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Risk Perceptions, Preferences, and the Adoption Dynamics of Pesticide-Free Production

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We study the adoption of a new pesticide-free wheat production system in Switzerland. Large-scale transitions to such production systems have implications for the entire agricultural and food sector. Using survey data from 1,073 Swiss wheat producers, we empirically test whether risk preferences and risk perceptions in four domains relate to farmers' decisions whether and when to adopt pesticide-free production. We observe heterogeneity in farmers' risk perceptions (e.g., early versus late adopter) and find that farmers' risk preferences—as well as their perceptions of production and institutional risk—are related to adoption behavior rather than to perceived market and investment risks.

Key words: adoption behavior, risk preferences, sustainable agriculture

Introduction

The agricultural and food sector faces the double challenge of an increasing demand for food while having to reduce adverse environmental and health impacts of production (Pretty, 2018). The choice between pesticides and alternative pest management strategies for crop protection is an important example for this trade-off in agricultural production (Savary et al., 2019). Europe is a global hot spot for pesticide use and pollutions (Tang et al., 2021); ambitious action plans have been enacted in response (e.g., Möhring et al., 2020). For example, the EU's "From Farm to Fork" strategy aims for a 50% reduction of pesticide use and risks by 2030 (European Commission, 2020; Schebesta and Candel, 2020). Achieving pesticide reduction goals will require rapid adjustments in farming practices and farmers' uptake of new production schemes and systems (Möhring et al., 2020). Recently, the emergence of (partially) pesticide-free but non-organic production systems has been highlighted as one key way to reach these goals.

In this study, we investigate farmers' adoption of a novel pesticide-free but not organic production system in Switzerland (Möhring and Finger, 2022b). More specifically, we study farmers' decision to adopt the production system in relation to their risk preferences as well as their risk perceptions in four domains (i.e., institutional, market, investment, and production risks). Our analysis is based on survey data from 1,073 farmers matched with geographically explicit environmental data (Möhring and Finger, 2022a).

Previous literature stresses the role of behavioral factors (e.g., risk and risk preferences) for farmers' uptake of more sustainable farming practices (see, e.g., Marra, Pannell, and Abadi Ghadim, 2003; Gardebroek, 2006).[1] When new farming systems and technologies become available to

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[1] See Piñeiro et al. (2020) and Streletskaya et al. (2020) for reviews.

farmers, potential outcomes of adoption are uncertain (Feder, 1980) and farmers need to rely upon their subjective beliefs. Pesticides are currently the main tool to tackle production losses; therefore, production systems with low or no pesticide use, as investigated here, are often considered riskier than conventional production systems (e.g., Chèze, David, and Martinet, 2020). For example, yield outcomes, continuity of new marketing channels, and stability of political support might be less predictable, and the use of new technologies can induce investment risks (Bouttes, Darnhofer, and Martin, 2019). Further, the introduced production systems are novel to farmers, and they must make (adoption) decisions under limited and uncertain information (Möhring and Finger, 2022b). In this context, farmers have the possibility to delay adoption decisions until uncertainties are resolved, eventually leading to slow conversion rates (Musshoff and Hirschauer, 2008).

Adoption of a new production system involves risks in multiple domains. The literature on perceived risks has mainly focused on production and market risks (see, e.g., Marra, Pannell, and Abadi Ghadim, 2003), often individually. An exception is Abadi Ghadim, Pannell, and Burton (2005), who explore the role of farmers' subjective distributions of both yields and prices on the adoption of a crop innovation. Although there is evidence that price premiums and subsidies have a positive influence on adoption of sustainable practices (e.g., Serra, Zilberman, and Gil, 2008), perceived risks associated with fluctuations in demand, price premiums, and stability of subsidies have been addressed to a lesser extent. For example, Wąs et al. (2021) explore how farmers' views regarding the public support in the European CAP budget relate to the decision to participate in agri-environmental schemes in Poland.[2] Kuminoff and Wossink (2010) explore the notion that besides production and market risks, the adoption of organic agriculture can entail additional institutional risks that can disincentivize farmers' adoption.

Identifying the multiple dimensions of risk is crucial for addressing specific barriers to adoption and for improving pesticide-free production policies and programs. However, the empirical evidence on the role of risk preferences and risk perceptions in adoption decisions mainly focuses on a limited number of risks (mostly production and market risks) and often relies on the negative relationship between risk aversion and adoption decisions as an indication that risk perceptions hinder adoption. Among the empirical studies, there is a focus either on risk preferences or risk perceptions independently, neglecting that spurious correlations between risk preferences and outcome variables can arise when the heterogeneity of risk perceptions is not accounted for (see, e.g., Lybbert and Just, 2007). Moreover, the extensive literature that explores the ranking of multiple domain-specific risk perceptions among farmers of different production systems (e.g., Koesling et al., 2004; Bouttes, Darnhofer, and Martin, 2019) does not provide empirical evidence of whether these perceptions ultimately relate to adoption decisions.[3] Finally, the transition to low-input agriculture requires the acceleration of the adoption of alternatives to pesticides, but the timing of adoption is rarely considered in studies on the adoption of sustainable farming practices.[4]

We contribute to this literature by investigating the role of domain-specific risk perceptions and risk preferences in the adoption of pesticide-free farming practices. First, by considering the incentives to delay adoption, we enrich the debate on the adoption of sustainable practices. Second, we consider jointly the role of risk preferences and the multiple domains of risk perceptions, offering a more accurate characterization of the risk behavior. Thus, we contribute with one of the first empirical analyses to explore how the interplay of the two behavioral constructs (i.e.,

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[2] Dessart, Barreiro-Hurlé, and Van Bavel (2019) present a compilation of behavioral factors affecting adoption decisions of sustainable agricultural practices. Few studies in their review show a significant relation between risk perceptions and adoption decisions. Roussy Roussy, Ridier, and Chaib (2017) present similar evidence. Despite the vast literature on adoption, evidence on the role of risk perceptions and perceptions of the technologies on adoption remains scarce.

[3] Koesling et al. (2004), Läpple and Van Rensburg (2011), and Bouttes, Darnhofer, and Martin (2019) discuss the ranking of risk perceptions of organic and conventional farmers in different domains, including institutional and market risks. Nevertheless, the analysis is purely descriptive.

[4] A few exceptions include Upadhyay et al. (2003) and Forté-Gardner et al. (2004) for conservation agriculture. Padel (2001), Läpple (2010), and Läpple and Van Rensburg (2011) consider the timing of adoption of organic agriculture. More related to our paper, Finger and El Benni (2013) explore the timing of adoption of a low input agricultural system.

risk preferences and perceptions) relates to adoption decisions of sustainable agricultural practices.[5] Finally, we contribute to the emerging literature on pesticide-free but non-organic farming practices. Jacquet et al. (2022) describe this as one pathway to achieve ambitious pesticide policy goals in Europe, but empirical examples remain rare (e.g., Finger and Möhring, 2022; Möhring and Finger, 2022b).

To this end, we use rich survey data on a novel pesticide-free wheat production system in Switzerland and estimate how risk preferences and perceptions relate to adoption decisions. Our analysis shows that adoption behavior (i.e., early adoption, postponing, and not adopting) varies significantly with farmers' risk assessments regarding the pesticide-free system. More specifically, production and institutional risks are relevant for adoption and the prospective timing of adoption as they relate to an increase in the waiting behavior, unlike market and investment risks.[6] Finally, we find that risk-loving farmers are more likely to adopt and less likely to postpone. Our analysis suggests that in order to be able to characterize more accurately farmers' risk behavior, it is important to consider both risk preferences and risk perceptions. We offer recommendations for policy makers and supply chain actors to ease the transition from conventional to pesticide-free agriculture.

Pesticide-Free Production Systems in Switzerland

Similar to the European Union, Switzerland aims to reduce pesticide risks, envisioning a risk reduction of 50% by 2027 (Finger, 2021). To reach this goal, coordinated actions between different value chain actors toward the reduction of pesticide risks and use are needed (Möhring et al., 2020). In Switzerland, pesticide-free production systems have become increasingly relevant, enabled by financial incentives from different direct payment schemes and market compensation (Finger, 2021).

The Swiss government has introduced different direct payments that compensate farmers if they adopt farming practices to reduce the use of pesticides. For example, farmers can get compensation to not use herbicides and use, for example, mechanical weed control. Moreover, a low-pesticide production scheme (called Extenso) compensates farmers for not using insecticides, fungicides, and growth regulators, while still allowing herbicide use (Finger and El Benni, 2013).[7] These payment schemes are always crop-specific (i.e., adopting low-pesticide practices can be made crop-specific and not for the entire farm at large). By combining these policy measures, farmers can create pesticide-free production for specific crops.

Up- and downstream actors further support a transition toward lower pesticide use. For example, the retail sector in Switzerland has started to pay price markups to farmers not only for organic production but also for low-pesticide and pesticide-free production (e.g., Finger, 2021). Important for our case study, the largest retailer, Migros, pays price markups for pesticide-free wheat. The retailer, moreover, announced that they planned to switch their entire sourcing for bread and bakery products toward pesticide-free cereals by 2023 (Möhring and Finger, 2022b). The link between farmers and retailers is made via the farmer association IP-Suisse, which takes over the marketing of the wheat (to several retailers) and advises farmers on farming practices.

The pesticide-free wheat production system that we analyze in this paper offers a unique opportunity to see the dynamics behind a new production system that integrates the actions of farmers, the food industry (e.g., retailers), and the government. We focus on the adoption of

[5] Empirical analyses that consider both risk preferences and risk perceptions are focused mainly on risk management practices (e.g., van Winsen et al., 2016; Meraner and Finger, 2019) and entrepreneurial practices (e.g., Pennings and Wansink, 2004) and less on adoption of sustainable agricultural practices. One exception is Pan, He, and Kong (2020), who estimate the role of risk preferences and environmental risk perceptions on farmers' pesticide application behavior in China. In our case, our focus is on adoption-related risk perceptions.

[6] In our setting, we refer to the prospective timing of adoption, given that we can differentiate between a late adopter from a never adopter. Prospective adopters indicate a willingness to adopt in the future, while nonadopters have no intention to adopt.

[7] Notable exception are chemical seed treatments, which would be allowed in direct payment schemes. In the system analyzed here, however, these are also not allowed, so that the system is truly pesticide-free.

