On the complexities of promoting environmentally friendly technologies in agriculture

Stefan Mann, PhD
Agroscope
Ettenhausen, Switzerland

Corresponding Author: stefan.mann@agroscope.admin.ch

An increasing number of countries pursues a 'multifunctional' agricultural policy, taking into account the many externalities linked to food production. It seems obvious that promoting environmentally friendly technology is one way to do so. However, a case study of resource efficiency payments in Swiss agriculture shows that such payments have complex side-effects, casting doubt on their overall positive contribution. A structural equation model, based on a survey of Swiss farmers, shows that promoting no-tillage leads to greater use of glyphosate and that other programs lead to overmechanization and increased pressure on the soil. The qualitative part of this paper focuses on structural weaknesses in terms of controllability. The paper concludes that public programs need to avoid over-simplification of cause-effect relationships and should not ignore transaction costs.

1. Introduction

Environmental economists have defined a good part of their message as emphasizing the need to set incentives for environmentally friendly behavior. This also applies to the realm of agriculture and the introduction of environmentally friendly technologies, where it is common sense that:

"farmers will only adopt conservation technology if it is profitable and (…) society must 'bribe' (or 'incentivize') farmers to protect social values" (Chouinard et al., 2008).

This paper claims that such a neoclassical view is not wrong as such, but suppresses a very large part of reality. It uses approaches taken by the proponents of complexity economics to show that agri-environmental programs, particularly when combined with the introduction of sustainable technologies, benefit if the complexities of social interdependencies are taken into account in their conception and organization. Many features of complex systems as described by authors such as Arthur et al. (1997) can be found in the experiences obtained with incentivizing programs.

A Swiss agri-environmental program setting three different incentives for implementing conservation technologies is used as a convenient case study and is introduced in the following section. The state of the literature on the introduction of such programs is summarized in Section 3. Our methodological approach is outlined in Section 4. The next two sections illustrate institutional dimensions contributing to the system's complexity: Section 5 concerns side-effects of the technologies promoted, and Section 6 considers the different subsidy modes and the options and effects of opportunistic behavior. Section 7 summarizes the empirical aspects and reflects on the contribution that complexity economics makes to environmental economics.
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2. Resource Efficiency Payments

Since the 1990's, Switzerland's agricultural policy has increasingly focused on internalizing the manifold externalities of agriculture, defining conservation as a constitutional objective of agriculture. Three theoretical approaches are used to provide a framework for this strategy: The concept of multifunctionality (Mann and Wüstemann, 2008), the concept of sustainability (Belz, 2004) and the concept of a circular economy (Gao et al., 2007).

The Swiss government saw untapped opportunities in farming technologies which would save resources and cut emissions. In this context, the concept of the circular economy was particularly applicable with respect to nitrogen and pesticides. In the case of nitrogen, for example, it is crucial that most of the nutrients being allowed into the system are taken up by the plant and not diffused into the air or the water (see Xi, 2011).

The reform of Switzerland's agricultural policy toward more targeted payments (Mann and Lanz, 2013) was a good opportunity to broaden the experience of some regional pilot programs into a federal program, in particular the circular elements as outlined above. Since 2014, three different groups of measures to which farmers can subscribe, labeled "Resource Efficiency Payments" (REP), are available on a national scale.

The most common pilot programs focused on slurry spreading with different banding technologies, as evidence is strong that this is an effective way to cut ammonia emissions (Pfluke et al., 2010) compared to traditional spraying techniques and to close the nitrogen cycle. Applying banding technologies is currently subsidized by the government at CHF 30 per hectare per application, with a maximum of four applications per year. Applications in winter are not eligible. 2,600 farms (approx. 5 % of the Swiss total) participated in the first year of the program.

Conservation tillage has been praised for its ability to diminish erosion, energy use, runoff of agricultural chemicals and carbon emissions (Uri et al., 1998; Holland, 2004; He et al., 2009). This scientific evidence has encouraged the federal government to grant payments for different conservation tillage practices. Mulch-till, whereby crop residues are mixed with the soil and a certain amount of residues remain on the soil surface during sowing, is subsidized at CHF 150 per hectare per year. Even less of the soil surface (not more than 25 percent) is affected by direct drilling, which is subsidized at CHF 250. In order to strengthen positive environmental effects, payments increase considerably (CHF 400/ha*y) if conservation tillage is coupled with non-use of herbicides. In the program's first year of implementation, almost 5,000 farms subscribed, making the program the most widely applied brick within Resource Efficiency Payments.

It has been shown that pesticide spreaders using mechanical protection significantly reduce drift and therefore emissions into the environment (Naef et al., 2013). This technology is mainly targeted toward fruit and vegetable farmers, so purchasing the special equipment needed is subsidized at CHF 6,000-10,000, depending on the specification applied. Under these conditions, 92 farm managers have bought the relevant technology.

