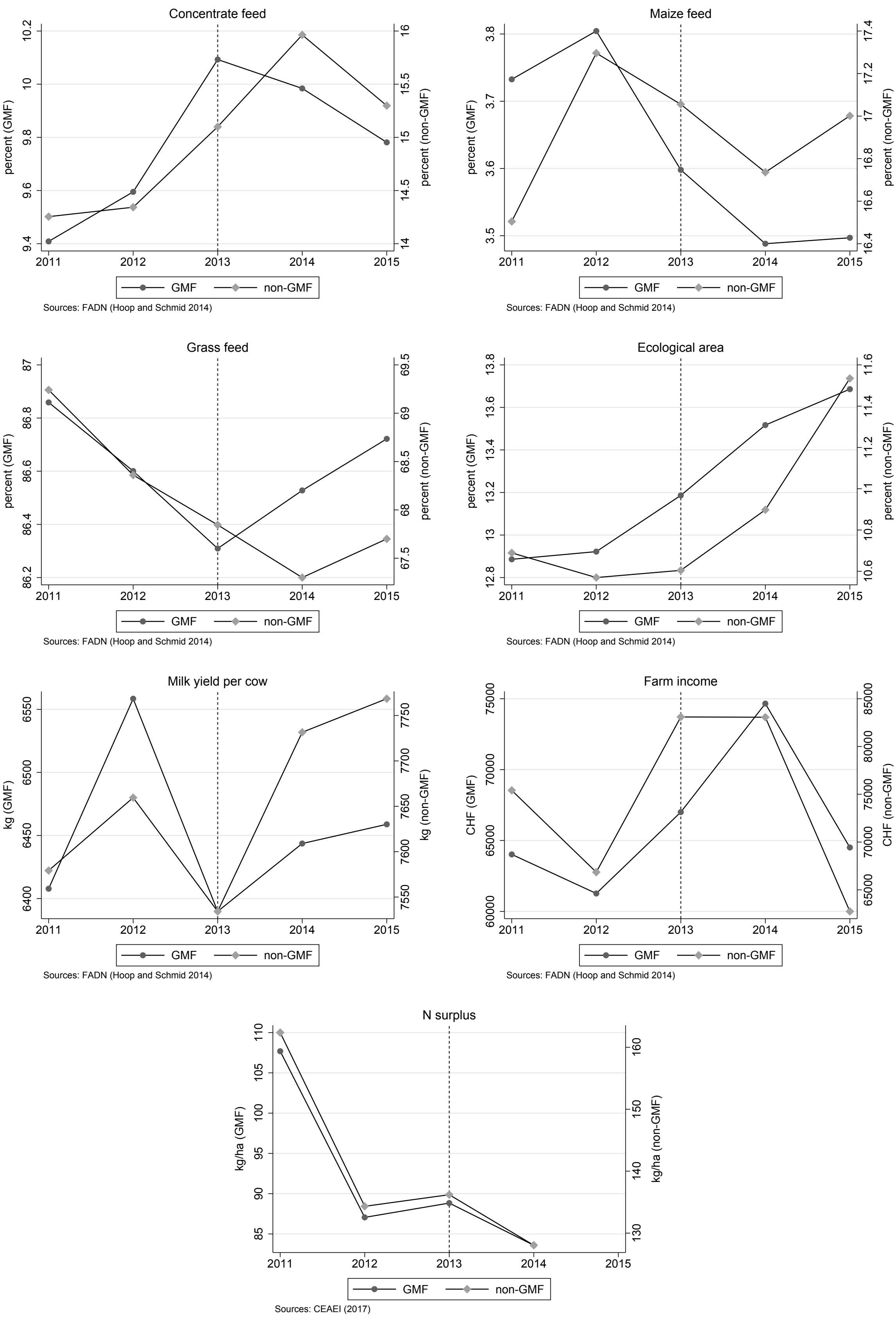

Figure 1: Evolution of outcomes for participating and non-participating farms

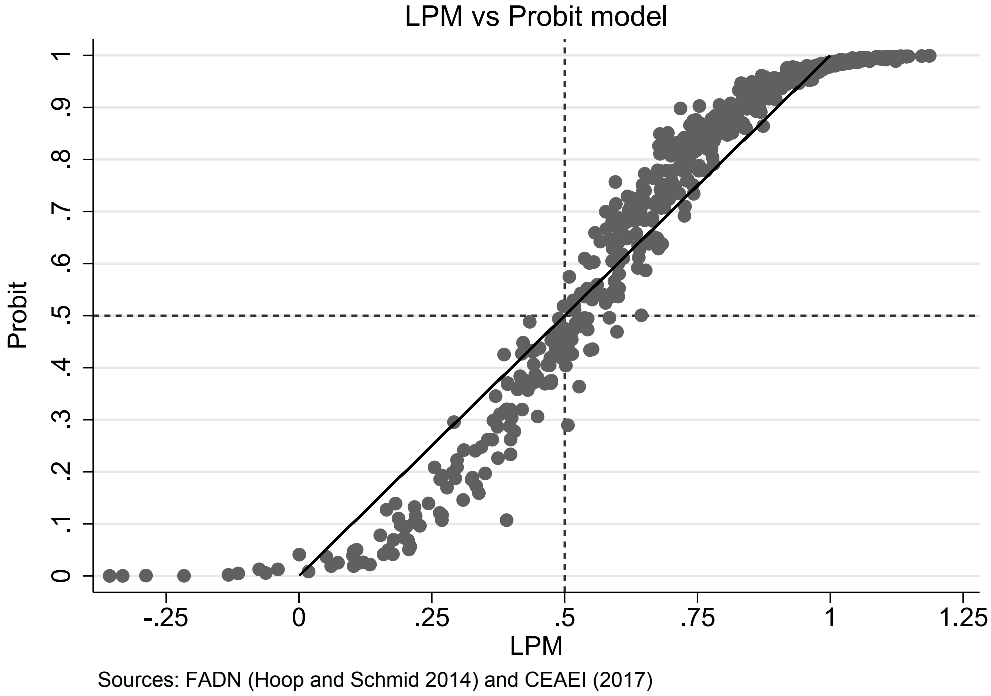

Figure 2: Linear Probability Model (LPM) vs. Probit Model

Table 1: Summary statistics pre-treatment period 2011-2013

	non-GMF	GMF	Difference	p-value
Outcomes				
concentrate feed (percent of total)	14.57	9.70	4.86	0.00
silo feed (percent of total)	16.95	3.71	13.24	0.00
milk yield per cow (kg)	7591	6452	1139	0.00
grass feed (percent of total)	68.48	86.58	-18.10	0.00
ecological area (percent of total)	10.62	12.99	-2.37	0.00
income (CHF)	75117	64095	11022	0.00
N surplus (kg/ha)	144.56	94.36	50.20	0.00
Background characteristics				
area (ha)	26.71	22.25	4.46	0.00
ruminants (livestock unit)	46.35	34.15	12.20	0.00
milk price (CHF/kg)	0.61	0.58	0.03	0.02
direct payments w/o GMF (CHF)	72153	67653	4500	0.00
location valley	0.29	0.63	0.34	0.00
location hill	0.33	0.35	-0.02	0.45
location mountain	0.04	0.36	-0.32	0.00
farm type crop	0.002	0.003	-0.001	0.71
farm type animal	0.26	0.72	-0.46	0.00
farm type combination	0.73	0.27	0.46	0.00
age (years)	49	47	2	0.00
no education	0.01	0.05	-0.04	0.00
vocational education	0	0.003	-0.003	0.22
vocational education completed	0.45	0.58	-0.13	0.00
further education	0.53	0.34	0.19	0.00
tertiary education	0.006	0.016	-0.01	0.07
N	510	1698		