Table 1. Expected Revenues under Pesticide-Free Production System with Direct Payments and Price Markups

	Initial Production System (Extenso, low pesticide use)	Pesticide-Free Production System
a. Expected average yield (dt/ha)[a]	55	52
b. Expected market price (incl. price markup) (CHF/dt)[a]	55	65
c. Direct payment per hectare (CHF/ha)[a]	400 (for Extenso program)	650 (Extenso plus nonuse of herbicides)
Expected average revenue:		
d. Including markup and payment (CHF/ha)	3,425	4,030
e. Excluding markup and payment (CHF/ha)	2,750	2,600
Share of economic incentives in total revenue[b]		
i. Percentage of direct payments (= c/d)	11.70%	16.10%
ii. Percentage of price markups (= a × markup/d)[c]	8%	19.40%
Requirements to participate		
Growth regulators, synthetic stimulators, fungicides, and insecticides	Not allowed	Not allowed
Treated seeds and synthetic herbicides	Allowed	Not allowed
Synthetic fertilizers	Allowed	Allowed

Notes: [a] Adapted from Möhring and Finger (2022b). Expected average yield is based on an average farmer.
[b] Compared to scenario d.
[c] The average markup is 5 CHF for Extenso and 15 CHF for pesticide-free production.

pesticide-free production by producers of the farmer association IP-Suisse, who have already been producing under the low-pesticide use program (Extenso production). Since the 2019/2020 growing season, they have been able to transition into the new pesticide-free wheat system. Similar to Extenso farmers, participating farmers must not use any herbicides or chemical seed treatments—translating to a pesticide-free production.[8,9] To transition, farmers enact a combination of integrated pest management measures (e.g., adapting crop rotations, adopting resistant varieties, and using mechanical weed control).[10] The complexity of the new production system therefore has long term implications and induces opportunity costs (e.g., if farmers acquire machinery). In contrast to organic farming, the pesticide-free production system investigated here has no restrictions on (synthetic) fertilizer use or the use of pesticides in other parts of the crop rotation (see Möhring and Finger, 2022b, for a detailed description of the program).

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[8] Table 1 summarizes the requirements for participation. Supplement Table S1 shows a comparison of the pesticide-free wheat production in relation to conventional, Extenso, and organic production.

[9] While payments refer only to wheat production, farmers implement wide crop rotations characterized by at least four different crops per year, as established by the regulation for arable farming (see, e.g., Swiss Federal Council, 2022).

[10] Differences in the cultivation conditions and the heterogeneity of pest pressure across farms lead to differences in the optimal alternatives to be implemented to substitute herbicides. In our case study of pesticide-free wheat production, pesticide use is substituted by a combination of measures. The main fields of action are (i) adjusted crop rotations to reduce pest pressure (e.g., there is no wheat after wheat), (ii) the use of varieties with higher resistance to fungal diseases, and (iii) replacing herbicide use with mechanical weed control. Note that all these measures have long-term consequences. For example, adjusting crop rotations has implications for several years, and switching to mechanical weed control usually requires long-term investments in machinery. In Swiss agriculture, specialized machinery (e.g., comb harrows, chisel ploughs, rotary hoes, finger weeders, and flame weeders) can be used to replace herbicides. These technologies are usually more expensive than herbicide use, require investment, and may raise concerns over the long-term profitability of acquiring such equipment. See Böcker, Möhring, and Finger (2019) for a description of machinery and associated fixed and variable costs.

The transition to pesticide-free production practices is expected to imply lower yields, while the expected average revenues are expected to be higher due to subsidies and price mark-ups (see also Table 1). First, the price markup under pesticide-free wheat production accounts for 19.4% of the potential average revenue. Second, the federal government offers farmers a higher payment of 650 CHF/ha for pesticide-free wheat compared to 400 CHF/ha for Extenso production, making up an average of 16% of expected revenues for pesticide-free wheat. In summary, the expected average revenues in pesticide-free production are higher, while costs may or may not be higher compared to conventional production, depending on the production conditions and farmers' choices of substitutes (see Böcker, Möhring, and Finger, 2019; Möhring and Finger, 2022b).

In this context, the transition toward pesticide-free production can entail higher risk exposure to farmers. First, not using any pesticides is expected to increase production risks (compared to production systems with pesticide use).[11] Second, farmers face higher market risks because of uncertainty on the durability of price markups. Generally, price markups are determined by the market. In this case, IP-Suisse determines the markups for its producers' products, including pesticide-free wheat, through price negotiations with downstream actors (e.g., bakeries and retailers). Although these price markups have historically been rather stable, they depend on general market conditions and production volumes, which translates into uncertainties about long-term prices for pesticide-free wheat. Third, farmers face investment risks (e.g., because new machinery is needed).[12] Fourth, farmers face higher institutional risk (e.g., because of uncertainty on the durability of direct payments). Risks, risk perceptions, and risk preferences of farmers might thus hinder or delay adoption and need further investigation. The next section presents, conceptually, how risk perceptions and risk preferences relate to the farmers' adoption decisions.

Conceptual and Econometric Framework

Conceptual Framework

Previous research has explored the different factors that influence the rate of adoption of sustainable agricultural practices (see, e.g., Sunding and Zilberman, 2001; Dessart, Barreiro-Hurlé, and Van Bavel, 2019). We are interested in the extent to which the presence of farmer heterogeneity in risk perceptions and risk preferences explains differences in adoption and the timing of adoption. To this end, a better understanding of farmers' choices and their tendency toward postponement behavior when it comes to adopting new technologies and practices can help improve the effectiveness of agri-environmental programs (Möhring et al., 2020).

A number of theoretical models attempt to explain farmers' adoption behavior, particularly the slow conversion rates when expected benefits of conversion are positive. Real options for example, explains the investment decisions regarding a risky option with sunk costs and a level of irreversibility of the investment. Kuminoff and Wossink (2010) modeled the farmers' decision to adopt organic agriculture using this approach. In their model, the crucial elements to explain behavior are the production, market, and institutional risk alongside irreversible sunk costs for the conversion to organic agriculture. The mechanisms of the model imply that the monetary compensation for the conversion of production systems could either increase conversion rates due to the induced gap in returns or induce a delay in adoption when the future of the policy program financing conversion compensations is uncertain. This application offers important elements to understand why farmers delay the adoption of technologies and practices that offer larger expected profits compared to their current practices. Most importantly, it recognizes that farmers face a variety of risks beyond production and markets, as their decisions are embedded in institutional arrangements for the promotion of sustainable practices.

[11] In comparable settings from organic agriculture, farmers during the first years after conversion focus their efforts on weed control and yield stabilization (Chongtham et al., 2017).

[12] Only 31% of the farmers in our sample have access to machinery for mechanical weed control, indicating that investment in this alternative to herbicides is necessary for most farmers when adopting pesticide-free farming.

Slow conversion rates can also be explained by the updating process of farmers' beliefs regarding the new technologies. For example, Leathers and Smale (1991) apply Bayesian updating, where individuals learn, update their subjective probabilities, and adjust their behavior regarding the adoption of a technology. In a setting where farmers can adopt individual components of a technology, the model predicts that farmers would be willing to adopt a particular component of technologies early on to gain useful information for subsequent periods. However, when farmers perceive high risks of the project and technology components, the incentive to adopt and learn is lessened.[13]

Farmers' subjective risk perceptions are needed to explain risk behavior (e.g., Abadi Ghadim, Pannell, and Burton, 2005; Menapace, Colson, and Raffaelli, 2013). Prospect theory—introduced by Kahneman and Tversky (1979)—speaks to this by looking at the different dimensions of risk preferences. The theory characterizes risk preferences as comprising three components: risk aversion, loss aversion, and probability of over- or underweighting. With the latter, the model captures the tendency of decision makers to interpret probabilities and weight them nonlinearly (e.g., by overweighting small probabilities and underweighting large ones). This tendency to distort probabilities is closely related to risk perceptions.[14] In the context of adoption of new technologies, Liu (2013) show that farmers in China with preferences of overweighting small probabilities (e.g., the probability of a severe pest infestation) were more likely to adopt Bt cotton, a pest-resistant cotton variety. The mechanism for this relation lies in the subjective interpretation of risks, which reassures the need to elicit the perceptions farmers have regarding the new technology, alongside risk preferences.

In connection with farmers' decisions to adopt the pesticide-free production system, the implications of these theoretical insights are manifold. At the program level, the pesticide-free production system induces higher risks in production, which increases the incentives to postpone adoption. Similarly, the substitution of pesticides requires long-term adjustments, such as the adaptation of crop rotations and the acquisition of machinery that increases incentives to postpone. Direct payments and price mark-ups increase the amount of risk that farmers can tolerate by generating higher expected returns and therefore decreasing the incentives to postpone. At the individual level, adoption decisions further depend on farmers' perceived risk and risk aversion. Both aspects are crucial to characterizing farmer's risk behavior. How farmers subjectively interpret multiple risks adds relevant information to the risk context in which risk preferences operate. Consequently, we expect, first, that farmers with higher willingness to take risks will be more likely to adopt pesticide-free production systems and less likely to delay adoption. Second, we expect that farmers with higher levels of perceived production, market, institutional, and investment risk due to the transition to pesticide-free production will be less likely to adopt of pesticide-free production system and more likely to delay adoption.

Econometric Framework

Main Specification

We propose an econometric framework to capture the role of risk on adoption and the prospective timing of adoption of the pesticide-free wheat production. In the linear model of equation (1), T_i represents the adoption behavior (i.e., adoption and adoption timing) of farmer i observed in our sample:

$$(1) \qquad T_i = \omega + \boldsymbol{\theta}_1 \boldsymbol{RP}_i + \theta_2 \boldsymbol{R}_i + \boldsymbol{\theta}_3 \boldsymbol{C}_i + \boldsymbol{\gamma}_c + \varepsilon_i,$$

[13] This model is particularly insightful as it explains partial compliance and limited adoption in the case of risk-neutral farmers. Including risk aversion, therefore, would further slow down the diffusion of the technology.

[14] Villacis, Alwang, and Barrera (2021), for example, show that farmers with tendencies to overestimate small probabilities consistently perceived larger climate change risks.

where $\boldsymbol{RP}_i$ are risk perceptions, including four domains of risk:production, market, investment, and institutional. Moreover, $\boldsymbol{RP}_i$ includes uncertainty on the expected return of the production system and probability of yield losses and crop failure. As all the risk sources might be positively correlated (Figure S2 in the online supplement, see www.jareonline.org), we first analyze them individually.[15] We consider risk preferences through farmers' willingness to take risks, R_i.[16] According to the hypotheses, when T_i represents the binary decision of adopting the system, we expect $\boldsymbol{\theta}_1$ to be negative for all the measures of risk perceptions and θ_2 to be positive; the opposite applies when the outcome variable is the incentive to postpone. By estimating an ordinary least squares (OLS) model, we treat the limited dependent variables (adoption and incentive to postpone) linearly given our interest in the marginal effects rather than the estimation of the conditional expectation function. In the robustness checks, we provide an alternative to the linear probability model.