All three programs rest on the advantages that innovative technologies can provide for the environment, an effect well documented in the literature (see Le Gal et al., 2011).

3. Discourses on promoting conservation technologies

Empirical studies concerned with the implementation of sustainable technologies generally confirm the notion that incentives work. However, these incentives may have different

institutional forms. “Innovation and technology diffusion do respond to the incentives of the market, and (…) properly designed regulation can create such incentives” (Jaffe et al., 2005; 166). Other experience tends to dismiss the power of incentives, emphasizing the success of targeted command and control policies (Chien and Shih, 2007).

If any consensus can be derived from the debate about effective settings for the implementation of sustainable technologies, it is that instruments should be flexible and adapted to the specific environment where technologies are to be disseminated (Jaffe and Palmer, 1997). In many cases, a single policy instrument will not be able to do the job, and a portfolio of adapted and adaptive tools will be required (Fischer and Nawell, 2008).

Single cases highlight the following aspects: a high diversity of different technical solutions should be maintained (Hoppmann et al., 2013); maintaining the balance between the supply and the demand side is a delicate issue (Dijk and Yarime, 2010; Constantini et al., 2015); emission trading regimes show significant spillovers into the adoption of innovative technologies (Borghesi et al., 2015 a,b). All these aspects are summarized effectively in a conclusion by Kemp and Pontfolio (2011; 34): “The specifics of policy and the situation in which they are applied are all-important for the outcomes”.

One case in point with regard to side-effects is the connection between no-tillage and glyphosate. Llewellyn et al. (2012; 208) label glyphosate as “the major herbicide used in no-tillage”. It is well-known that glyphosate has extremely harmful impacts on the environment (World Health Organization, 1994; Annett et al., 2014). If it could be shown that the use of no-tillage would increase the frequency of glyphosate application, this would compromise no-tillage as a technology with net positive externalities as compared to conventional tillage.

4. Method

As many different specific characteristics of the program had to be considered, a mixed-method approach appeared the only option to encompass every facet of the program. Both a quantitative survey and a qualitative part building on survey results were carried out and are described below:

A written survey of 2,000 farmers was conducted in March 2015. In order to collect enough data about participation in the scheme, the sample used contained 1,000 participants in at least one of the resource efficiency schemes and 1,000 non-participants. The 2,000 farmers were asked to participate in an online survey. Those who did not were approached with a written questionnaire three weeks later. This two-wave procedure resulted in a response rate of 50.2 %, so that 1048 questionnaires could be evaluated.

“Structural equation modeling permits complex phenomena to be statistically modeled and tested” (Schumacker and Lomax, 2004; 34). To understand the program’s indirect effects, structural equation modeling (SEM) appeared to be an attractive option. One SEM used the supposed connection between no-tillage and glyphosate use as mentioned in the previous section. It could be hypothesized that only farmers with a high environmental awareness would be likely to subscribe to the agri-environmental program, and that size would play a role as well, as hectare-based payments would make a difference only for farms of a certain minimum size. If farmers practicing no-tillage could not cope with weeds without increasing the use of glyphosate, would this mean that farmers with a high environmental awareness would end up using more glyphosate than their peers?

A similar discussion, albeit only within the Swiss context, has emerged around the use of banding technologies for slurry application. These technologies require higher investments

than traditional ones. Some critics suspect that contractors are hired in order to qualify for the payments and that these contractors use heavier machinery, leading to unnecessary and harmful soil contraction. This, again, is a mechanism by which dedication to the environment could possibly be linked to environmental damage.

All this leads to the selection of variables as depicted in Table 1, containing attitudinal and farm-related variables. In addition to farm size, both a devotion to conservation and a preference for innovative technologies can be considered as motivations for participation in one of the schemes. Side-effects resulting from the subscription can be the increased frequency of glyphosate application and the increased use of contractors and larger spreaders, both of which are indicators of increased soil pressure.

Table 1: Variables used for the structural equation model

	Meaning	Coding	Mean	minimum	maximum
Arable land	Arable land of farm	hectares	11.41	0	105
Environment	Agreement with "Conservation is an important task of farmers"	From 1- totally agree to 5 – totally disagree	1.70	1	5
Innovation	Agreement with "It is important to me to use innovative technology"	From 1- totally agree to 5 – totally disagree	2.37	1	5
Banding technologies	Subscribed to the payment scheme	0-No; 1-yes	0.48	0	1
Direct drilling	Subscribed to the payment scheme	0-No; 1-yes	0.20	0	1
Mulch-till	Subscribed to the payment scheme	0-No; 1-yes	0.26	0	1
Glyphosate	Average number of glyphosate treatments per parcel		0.82	0	25
Spreader	Size of the slurry spreader	m^3	5.1	0	10
Contract	Use of machinery contractors	0 – no; 1 - yes	0.83	0	1

The qualitative part of the study did not attempt to interview a representative sample of farmers. Instead, the emphasis was on a thorough understanding of single cases. Only one member of a cantonal administration, one controller and three program participants (and participants in the survey) who were typical for the causalities detected in the quantitative part were interviewed. These interviews lasted 30-90 minutes. They were partly transcribed and a few sequences were evaluated by the method of objective hermeneutics. Although this method was developed in the area of family analysis (Oevermann, 1979), it was later also applied to policy evaluation (Mann and Schweiger, 2009).

