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

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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 of more than 3000 Swiss farms over a five year time 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 intensive wheat and sugar beet producer; while corn and barley producer tend to suffer more form 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; JEL: Q12, Q10

Où est le risque? Le prix, le rendement et le coût du risque dans la production agricole 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 3000 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 spécifique à la culture. Par exemple, les risques liés au prix sont plus importants pour les producteurs de blé intensif et de betterave sucrière; pendant 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 intensive 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 clé: décomposition de la variance, risque de revenu, risque de coût, production agricole, la haie naturelle

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). Market support measures such as import and export tariffs and quotas raised national prices in several developed countries 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 liberalization 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. Beside the income level, also the stabilization of farm revenues is a central goal of agricultural policies in Europe (Tyner et al., 2005). Concerns on increasing farm income volatility, due to e.g. market liberalization 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, Cafiero et al., 2007, Meuwissen et al., 2008, Meuwissen et al., 2011, OECD, 2000, Bielza Diaz-Caneja et al., 2008, EC, 2001, Reynaud, 2009, Phélippé-Guinvarc'h and Cordier, 2010) 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 USA (e.g. yield and revenue insurance, whole-farm income insurance, and area index insurance), Australia (stabilization account), Canada (single risk insurance, yield and area index insurance, stabilization account) or 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 hardly developed. In contrast, single-risk insurances such as hail insurance are wide spread across the European countries. Some countries also have combined-risk insurance schemes (e.g. France, Italy, Spain), securing against different kind 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) increase the demand for new and more complex insurance schemes in European agriculture. For instance, the European Union has proposed an income stabilization 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 be addressed empirically at first: what type of risk management strategies is needed? Information on the perils faced by farmers is of major interest (Wolf et al., 2009) as the risk reducing effect of different possible risk management instruments among others depends on the extent of risk coming from yields and prices. Furthermore, also input costs may 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 risk[2] 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, potato, canola and sugar beet (Bohrnstedt and Goldberger, 1969). Swiss crop production is used a case study because risk management tools are hardly developed yet, but will be of increasing importance in the future. First, increasing liberalization 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). Recognizing these significant potential changes in the risks Swiss crop producer face, the Swiss farmers' Union initiated discussions on the introduction of insurances against weather and market based risks (SBV, 2011). Thus, the empirical analysis presented in this paper aims to provide 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 characteristics on their risk profile. 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 or price risks that are revealed in this study are expected to indicate target groups for possible risk

[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 EC (2006).

[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).

management tools. This classification will facilitate the tailoring of risk management instruments towards the need of farmers. The here presented classification of farms according to major risk sources has not been considered so far, and represents a first empirical step towards 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 its 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 subsidized 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 to ecological direct payments is voluntary for Swiss farmers (for more details see El Benni and Lehmann, 2010, Mann, 2003).

In crop production, the most important ecological direct payment program is the so called Extenso program. In this program, 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 extensive production program covers all cereals (except corn) as well as rapeseed and is available for all Swiss farmers without any regional restrictions. Its obligations are, however, on the top of the cross-compliance requirements that farmers have to fulfill to receive general direct payments (Finger and El Benni, 2013). Extensively produced crops cover more than 50% of the area under cereals, and are thus a fundamental aspect of Swiss crop production. We expect that extensive and intensive producers face different types of risk. For instance, intensive producers can cope better with environmental harms to crops (e.g. pest pressure) and yield risk is thus expected to be lower. However, extensive producer 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 extensive and intensive wheat and barley production separately throughout our analysis[4].

Beside direct payments, the production of oil seeds, grain legumes, fiber 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).

The Swiss hail insurance provides different types of insurances to crop producers. The by far most important insurance scheme covers hail damages as well as elementary damages (e.g. from storm, floods, and landslides). This insurance is available at the farm- or crop specific level (see e.g. Finger and Calanca, 2011, and 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 extents the risk covered by the hail insurance by including also risk from drought and heavy rainfalls. No explicit market based price risk management tools are available to Swiss crop producers yet. However, Switzerland is in negotiations with the European Union with the aim to further liberalize the agricultural market by a bilateral trade agreement. This raises the concerns on decreasing incomes and increasing 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 concerning the period 2014-2017, parts of the current farm-level support are transferred from general direct payments to ecological direct payments. The change to less intensive production techniques may change the production risk farmers face (Meuwissen et al., 2011, Gardebroek, 2010,