Given that risk perceptions are a cognitive construct, they might depend on the context and characteristics of farmers, raising concerns of omitted variable bias. To reduce this risk, we include a vector, $\boldsymbol{C}_i$, of farmers' characteristics, including age, education, share of income from agriculture, succession of farm, workforce, machinery availability, farmers' main language (i.e., German or French), farm geographic characteristics (i.e., temperature, precipitation, mountainous geography), and local conditions captured with weed presence and herbicide resistance. To limit geographic-specific sources of endogeneity, we include canton dummies, $\boldsymbol{\gamma}_c$. The error term, ε_i, is assumed to have a 0 mean and is clustered at the canton level. To further identify the mechanisms of the relationship between risk preferences and perceptions and adoption behavior, we split the sample of farmers according to the share of wheat in their production system at the median and estimate equation (1) for each of the two samples, reflecting the fact that specialized and less specialized farms may perceive risks differently.

Throughout the analysis, we carefully interpret our results as correlations and not as causal relations, given that risk perceptions and preferences are likely to be determined by the complex risk context surrounding farming activities and beyond (e.g., social, and cultural characteristics). Nevertheless, we provide extensive checks to test the robustness of our results.

Robustness Checks

In our analysis, the role of risk perceptions and risk preferences is assumed to relate to adoption decisions independently. This aspect would not hold if risk preferences and risk perceptions were closely linked. To explore this aspect, we estimate four alternative specifications: (i) a model including only risk preferences (and the set of all control variables), (ii) a model including only risk perceptions (and the set of all control variables), (iii) a model including both risk preferences and risk perceptions alongside an interaction term to capture whether risk perceptions are more important for more risk-averse farmers (Pennings and Wansink, 2004; Trujillo-Barrera, Pennings, and Hofenk, 2016), and (iv) following Acharya, Blackwell, and Sen (2016), a mediation analysis with a sequential g-estimation to identify whether there is a direct relation between risk preferences and adoption decisions that is not mediated by risk perceptions.[17] This will allow us to capture

[15] We can expect that risks regarding program continuation (i.e., market risk) are correlated with risks related to changes in the direct payments for the reduction of herbicides. In this setting, to identify the marginal contribution of each of the risk domains to adoption, the preferred specification considers them independently. Table S4 in the online supplement shows the results of the estimation with all sources jointly.

[16] While the main specification considers risk preferences and risk perceptions as independent factors influencing adoption, both constructs can be interrelated. There is no consensus in the literature regarding the interplay between the two constructs. In robustness checks, we introduce two specifications that capture different forms of the interplay (i.e., an interaction of independent constructs and a mediated relation).

[17] The two models with interaction and mediation effects (i.e., models 3 and 4) offer complementary information. While an interaction between risk preferences and risk perceptions reveals whether the role of risk perception depends on risk preferences, a mediated relationship reveals whether risk perceptions are the sole mechanism through which risk preferences relate to adoption. In short, the first explores moderation and the second mediation.

whether farmers who are more risk averse perceive risks differently, thereby influencing adoption decisions (e.g., Menapace, Colson, and Raffaelli, 2013).

The mediation analysis proposed by Acharya, Blackwell, and Sen (2016) decomposes a relation of interest into indirect and direct effects in two stages (equations 2 and 3). In the first stage, the dependent variable is transformed by removing the effect of the mediator. In the second stage, the effect of the variable of interest is estimated with the de-mediated outcome.[18] To understand the relevance of risk preferences, net the role of risk perceptions, we first de-mediate the dependent variable (i.e., adoption and prospective timing of adoption) from the role of risk perceptions and, second, estimate the role of risk preferences in the transformed dependent variable. If the g-estimate coefficient of risk preferences (θ_2) remains significant and robust compared to a baseline model that considers only risk preferences, this implies that risk perceptions are not the sole mechanism through which risk preferences relate to adoption.

Stage 1: Demediation of the outcome

$$\widehat{T_i} = T_i - \boldsymbol{\theta}_1 \boldsymbol{RP_i} \tag{2}$$

Stage 2: Estimation on risk preferences

$$\widehat{T_i} = \omega + \theta_2 \boldsymbol{R_i} + \boldsymbol{\theta}_3 \boldsymbol{C_i} + \boldsymbol{\gamma_c} + \varepsilon_i \tag{3}$$

Moreover, to acknowledge the nature of the dependent variable, we estimate a probit model for the adoption outcome and a generalized ordered logit for the adoption timing specification.[19] Another aspect of concern is the omitted variable bias. To address this possibility, we test whether our results are robust to the inclusion and exclusion of control variables to account for selection on observables and test for robustness to nonobservables with Oster (2019) bounds.[20] To reduce the concerns of reverse causality due to previous experience with the system, we limit the sample of farmers to those who did not participate in a pilot of the program in the 2018/2019 season. Last, to address potential concerns regarding the robustness of our measure of risk preferences, we estimate equation (1) in a specification where risk preferences are measured with a dummy variable equal to 1 for risk-averse farmers and 0 otherwise.

Data

The data used in this analysis are publicly available and described in Möhring and Finger (2022a). They were collected from December to January 2019 and consist of a standalone survey of 1,073 wheat farmers in Switzerland who answered an online questionnaire on the determinants and challenges for adopting a pesticide-free production standard.[21] The survey consists of two sections: The first comprises questions regarding participation in the pesticide-free wheat production program, and the second asks about the personal characteristics of the farmers and farms.

Given the cross-sectional nature of the data, we infer the timing of adoption by looking at participation in the program in previous periods and the intention to join the program at a later point (Table 2). The variable is constructed as a categorical variable that takes a value of 1 if the

[18] The approach has been used in other applications to identify the mechanisms through which personality constructs are related to technology adoption (e.g., Kreft et al., 2021).

[19] In our case, the generalized ordered logit is preferred to the ordered probit/logit given the rejection of the parallel regression assumption. This is the case due to the dissimilarity of the ordered categories and the fact that the estimated coefficients are not equal across them. See Williams (2006) for a description of the method.

[20] Oster (2019) proposes a way to estimate the degree of selection on unobservable variables that would change the significance and magnitude of relationships. See Möhring and Finger (2022a) for an explanation of the method.

[21] The survey was designed after discussions with farmers, extension service experts, and farm advisors. This process informed the survey design that was later pretested with ten producers and adjusted before rollout. More details on survey design are available in Möhring and Finger (2022a).

Table 2. Categorization of Adoption Timing (*N* = 1,073)

Value	Categories	%
1	Early adopter	17.8
2	Stated to adopt at some later point	45.4
3	Stated to never adopt	36.8

farmer is an early adopter, a value of 2 if the farmer indicated that they plan to participate in the next or future growing seasons, and a value of 3 if the farmer reports that they will certainly not participate. The variable can be interpreted as a propensity to postpone.[22] Under this definition, the largest share of farmers are nonadopters located between joining the program at some point (45.4%) and not willing to join the program at any point (36.8%) (Table 2).

Risk Preferences

Following Meuwissen, Huirne, and Hardaker (2001) and Weber, Blais, and Betz (2002), we collect domain-specific risk preferences using self-assessment questions. More specifically, we retrieve willingness to take risks in four domains: plant protection, production, marketing, and general agriculture.[23] Following Dohmen et al. (2005), we retrieve an 11-point Likert-type assessment question (see Iyer et al., 2020, for an overview of further applications) and compute the average of the scale over those four domains.[24] The average farmer in our sample is nearly risk neutral, although there is important heterogeneity around neutrality (standard deviation is 1.94 on a scale from 0 to 10).

Risk Perceptions

Farmers were asked to assess the risk of the investment in machinery in the context of wheat production without plant protection products and to state the factors contributing to this assessment. From these factors we retrieve four domains of risk: production, market, investment, and institutional risks.[25],[26] Production risks are measured as fear of high yield losses in wheat production without pesticides, high weed pressure in other cultures of the crop rotation, and quality risk. Market risks are measured as fear of the discontinuation of the IP-Suisse price premium, investment risks as fear of the profitability of investment and institutional risks as fear of changes in direct payments. The phrasing of the question includes the word "fear," which sets these sources of risk in the domain of losses. Farmers report their views on these aspects on a scale that ranges from 1 (not important) to 5 (very important).[27] Values below 3 would suggest that the risk source is not important for the farmer, while values above that threshold suggest relevant risks.[28]

In addition to domain-specific risk perceptions, farmers were asked to express their expectations about the magnitude of the yield decrease and the probability of crop failure or low yield when adopting.[29] Farmers reported their expectations regarding a yield decrease comprising losses from 0

[22] "Early adopters" refers to farmers that adopted in season 2018/2019 or 2019/2020.

[23] The exact wording of the question is: "Do you avoid taking risks or are you willing to take risks in the following areas?" Supplement Table S2 reports the details of the elicitation question.

[24] The correlation between the different domains is low (see Supplement Table S2), which suggests that each domain contains potentially useful information for adoption decisions. In line with previous literature, we use the average of the domains, as it preserves the original range of values (i.e., 0 to 10).

[25] Supplement Table S2 reports the exact wording of the question.

[26] See Organisation for Economic Co-operation and Development (2009) for the categorization of risks.

[27] Similar risk assessments have been used previously in the literature (e.g., Meuwissen, Huirne, and Hardaker, 2001; Flaten et al., 2005; Menapace, Colson, and Raffaelli, 2013).

[28] Table S1 in the online supplement describes these variables.

[29] The perceived frequency (or probability) and perceived magnitude of the loss is a common simplification of risk perceptions. A fully specified characterization of risk would require the complete (subjective) probability distribution of the returns of the new production system. Attanasio (2009) offers a discussion on the elicitation of expectations and perceptions.

Table 3. Descriptive Statistics (N = 1,073)

Variables	Mean	Std. Dev.	Description
Adoption[a]	0.63	–	Adopter (1/0)
Adoption timing	2.19	0.71	Range 1-3 (see Table 2)
Willingness to take risks (0-10)	4.97	1.94	Average risk willingness over four domains from 0 (not willing to take risks) to 10 (high willingness to take risks)
Perceived risks			
Production risk: Yield decrease	3.18	1.22	Perceived risk of yield decrease[b]
Production risk: More weeds in crop rotation	3.97	1.13	Perceived risk of more weeds in the crop rotation[b]
Production risk: Decreased wheat quality	3.39	1.25	Perceived risk of a decreased wheat quality[b]
Market risk: Risk of reduced-price markups	3.28	1.22	Perceived risk of a reduction in price markups[b]
Institutional risk: Reduced direct payments	3.72	1.20	Perceived risk of reduced direct payments for pesticide-free production[b]
Risk of investment	3.20	1.31	Perceived risk of investment not being profitable[b]
Perceived magnitude of yield decrease	3.06	1.34	Magnitude of the yield decrease, where 1 = no decrease, 2 = 0%–5% decrease, 3 = 5%–10% decrease, 4 = 10%–15% decrease, and 5 = >15% decrease
Perceived probability of an increase in yield losses	2.93	1.29	Probability of an increase in “bad years” (with complete crop failure or low yield), where 1 = no increase in bad years, 2 = 1 “bad year” every 20 years, 3 = every 10 years, and 4 = every 5 years

Notes: All control variables are described in the online supplement.
[a] Adoption takes a value of 1 when the farmer is an early adopter or adopter of subsequent seasons and 0 otherwise.
[b] On a scale from 1 (not important) to 5 (very important)

to more than 15%. The variable was asked on a scale from 1 to 5 as described in Table 3. Similarly, farmers responded how often they expected an additional “bad year” with a complete crop failure or very low yield due to conversion. The responses range from no increase of bad years to one additional bad year every 5 years. Table S2 in the online supplement presents the specific phrasing of these variables.