The method's aim is not to make a standardized statement: according to its founder, Ulrich Oevermann (2004), standardizations miss the object of research insofar as the object is not itself standardized. Instead, an attempt is made to explore the lowest level, or substance, of social reality. This exploration does not claim to be representative, but the specific characteristics of the case to be analyzed are important. In our context, it is intended to serve as an illustration of a possible reality behind the statistical connections.

5. Quantitative results

The results of the two structural equation models are depicted in Figure 1. Not all, but most of the causal relationships assumed in Section 3 are significant. Starting on the left, the preference for innovative technology can be confirmed as a significant predictor for using banding technologies. Using the drop hose on a farm, in turn, has at least two important implications by itself, and both point in the same direction. Custom workers on the farm usually work with heavier machinery than farm managers themselves, and they are more frequently contracted if banding technologies are applied. The size of the spreader is also very strongly correlated with the use of a drop hose for spreading slurry. Taken together, it is likely that soil pressure will be higher once a drop hose is applied.

The size of the arable land strongly influences different varieties of no-tillage. The influence of a pro-conservation attitude is less marked, but it can still be shown to significantly influence mulch-tilling. However, the frequency with which glyphosate is applied on the farmer's arable land is largely explained by the choice of either of the two varieties of no-tillage.

Taken together, the two models show two cases in which unwanted side-effects can be demonstrated clearly and significantly. It should be emphasized that these side-effects could well be the main effects if compared to the positive environmental impacts such as reduced nitrogen losses and less erosion. As the negative effects were not taken into account when designing the programs, a process to rank the effects by greatest societal relevance would never have taken place.

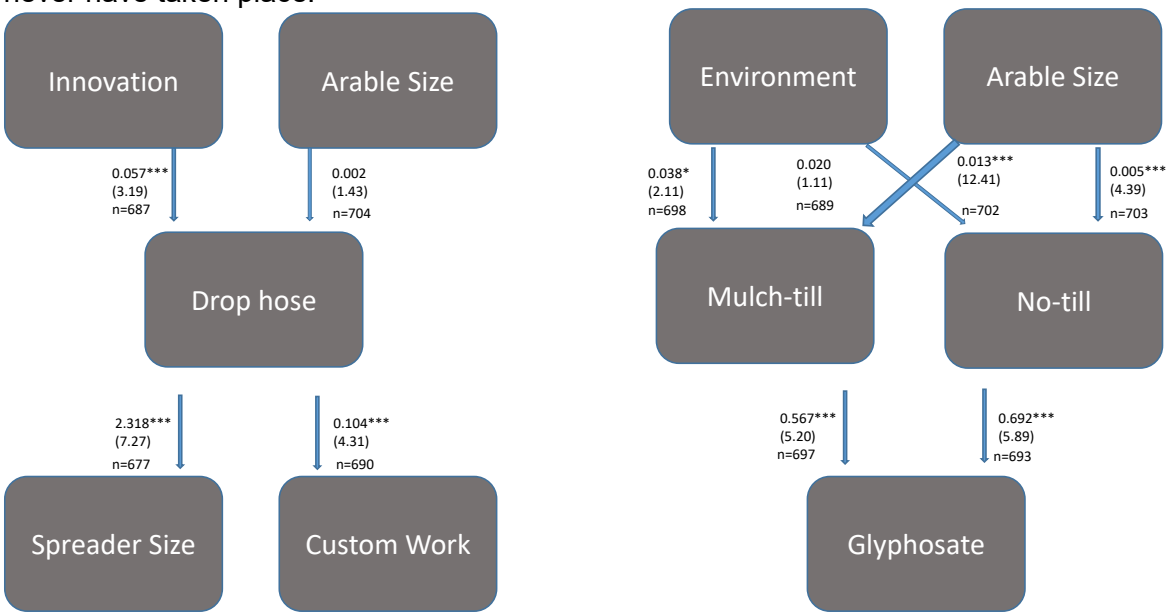

Figure 1: Structural Equation Models

6. Qualitative results

The sequence chosen for the qualitative analysis is taken from an interview with a cantonal controller. The interview was not labeled as one with particular emphasis on resource efficiency payments, but, luckily, the controller brought up the issue by himself. This happened when talking about the shortcomings in terms of controllability of another direct payment program, the payments for grassland-based milk and meat production (GMM). One of the interviewers is a part-time farmer himself and, over the course of the sequence, changes his role.