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

Schläpfer et al., 2002). Altogether, these changes may lead to an increasing interest for risk management instruments, also 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 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 of 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 fertilizer, seed and pesticide costs, all expressed in monetary values. Note that neither information on the quantities on input use, nor on per hectare machinery and labor costs are available. Hence, per hectare net revenues *nr* of crop *i* are defined as the product of prices *p* and yields *q* minus the costs *c* for fertilizer, seed and pesticides:

$$Enr_i = p_i * q_i - c_{i,fertilizer} - c_{i,seed} - c_{i,pesticides} \quad (1)$$

The variability of net revenues is measured by its variance over time at 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 relative 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. Furthermore, by using a five-year period, we reduce the effects of possible trends or structural breaks within the single variables of interest. For instance, input and output prices as well as crop yields have not shown characteristic trends or breaks in the considered period, but rather fluctuated about a common mean. Note that even though crop prices in other countries increased significantly in 2008, only small changes in crop prices were observed in the high protected Swiss market.

In our analysis, we have chosen those farms that have recorded acreage of the specific crop in three of the five years under consideration. In addition, wheat and barley producing farms were separated into those with intensive and those with extensive production as outlined above. For instance, this led to a total amount of 4238 wheat records across all years, of which 1600 (38%) coming from intensively and 2638 (62%) from extensively producing farms. These observations represent 395 different farm operations for intensive production and 659 different farm operations for extensive production (for details on other crops see Table 1).

We use variance decomposition to disentangle the effects of different income components (i.e. yields, prices and costs) on farms` net revenues of the different crops[5]. To decompose net revenue variance into specific contributors, we account for the fact that net revenues consist of products and sums of correlated variables (Equation 1). Following Goodman (1960), Bohrnstedt and Goldberger (1969), and Burt and Finley (1968), we have chosen the following strategy to decompose net revenue variance for each crop:

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

Note that 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

[5] Applications of variance decomposition in agriculture can also be found in Schmit et al. (2001), Chang et al. (2007) and Wolf et al. (2009).

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 use the estimates derived from this procedure to derive estimates for net revenue variability at each farm. Subsequently, we test if these estimate deviate from the observed net-revenue variability using Wilcoxon rank 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, fertilizer, and pesticides on the variance of net revenues. The second line depicts the first-order interaction effects between prices and yields and gross revenues and the single cost components respectively. The first-order interaction effects between seed, fertilizer, 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 normalize 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 each of the three cost components sum to 100, and increasing variance of either components 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 correlation 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 Characterization of farms being more exposed to either price or yield risk

In order to analyze which type of farm could require either price or yield risk management instruments, we conduct non-parametrical group comparisons as well as logistic regression analyses. For the group comparisons, Mann-Whitney tests are used. Based on the results of the variance decomposition, group 1 is formed by 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 than 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 why farms being 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.

First, we expected that environmental influences differ across space and thus lead to heterogeneous spatial patterns of crop yield variability. Thus, the farms' location may partially explain if 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 the farm is located in. The number of cantons in which the specific crops are produced range from 11 (for potato) to 17 (for extensive wheat production). To test whether the canton significantly affects the kind of farm risk (i.e. whether the farm face higher yield or price risk respectively) 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 fertilizer and pesticides as proxy for production intensity. Furthermore, the farm's crop yield level is used as 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. 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 whether price or yield risk dominates if farms produce high qualities is ambiguous. High quality crop production may enable to produce in a niche that faces little competition and little price variability. But, also the production of low qualities can imply lower price risks because fodder production may face less variable demand and price than crops for human nutrition. Because quality information is not included in the FADN data, we use the price level as 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 reduce total (i.e. farm-level) yield variability.

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 indicated in Table 1. Wilcoxon rank sum tests show that there are significant differences between intensive and extensive 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 extensive barley and wheat production are significantly lower than of intensive production. As expected, lower levels of input use lead to lower yield levels. While extensive wheat can be sold to significantly higher prices than intensively 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 extensively produced baking wheat is distributed in separate marketing channels by a private organization (IP Suisse), which is not the case for fodder crops such as barley (there is no malting barley production in Switzerland). In average, gross revenues of extensive wheat are by about 20% lower than for intensive wheat. Extensively producing barley farms even generate 26% lower gross revenues compared to those producing intensively. Seed costs of extensive varieties are about 10% higher than for intensive varieties, pesticide costs and fertilizer costs, however, are markedly lower. Altogether, higher prices and lower fertilizer and pesticide costs almost compensate extensive wheat producers for foregone profits (due to lower yields) and higher seed costs; and net revenues are only slightly lower in extensive wheat production. In contrast, net revenues of extensive barley production is about 24% less compared to intensive production and savings in costs cannot compensate lower yields and higher seed prices. Note that extensive producers receive an ecological direct payment of 400 CHF/ha. Thus, extensive 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 beet), even though input costs are significantly higher than in cereal production. However, because machinery and labor costs (which are higher for potatoes and sugar beet) are not taken into account, these results must be interpreted with caution.