Results

Figure 1 shows the average perceived risk level for each domain across three groups of farmers (i.e., early adopters, potential or delayed adopters, and never adopters). For all groups of farmers, risks related to weeds in crop rotation and changes in direct payments are the most important. As expected, risk perceptions are lowest for early adopters and highest for never adopters—with potential adopters in between. This result is consistent over all domains. Among never adopters, the risk of more weeds in crop rotation is assessed particularly high, with an average of 4.51. This group also assesses other production risks (e.g., wheat quality risk and risk of yield decreases) significantly higher compared to the other two groups. These assessments reflect farmers’ perceived operational challenges of adoption. In addition, institutional risks seem to be the most important source of risk after risks related to weeds in crop rotations, highlighting the role of economic incentives in inducing adoption. Interestingly, the assessment of market and investment risks is similar for all groups of farmers, suggesting a level of agreement regarding the nature and potential dynamics of these risks.

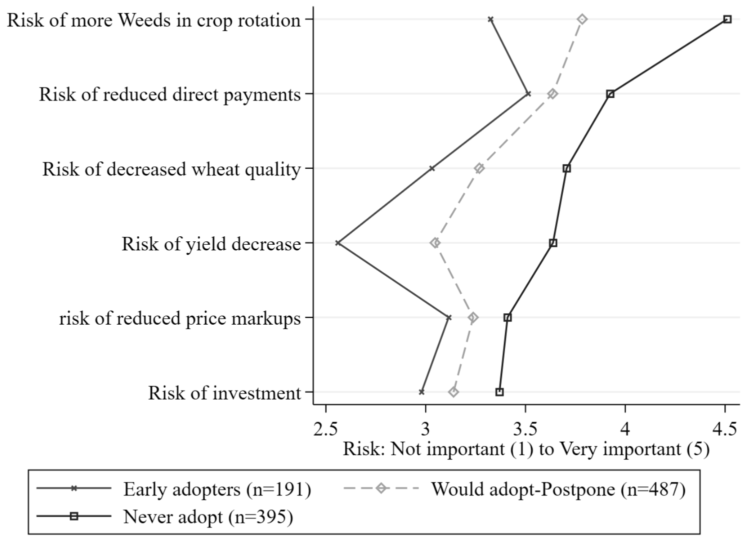

Figure 1. Risk Sources by Farmer's Prospective Timing of Adoption

Notes: All differences are significant, with only three exceptions: Direct payments, IP-SUISSE program, and investment risk between early adopters and farmers that postpone (see Table S3 in the online supplement). Moreover, the Cronbach's alpha statistic is equal to 0.72, compared to the rule of thumb of 0.7. This suggests an acceptable internal consistency of the risk perception measures (see, e.g., Nunnally and Bernstein, 1994).

These results are descriptive and do not control for other covariates. Next, we analyze in more detail how risk perceptions and risk preferences relate to adoption and adoption timing of the pesticide-free system using regression analysis. Tables 4 and 5 show the results of the estimation of equation (1) for adoption and for adoption timing, respectively. For every set of coefficients, we include a specification with and without control variables.

The main results are as follows: First, farmers who are more willing to take risks are more likely to adopt the system and also tend to delay its adoption less. An increase of 1 unit on the risk-willingness scale from 0 to 10, *ceteris paribus*, is related to a 2–4 percentage point increase in adoption (Table 4). Second, perceived production risks are associated with the decisions to adopt and to delay adoption (Tables 4 and 5, columns 1 to 4). While the expected yield-level decrease is not relevant for farmers' decisions, the expected probability of yield losses (variability) and crop failure is highly significant. The higher the perceived probability of yield losses, the higher the postponement and the lower the adoption. For production risks measured with Likert scales, an increase of 1 unit in the risk perception of weeds in crop rotations is associated with a 10-percentage-point decrease in adoption. The coefficients for importance of the risk of yield decrease and decreased wheat quality are negative and significant, although smaller in magnitude. Third, risks of changes in federal direct payments are related to less adoption and more postponement, while market risks and investment risks do not seem to play a role in farmers' adoption decisions (column 5–8). More specifically, the market and investment risks are significantly associated with adoption and postponement, although the relationships are not robust after the inclusion of control variables.[30]

[30] The models with control variables offer greater explanatory power compared to models that only include preferences and risk perceptions. Moreover, their inclusion seems to explain part of the variation comprised in the constant term. The interpretation of the latter, however, is limited due to the range of values of risk perceptions (ranging from 1 to 5).

Table 4. Estimation Results per Domain of Risk: Outcome Adoption (*N*= 1,073)

Dependent Variable: Adopt No/Yes (0/1)	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**
Willingness to take risks (0–10)	0.03***	0.03***	0.03***	0.02***	0.04***	0.04***	0.04***	0.04***	0.04***	0.04***
	(0.01)	(0.01)	(0.00)	(0.01)	(0.00)	(0.01)	(0.00)	(0.01)	(0.00)	(0.01)
Perceived risks										
Perceived magnitude of yield decrease	−0.02	−0.00								
	(0.02)	(0.02)								
Perceived probability of an increase in yield losses	−0.09***	−0.07***								
	(0.01)	(0.01)								
Production risk: Risk of yield decrease			−0.04**	−0.03*						
			(0.02)	(0.02)						
Production risk: Risk of more weeds in crop rotation			−0.12***	−0.10***						
			(0.01)	(0.01)						
Production risk: Risk of decreased wheat quality			−0.02*	−0.01*						
			(0.01)	(0.01)						
Market risk: Risk of reduced-price markups					−0.03**	−0.01				
					(0.01)	(0.01)				
Institutional risk: Reduced direct payments							−0.05***	−0.03**		
							(0.01)	(0.01)		
Risk of investment									−0.03***	0.00
									(0.01)	(0.01)
Constant	0.78***	1.18*	1.14***	1.49**	0.50***	1.16	0.59***	1.22	0.52***	1.07
	(0.05)	(0.67)	(0.04)	(0.68)	(0.04)	(0.71)	(0.04)	(0.73)	(0.03)	(0.73)
Set of controls[a]	No	Yes	No	Yes	No	Yes	No	Yes	No	Yes
R^2 (adjusted)	0.10	0.15	0.16	0.2	0.04	0.12	0.04	0.12	0.04	0.12

Notes: Values in parentheses are clustered robust standard errors. Single, double, and triple asterisks(*, **,***) indicate significance at the 10%, 5%, and 1% level, respectively. Linear model of equation (1) with dichotomous dependent variable and risk perceptions ranging from 1 to 5.

[a] Set of controls includes canton dummies, farm/farmer level characteristics, and geographic characteristics.

Table 5. Estimation Results per Domain of Risk: Outcome Postpone (N= 1,073)

Dependent Variable: Postpone **Early adopter/postponer/ never adopter (1–3)**	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**
Willingness to take risks (0-10)	−0.05***	−0.04***	−0.04***	−0.03***	−0.06***	−0.05***	−0.06***	−0.05***	−0.06***	−0.05***
	(0.01)	(0.01)	(0.01)	(0.01)	(0.01)	(0.01)	(0.01)	(0.01)	(0.01)	(0.01)
Perceived risks										
Perceived magnitude of yield decrease	0.04	0.02								
	(0.02)	(0.02)								
Perceived probability of an increase in yield losses	0.13***	0.10***								
	(0.02)	(0.02)								
Production risk: Risk of yield decrease			0.07***	0.07***						
			(0.02)	(0.02)						
Production risk: Risk of more weeds in crop rotation			0.18***	0.15***						
			(0.02)	(0.02)						
Production risk: Risk of decreased wheat quality			0.02	0.01						
			(0.02)	(0.02)						
Market risk: Risk of reduced-price markups					0.05**	0.03				
					(0.02)	(0.02)				
Institutional risk: Reduced direct payments							0.07***	0.05**		
							(0.02)	(0.02)		
Risk of investment									0.05***	−0.01
									(0.01)	(0.02)
Constant	1.90***	1.48	1.32***	0.99	2.34***	1.48	2.23***	1.39	2.32***	1.65
	(0.09)	(0.97)	(0.07)	(0.95)	(0.07)	(1, 04)	(0.08)	(1.08)	(0.05)	(1.07)
Set of controls[a]	No	Yes	No	Yes	No	Yes	No	Yes	No	Yes
R^2 (adjusted)	0.10	0.18	0.18	0.24	0.03	0.15	0.04	0.15	0.04	0.15

Notes: Values in parentheses are clustered robust standard errors. Single, double, and triple asterisks(*, **,***) indicate significance at the 10%, 5%, and 1% level, respectively. Linear model of equation (1) with ordered dependent variable and risk perceptions ranging from 1 to 5.

[a] Set of controls includes canton dummies, farm/farmer level characteristics, and geographic characteristics.

Both risk preferences and risk perceptions are relevant for explaining postponement behavior (see Table 5). The marginal effect, for example, suggests that a change from very risk averse to very risk loving is related to a 0.4-unit decrease (out of 3) in the postponement outcome, *ceteris paribus*, toward nonadoption (see Table 5, column 2). Similarly, the shift from not perceiving risks of more weeds in the crop rotation to assessing them as very important implies a 0.6-unit increase in the measure of postponement toward nonadoption, which translates to a 35.8% increase in the postponement measure (see Table 5, column 4).[31] Farmers that consider the institutional risk to be highly important have an 8.8% larger postponement measure than farmers that do not consider this risk to be as important for adoption. The results suggest that farmers' perceptions of production and institutional risks and farmers' risk preferences explain farmers' waiting behavior to a large extent.[32] Moreover, they support the notion that it is not enough to account for risk preferences only, as risk perceptions capture important information about the nature of the risks farmers perceive after adoption (see, e.g., Pennings and Wansink, 2004).

