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Where is the risk? Price, yield and cost risk in Swiss crop production

Nadja EL BENNI*, Robert FINGER**

* ETH, Institute for Environmental Decisions, S-8092 Zurich, Switzerland
e-mail: elbennin@ethz.ch

** Wageningen University, NL-6706 Wageningen, The Netherlands

Abstract – Risk management strategies are of increasing importance in agriculture. An important question is what type of risk management strategies are required to reduce farmers' income risks? Applying a variance decomposition approach using data from more than 3,000 Swiss farms over a five-year period, this paper quantifies the direct and indirect effects of yields, prices and costs on net revenue variability at the farm level. We find that costs play only a minor role in determining income variability, but price and yield risks are of outmost importance and very crop-specific. For instance, price risks dominate for conventional wheat and sugar beet producers; while corn and barley producers tend to suffer more from production risks. Group comparisons and logistic regressions results show that more intensively producing farms tend to suffer more from price risk, while yield risks are dominant for less intensive producers.

Keywords: variance decomposition, revenue risk, cost risk, crop production, natural hedge

Où est le risque ? Le prix, le rendement et le coût du risque dans la grande culture en Suisse

Résumé – Les stratégies de gestion du risque sont d'une importance croissante dans l'agriculture. Pour identifier les stratégies de gestion du risque nécessaire pour réduire les risques de revenu des fermiers, une approche de décomposition de la variance a été appliquée à plus de 3 000 fermes suisses sur cinq ans ; ce papier a ainsi permis de mesurer les effets directs et indirects des productions, des prix et des coûts sur la variabilité du revenu net au niveau de la ferme. Nous constatons que les coûts jouent seulement un rôle mineur dans la détermination de la variabilité du revenu, mais les prix et les risques de production sont plus significatifs et très spécifiques à la culture. Par exemple, les risques liés au prix sont plus importants pour les producteurs de blé conventionnel et de betterave sucrière; tandis que les producteurs de maïs et d'orge ont tendance à souffrir plus des risques de production. Les comparaisons de groupes et les résultats de la régression logistique montrent que les fermes de production conventionnelle ont tendance à souffrir plus des risques liés au prix, alors que les risques de production sont plus importants chez les producteurs les moins intensifs.

Mots-clés : décomposition de la variance, risque de revenu, risque de coût, production agricole, la haie naturelle

JEL classification: Q12, Q10

1. Introduction

Farm incomes, especially in terms of distribution or equity, have always been one of the major concerns of agricultural policy makers (OECD, 1998). In several developed countries, market support measures such as import and export tariffs and quotas have raised national prices above world market prices and, due to reduced transmission of world market prices in domestic markets, led to high and stable incomes (OECD, 2009). With the liberalisation of agricultural markets, income support of agricultural policies shifted from market to direct farm-level support systems. In European agriculture, direct payments are currently the primary policy measure to maintain incomes at high or at least acceptable levels. Besides the income level, the stabilisation of farm revenues is also a central goal of agricultural policies in Europe (Tyner *et al.*, 2005). Concerns about increasing farm income volatility, due to *e.g.* market liberalisation and climate change, have induced a wide range of research and have led the European Commission to assess possible risk management tools for farmers (*e.g.* Meuwissen *et al.*, 1999; OECD, 2000; EC, 2001; Cafiero *et al.*, 2007; Meuwissen *et al.*, 2008; Bielza Diaz-Caneja *et al.*, 2008; Reynaud, 2009; Phélippé-Guinvarc'h and Cordier, 2010; Meuwissen *et al.*, 2011) including, for instance, yield and revenue insurances as well as future and option contract markets.

While several risk management tools are available for farmers in countries such as the US (*e.g.* yield and revenue insurance, whole-farm income insurance, and area index insurance), Australia (stabilisation account), Canada (single risk insurance, yield and area index insurance, stabilisation account)¹ and Brazil (combined insurance, yield insurance and area index insurance)¹, such tools are available to European farmers to a much lower extent. For instance, whole-farm income insurance and area yield or area revenue insurance do not exist in Europe, and future and option markets are minimally developed. In contrast, single-risk insurances such as hail insurance are widespread across the European countries. Some countries also have combined-risk insurance schemes (*e.g.* France, Italy, Spain), securing against different kinds of weather risk events, while yield insurances are far less developed (see Bielza Diaz-Caneja *et al.*, 2008 for details). However, increasing climatic and market risks as well as policy reforms (*e.g.* changes in the direct payments system)

¹ Yield insurance: multi-peril insurance where the main important risks are comprised (including *e.g.* drought); revenue insurance: covers yield and price risks for a single product ; whole-farm income insurance: a combination of revenue insurance policies for various crops and/or livestock in the farm as well as products with directly cover the total revenue of the farm; area index insurance: area yield insurance or area income insurance where indemnities are computed from the decrease on the average yields or income in an area; stabilization account: individual bank accounts for self-insurance but which are publicly regulated or promoted; single risk insurance: hail or hail and fire insurance, or one single peril for livestock; combined insurance: a combination of several risks protection. More detailed information on available risk management instruments of different countries are provided by Bielza Diaz-Caneja *et al.* (2008).

increased the demand for new insurance schemes that cover more than single risks in European agriculture. For instance, the European Union has proposed an income stabilisation tool to compensate farmers against income drops below a certain level, which might occur after the 2013 CAP reforms (EC, 2011; Meuwissen *et al.*, 2011).

However, before proposing specific risk-management strategies, an important question should first be addressed empirically: what types of risk management strategies are needed? Information on the perils faced by farmers is of major interest (Wolf *et al.*, 2009), as the risk-reducing effects of different possible risk management instruments, among other things, depends on the extent of risk coming from yields and prices. Furthermore, input costs may also vary and thus affect net revenues of crop producers.

Based on this background, the goal of this paper is to assess the main sources of business risk² for Swiss crop producers. To this end we decompose the observed income risk for Swiss crop producers in price, yield and cost risk focusing on wheat, barley, corn, rapeseed, sugar beet and potatoes. Swiss crop production is used as a case study because risk management tools are hardly developed yet, but will be of increasing importance in the future. First, increasing liberalisation of Swiss agricultural markets is expected to increase market risks, *e.g.* by increasing output and input price variability (*e.g.* Finger, 2012c)³. Second, climate change and particularly the higher frequency of climatic extreme events increases the production risks in Swiss crop production (*e.g.* Torriani *et al.*, 2007a, b, Lehmann, 2011). Recognising these significant potential changes in the risk Swiss crop producer face, the Swiss farmers' Union initiated discussions on the introduction of insurances against weather and market based risks (SBV, 2011). While future policy and climate conditions may change, the empirical analysis presented in this paper provides important information for stakeholders and policy makers in the development process of sufficient risk management strategies. Moreover, these results can help agricultural policy makers to develop the potential directions of support for farmers with regard to risk management. For instance, revenue insurances may focus on gross or net revenues. To clarify which type of insurance is most appropriate for Swiss crop production, we explicitly address the role of volatile cost levels for net revenue variability.

A second aim of this study is to explore differences in risk profiles across crops and farms. More specifically, we investigate the relevance of different risk sources across crops. Furthermore, we investigate the influence of farm

² According to Unterschultz (2000) business risk arises from production risk, input price risk and output price risk.