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

	wheat			barley			corn	rapeseed	Sugar beet	Potato
	intensive	extensive	% of intensive	intensive	extensive	% of intensive				
Yield dt/ha	66.27 [60,72]	52.88 [48,58]	**79.8**	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]	**113.5**	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]	**89.6**	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 % of total cost	261.2 [236,287] 28.76 %	288.6 [253,306] 45.75 %	**110.5**	180.20 [156,198] 22.64%	197.80 [169,216] 39.77 %	**109.77**	299.90 [257,315] 36.90 %	160.82 [129,181] 17.87 %	404.90 [376,427] 28.96 %	2551.30 [2177,2949] 63.66 %
Fertilizer CHF/ha % of total cost	320.2 [223,393] 37.87 %	232.9 [157,311] 32.82 %	**65.8**	266.70 [169,351] 33.51%	187.10 [118,254] 32.92 %	**70.15**	316.00 [196,413] 35.48 %	404.80 [274,520] 41.20 %	420.90 [281,540] 28.12 %	606.30 [398,772] 14.86 %
Pesticides CHF/ha % of total cost	353.8 [287,413] 33.37 %	147.7 [111,188] 21.44 %	**46.1**	349.00 [278,402] 43.85%	152.50 [105,201] 27.32 %	**43.70**	239.40 [164,301] 27.23 %	390.30 [287,467] 40.93 %	621.00 [500,721] 42.92 %	867.70 [668,1045] 21.48 %
Costs total CHF/ha	935.3 [806,1047]	669.2 [572,769]	**71.6**	795.90 [674,913]	537.50 [445,627]	**67.53**	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]	**96.4**	2156.20 [1791,2454]	1'617.00 [1290,1830]	**74.99**	3'214.00 [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

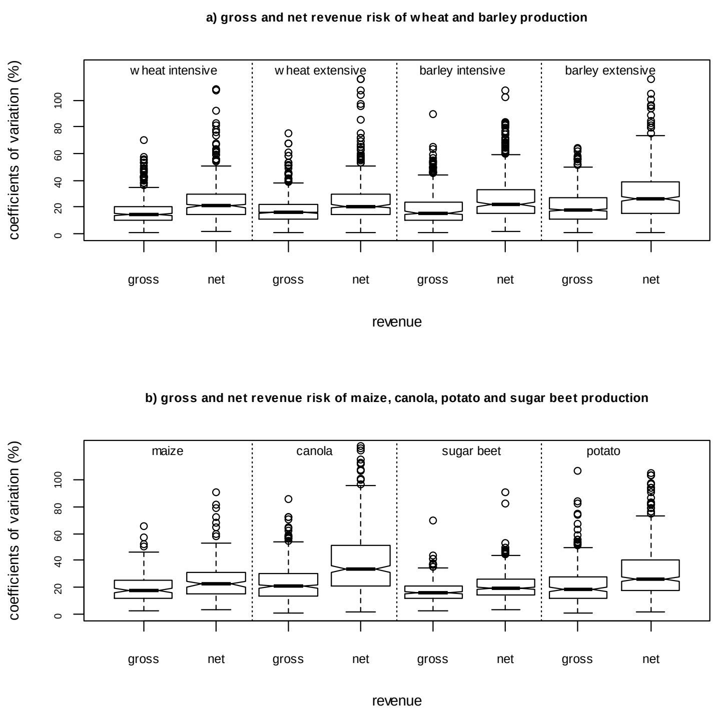
CHF: Swiss Francs; ha: hectare; dt: deci tons; values in bold show significant difference between intensive and extensive production at least at the 5% level, interquartile ranges (differences in the mean values between farms) are given in square brackets.

4.2 Revenue risk in Swiss crop production

Figure 1 shows the distribution of the coefficients of variation of net and gross revenue for the 8 considered crops. In general, all distributions of coefficients of variation are skewed to the right, showing that some farmers face very high revenue 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%. We find that net revenue risk is significantly higher than gross revenue risk for all of the crops considered. This is due to the fact that more potential sources of risk are considered in net revenue calculation.