To explore whether specialized and less specialized farms may perceive risks differently, we estimate the model for two samples of farmers, distinguished by their share of wheat in the production system (see Tables S5 and S6 in the online supplement).[33] Production risks remain important determinants of farmers adoption decisions. For farmers more specialized in wheat (higher share than the median), the risk of weeds in crop rotations is twice as large as the estimate for farmers not specialized (share of wheat below the median). This result implies that farmers with more diversity in their production systems (i.e., producing wheat alongside other crops) are less afraid of weed pressure. In contrast, institutional and market risks seem to be relevant only for farmers with less than 15% of wheat in their land, which could suggest that these farmers have a certain level of reliance on the economic incentives provided by the government and the farmer's association (i.e., low economies of scale). Regardless of farmers' wheat specialization level, the expected probability of yield losses and crop failures remain important for adoption decisions (i.e., the coefficient has the same magnitude and significance for both samples).

Robustness Checks

Regarding the interplay between risk preferences and risk perceptions, we estimate models that include risk preferences and risk perceptions separately (Table S7). We find that the coefficients are robust although slightly larger compared to the main model in equation (1). This small change could reflect the positive correlation between both concepts and their potential interplay. To further investigate this interplay, we estimate a model that includes risk preferences, risk perceptions, and the interaction between them (Tables S8 and S9).[34] We find that the interaction terms, regardless of the risk domain considered, are not significantly associated with adoption decisions. The second model aims to identify the relationship between risk preferences and adoption that is mediated by risk perceptions. We perform a sequential g-estimation as specified in equations (2) and (3). In Figure 2 we report the coefficients of risk preferences in relation to the baseline (i.e., model in equation 1 excluding risk perceptions). Significant differences between the coefficients and the baseline would point toward risk perceptions as mediators of the relationship between risk preferences and adoption behavior. Results from this procedure suggest that risk preferences have a

[31] The prediction considers all covariates at the mean. It estimates a postponement measure of 1.73 for farmers not perceiving risks of weeds in crop rotation and 2.35 for farmers considering this risk as highly important. Similarly, the prediction suggests a measure of 2.07 and 2.25 for farmers not perceiving and perceiving institutional risks, respectively.

[32] The adjusted R^2 of the model without risk preferences and risk perceptions is around 13%, while the model that includes production risks with Likert scales, for example, is almost twice that percentage (24%).

[33] In our sample, the median share of wheat is equal to 15%.

[34] Following Pennings and Wansink (2004), the interaction term is positive and increasing with larger risk aversion or larger risk perceptions. The term is negative when the farmer is risk loving and equal to 0 when the risk domain is not an important source of risk, the farmer does not expect a yield decrease or an increase in "bad years" due to adoption, and/or the farmer is risk neutral.

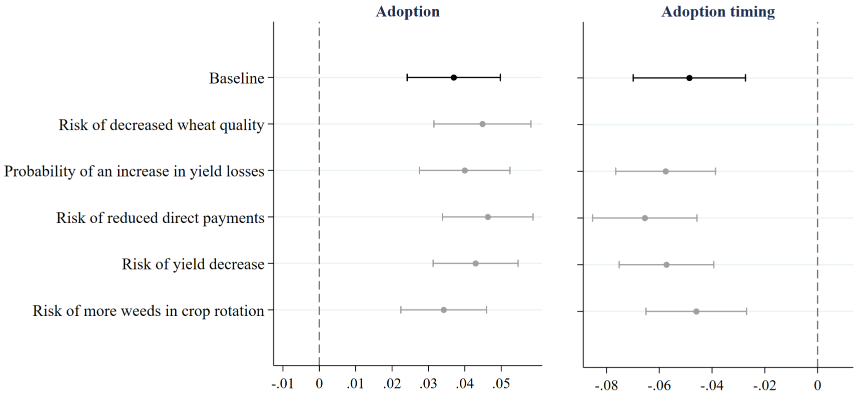

Figure 2. Risk Preferences Have a Direct Relation to Adoption Not Mediated by Risk Perceptions

Notes: Sequential g-estimates for risk preferences. Baseline estimation refers to the model that includes all risk perceptions at once. For testing the mediation of each of the risk perception variables, we set to intermediate confounders the other risk perceptions. Only significant risk perceptions are tested as mediators.

direct relation with adoption and adoption timing that is not mediated by risk perceptions, regardless of what domain and measure is considered as mediator. This means that risk perceptions alone cannot explain the lower adoption and higher postponement of those farmers with high risk aversion. The result instead points toward a direct relation of risk preferences and adoption decisions or the existence of other mediators (e.g., nonadoption-related risk perceptions).

These results shed light on the literature that finds mixed evidence for the significance of the interaction between preferences and risk perceptions for decision making.[35] Intuitively, the larger the perceived risks, the more adoption should be observed from risk-loving farmers. We do not find evidence for this dynamic. In contrast, results from alternative model specifications (i.e., including interaction and mediation effects) support our original model, as they point to an independent influence of risk perceptions and preferences on adoption decisions.

Next, we estimate a probit model for the outcome adoption and a generalized ordered logit for the adoption timing outcome (Tables S10 and S11) and find that the estimates for production and institutional risks are robust. Second, we test for selection on observables and find that the coefficients for production risks are more robust than the institutional risks (see Tables 4 and 5). In particular, the coefficient of risks of yield decreases does not change after the inclusion of farmer and farm characteristics, while the coefficients of weeds in crop rotation and institutional risk change by up to 29% in the different specifications. To further explore the stability of our coefficients, we follow Oster's (2019) proposed approach, using a test to assess whether unobserved controls have the potential of shifting the estimated coefficients toward 0.[36] We find that nonobservables would need to be more than 3 times as important as the rich set of used observables to bring the coefficient of risk preferences to 0 (Table S12). Similarly, the estimates of production and institutional risks are stable. For example, for risk of weeds in crop rotation, potential omitted variables would need to be at least 1.61 times as important as the observables to move the coefficient to 0.

[35] In previous literature, the interaction of risk preferences and risk perceptions offers mixed results. For example, Pennings and Smidts (2000) find no significant association between the interaction and the outcome variable—trading frequency in a risky market—when risk preferences are measured with the psychometric scale, but a significant association when they are measured with an intrinsic risk preference. Pennings and Wansink (2004) find that the interaction between risk preference and risk perception influences contracting behavior.

[36] The test consists of the estimation of a parameter delta that measures the degree of selection on unobservable that would move the coefficients toward 0. For a true coefficient of 0 (beta = 0), a delta of 1 suggests that nonobservables need to be as important (in terms of explanatory power) as the observables to move the coefficient to 0.

We find that results are robust when we restrict the sample to farmers who only report risk perceptions about the program prior to adoption (Table S13). In our sample, 132 farmers adopted during the piloting of the system, which means that their risk perceptions might be influenced by their experience during these trials. After excluding these farmers from the analysis, the results remain robust in magnitude and significance. Finally, our results are robust to alternative specifications of risk preferences. Consistently with the main results, risk-averse farmers are less likely to adopt and show more postponing behavior (Table S14). All in all, our results are robust to the model specification, selection on both observables and unobservables, and different samples of farmers considered.

Discussion

We study the risk-related barriers for the adoption of a pesticide-free production system in Switzerland. We find that perceived risks related to weeds in crop rotations and changes in direct payments are the most relevant risks for farmers' adoption decisions. Moreover, we observe that perceived risk levels in the production, market (i.e., price markups), institutional (i.e., federal direct payments), and investment domains are lowest for early adopters and highest for never adopters. This finding is in line with previous literature, where risk perceptions differ for farmers under different production systems (e.g., organic vs. conventional, Koesling et al., 2004; Flaten et al., 2005).

The pesticide-free wheat production system is based on a comprehensive set of incentives, including dedicated marketing channels, price mark-ups, and direct payments. There is an ongoing discussion in the literature about whether such tools should be used to encourage adoption of sustainable practices (e.g., Offermann, Nieberg, and Zander, 2009; Lefebvre, Langrell, and Gomez-y Paloma, 2015; Ricome et al., 2016). Läpple and Kelley (2013), for example, study the decision of Irish farmers to transition to organic farming and find that the prospect of increasing farm income through support payments are more important than the prospect of receiving higher prices. Our main result is that despite the prevalence of several risks, only production and institutional risks are related to lower adoption and more waiting behavior.

Regarding perceived production risks, we focus on three measures (i.e., risks of yield-levels, weed pressure in crop rotations, and quality risks). The results indicate that farmers expect the renunciation of herbicides in wheat production to result in increased weed competition with crops and, thus, lower yields and higher production risks. Risks related to wheat quality, relevant for revenues in Switzerland, ranked third and above the risks related wheat yields, but the estimated coefficient is small. This suggests that farmers mainly attribute quality downgrades to factors unrelated to herbicide use (e.g., extreme weather events) (Gibson, Young, and Wood, 2017).

The risk literature usually distinguishes between the magnitude and the probability of a risk scenario. There is evidence, for example, that people prefer risk coming from the probability of winning over risk coming from the magnitude of the reward (Bruner, 2009).[37] Our results conform to this idea and suggest that the expected probability of yield losses and crop failures is a strong predictor of farmers' adoption decisions, while the magnitude of the expected yield loss is not.

Moreover, we find that the perceived risk related to direct payments is significant—a 1-unit increase in the risk perception scale is associated with a 3-percentage-point increase in the probability that farmers never adopt. This finding is in line with the literature that finds a key role of payments in the participation of agri-environmental schemes (e.g., Jaime, Coria, and Liu, 2016). We argue that the participation of different actors in the incentive schemes (i.e., federal government and farmers' associations), while desirable to foster pesticide-free agriculture, can also introduce collateral dimensions of risk, such as institutional risk.

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[37] Bruner (2009) studies the preferences of risk-averse individuals to changes in the probability of gains and the magnitude of the reward in a set of gambles. The set of preferences are elicited through an experiment with two settings in which the probability varies and the reward is kept constant, and the contrary case.

In addition to receiving direct payments, farmers can sell their wheat with a price markup for pesticide-free production. We find that that perceived risks of a discontinuation of price premiums are relatively important in farmers' interpretation of risks (with average importance of 3.28 out of 5) but are not significantly related to adoption and prospective timing of adoption. This finding is surprising, as price markups and direct payments are economically almost equally relevant for pesticide-free production (see Table 1). However, the farmers' organization IP-Suisse has long-standing relationships with farmers (i.e., they have operated for more than 30 years; Finger and El Benni, 2013), which may explain the higher trust in IP-Suisse (and the continuation of price mark-ups) than in the continuation of governmental policies, which change regularly. This is further emphasized by the high public pressure the Swiss agricultural sector has faced in the last few years to reduce its reliance on chemical inputs (e.g., through popular initiatives for pesticide bans, see Finger, 2021). This highlights the important role of trusted supply chain partners in reducing the risks faced by farmers and supporting the transition to pesticide-free production.