Note: P-value is for a test of equality of means for non-GMF and GMF participants. Means for N surplus are computed based on 248 observations. Variables refering to location, farm type and education are indicator variables. Thus, means are to be interpreted as shares or percent of total. Farm type crop subsumes farm types arable crops, and special crops; farm type animal subsumes farm types dairy, suckling cows, other cattle, horses/sheep/goats, and pigs/poultry; farm type combined subsumes farm types combined dairy/arable crops, combined suckling cows, combined pigs/poultry, and combined combined others.

Sources: FADN (Hoop and Schmid 2014) and CEAEI (2017)

Table 2: Short-run effects (ATT) based on DiD regressions

	concentrate feed (percent)	maize feed (percent)	grass feed (percent)	milk yield (kg/cow)	ecological area (percent)	income (CHF)	N surplus (kg/ha)
mean	11	7	82	6715	12	66641	104
GMF	-0.9***	-0.2	1.1***	-172***	0.29	6342***	-4.7
	(0.2)	(0.3)	(0.4)	(56)	(0.5)	(2230)	(36.6)
N	3680	3680	3680	3680	3680	3680	248

Clustered standard errors in parentheses (at farm level)

* $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$

Notes: ATT is short for average treatment effect on the treated. The row "mean" refers to the mean of the dependent variables for the pre-treatment period 2011-2013. All models control for age, education, farm type, total direct payments, total area, number of ruminants, and milk prices.