C: We can discuss till doomsday. But this is not only the case for GMM. REP, REP, REP is actually much worse. No-tillage, that is actually much worse.

I1: Are you going outside and look at the soils?

C: Yes, yes, what do I see, what do I see now? Do I see whether the wheat, whether the wheat has been grown with mulch-till?

I2: A heap of rubbish. You have to register, you prepare, you say I am doing mulch-till, mulch-till, mulch-till. I have also this year, I registered for mulch-till, I grew leek for the first time, right? And now the leek has come later and later, until June 30 you had to register, so I said, what do I do, the leek is not inside yet, but I have registered mulch-till. If now the controller arrives, no matter what you say, he just has to believe me, full stop, doesn't he?

C: Yes, and particularly, I generally have to believe if it is mulch-till. I do not see what has been done with the seed. So it is exactly the same at this point. And therefore I say, it is a, I think one should, one should control things which can be controlled, not only just believe, shouldn't you? But it is difficult.

The controller's intention seems to be to put the points being raised into a broader context. Resource Efficiency Payments are chosen to produce (probably) the worst possible example. The many repetitions catch the eye, a pattern Ochs (1979) has correlated with oral and unplanned discourse, McTear (1978) with self-reference. In any case, it appears that the five functions of repetitions that Murata (1995) has identified (interruption-oriented, solidarity, silence-avoidance, hesitation, and reformulation repetitions) need to be broadened to allow for the affirmative and emphasizing function of repetitions as stressed by Kim (2002).

The statement that REP is worse in terms of controllability than GMM is now specified with regard to the three bricks which REP entail. It is no-tillage rather than drop hose or pesticide application which causes most of the pain.

Interviewer 1 takes up the emotional drive by switching into present tense, even though the controller will hardly go outside during the interview. In terms of content, however, Interviewer 1 ignores both the normative and emotional content of what has been said, restricting his focus to the control's organization. He suggests what a control could look like, and it is not entirely clear which function the controller's "yes" actually serves. In any case, the controller subscribes to the image of him going outside now, applying the present tense himself. The core problem, the missing possibility to observe no-tillage on the farm, is transformed into a rhetorical question. It seems obvious enough that it is impossible to control mulch-till on the field, so it is not even necessary to put this into a statement.

This is where Interviewer 2's story comes in, starting with an only-normative statement with which he affirms the controller's attitude. The story then circles around the incompatibilities

between the phasing of the application for REP and the production phases for leek. His point is that controllers would have no factual evidence to check the compliance with no-tillage.

When the interviewee speaks again, he affirms what has been said, even though he wants to make his own case. While he introduces this with a “particularly”, the opposite would be more correct. This is not a special case in the general remark by Interviewer 2; rather, Interviewer 2’s story is a special case in the general concern of the controller. He now answers his rhetorical question, apparently doubting whether his underlying point was understood before. He then needs a few attempts to draw his general conclusion. The “I say” denotes subjectivity, whereas the “it is a” signals a high degree of objectivity. He then steps back from this in order to finally choose “I think”, carefully enough for the fact that his sentence that “one should control what can be controlled” should go largely undisputed.

7. Conclusions

Textbook economics teach us that externalities should be internalized in order to obtain the maximum welfare effect. It is a good guess that many policy-makers have been inspired by this principle, and have identified negative externalities such as erosion of arable land and developed technical solutions (such as no-tillage) to counterbalance these negative effects.

It appears as if these policy-makers fell prey to the over-simplification inherent in mainstream economics. Two important elements of the policy were disregarded. One is the negative side-effects which agronomic measures may have, even if they are associated with positive effects at first glance. Some of these negative effects are indirect (drop hose technologies cause farmers to employ custom workers, custom workers use heavier machinery, heavier machinery increases soil compaction, increased soil compaction leads to crop productivity in the long run), but they are nevertheless extremely relevant.

The second point refers to the operationalization of the policy. While the disregarding of transaction costs in mainstream economics has often been criticized in the past (Arnott and Wagner, 1990; Gray, 1994; Morriss, 2006), the case highlighted here shows a new dimension of the problem. In the case of no-tillage, transaction costs to implement a literal control on the field would be prohibitively high, as full-time surveillance of participating farms would be indispensable. Thus, the standard system is applied – even though, in fact, it cannot deliver real implementation control at all.

Overall, the case study illustrates that the integration of real-world complexities into economic thinking will not offer new and simple solutions. However, it has the potential to deconstruct and unveil undue and inefficient solutions. More grassroots debates on the ground before the implementation of such and similar programs are likely to generate added value. A shift from “activist” programs towards research would probably generate added value.

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