³ Of course, even if market liberalization may lead to an increase in price risk, this does not necessarily imply riskier revenues for farmers in European countries, including Switzerland. This is because the drop of prices is coupled to farm-level governmental support (direct payments) which not only maintains revenue levels but also reduces its variance (Cafiero *et al.*, 2007).

characteristics on risk profiles. The results of these analyses are not only relevant for the development of possible risk management instruments under current policy and climate conditions, but also provide important information on factors that affect risk and can be used for further risk assessments (e.g. if policy conditions change). Non-parametrical group comparisons and regression analysis are used to test differences in farm characteristics for the different crops considered. The specific characteristics of farms that face either high yield risks or price risks, as examined in this study, are expected to indicate target groups for possible risk management tools. This classification will facilitate the tailoring of risk management instruments toward the need of farmers. The classification of farms according to major risk sources as presented in this paper has not been previously considered, and represents a first empirical step toward improved risk management instruments in crop production.

2. Background on crop production and risk management in Swiss agriculture

Even though Swiss agriculture is grassland-based in hilly and mountainous regions, crop production is an important activity in particular in the Swiss Plateau region. Wheat is the most important crop, covering 32% of the arable land, followed by corn with 23.4% (73% used as silage), barley with 11%, rapeseed with 8%, sugar beet with 7% and potatoes with 4% (FSO, 2011).

Within the last two decades, Swiss agricultural policy shifted from market to direct payment support, and Swiss farmers are currently subsidised with direct payments of about 2.7 billion Swiss Francs (FOAG, 2010). The Swiss direct payment system divides support payments into general and ecological direct payments. To be eligible for general direct payments, farmers have to comply with baseline criteria regarding environmental and animal-friendly production (cross-compliance approach). In contrast, the application for ecological direct payments is voluntary for Swiss farmers (for more details see Mann, 2003; El Benni and Lehmann, 2010).

In crop production, the most important ecological direct payment programme is the Extenso programme. In this programme, the use of fungicides, plant growth regulators, insecticides and chemical-synthetic stimulators of natural resistance is not allowed (FOAG, 2008; see Finger, 2010, for details). The Extenso programme covers all cereals (except corn) as well as rapeseed and is available for all farmers without any regional restrictions. Its obligations are, however, on top of the cross-compliance requirements that farmers have to fulfil to receive general direct payments (Finger and El Benni, 2013). Crops produced under the requirements of the Extenso programme cover more than 50% of the area under cereal production, and are thus a fundamental aspect of Swiss crop production. We expect that Extenso and conventional (*i.e.* non-Extenso) producers face different types of

risk. For instance, conventional producers can cope better with environmental threats to crops (*e.g.* pest pressure) and yield risk is thus expected to be lower. However, Extenso producers rely to a much smaller extent on agricultural inputs and are thus expected to face lower risks from volatile input prices. Along these lines, we investigated Extenso and conventional wheat and barley production separately throughout our analysis⁴.

Beside direct payments, the production of oil seeds, grain legumes, fibre crops, potato seed, corn and fodder plants are supported by arable payments. With these payments, policy makers aim to enrich crop rotation and increase self-sufficiency in crop production (El Benni *et al.*, 2012).

Swiss hail insurance provides different types of insurances to crop producers. The by far most important insurance scheme covers hail damage as well as elemental damage (*e.g.* from storm, floods and landslides). This insurance is available at the farm- or crop-specific level (see *e.g.* Finger and Lehmann, 2012, for details). In a current pilot phase, multiple-peril insurance is now available to certain cantons (federal states of Switzerland). This insurance scheme extends the risk covered by hail insurance by also including risk from drought and heavy rainfalls. No explicit market-based price risk management tools are yet available to Swiss crop producers. However, Switzerland is in negotiations with the European Union with the aim of further liberalising the agricultural market *via* a bilateral trade agreement. This raises concerns over decreasing incomes and increased income volatility due to an increase in price volatility. In addition, the Swiss government is currently working on a proposal that puts further emphasis on the targeting and tailoring of the Swiss direct payments system (FOAG, 2009). With the next policy reform cycle for the period 2014-2017, parts of the current farm-level support are scheduled to be transferred from general direct payments to ecological direct payments. The change to less intensive production techniques may change the production risk farmers face (Schlöpfer *et al.*, 2002; Gardebroek, 2010; Meuwissen *et al.*, 2011). Altogether, these changes may lead to an increasing interest in risk management instruments, including improved strategies against price volatility.

3. Data and Method

3.1. Measuring sources of net revenue variability at farm level

Our analysis is based on the assumption that growing a crop is a single-period investment where farmers will not change the fixed resource base as a result of a single year's decision to produce a crop. Hence, the relevant measure of

⁴ For rapeseed, a distinction was not possible with the employed data. However, the share of Extenso rapeseed producers is smaller than for other crops and thus no large error is expected by not separating production techniques.

net returns is gross margins *minus* variable costs (Mumey *et al.*, 1992; Burton and Claassen, 1993). To assess the contribution of different components on the observed total variance of net revenues, data from the Swiss farm accountancy network (FADN) are used. These data include *per* hectare crop yields, prices and costs at the farm-level. We consider the main crops produced in Switzerland, namely wheat, corn, barley, rapeseed, sugar beet and potatoes.

Total *per* hectare costs are the sum of fertiliser, seed and pesticide costs, all expressed in monetary values. Note that neither information on the quantities of input use, nor on *per* hectare machinery and labour costs are available. Hence, *per* hectare net revenues nr of crop i at farm j in year t are defined as the product of prices p and yields q *minus* the costs c for fertiliser, seed and pesticides:

$$nr_{ijt} = p_{ijt} * q_{ijt} - C_{ijt, fertilizer} - C_{ijt, seed} - C_{ijt, pesticides} \quad (1)$$

The variability of net revenues is measured by its variance over time at the farm-level. More precisely, we assess the variance of net revenues for each single farm operation and crop considered over five years between 2005 and 2009. This relatively short time period was chosen to increase the number of available observations (*i.e.* the number of farms with continuous records). This was necessary because the FADN data is an unbalanced data set and recorded farm operations change over time. We thus had to balance the number of farms to be represented by our analysis and the number of observations available *per* farm. Our choice led to estimates of farm-level risks for a large number of farms (see below), allowing us to test for differences across crops and farms as well as to draw conclusions for Swiss crop production at large. Furthermore, by using a five-year period, we reduce the effects of possible trends or structural breaks within the single variables of interest. More specifically, the period chosen ensures that our observations on input and output prices as well as crop yields do not show characteristic trends or breaks, but rather fluctuate about a common mean. This is due to the fact that no structural changes in the boundary conditions (*e.g.* with respect to agricultural policy) took place in this period (see El Benni and Lehmann, 2010, for an overview). For this reason, our choice to focus on the period 2005-2009 implies that no change in expected values as well as variances of the considered variables are expected in this period. Note that even though crop prices in other countries increased significantly in 2008 leading to structural breaks, changes in crop prices in Switzerland showed only relatively small price peaks. This is due to the fact that Swiss agricultural markets face rather strong levels of protection, making domestic markets less sensitive to developments in international markets (*e.g.* Finger and El Benni, 2012).

In our analysis, we have chosen those farms that recorded acreage of the specific crop in at least three of the five years considered. In addition, wheat- and barley-producing farms were separated into those with conventional and those with Extenso production, as outlined above. For instance, this led to a

total amount of 4,238 wheat records across all years, of which 1,600 (38%) coming from conventional and 2,638 (62%) from farms producing according to the Extenso programme requirements. These observations represent 395 different farm operations for conventional production and 659 different farm operations for Extenso production (for details on other crops see Table 1).