Finally, farmers who tend to postpone the adoption decision more also tend to be more risk averse. This finding is consistent with the empirical literature that finds a negative correlation between adoption and timing of adoption of organic agriculture and risk aversion (e.g., Läpple and Kelley, 2015). Intuition from previous literature suggests that risk preferences play a role in decision making mainly through risk perceptions (e.g., Menapace, Colson, and Raffaelli, 2013). In contrast, we find that both farmers' risk preferences and perceptions play a role in adoption decisions and find no evidence of an interaction or mediation between the two constructs. This is consistent with literature finding that risk preferences remain a key factor for adoption, even after accounting for risk perceptions in different domains (e.g., Meraner and Finger, 2019).

There are important limitations in our analysis. For example, while we focus on risk, farmers might also have uncertainty regarding the probability of different scenarios, leading to considerations of ambiguity aversion (Cerroni, 2020). Moreover, we analyze system-specific risk perceptions of a low-input agricultural scheme, but farmers are exposed to a wide range of risks, some not associated with adoption (i.e., background risk). Recent findings suggest that the presence of background risk reduces the adoption of sustainable practices in the presence of foreground risk (i.e., risk associated with adoption) (Lefebvre, Midler, and Bontems, 2020). Future efforts could elicit risk perceptions for both types of risk to better characterize farmers' risk context. These issues are beyond the scope of this paper but define an important research avenue in the adoption of agricultural innovations.

Conclusion

Pesticide-free production systems could be a cornerstone for achieving policy targets of pesticide use reduction. Our analysis offers insights into the different dimensions of farmers' risk behavior in relation to the adoption of a pesticide-free wheat production system. Our main result is that higher production and institutional risks and risk aversion are associated with lower adoption and waiting behavior, whereas market and investment risks do not seem to be relevant for farmers' decision making.

Industry and policy makers could address (perceived) production risks and institutional risks in different ways. First, communication channels to provide farmers with information and technical advice could reduce differences between perceptions of production risk and risk exposure. Moreover, our analysis implies that information about the production system should focus on the potential frequency of yield losses rather than on the potential magnitude of yield losses. Policies can also aim to reduce production risk for farmers who adopt pesticide-free systems. This may include additional extension services on pest management, the design of production systems (e.g., specific crop rotations), or—in general—the support of cost-efficient and reliable innovations (e.g., Jacquet et al., 2022). Risk management instruments, such as system-specific insurance solutions, could further increase the amount of risk farmers are able to tolerate and thus encourage adoption.

Moreover, in the presence of high perceived institutional risk and unexpected policy changes, a stable regulatory framework for the use of pesticides and marketing channels could decrease the institutional risks of conversion to pesticide-free agriculture (Bouttes, Darnhofer, and Martin, 2019). On the positive side, findings from our case study suggest that long-standing relations between producers and producer organizations (here, IP-Suisse) can reduce potential effects of market-related risks.

The current incentive scheme for pesticide-free wheat is constant across farmers' actual production risk levels under adoption. The implication of this setting is that farmers facing lower risks tend to adopt, while those exposed to higher risks tend to maintain their current practices. An important question that arises is whether incentive schemes can introduce risk considerations, for example, by defining categories of adoption risk levels using objective measures (e.g., different levels of pest pressure). Answering this question deserves further attention in the empirical literature on adoption behavior and the diffusion of low input agriculture.

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Online Supplement: Risk Perceptions, Preferences, and the Adoption Dynamics of Pesticide-Free Production

Viviana Garcia, Niklas Möhring, Yanbing Wang, and Robert Finger

Pesticide-Free Wheat Production System

Requirements: i) have a proof of ecological performance (ÖLN), ii) use of untreated seeds, iii) avoid the use of pesticides (i.e., growth regulators, fungicides, herbicides, insecticides and chemical-synthetic stimulators of the natural immune system), and iv) ensure that at least one year passes between wheat and wheat on the same plot.

Wheat Production:	Conventional	Extenso	Pesticide-Free (IP-Suisse)	Organic (Bio-Suisse)
Growth regulators	✓	✗	✗	✗
Fungicides	✓	✗	✗	✗
Insecticides	✓	✗	✗	✗
Chemical-synthetic stimulators	✓	✗	✗	✗
Treated seeds with chemical-synthetic additives	✓	✓	✗	✗
Chemical-synthetic herbicides	✓	✓	✗	✗
Synthetic fertilizers (e.g., mineral nitrogen)	✓	✓	✓	✗

Variables of Interest

Risk Preferences

Likert scale-type risk perceptions have been extensively used in the literature. The advantage of these type of assessments is that they reduce the cognitive burden for individuals while retrieves meaningful patterns across risks (see Patrick, et al, 1985). We use such assessments for eliciting risk preferences and risk perceptions. In a Likert scale from 0 to 10, where 0 refers to “not willing to take risks” and 10 “high willingness to take risks”, farmers answer to the question: “Do you avoid taking risks or are you willing to take risks in the following areas?”

- Plant protection
- Agricultural production
- Marketing
- Decisions on my farm (in general)

The material contained herein is supplementary to the article named in the title and published in the *Journal of Agricultural and Resource Economics* (*JARE*).

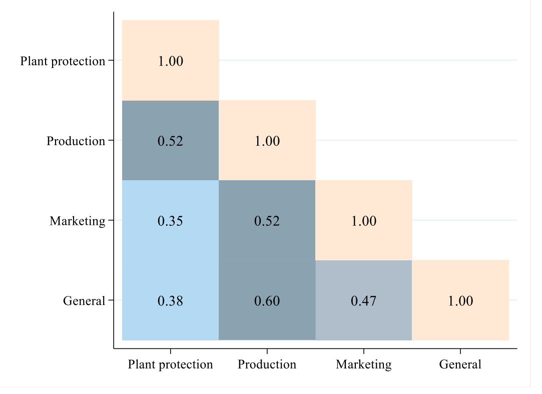

Figure S1. Risk Preferences

Table S1. Risk Perceptions Phrasing- Likert Scales

Domain	Question- Risk perception domain	Scale
Institutional	I fear that direct payment programs will change again (soon)	1= Not important 5= Important
Market	I fear that the IPSUISSE program will not be continued	1= Not important 5= Important
Production	I fear high yield loss in wheat production without PPP	1= Not important 5= Important
Production	I fear a high weed pressure in the other cultures of the crop rotation	1= Not important 5= Important
Investment	I fear that the machinery will not be used sufficiently (investment is not profitable)	1= Not important 5= Important
Production	Higher quality risk[a]	1= Not important 5= Important

Notes: [a] The phrasing of this question is slightly different. It asks farmers whether they consider a higher quality risk as important or not important. Risk domains are embedded in the investment risks farmers face for conversion.

Figure S1 shows there is a positive correlation between the four domains, although not close to one. For this reason, we aggregate the different domains in an average as our measure of risk preference. This metric preserves the original range of values (i.e., 0 to 10), facilitating the interpretation of coefficients.

Risk Perceptions

Following the conceptual framework, the elicitation of risk perceptions was framed in the context of investment. Farmers were asked: "How economically risky do you assess the investment on new machinery for the IP-Suisse wheat production without PPP?" in a scale from 1(not risky) to 5(very risky). This risk was further decomposed by asking farmers "How strongly do the following factors contribute to your assessment of investment risks for new machinery?" The factors refer to the different domains of risk preferences considered in our analysis. Risk perceptions were captured for four domains of risk as indicated in the following table.

Table S. 2 Risk Perceptions Phrasing: Magnitude and Probability

Perceived Magnitude of Yield Decrease	Perceived Probability of an Increase in Yield Losses
I would expect with the conversion (...) that in the long term my average wheat yield (dt/ha) will… 1)…not change. 2)…decrease by 0–5%. 3)…decrease by 5–10% 4)…decrease by 10–15% 5)…decrease by more than 15%.	*Due to the conversion, I expect…* 1)…No increase in bad years *An additional "bad year" (with complete crop failure/ very low yield) every…* 2)…20 years. 3)…10 years 4)…5 years.

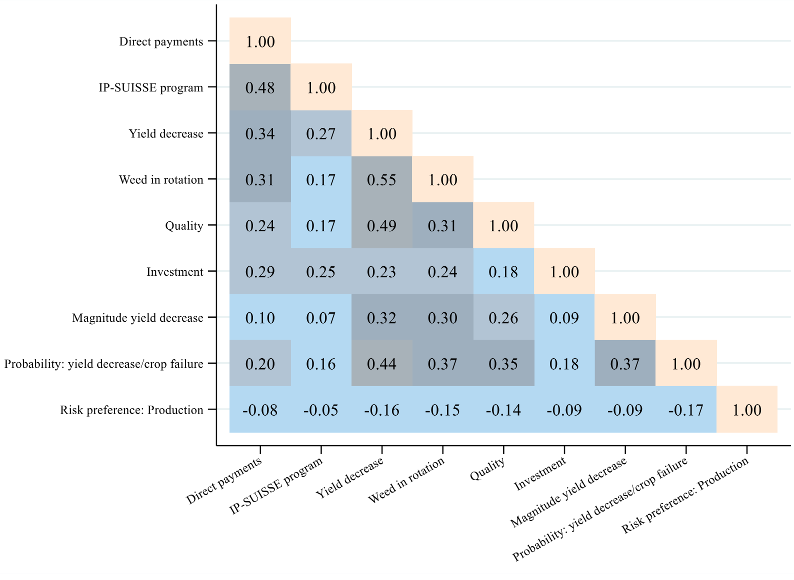

Figure S2. Correlation between Risk Perceptions Domains and Risk Preferences

Observing the correlation between risk sources and risk preferences serves several purposes. First, to evaluate the validity of our risk perceptions variables, we observe the correlation between the risk perceptions elicited through Likert scales in the production domain with those elicited through categories of magnitude and probability of yield losses. We find that the correlation between the two types of measure is positive and mostly above 0.30.

Control Variables

In our sample, the average farmer is 47 years old, has 35 hectares of agricultural land, and produces wheat in 16% of her agricultural land. A large percentage of farmers produce in lands suitable for grain cultivation (63%), approximately 67% have arranged succession, 64% have at least a "Meister" degree and 22% chose the survey in French. On average, farmers report 1.68 units of labour force in their farms. Availability of machinery is a categorical variable that takes the value of 1 if machinery is available to farmer, 2 if it is not available but could potentially be, and 3 if it is not available and there are no means of acquisition. On average, farmers tend to not have machinery available although consider possible to acquire. Regarding weed control, farmers experience 48% of the 21 weed species present in wheat in their lands (see Böcker, et al 2019). Herbicide resistance is measured through the number of herbicide resistant varieties in the municipality of the farmer (see Möhring and Finger, 2021). On average farmers are exposed to 0.11 herbicide resistant kind of weeds.

Mostly, farms in our sample are located outside the mountainous area. On average, the share of land in mountainous area is 5%. Temperature is considered through two variables: the historical mean of yearly averages of temperature between 1971 and 2018 that on average is 9 °C for our sample of farmers, and the historical mean of precipitation between 2008 to 2018 that has a mean of 704 mm.