Sources: FADN (Hoop and Schmid 2014) and CEAEI (2017)

Table 3: Long-run effects based on SWISSland simulations

	concentrate feed (percent)	maize feed (percent)	grass feed (percent)	milk yield (kg/cow)	ecological area (percent)	income (CHF)	N surplus (kg/ha)
				Average treatment effects (ATE)			
GMF 2015	-1.8	0	1.4	-61	-0.1	6521	-3
GMF 2020	-2.2	0	1.7	-238	-0.2	5346	-3
GMF 2025	-2.6	0	2	-443	-0.1	7722	-4
				Average treatment effects on the treated (ATT)			
GMF 2015	-2.3	0	1.9	-94	-0.1	7305	-4
GMF 2020	-2.5	0.1	4.1	-324	0.2	6985	-2
GMF 2025	-3.1	0.1	4.4	-594	0.1	8729	-2
				Average treatment effects on the untreated (ATU)			
GMF 2015	0	0	0	-1	0	3307	0
GMF 2020	0.1	0.2	0.7	-16	0	4345	1
GMF 2025	0.2	0.3	1.2	-38	0.1	10446	2

Notes: Computations with SWISSland showing mean differences in scenarios with and without the GMF program in place for all farms (ATE), farms participating in GMF (ATT) and farms not participating (ATU), respectively.

Sources: SWISSland

Table 4: Long-run analysis at sector level

	Scenario without GMF			Scenario with GMF		
	2015	2020	2025	2015	2020	2025
	(Aggregate level)			(Absolute difference)		
concentrate use for ruminants (1000 ha)	885	936	982	-127	-144	-166
domestic concentrate production (1000 t)	678	626	607	-13	-6	-5
concentrate imports (1000 t)	936	1084	1199	-102	-143	-181
maize silage (1000 ha)	48	47	46	0	0	0
intensively used grassland (1000 ha)	613	616	620	6	7	10
extensively used grassland (1000 ha)	123	122	126	-1	-2	-2
number of dairy farms	30643	27105	24741	84	589	543
dairy cows (in thousands)	583	565	646	-2	10	14
milk production (1000 t)	4245	4333	4401	-49	-63	-139
milk producer price (CHF/kg)	0.57	0.55	0.54	0.02	0.03	0.06
milk sales (1000 t)	3567	3658	3730	-10	-27	-97
revenue milk sales (million CHF)	2565	2354	2274	45	64	127
farm income (million CHF)	2983	2727	2920	125	89	117
GMF budget outlay (million CHF)	0	0	0	94	93	92
N surplus (1000 t)	74	72	72	-1	-1	-2
N input (1000 t)	141	138	138	-2	-2	-3
N input concentrated feed (1000 t)	42	44	46	-3	-4	-5
N input hay purchases (1000 t)	9	8	7	0	0	0
N fixation and deposition (1000 t)	43	42	41	0	1	1
N input fertilizer (1000 t)	44	41	40	0	1	1
N output (1000 t)	67	66	66	-1	-1	-1
N output of milk sales (1000 t)	21	22	22	0	0	-1

Note: SWISSland simulation results at sector level.

Sources: SWISSland

Table 5: Summary statistics 2011-2015

	min	mean	max	sd	N
GMF participation	0.00	0.77	1.00	0.42	3680
Outcomes					
concentrate feed (percent of total)	0.00	10.98	40.15	5.15	3680
silo feed (percent of total)	0.00	6.69	52.74	9.46	3680
milk yield per cow (kg)	1047	6730	13089	1412	3680
grass feed (percent of total)	28.38	82.33	100.00	12.15	3680
ecological area (percent of total)	0.00	12.69	100.00	12.55	3680
income (CHF)	-138646	68170	363554	46886	3680
N surplus (kg/ha)	-88.28	101.25	1011.06	82.98	248
Background characteristics					
area (ha)	5.09	23.57	80.94	10.89	3680
ruminants (livestock unit)	5.00	37.09	231.99	20.20	3680
milk price (CHF/kg)	0.00	0.60	11.23	0.27	3680
direct payments w/o GMF (CHF)	0.00	67455	198299	29201	3680
location valley	0.00	0.37	1.00	0.48	3680
location hill	0.00	0.34	1.00	0.47	3680
location mountain	0.00	0.29	1.00	0.45	3680
farm type crop	0.00	0.00	1.00	0.06	3680
farm type animal	0.00	0.62	1.00	0.49	3680
farm type combined	0.00	0.38	1.00	0.49	3680
age (years)	20.00	48.53	69.00	8.10	3680
no education	0.00	0.04	1.00	0.20	3680
vocational education	0.00	0.00	1.00	0.04	3680
vocational education completed	0.00	0.55	1.00	0.50	3680
further education	0.00	0.39	1.00	0.49	3680
tertiary education	0.00	0.01	1.00	0.12	3680

Note: Farm type crop subsumes farm types arable crops, and special crops; farm type animal subsumes farm types dairy, suckling cows, other cattle, horses/sheep/goats, and pigs/poultry; farm type combined subsumes farm types combined dairy/arable crops, combined suckling cows, combined pigs/poultry, and combined combined others. Variables refering to location, farm type and education are indicator variables. Thus, means are to be interpreted as shares or percent of total.