We use a commonly applied variance decomposition approach to disentangle the effects of different income components (*i.e.* yields, prices⁵ and costs) on farms' net revenues of the considered crops for each farm⁶. To decompose net revenue variance at farm level into specific contributors, we account for the fact that net revenues consist of products and sums of correlated variables (Equation 1). Following Goodman (1960), Burt and Finley (1968) and Bohrnstedt and Goldberger (1969) we have chosen the following strategy to decompose net revenue variance for each crop at the farm level:

$$\begin{aligned}
 var(nr) = & \mu_q^2 var(p) + \mu_p^2 var(q) + var(c_{fertilizer}) + var(c_{seed}) \\
 & + var(c_{pesticides}) + 2\mu_p\mu_q cov(p, q) - 2cov(gr, c_{fertilizer}) \\
 & - 2cov(gr, c_{seed}) - 2cov(gr, c_{pesticides}) \\
 & - 2cov(c_{fertilizer}, c_{seed}) - 2cov(c_{fertilizer}, c_{pesticides}) \\
 & - 2cov(c_{seed}, c_{pesticides}) + var(p) var(q) + cov(p, q)^2
 \end{aligned}
 \tag{2}$$

where *gr* represents gross revenue and its expected value is defined as $E[gr] = \mu_p\mu_q + cov(p, q)$ (Burt and Finley, 1968). $Var(.)$ and $cov(.)$ denote variances and covariances respectively, and μ_p and μ_q are the expected values of price and quantity. Following Bohrnstedt and Goldberger (1969), we assumed that third and higher moments are not relevant for variances of net revenues, *i.e.* only first-order interaction terms are considered. Thus, the decomposition approach presented in Equation 2 is only an approximation. To test if this approximation is sufficient to represent net revenue variability in Swiss crop production, we compared the estimates of the net revenue variance derived by Equation 2 with the observed net revenue variance using Wilcoxon rank

⁵ Note that crop prices in Switzerland usually do not change within a year. To illustrate this, we give an example for the price index for cereals, which was constant from December 2010 till July 2011, but increased by 3% in August 2011 were it remained till January 2012 (SBV, 2013). Thus, there is variability of crop prices across years, but not within a year. Accordingly, usually also no storage of the harvest for purposes of speculation does take place. Focussing on the use of a single crop price *per* year and farm thus leads to unbiased estimates for crop price distributions.

⁶ Recent applications of variance decomposition in agriculture can also be found in Schmit *et al.* (2001), Chang *et al.* (2007), Wolf *et al.* (2009), Kimura *et al.* (2010), and El Benni and Finger (2013).

sum tests. If no significant differences are indicated, the non-inclusion of some possible (second order) interaction terms is sufficient.

The first line of Equation 2 depicts the direct effects of prices p and yields q as well as the costs for seed, fertiliser and pesticides on the variance of net revenues. The second line depicts the first-order interaction effects between prices and yields and between gross revenues and the single cost components respectively. The first-order interaction effects between seed, fertiliser and pesticide costs are shown in the third line. Finally, the last line includes the terms of the variance decomposition of the product of price and quantity, which are expected to be unimportant (Burt and Finley, 1968).

For interpretation of our results, we follow Burt and Finley (1968) and normalise the direct and first-order interaction effects by dividing the corresponding terms of Equation 2 by the sum of all direct effects. Thus, the direct effects of prices, yields and costs sum to 100, and increasing variance of either component increases net revenue variability. In contrast, the interaction effects can be of either sign. Volatilities in different components of the net revenue may offset each other and positive correlation may amplify net revenue variability. For instance, positive covariances between yield and price lead to higher net revenue variability. In contrast, a positive covariance between a cost and revenue component implies a decrease in this variance. To additionally investigate gross revenue variability, we conducted the above-described procedure without taking costs into account.

3.2. Characterisation of farms being more exposed to either price or yield risk

In order to analyse which type of farm could require either price or yield risk management instruments, we conducted non-parametrical group comparisons as well as logistic regression analyses. For the group comparisons, Mann-Whitney tests were used. Based on the results of the variance decomposition, group 1 includes farms for which net revenue variability is mainly dependent on price variability, *i.e.* those farms facing higher-than-average price and lower-than-average yield risk. Group 2 is formed by farms for which net revenue variability is mainly dependent on yield risk, *i.e.* farms facing higher-than-average yield and lower-than-average price risk. These groups are then compared based on their farm characteristics, including farm size and production intensity measures as well as yield, prices and revenues. Explanatory variables and associated hypotheses are discussed below. To investigate the joint impact of a set of explanatory variables on the farms' classification, we use binary logistic regressions in addition to group comparisons.

There is little economic theory suggesting hypotheses as to why farms are either more exposed to yield or more exposed to price risk. In addition, no empirical investigation on this question has been conducted so far in Switzerland. Thus, our analysis has a highly explorative character, and the

following hypotheses are far less clear-cut but rather represent assumptions and expectations on differences in price and yield risk exposure.

First, we expect that environmental influences differ across space and thus lead to heterogeneous spatial patterns of crop yield variability (*e.g.* Lehmann, 2011). Thus, the farms' location may partially explain whether farms suffer mainly from production or price risk. To test the hypothesis that location matters, we introduce a dummy variable into the analysis describing the canton in which the farm is located. The number of cantons in which the specific crops considered are produced range from 11 (for potato) to 17 (for Extensio wheat production). To test whether the canton significantly affects the kind of farm risk (*i.e.* whether the farm faces higher yield or higher price risk) we test for the factor canton as a whole and not for the different cantons separately.

Second, we expect that production intensities have an influence on dominant sources of risk. We use expenses for fertiliser and pesticides as a proxy for production intensity. Furthermore, the farm's crop yield level is used as a proxy variable for production intensity. We expect that lower production intensities can be associated with higher production risks because farms have lower capacities to cope with volatile environmental conditions (*e.g.* Gardebroek *et al.*, 2010). Thus, price risks are expected to be of lower relevance for farms with low input use compared to yield risk.

Third, we expect that the (crop) quality strategy of the crop producer has an influence on the classification. For instance, wheat production in Switzerland involves a wide range of quality levels from fodder to first-class baking wheat. The effect on the question of whether price risk or yield risk dominates when farms produce high quality crops is ambiguous. High quality crop production may enable production in a *niche* that faces little competition and little price variability⁷. However, the production of low quality crops can also imply lower price risks because fodder production may face less variable demand and prices than crops for human nutrition. Because quality information is not included in the FADN data, we use the price level as a proxy. Thus, we assume that if a producer receives a higher price, he delivered a higher quality of the same crop.

Fourth, we expect that on-farm risk smoothing has an influence on farm classification. Using the example of wheat production in Kansas, Marra and Schurle (1994) showed that farms with a larger area under a certain crop face lower production risks, which has been also found for Swiss crop production by Finger (2012a). This relationship is based on the fact that larger acreages of a specific crop involve usually more locations. Because yield variabilities at these different locations are not identical (*e.g.* due to different soil and weather conditions), but yields are still correlated with each other, aggregating over different locations reduces total (*i.e.* farm-level) yield variability.

⁷ Note price risk may differ across farms not only due to quality differences but also due to regional structures of agricultural markets.