Variables	**Mean (1)**	**Std. (2)**	**Description (3)**	**Type (4)**
Farm characteristics				
Farm-level work force	1.68	1.19	Standardized farm-level work force	Working unit
Age of farmer	47.08	9.35	Age of farmer in years	Years
Agricultural land	34.63	21.65	Hectares of agricultural land	Hectares
Presence of weed species	0.48	0.29	Percentage of weed species in land (out of 21 types of weeds)	Percentage
Share of wheat	0.16	0.11	Percentage of wheat in agricultural land	Percentage
Arranged succession	0.67	-	Farm succession established (1) or not (0)	Binary
Education of farmer	0.64	-	Has higher agricultural degree, i.e., “Meister” degree (1) or not (0)	Binary
Language	0.22	-	Survey responded in French (1) or German (0)	Binary
Machinery	1.83	0.66	Availability: 1(machinery available), 2(possible to acquire or borrow), 3(machinery not available at all)	Categorical
Geograp. Information				
Share of mountainous area	0.05	0.20	Share of farmers’ land in mountain region	Percentage
Yearly average of temperature	9	0.63	Mean temperature 1971–2018, in °C	°C
Historical mean of precipitation	703.54	73.77	Mean precipitation 2008–2018, in mm	mm
Land suitable for grain cultivation	0.63	-	Suitable (1) or not (0)	Binary
Herbicide resistance	0.11	0.33	Number of herbicide resistant weed varieties observed in municipality of farmer	Number

Notes: Observations = 1,073.

Table S3. Difference of Means for Two Groups (paired t-test)

Test of differences:	Early Adopters vs Would Adopt			Would Adopt vs Never Adopter		
Variable/ Group	**Early Adopter**	**Would Adopt**	**Difference**	**Would Adopt**	**Never Adopter**	**Difference**
Reduced direct payments	3.51	3.64	−0.12	3.64	3.92	−0.29***
	(1.29)	(1.15)		(1.15)	(1.20)	
Reduced price-markups	3.12	3.24	−0.12	3.24	3.41	−0.17**
	(1.29)	(1.16)		(1.16)	(1.26)	
Yield decrease	2.56	3.05	−0.49***	3.05	3.64	−0.59***
	(1.15)	(1.14)		(1.14)	(1.18)	
More weeds in crop rotation	3.32	3.78	−0.46***	3.78	4.51	−0.73***
	(1.20)	(1.10)		(1.10)	(0.86)	
Risk of investment	2.98	3.14	−0.16	3.14	3.37	−0.23***
	(1.33)	(1.26)		(1.26)	(1.34)	
Decreased wheat quality	3.03	3.27	−0.24**	3.27	3.71	−0.44***
	(1.17)	(1.21)		(1.21)	(1.28)	

Notes: Standard errors in parenthesis *** p<0.01, ** p<0.05, * p<0.1.

Robustness and Mechanisms

Table S4. All Risk Sources Estimated Jointly

Dep. Var:	Adopt (0/1) (1)	Postpone (1–3) (2)
Willingness to take risks (0–10)	0.02***	−0.03**
	(0.01)	(0.01)
Perceived risks		
Production risk: Risk of yield decrease	−0.03*	0.07***
	(0.02)	(0.02)
Production risk: Risk of more weeds in crop rotation	−0.11***	0.16***
	(0.01)	(0.02)
Production risk: Risk of decreased wheat quality	−0.01	0.01
	(0.01)	(0.02)
Market risk: Risk of reduced-price markups	0.00	−0.00
	(0.01)	(0.02)
Institutional risk: Reduced direct payments	0.01	−0.01
	(0.01)	(0.01)
Investment risk	0.03**	−0.05**
	(0.01)	(0.02)
Perceived magnitude of yield decrease	0.02	−0.01
	(0.01)	(0.02)
Perceived probability of an increase in yield losses	−0.04**	0.04*
	(0.01)	(0.02)
Constant	1.40*	1.13
	(0.68)	(0.96)
R adjusted	0.21	0.25

Notes: Clustered- robust standard errors in parentheses *** p<0.01, ** p<0.05, * p<0.1. All set of control variables are included: canton dummies, farm and farmer characteristics and geographic controls. Observations= 1,073

Table S5. Mechanisms: Sample According to Wheat Share- Outcome Adopt

Dep. Var: Adopt (0/1)	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)
Share of wheat	Below Mean	Above Mean	Below Mean	Above Mean	Below Mean	Above Mean	Below Mean	Above Mean	Below Mean	Above Mean
Willingness to take risks (0–10)	0.03***	0.02	0.04***	0.03***	0.04***	0.03***	0.04***	0.03***	0.04***	0.02**
	(0.01)	(0.01)	(0.01)	(0.01)	(0.01)	(0.01)	(0.01)	(0.01)	(0.01)	(0.01)
Perceived risks										
Production risk: Risk of yield decrease	−0.05*	−0.01								
	(0.02)	(0.02)								
Production risk: Risk of more weeds in crop rotation	−0.08***	−0.14***								
	(0.02)	(0.02)								
Production risk: Risk of decreased wheat quality	−0.01	−0.02								
	(0.02)	(0.02)								
Market risk: Risk of reduced-price markups			−0.03*	−0.00						
			(0.01)	(0.02)						
Institutional risk: Reduced direct payments					−0.03**	−0.02				
					(0.01)	(0.02)				
Risk of investment							0.00	0.01		
							(0.03)	(0.02)		
Perceived magnitude of yield decrease									−0.00	−0.01
									(0.02)	(0.02)
Perceived probability of an increase in yield losses									−0.07***	−0.07***
									(0.02)	(0.02)
Constant	0.66	2.56**	0.43	2.11**	0.47	2.19**	0.28	2.09**	0.55	1.99**
	(0.93)	(0.86)	(0.93)	(0.94)	(0.98)	(0.92)	(0.92)	(0.95)	(0.87)	(0.89)
Observations	537	536	537	536	537	536	537	536	537	536
R adjusted	0,18	0,21	0,10	0,12	0,10	0,12	0,09	0,12	0,12	0,15

Notes: Clustered- robust standard errors in parentheses *** p<0.01, ** p<0.05, * p<0.1. All set of control variables are included: canton dummies, farm and farmer characteristics and geographic controls.

Table S6. Mechanisms: Sample According to Wheat Share- Outcome Adoption Timing

Dep. Var: Postpone(1–3) **Share of wheat**	**(1)** **Below Mean**	**(2)** **Above Mean**	**(3)** **Below Mean**	**(4)** **Above Mean**	**(5)** **Below Mean**	**(6)** **Above Mean**	**(7)** **Below Mean**	**(8)** **Above Mean**	**(9)** **Below Mean**	**(10)** **Above Mean**
Willingness to take risks (0–10)	−0.03	−0.03**	−0.04**	−0.05***	−0.04**	−0.05***	−0.05**	−0.05***	−0.04**	−0.04**
	(0.02)	(0.01)	(0.02)	(0.01)	(0.02)	(0.01)	(0.02)	(0.01)	(0.02)	(0.01)
Perceived risks										
Production risk: Risk of yield decrease	0.12**	0.01								
	(0.05)	(0.03)								
Production risk: Risk of more weeds in crop rotation	0.11***	0.22***								
	(0.03)	(0.03)								
Production risk: Risk of decreased wheat quality	0.02	0.01								
	(0.03)	(0.03)								
Market risk: Risk of reduced-price markups			0.04*	0.01						
			(0.02)	(0.03)						
Institutional risk: Reduced direct payments					0.06**	0.03				
					(0.02)	(0.03)				
Risk of investment							0.01	−0.03		
							(0.04)	(0.03)		
Perceived magnitude of yield decrease									0.03	−0.00
									(0.03)	(0.03)
Perceived probability of an increase in yield losses									0.10***	0.08***
									(0.04)	(0.03)
Constant	2.22**	−0.37	2.52**	0.19	2.41*	0.11	2.76**	0.28	2.35**	0.38
	(0.92)	(1.17)	(1.04)	(1.28)	(1.14)	(1.27)	(1.00)	(1.32)	(0.90)	(1.27)
Observations	537	536	537	536	537	536	537	536	537	536
R adjusted	0.22	0.26	0.11	0.17	0.11	0.18	0.10	0.17	0.14	0.19

Notes: Clustered- robust standard errors in parentheses *** p<0.01, ** p<0.05, * p<0.1 All set of control variables are included: canton dummies, farm and farmer characteristics and geographic controls.

Table S7. Specification with Risk Preferences and Risk Perceptions Independently

Dep. Var: Adopt	**(1)**	**(2)**	**(3)**	**(4)**	**(5)**	**(6)**
Willingness to take risks (0–10)	0.04***					
	(0.01)					
Perceived risks						
Perceived magnitude of yield decrease		−0.00				
		(0.02)				
Perceived probability of an increase in yield losses		−0.08***				
		(0.01)				
Production risk: Risk of yield decrease			−0.04**			
			(0.02)			
Production risk: Risk of more weeds in crop rotation			−0.11***			
			(0.01)			
Production risk: Risk of decreased wheat quality			−0.02*			
			(0.01)			
Market risk: Risk of reduced price markups				−0.02		
				(0.01)		
Institutional risk: Risk of reduced direct payments					−0.03***	
					(0.01)	
Risk of investment						0.00
						(0.01)

Dep. Var: Postpone	**(1)**	**(2)**	**(3)**	**(4)**	**(5)**	**(6)**
Willingness to take risks (0–10)	−0.05***					
	(0.01)					
Perceived risks						
Perceived magnitude of yield decrease		0.02				
		(0.02)				
Perceived probability of an increase in yield losses		0.11***				
		(0.02)				
Production risk: Risk of yield decrease			0.08***			
			(0.02)			
Production risk: Risk of more weeds in crop rotation			0.16***			
			(0.02)			
Production risk: Risk of decreased wheat quality			0.02			
			(0.02)			
Market risk: Risk of reduced price markups				0.03		
				(0.02)		
Institutional risk: Risk of reduced direct payments					0.05**	
					(0.02)	
Risk of investment						−0.01
						(0.02)

Notes: Clustered- robust standard errors in parentheses *** p<0.01, ** p<0.05, * p<0.1. All set of control variables are included: canton dummies, farm and farmer characteristics and geographic controls. Observations= 1,073