Sources: FADN (Hoop and Schmid 2014) and CEAEI (2017)

Table 6: Swissland simulation results at farm level

	Scenario without GMF			Scenario with GMF		
	2015	2020	2025	2015	2020	2025
all farms						
participation rate (percent)	0	0	0	81	79	79
area (ha)	22	25	27	22	25	27
ruminants (livestock unit)	26	28	30	26	28	30
revenue milk production (CHF)	83708	86862	91898	84948	87321	94965
direct payments for GMF (CHF)	0	0	0	3051	3374	3645
concentrate feed (percent of total)	11.5	12.3	13.1	9.7	10.1	10.5
maize feed (percent of total)	6.9	7	6.9	6.9	6.9	6.9
grass feed (percent of total)	82.9	82.2	81.7	84.3	84	83.7
milk yield (kg/cow)	7162	7538	7921	7101	7300	7478
ecological area (percent)	14	13	13	13	13	13
farm income (CHF)	66312	65158	71873	72832	70504	79594
N surplus (kg/ha)	63	61	60	60	58	57
participating farms						
area (ha)	21	23	25	21	24	26
ruminants (livestock unit)	24	26	28	24	27	29
revenue milk production (CHF)	76213	77537	82450	76840	78738	85228
direct payments for GMF (CHF)	0	0	0	3784	4245	4632
concentrate feed (percent of total)	10.7	11.2	12	8	9	9
maize feed (percent of total)	3.2	3	3	3	3	3
grass feed (percent of total)	87.1	84.8	84.4	89	89	89
milk yield (kg/cow)	6923	7263	7640	6829	6940	7046
ecological area (percent)	14	13	13	14	13	13
farm income (CHF)	62971	60680	67048	70276	67666	75778
N surplus (kg/ha)	62	58	57	58	56	55
non-participating farms						
area (ha)	28.1	30.4	31.5	28.1	30.2	31.7
ruminants (livestock unit)	32.8	35.1	36.1	32.8	35	36.4
revenue milk production (CHF)	115237	115817	118986	118673	120564	130909
direct payments for GMF (CHF)	0	0	0	0	0	0
concentrate feed (percent of total)	15	15.6	16.2	15	15.7	16.4
maize feed (percent of total)	22.3	21.6	20.8	22.3	21.8	21.1
grass feed (percent of total)	64.8	64.2	63.8	64.8	64.9	65
milk yield (kg/cow)	7905	8350	8727	7904	8334	8690
ecological area (percent)	12.2	12.5	12.8	12.2	12.5	12.9
farm income (CHF)	80160	77154	83238	83467	81499	93685
N surplus (kg/ha)	78.8	74.5	79	79	76	74

Note: SWISSland simulation results at farm level. Data show mean values across corresponding groups.
Sources: SWISSland

Table 7: Probability models

	LPM	Probit	Logit
concentrate feed (percent of total)	-0.02***	-0.02***	-0.02***
	(0.00)	(0.00)	(0.00)
maize feed (percent of total)	-0.02***	-0.01***	-0.01***
	(0.00)	(0.00)	(0.00)
ruminants (livestock unit)	0.00	0.00	0.00
	(0.00)	(0.00)	(0.00)
cow density (cows/ha)	-0.04**	-0.05**	-0.04**
	(0.02)	(0.02)	(0.02)
ruminants with high concentrate intake (share)	0.09	0.02	0.04
	(0.08)	(0.09)	(0.09)
milk yield per cow (kg)	0.00	0.00	0.00
	(0.00)	(0.00)	(0.00)
age (years)	0.00	0.00	0.00
	(0.00)	(0.00)	(0.00)
crop area (ha)	0.08	0.01	0.02
	(0.14)	(0.11)	(0.11)
constant	1.22		
	(0.11)		
N	740	740	740
R-squared (pseudo)	0.42	0.42	0.42
F-test / Wald test statistic	72.46	198.93	164.01

Robust standard errors in parentheses

* $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$

Notes: Column LPM shows the estimated coefficients from a Linear Probability Model (LPM). Columns Probit and Logit show marginal effects (at the mean) from Probit and Logit models, respectively. The F-test and Wald test statistics are computed with 8 degrees of freedom.

Sources: FADN (Hoop and Schmid 2014) and CEAEI (2017)