4. Results

4.1. Revenue composition of Swiss crop production

Table 1 shows the descriptive statistics of the variables used for the variance decomposition. Note that all analyses presented are based on calculations for each farm individually, but averages and interquartile ranges (in brackets) over all farms are presented in Table 1. Wilcoxon rank sum tests show that there are significant differences between conventional and Extenso wheat and barley production with respect to yields, prices, costs and cost composition (see Table 1). The first two columns of Table 1 show that the yields of Extenso barley and Extenso wheat production are significantly lower than of conventional production. As expected, lower levels of input use lead to lower yield levels. While Extenso wheat can be sold at significantly higher prices than conventionally produced wheat (prices are 13.5% higher), only low price differences (even if significant) can be observed for barley production. This is due to the fact that Extenso-produced baking wheat is distributed in separate marketing channels by a private organisation (IP Suisse), which is not the case for fodder crops such as barley (there is no malting barley production in Switzerland). On average, gross revenues of Extenso wheat are about 20% lower than for conventional wheat. Farms producing barley according to the requirements of the Extenso programme even generate 26% lower gross revenues compared to those producing conventionally. Seed costs of Extenso varieties are about 10% higher than for conventional varieties; pesticide costs and fertiliser costs, however, are markedly lower. Altogether, higher prices and lower fertiliser and pesticide costs almost compensate Extenso wheat producers for foregone profits (due to lower yields) and higher seed costs, and net revenues are only slightly lower in Extenso wheat production. In contrast, net revenues of Extenso barley production are about 24% less compared to conventional production, and savings in costs cannot compensate lower yields and higher seed prices. Note that Extenso producers receive an ecological direct payment of 400 CHF/ha (see Finger and El Benni, 2013, for details). Thus, Extenso production is, on average, more profitable for both crops if this direct payment is taken into account. Table 1 shows, furthermore, that gross and net revenues are highest for root crops (*i.e.* potatoes and sugar beets), even though input costs are significantly higher than in cereal production. However, because machinery and labour costs (which are higher for potatoes and sugar beets) are not taken into account, these results must be interpreted with caution.

4.2. Revenue risk in Swiss crop production

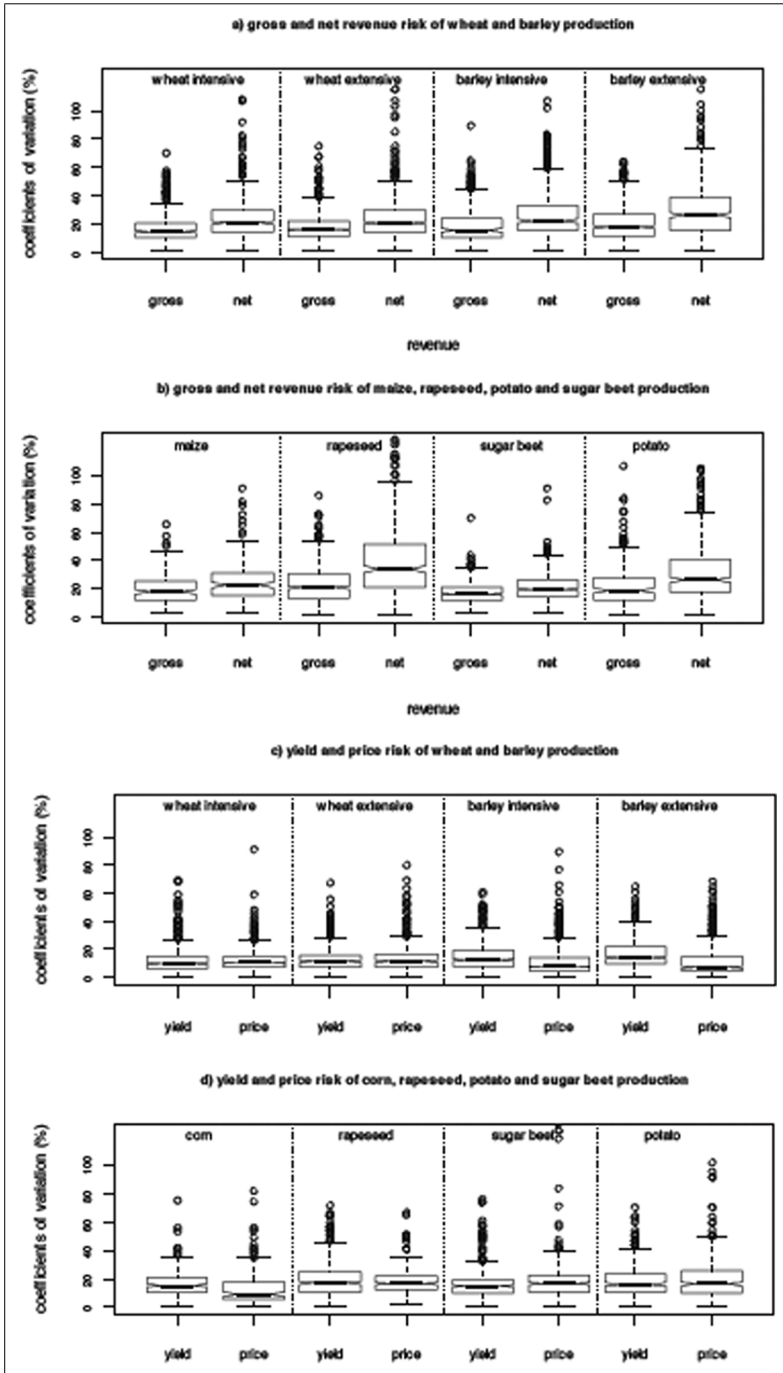
Figure 1 shows the distribution (across farms) of the coefficients of variation of net and gross revenue as well as for yields and prices for the eight considered crops. In general, all distributions of coefficients of variation are skewed to

Table 1. Mean prices, yields and costs of the main crops produced in Switzerland (in average over all farms for the years 2005-2009)

	wheat		barley		difference between conventional and Extenso in %	corn	rapeseed	sugar beet	potato
	conventional	Extenso	conventional	Extenso					
yield dt/ha	66.27 [60,72]	52.88 [48,58]	71.30 [64,79]	52.49 [47,58]	73.62	96.98 [89,106]	31.41 [28,36]	763.30 [696,837]	361.00 [285,436]
price CHF/dt	52.16 [47,56]	59.21 [51,60]	41.66 [39,43]	41.57 [38,42]	99.78	42.63 [40,43]	84.72 [81,89]	11.84 [10,12]	42.28 [32,50]
gross revenues CHF/ha	3'434 [3079,3798]	3077 [2640,3384]	2952.00 [2584,3281]	2'154.50 [1865,2382]	72.98	4'069.00 [3557,4501]	2'636.40 [2260,2994]	8'251.00 [7501,8976]	14'040 [11945,15772]
seed CHF/ha	261.2 [236,287]	288.6 [253,306]	180.20 [156,198]	197.80 [169,216]	109.77	299.90 [257,315]	160.82 [129,181]	404.90 [376,427]	2551.30 [2177,2949]
% of total cost	28.76%	45.75%	22.64%	39.77%	70.15	36.90%	17.87%	28.96%	63.66%
fertiliser CHF/ha	320.2 [223,393]	232.9 [157,311]	266.70 [169,351]	187.10 [118,254]		316.00 [196,413]	404.80 [274,520]	420.90 [281,540]	606.30 [398,772]
% of total cost	37.87%	32.82%	33.51%	32.92%	43.70	35.48%	41.20%	28.12%	14.86%
pesticides CHF/ha	353.8 [287,413]	147.7 [111,188]	349.00 [278,402]	152.50 [105,201]		239.40 [196,401]	390.30 [287,467]	621.00 [500,721]	867.70 [668,1045]
% of total cost	33.37%	21.44%	43.85%	27.32%	67.53	27.23%	40.93%	42.92%	21.48%
costs total CHF/ha	935.3 [806,1047]	669.2 [572,769]	795.90 [674,913]	537.50 [445,627]	74.99	855.30 [694,993]	955.90 [766,1119]	1446.70 [1251,1607]	4025.00 [3513,4571]
net revenues CHF/ha	2'498.60 [2173,2814]	2'407.80 [1921,2686]	2'156.20 [1791,2454]	1'617.00 [1290,1830]		3'214 [2683,3661]	1'680.50 [1322,2067]	6'805.00 [6080,7569]	10'015.00 [8043,11717]
number of farms	395	659	451	454		147	363	401	348