Table S8. Adoption Outcome- Interaction Terms

Dep. Var: Adopter	**(1)**	**(2)**	**(3)**	**(4)**	**(5)**
R= Risk aversion index (−5, 5)	−0.03	−0.01	−0.06***	−0.04*	−0.05***
	(0.02)	(0.02)	(0.02)	(0.02)	(0.02)
RP1=Perceived magnitude of yield decrease	−0.00				
	(0.01)				
RP2=Perceived probability of an increase in yield losses	−0.07***				
	(0.01)				
R X RP1	*−0.00*				
	(0.00)				
R x RP2	*−0.00*				
	(0.01)				
RP3=Production risk: Risk of yield decrease		−0.03**			
		(0.02)			
RP4=Production risk: Risk of more weeds in crop rotation		−0.10***			
		(0.01)			
RP5=Production risk: Risk of decreased wheat quality		−0.01*			
		(0.01)			
R X RP3		*0.00*			
		(0.01)			
R X RP4		*0.00*			
		(0.01)			
R X RP5		*−0.01*			
		(0.01)			
RP6=Market risk: Risk of reduced price markups			−0.01		
			(0.01)		
R X RP6			*0.01*		
			(0.01)		
RP7=Institutional risk: Risk of reduced direct payments				−0.03**	
				(0.01)	
R X RP7				*0.00*	
				(0.01)	
RP8=Risk of investment					0.00
					(0.01)
R X RP8					*0.00*
					(0.01)
Constant	1.33*	1.61**	1.36*	1.39*	1.24
	(0.66)	(0.67)	(0.72)	(0.73)	(0.74)
R adjusted	0.146	0.196	0.117	0.119	0.115

Notes: Clustered- robust standard errors in parentheses *** p<0.01, ** p<0.05, * p<0.1. All set of control variables are included: canton dummies, farm and farmer characteristics and geographic controls. a The measure for risk preferences (i.e., Risk aversion index) is centred around risk neutrality. Larger values of this measure refer to lower levels of risk willingness. This allows us to interpret meaningfully the interaction terms. Observations= 1,073

Table S9. Postpone Outcome: Interaction Terms

Dep. Var: Postpone (1–3)	(1)	(2)	(3)	(4)	(5)
R= Risk aversion risks (−5, 5)	0.05*	0.02	0.08***	0.05*	0.06**
	(0.02)	(0.03)	(0.03)	(0.03)	(0.02)
RP1=Perceived magnitude of yield decrease	0.01				
	(0.02)				
RP2=Perceived probability of an increase in yield losses	0.10***				
	(0.02)				
R X RP1	*0.01*				
	(0.01)				
R X RP2	*−0.01*				
	(0.01)				
RP3=Production risk: Risk of yield decrease		0.07***			
		(0.02)			
RP4=Production risk: Risk of more weeds in crop rotation		0.16***			
		(0.02)			
RP5=Production risk: Risk of decreased wheat quality		0.01			
		(0.02)			
R X RP3		*−0.01*			
		(0.01)			
R X RP4		*0.00*			
		(0.01)			
R X RP5		*0.01*			
		(0.01)			
RP6=Market risk: Risk of reduced price markups			0.03		
			(0.02)		
R X RP6			*−0.01*		
			(0.01)		
RP7=Institutional risk: Risk of reduced direct payments				0.05**	
				(0.02)	
R X RP7				*−0.00*	
				(0.01)	
RP8=Risk of investment					−0.01
					(0.02)
R X RP8					*−0.00*
					(0.01)
Constant	1.32	0.86	1.21	1.17	1.42
	(0.98)	(0.96)	(1.04)	(1.09)	(1.10)
R adjusted	0.175	0.241	0.148	0.149	0.144

Notes: Clustered- robust standard errors in parentheses *** p<0.01, ** p<0.05, * p<0.1. All set of control variables are included: canton dummies, farm and farmer characteristics and geographic controls. [a] The measure for risk preferences (i.e., Risk aversion index) is centred around risk neutrality. Larger values of this measure refer to lower levels of risk willingness. This allows us to interpret meaningfully the interaction terms. Observations= 1,073

Table S10. Probit Estimation (Marginal Effects)

Dep. Var: Adopt (0/1)	**(2)**	**(4)**	**(6)**	**(8)**	**(10)**
Willingness to take risks (0–10)	0.02***	0.04***	0.03***	0.04***	0.03***
	(0.00)	(0.01)	(0.00)	(0.01)	(0.00)
Perceived risks					
Production risk: Risk of yield decrease	−0.03**				
	(0.01)				
Production risk: Risk of more weeds in crop rotation	−0.11***				
	(0.02)				
Production risk: Risk of decreased wheat quality	−0.01**				
	(0.01)				
Market risk: Risk of reduced price markups		−0.01			
		(0.01)			
Institutional risk: Risk of reduced direct payments			−0.03***		
			(0.01)		
Risk of investment				0.00	
				(0.01)	
Perceived magnitude of yield decrease					−0.00
					(0.01)
Perceived probability of an increase in yield losses					−0.08***
					(0.01)
Set of controls	Yes	Yes	Yes	Yes	Yes
Observations[a]	1,072	1,072	1,072	1,072	1,072

Notes: [a] One observation excluded from the analysis refers to one cluster with only one observation, for which adoption is fully explained by the dummy variable. Clustered- robust standard errors in parentheses *** p<0.01, ** p<0.05, * p<0.1.

Table S11. Generalized Ordered Logit Estimation (marginal effects reported with respect to never adopters)

Dep. Var: Postpone (1–3)	**(1)**	**(2)**	**(3)**	**(4)**	**(5)**
Willingness to take risks (0–10)	−0.03***	−0.04***	−0.04***	−0.04***	−0.04***
	(0.01)	(0.01)	(0.01)	(0.01)	(0.01)
Perceived risks					
Production risk: Risk of yield decrease	0.04***				
	(0.02)				
Production risk: Risk of more weeds in crop rotation	0.14***				
	(0.02)				
Production risk: Risk of decreased wheat quality	0.01				
	(0.01)				
Market risk: Risk of reduced price markups		0.01			
		(0.01)			
Institutional risk: Risk of reduced direct payments			0.03***		
			(0.01)		
Risk of investment				−0.00	
				(0.01)	
Perceived magnitude of yield decrease					0.00
					(0.02)
Perceived probability of an increase in yield losses					0.09***
					(0.01)
Set of controls	Yes	Yes	Yes	Yes	Yes

Notes: Clustered- robust standard errors in parentheses *** p<0.01, ** p<0.05, * p<0.1. Canton Dummies are replaced with region dummies due to convergence. Observations= 1,073

Table S12. Oster Bounds: Delta Parameter

Outcome variables	**Adoption (0/1)**	**Postpone (1–3)**
Willingness to take risks (0–10)	3.34	2.78
Production risk: Risk of yield decrease	0.83	1.18
Production risk: Risk of more weeds in crop rotation	1.61	1.68
Production risk: Risk of decreased wheat quality	0.78	0.46
Market risk: Risk of reduced price markups	0.72	1.04
Institutional risk: Risk of reduced direct payments	1.03	1.37
Risk of investment	−0.07	−0.14
Perceived magnitude of yield decrease	0.08	0.26
Perceived probability of an increase in yield losses	1.34	1.13

Notes: The maximum R squared in our model is 0.20 for the outcome adoption and 0.24 for outcome adoption timing. We add 1/3 of this to set the maximum R squared. This leads to an R-max of 0.27 for the first and 0.32 for the second, respectively.

Table S13. Robustness: Sample with Ex-Ante Perceptions Only

Dep. Var:	(1) Adopt (0/1)	(2) Adopt (0/1)	(3) Adopt (0/1)	(4) Adopt (0/1)	(5) Adopt (0/1)	(6) Postpone (1–3)	(7) Postpone (1–3)	(8) Postpone (1–3)	(9) Postpone (1–3)	(10) Postpone (1–3)
Willingness to take risks (0–10)	0.02***	0.04***	0.04***	0.04***	0.03***	−0.02***	−0.04***	−0.04***	−0.04***	−0.03***
	(0.01)	(0.01)	(0.01)	(0.01)	(0.01)	(0.01)	(0.01)	(0.01)	(0.01)	(0.01)
Perceived risks										
Production risk: Risk of yield decrease	−0.03*					0.05***				
	(0.01)					(0.02)				
Production risk: Risk of more weeds in crop rotation	−0.11***					0.13***				
	(0.01)					(0.02)				
Production risk: Risk of decreased wheat quality	−0.01					0.02				
	(0.01)					(0.01)				
Market risk: Risk of reduced price markups		−0.02					0.03			
		(0.02)					(0.02)			
Institutional risk: Risk of reduced direct payments			−0.03**					0.03*		
			(0.01)					(0.02)		
Risk of investment				−0.00					0.00	
				(0.01)					(0.02)	
Perceived magnitude of yield decrease					−0.00					0.02
					(0.02)					(0.02)
Perceived probability of an increase in yield losses					−0.08***					0.09***
					(0.01)					(0.02)
R adjusted	0.17	0.09	0.10	0.09	0.13	0.17	0.09	0.09	0.09	0.13

Notes: Clustered- robust standard errors in parentheses *** p<0.01, ** p<0.05, * p<0.1
All set of control variables are included: canton dummies, farm and farmer characteristics and geographic controls. Observations= 941

Table S14. Alternative Specification of Risk Preferences: Dummy of Risk Averse Farmer

Dep. Var:	(1) Adopt (0/1)	(2) Adopt (0/1)	(3) Adopt (0/1)	(4) Adopt (0/1)	(5) Adopt (0/1)	(6) Postpone (1–3)	(7) Postpone (1–3)	(8) Postpone (1–3)	(9) Postpone (1–3)	(10) Postpone (1–3)
Risk averse farmer (0/1) [a]	−0.12***	−0.10***	−0.15***	−0.15***	−0.15***	0.17***	0.13***	0.20***	0.20***	0.21***
	(0.02)	(0.02)	(0.02)	(0.02)	(0.02)	(0.04)	(0.04)	(0.04)	(0.04)	(0.04)
Perceived magnitude of yield decrease	−0.00					0.02				
	(0.01)					(0.02)				
Perceived probability of an increase in yield losses	−0.07***					0.10***				
	(0.01)					(0.02)				
Production risk: Risk of yield decrease		−0.03*					0.07***			
		(0.02)					(0.02)			
Production risk: Risk of more weeds in crop rotation		−0.10***					0.15***			
		(0.01)					(0.02)			
Production risk: Risk of decreased wheat quality		−0.01*					0.01			
		(0.01)					(0.02)			
Market risk: Risk of reduced price markups			−0.01					0.03		
			(0.01)					(0.02)		
Institutional risk: Risk of reduced direct payments				−0.03**					0.05**	
				(0.01)					(0.02)	
Risk of investment					0.00					−0.01
					(0.01)					(0.02)
R adjusted	0.15	0.20	0.12	0.12	0.12	0.18	0.25	0.15	0.15	0.15

Notes: Robust standard errors in parentheses *** p<0.01, ** p<0.05, * p<0.1. All set of control variables are included: canton dummies, farm and farmer characteristics and geographic controls. [a] Risk aversion dummy is defined as farmers that on the average risk preference over four domains have a value lower than 5, where 5 defines risk neutrality. Observations= 1,073