CHF: Swiss Francs; ha: hectare; dt: deci tons; values in bold show significant differences between conventional and Extenso production, at least at the 5% level; interquartile ranges (differences in the mean values between farms) are given in square brackets.

Figure 1. Coefficients of variation of gross and net revenues and yields and prices in Swiss crop production



the right, showing that some farmers face very high risk compared to the median farmer. For some farms, we even find that the standard deviation exceeds the mean revenues, leading to coefficients of variation above 100%. Net revenue risk is significantly higher than gross revenue risk for all of the crops considered (comparing Figures 1a and b).

As shown in Figures 1a and b, the median coefficients of variation of gross revenues are located between 0.15 (conventional wheat) and 0.21 (Extenso barley). In contrast, the median coefficients of variation of net revenues range from 0.19 (sugar beets) to 0.33 (rapeseed). The difference between gross and net revenue risk is lower for sugar beet production, where net revenue variability is 1.22-fold higher than gross revenue variability. The difference is higher for rapeseed production, where net revenue variability is 1.60-fold higher than gross revenue variability. Figures 1c and d show median coefficients of variation of yields ranging between 0.10 (conventional wheat) and 0.17 (rapeseed) and median coefficients of variation of prices ranging between 0.08 (Extenso barley) and 0.17 (rapeseed). For barley and corn, price risk is significantly higher than yield risk. In contrast, price risk is significantly higher than yield risk in sugar beet production. No significant differences between the coefficients of variation for yields and prices can be observed for wheat, rapeseed and potatoes⁸.

4.3. Decomposition of net revenue risk

Table 2 shows the results of the net revenue variance decomposition for the main crops produced in Switzerland. Wilcoxon rank sum tests are used to test whether yield or price risk is the main source of net revenue variability for the different crops (again, conventional and Extenso production is analysed separately). Note that the decomposition has been conducted at the farm-level (*i.e.* for each farm separately), and mean values across all farms are presented in Table 2. Bold numbers indicate whether (the direct effects of) yields or prices have a significantly higher impact on net revenue variability. In addition, Figure 2 depicts the distributions of the estimated direct price and yield effects of the different crops across all farms. Wilcoxon sum rank and Ansari-Bradley tests were used to test for significant differences in the means and variances between the approximated net revenue variability (based on Equation 2) and the observed net revenues variability. Neither test indicated significant differences at the 5% level, showing that observed values are well approximated by the approach used and that decomposition results are reliable.

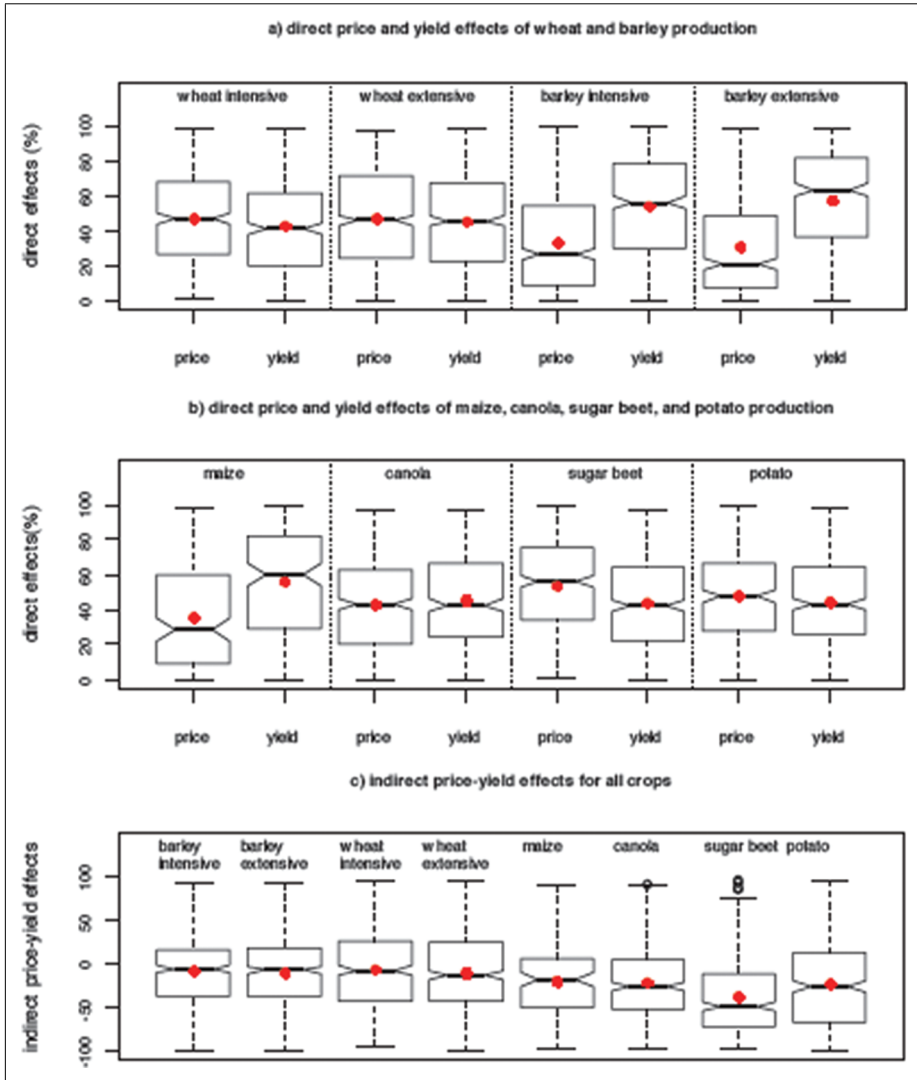
⁸ In general, differences in yield risk between farmers can be explained by differences in *e.g.* pest and weed pressure, soils and weather conditions and the farms' management. Differences in price risk can be the result of selling the crop to different markets (*e.g.* for fodder production or human consumption) or quality differences. Unfortunately, information on purchasers or quality is not available in the FADN data and can thus not be included in the analysis.

Table 2. Net revenue variance decomposition results for the main crops produced in Switzerland

	wheat			barley			corn	rapeseed	sugar beet	potato
	conventional	Extenso	conventional	Extenso	conventional	Extenso				
	direct effects	47.03	47.30	33.72	30.54	35.46				
price	42.74	45.68	54.12	57.84	56.47	45.14	45.14	43.64	45.01	
yield	10.23	7.03	12.16	11.62	8.07	12.13	12.13	2.43	7.00	
Σ direct cost effect	1.13	1.48	0.71	1.87	1.47	1.07	1.07	0.23	5.35	
seed cost effect	5.02	3.43	5.64	4.95	4.31	5.61	5.61	1.06	0.60	
fertiliser cost effect	4.08	2.12	5.81	4.80	2.29	5.45	5.45	1.14	1.05	
pesticides cost effect										
indirect effects	-5.57	-8.71	-7.98	-11.10	-18.16	-20.56	-20.56	-36.82	-22.08	
price/Yield	1.34	0.88	0.73	1.39	1.85	0.60	0.60	0.37	4.05	
gross revenue/seed	0.53	1.36	0.82	-2.31	1.47	3.80	3.80	-0.62	1.89	
gross revenue/fertiliser	1.64	0.53	3.58	2.92	2.57	1.74	1.74	0.91	1.02	
gross revenue/pesticides	0.08	0.10	0.03	0.30	0.58	0.50	0.50	0.04	0.31	
seed/fertiliser	0.23	0.22	0.45	0.42	0.36	0.26	0.26	0.10	0.05	
seed/pesticides	-0.09	0.44	0.43	0.79	0.98	1.11	1.11	-0.06	0.19	
fertiliser/pesticides	395	659	451	454	147	363	363	401	348	
No. of obs.										

Values in bold show if either yield risk or price risk is the main and significant (at the 5% level) source of net revenue variability. Significance testing is based on Wilcoxon rank sum tests. Note that we normalised the direct and first-order interaction effects by dividing the corresponding terms by the sum of all direct effects. Thus, all direct effects sum up to 100.

Figure 2. Normalised direct and indirect price and yield effects in Swiss crop production



The dots denote the mean values (see also Table 2), and the bold horizontal bars denote the medians.

Table 2 and Figure 2 show that net revenue variability of sugar beet and conventional wheat-producing farms is significantly more affected by price than by yield variability. Thus, the price risk effect significantly dominates the yield risk effect. In contrast, corn and barley (both Extenso and conventional) production are particularly affected by yield variability. No significant difference between the direct effects of yields and prices could

be observed for Extensio wheat, potato and rapeseed production. We find that the contribution of costs to the variability in net revenues is relatively small (Table 2), with direct cost effects ranging from about 2.4% (sugar beet) to 12.2% (conventionally produced barley)⁹. For all crops considered except potatoes, fertiliser and pesticide costs contribute much more to net revenue variability than seed costs do. For instance, for barley, rapeseed and conventional wheat production, fertiliser and pesticide costs contribute about 5% each to net revenue variability. In contrast, seed costs make up about 5% of net revenue variability in potato production, while the variability in fertiliser and pesticide costs are negligible.

The results for the first-order interaction effects (lower panel of Table 2) show negative (normalised) covariance terms for the price-yield relationship, which is in line with the results from other farm-level based studies (Antón and Kimura, 2009; Kimura and Le Thi, 2010). The negative covariance between yields and prices indicates that an increase in yields is accompanied by a decrease in prices and *vice versa*. This negative relation between prices and yields implies a natural hedge at farm level, which reduces net revenue variability. This natural hedge is stronger for sugar beet production (reducing net revenue variance by 36%), followed by potato, corn and rapeseed production. For wheat and barley, the natural hedge is much lower. The—on average—smallest natural hedge effect has been found for conventional wheat (reducing net revenue variance by 6%). Note, however, that the covariance between prices and yields can be positive for some farms, even if average values across all farms are negative (see Figure 2c). A detailed discussion of the levels of natural hedge in Swiss crop production is provided in Finger (2012b). Table 2 shows furthermore, that most of the normalised covariance terms between gross revenues and costs have positive signs. In addition, the interaction effects between the different cost components are positive. Following equation 2, this positive relation leads to a decrease in net revenue variability.

In summary, the results of the variance decomposition show that production costs are not the main source of income risk faced by Swiss crop producers. In contrast, the variability in prices and yields make up between 88% (barley) and 98% (sugar beet) of the variability in net revenues. Hence, an optimal portfolio of risk management strategies should address both yield risk and price risk. Furthermore, farms may ask for different risk management tools depending on the crops produced. The net revenue variability of sugar beet and conventional wheat production is significantly more affected by price than by yield variability. In contrast, the revenues of corn and barley production are more affected by yield variability. Under current market conditions, the natural hedge plays a substantial role in reducing revenue risk at the farm level (reducing net revenue variance by between 6-36%).

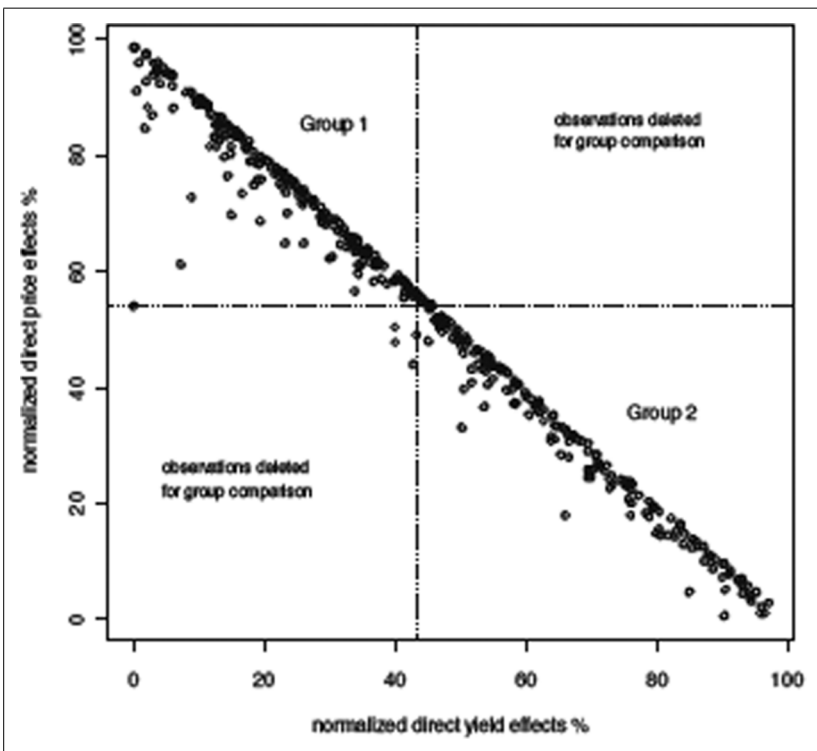
⁹ Note that the direct effects sum to 1 or 100 respectively as we normalized the direct and first-order interaction effects by dividing the corresponding terms by the sum of all direct effects as proposed by Burt and Finley (1968).

This is especially true for sugar beet, potato, rapeseed and corn production. In contrast, the natural hedge at farm-level is much lower for wheat and barley production.

4.4. Group comparison and logistic regressions

In order to analyse which type of farm could require either price or yield risk management instruments, we conduct group comparisons using Mann-Whitney tests and logistic regressions. Taking sugar beet as example, Figure 3 depicts how farms are grouped. The figure shows the direct yield and price effects estimated for each sugar beet farm in the sample by the variance decomposition approach at the x-axis and y-axis respectively. The dotted lines depict the mean over all farms for the direct yield and price effect respectively. Group 1 includes farms for which net revenue variability is mainly dependent on price variability, *i.e.* those farms facing higher-than-average price and lower-than-average yield risk. Group 2 includes farms for which net revenue variability is mainly dependent on yield risk,

Figure 3. Groups of farms with on-average higher yield (price) risk measured by the normalised direct yield (price) effects—the example of sugar beet producers



i.e. farms facing higher-than-average yield and lower-than-average price risk. Observations in the top right and bottom left corner of the graph, *i.e.* those with inconclusive dominance of either risk source, are excluded for the group comparison and logistic regression analysis.

Table 3 shows the results of the group comparisons. Not surprisingly, the coefficients of variation for yields (prices) are significantly lower for farms facing higher-than-average price (yield) risk than for those facing higher-than-average yield (price) risk. The differences in the coefficients of variation of price and yield variability, respectively, are significant for all of the crops considered. For farms facing higher price risk than yield risk (group 1) the coefficients of variation for prices range between 0.16 for conventional wheat and 0.32 for sugar beet production. High price variability was also found for potatoes ($cv\ prices=0.28$) and corn ($cv\ prices=0.25$). In contrast, yield variability was much lower for these farms. These results clearly show that farms differ with respect to the risk they face, independently of the crops they produce. For instance, while net revenue variability of conventional wheat production is on average more affected by price variability (as shown in Table 2) strong differences exist between farms. Furthermore, while the magnitude of yield and price variability differs significantly between the groups, this is not automatically true for net revenue risk. For instance, the revenue risk of barley producing farms facing high yield risk does not differ from barley farms facing high price risk. For both groups, the coefficient of variation of net revenues is about 0.30. However, in the case of wheat and rapeseed production, farms with high yield risk face also significantly higher net revenue risk than farms with high price risk. The opposite is true for root crops. Potato and sugar beet producers with high yield risk are those with significantly lower net revenue risk.

In general, Table 3 shows that farms facing higher yield risk than price risk (Group 2) have lower yields than farms facing higher price risk than yield risk (Group 1). The differences in yields are significant for all crops except corn and sugar beets. We compared groups also with respect to other proxies for intensity, *i.e.* fertiliser and pesticide expenditures. We find that farms facing high yield risk produce less intensively (*i.e.* have lower expenditures for fertiliser and pesticides) than farms facing high price risk¹⁰. The results, however, are only significant in the case of wheat and rapeseed production. Furthermore, Table 3 indicates that farms where price risks dominates (group 1), receive higher prices for their crops. This pattern was found for all crops except Extensio wheat and potatoes. Thus, producers generating higher price levels (due to higher quality levels) tend to face higher price risks than yield

¹⁰ The results suggest that pesticide and fertiliser use (*i.e.* measured by expenditures for pesticides and fertiliser) reduce yield risk for most of the crops considered. The estimation of risk effects of different inputs is, however, beyond the scope of this paper and should be analysed in future research.

Table 3. Group comparisons between farms facing higher-than-average price risk (Group 1) and farms facing higher-than-average yield risk (Group 2)

group	wheat		wheat Extenso		barley		barley Extenso		corn		rapeseed		sugar beet		potato		
	1	2	1	2	1	2	1	2	1	2	1	2	1	2	1	2	
coefficients of variation cv																	
yield	0.08	0.18	0.09	0.17	0.11	0.20	0.12	0.21	0.14	0.20	0.13	0.29	0.16	0.18	0.15	0.22	
price	0.16	0.09	0.18	0.09	0.20	0.07	0.23	0.06	0.25	0.07	0.22	0.14	0.32	0.12	0.28	0.14	
net revenue	0.22	0.28	0.23	0.25	0.29	0.28	0.33	0.29	0.25	0.27	0.35	0.51	0.23	0.19	0.36	0.28	
output																	
yield	67.77	64.48	54.31	42.57	72.55	70.16	54.99	51.49	97.91	96.47	33.46	29.06	763.93	761.97	371.25	354.66	
price	53.46	51.06	57.47	61.16	42.92	40.93	43.30	40.55	44.93	41.222	85.02	84.67	12.67	10.97	40.47	42.78	
net revenue	2641.40	2372.21	2407.63	2433.46	2260.53	2090.99	1777.19	1550.78	3402.70	3114.52	1837.40	1519.43	6804.69	6800.65	9861.21	9984.12	
intensity (input costs)																	
fertiliser	35.94	296.02	244.97	216.73	276.89	257.47	188.80	182.64	316.15	310.02	415.68	386.35	426.06	415.52	619.97	602.06	
pesticide	348.86	348.54	152.17	142.55	351.16	340.28	153.31	150.34	216.13	247.75	412.17	360.18	613.44	624.40	884.52	861.82	
size																	
area of crop	5.68	4.69	4.62	3.29	2.58	2.59	2.00	2.01	2.88	2.62	3.02	2.56	2.93	2.71	2.59	2.75	
ha	178	170	304	307	174	220	153	237	56	77	167	149	206	184	161	158	
% of all	51%	49%	50%	50%	44%	56%	39%	61%	42%	58%	53%	47%	53%	47%	50%	50%	

Values in bold show significant differences between Group 1 (higher-than-average direct price and lower-than-average direct yield effects, *i.e.* price risk dominates) and Group 2 farms (higher-than-average direct price effects, *i.e.* yield risk dominates) at the 10% level.

risks. For five of the eight considered crops, farm-level crop acreage is – on average – larger for those farms where price risks dominate. Differences are significant for Extenso and conventional wheat as well as for rapeseed. This finding underlines our expectation that farms with larger crop acreage face lower production risks, and thus, price variability is the important factor for these farms.

To analyse the influence of these explanatory variables on farm classification jointly, we use logistic regressions. For each single crop (*i.e.* regression model), the independent variable takes the value 1 if the farm faces higher-than-average price risk and the value 0 if the farm faces higher-than-average yield risk. Due to multicollinearity problems, the variable fertiliser expenditure is not considered in the logistic regression model. To account for spatial heterogeneities, we included dummy variables for the farms' location (canton).

Table 4 shows the regression results of the logistic binary response model. The estimates are presented as odds ratios with values above 1 indicating a positive and values below 1 a negative relationship to the odds of being exposed to higher price risk than yield risk. For instance, in the case of conventional wheat production (column 2), the interpretation is as follows: Holding all other variables constant, a one dt higher yield leads to a 1.09-fold increase in the odds that a farm is more exposed to price risk than to yield risk.

The results of the regression models show that for most of the crops considered, the level of crop prices (used as proxy for crop quality, see section 3.2) significantly affects the odds of a farm being more exposed to price risk than to yield risk. This is in accordance with the group comparison results. For instance, a 1 CHF higher price *per* dt of conventionally produced wheat increases the odds that a farm is more exposed to price risk than to yield risk by a factor of 1.11. The effect of the price level is also found to be significant for barley (conventional and Extenso) and sugar beet production, as well as for corn production (however, for the latter only at the 10% significance level). Furthermore, higher yields (used as proxy for production intensity, see section 3.2) also increase the odds of being more exposed to price risk than to yield risk. The effect is significant for Extenso barley, wheat, and rapeseed and potato production. The crop acreage is only significant for wheat production, where we find that an increase in the area under wheat increases the odds of a farm being more exposed to price risk than to yield risk. Regional-specific production conditions, captured by the variable *canton*, are significant for conventional barley and conventional wheat production as well as corn and rapeseed production. Spatial heterogeneity thus has no influence on farms' risk profiles for wheat produced according to the Extenso programme requirements or for barley, potato or sugar beet production.

Table 4. Regression results explaining higher-than-average price risk

	wheat conventional	wheat Extenso	barley conventional	barley Extenso	corn	rapeseed	sugar beet	potato
intercept	0.000***	0.226	0.006***	0.003***	0.002**	0.001***	0.167	0.302
crop area	1.086*	1.157***	1.091	1.032	1.071	0.998	1.051	0.906
yield	1.061***	1.043***	1.012	1.057***	1.024	1.185***	1.002	1.003*
price	1.106***	0.990	1.064***	1.065***	1.053*	1.014	1.169***	0.995
pesticide	0.999	0.999	1.000	1.001	0.998	1.002	0.999	0.999
costs								
canton (no)	* (12)	n.s. (17)	*** (14)	n.s. (16)	* (11)	** (15)	n.s. (12)	n.s. (11)
AIC	396.56	748.9	455.33	473.31	164.61	359.76	480.55	408.25
pseudo	0.13	0.08	0.10	0.10	0.17	0.18	0.07	0.05
R-squared								
no of farms	303	556	338	354	119	281	349	287

*, **, *** denotes significance at the 10%, 5%, and 1% level, respectively. Due to missing observations for the dummy variable canton, the number of farms used in the regression models differs from the number of farms used in the group comparisons.
n.s. denotes no significance.

5. Summary and Discussion

The aim of this paper was to assess what types of risks are more relevant in Swiss crop production, in order to derive conclusions about what types of risk management measures are required to cope adequately with income risk. To this end, we quantified the variability in net revenues due to prices, yields and costs for the six major crops produced in Switzerland. A variance decomposition approach was applied to FADN data from more than 3000 farms over the period 2005 to 2009.

We find that input costs, such as expenditures for fertiliser, pesticides and seeds, are rather stable in Swiss crop production and are therefore not the main source of net revenue variability. In contrast, both prices and yields contribute on average 88% (barley) to 98% (sugar beet) to net revenue variability. Thus, even though strategies to mitigate the impact of volatile input costs can probably reduce net revenue risk to a certain extent, they might not be of primary interest for Swiss crop producers. This means, for instance, an insurance strategy targeting gross revenues may be sufficient.

Because yield risk and price risk are dominant in Swiss crop production, management tools to address them seem to be more effective to reduce income risks in Swiss crop production. Thus, stakeholders and policy makers should focus on the development of risk management tools in these fields. However, our results suggest that the demand for either price risk or yield risk management strategies depends on the specific crop produced. For instance, sugar beet and conventional wheat production are significantly more affected by price risk, while corn and barley production are more affected by yield risk. Thus, non-uniform (*i.e.* crop-specific) strategies may be required to manage income risks of Swiss crop producers effectively. In addition, our results show that natural hedge plays a substantial role in reducing revenue risk at farm level. This is especially true for root crops (sugar beet and potatoes), rapeseed and corn. In contrast, the natural hedge is much lower for cereals. These results are in line with earlier research (*e.g.* Mahul, 2003) and might be explained by the fact that broader protections measures make Switzerland a rather closed economy for agricultural goods and that most of the crops produced in Switzerland are concentrated in a small area on the Swiss Plateau (*e.g.* Finger, 2012b). The particularly strong natural hedge in potato production might be furthermore explained by the fact that potatoes are perishable crops, and storage is more difficult than for other crops; prices are thus directly influenced by supply and demand at harvesting (Pavlista and Feuz, 2005).

The observed correlations between prices and yields for different crops have implications for the effectiveness of possible risk management instruments. In general, a weak negative price-yield correlation (natural hedge) for a certain crop implies that forward pricing by hedging in futures or by selling forward on the cash market is *ceteris paribus* more effective in reducing revenue risk than when a strong natural hedge exists (Harwood *et al.*, 1999). Hence, forward contracts and future markets might be valuable

risk management instruments for Swiss cereal producers and only to a small extent for producers of root crops such as potatoes and sugar beet. Of course, even if the natural hedge were shown to be of relevance under current market conditions, it will likely decrease with further market liberalisation, as already shown for Swiss milk production (El Benni and Finger, 2013). Nevertheless, the natural hedge should not be neglected in future risk assessments, as regional components (*e.g.* transportation costs) determine the interaction between demand and supply and thus risk, at least to a certain extent.

To investigate whether farm characteristics can be used to classify for a specific crop whether price risks or yield risks are more important, we used group comparisons and logistic regressions. These show that more intensively producing farms that are characterised by higher yields as well as higher expenditures for pesticides and fertiliser tend to suffer more from price risk, while yield risks are dominant for less intensive producers. Thus, the demand for yield and price management instruments is expected to differ not only between crops but also across farms and is dependent on the production intensity. A distinction of intensity levels may be based on farms' participation in the Extenso programme. This is already used in practice as Swiss hail insurance adjusts hail insurance premiums of farms based on information about participation in the Extenso programme¹¹. Moreover, our results suggest that intensity levels that go beyond the information on programme participation can provide even more information on the farms' risk profile. This is because in both groups (*i.e.* within the group of conventionally producing farms and within the group of farms that produce according to the requirements of the Extenso programme), risk profiles differ with the level of production intensity expressed in expenditures for fertiliser and pesticide use. For some crops, regional differences in exposure to either price risk or yield risk were also observed and should be analysed in more detail in further research.

Moreover, our results show that even if farms differ with respect to price and yield risk, they might not be different with respect to revenue risk. For instance, barley farms facing high yield risk face similar net revenue risk as barley farms facing high price risk. In contrast, potato and sugar beet farms with high yield risk are those with significantly lower net revenue risk. These results suggest that risk analysis in agriculture should not focus on either price, yield or revenue risk alone, but should consider the interaction between the different risk sources as well as their contribution to overall risk. Furthermore, our analysis shows that the variability of prices, yields and revenues should be considered directly at farm level and for different crops, to better approximate the possible demand for different risk management tools. Information on the extent of risk coming from different sources is valuable for politicians to gain insights into the primary risks farmers face.

¹¹ Information was obtained from: www.hagel.ch, accessed February 19, 2013.

This study revealed some interesting information on current yield, price, cost and revenue risk in Swiss crop production using farm-level data from 2005 to 2009. The time period was chosen a) to balance between the availability of observations (*i.e.* the longer the period is, the smaller the amount of farms to be included are), and b) to allow for accurate variance estimates based on data that show neither structural breaks nor trends (*e.g.* due to policy reforms). While the decomposition results were shown to be robust for the time period considered (*i.e.* the estimated revenue variances do not significantly differ from observed revenue variances), longer time periods would increase the understanding of risk evolution due to *e.g.* policy changes and, given appropriate data, should be considered in further research. Analysis based on longer time periods can reveal the underlying stochastic data generating processes, which cannot be detected across five years of observations. Based on the data used in this study, no prediction can be made for future *scenarii* in which boundary conditions may change (*e.g.* an increase in price variability due to liberalisation and changes in the natural hedge). Therefore, farm-level programming or simulations models (*e.g.* Lehmann *et al.*, 2013) should be used to address such questions. The results of this study can be used as basis for such modelling approaches and for further analysis of the viability of different risk management instruments under changing boundary conditions.

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