The median coefficients of variation of gross revenues are located between 0.15 (intensive wheat) and 0.21 (extensive barley). In contrast, the median coefficients of variation of net revenues range from 0.19 (sugar beet) to 0.33 (rapeseed). The difference between gross and net revenue risk is lowest for sugar beet production, where net revenue variability is 1.22-fold higher than gross revenue variability. The difference is highest for rapeseed production, where net revenue variability is 1.60-fold higher than gross revenue variability.

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



4.3 Decomposition of net revenue risk

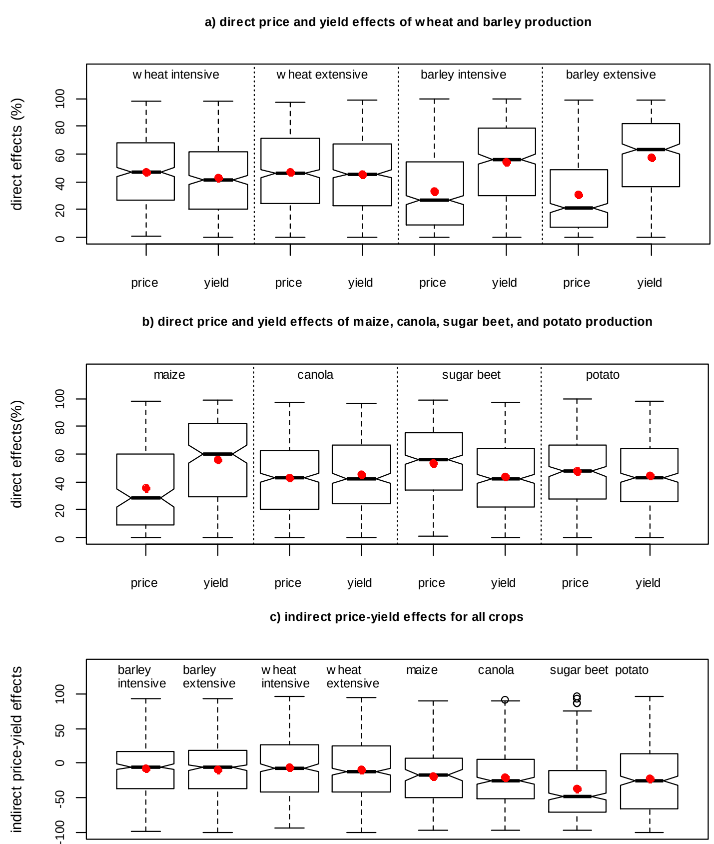
Table 2 shows the results of the net revenue variance decomposition for the main crops produced in Switzerland. Wilcoxon rank sum tests are used to test whether yield or price risk is the main source of net revenue variability for the different crops (again, intensive and extensive production is analyzed separately). Note that the decomposition has been conducted at the farm-level, 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. Comparing approximated net revenue variability (based on Equation 2) with observed net revenues variability using Wilcoxon rank sum tests, indicates no significant differences at the 5% level.

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

	Wheat		Barley		Corn	rapeseed	Sugar beet	Potato
Direct effects	intensive	extensive	intensive	extensive				
Price	**47.03**	47.30	33.72	30.54	35.46	42.73	53.93	48.00
Yield	42.74	45.68	54.12	**57.84**	**56.47**	**45.14**	43.64	45.01
Seed	1.13	1.48	0.71	1.87	1.47	1.07	0.23	5.35
Fertilizer	5.02	3.43	5.64	4.95	4.31	5.61	1.06	0.60
Pesticides	4.08	2.12	5.81	4.80	2.29	5.45	1.14	1.05
∑direct cost effects	10.23	7.03	12.16	11.62	8.07	12.13	2.43	7.00
Indirect effects								
Price/Yield	-5.57	-8.71	-7.98	-11.10	-18.16	-20.56	-36.82	-22.08
Gross revenue/seed	1.34	0.88	0.73	1.39	1.85	0.60	0.37	4.05
Gross revenue/fertilizer	0.53	1.36	0.82	-2.31	1.47	3.80	-0.62	1.89
Gross revenue/pesticides	1.64	0.53	3.58	2.92	2.57	1.74	0.91	1.02
Seed/fertilizer	0.08	0.10	0.03	0.30	0.58	0.50	0.04	0.31
Seed/pesticides	0.23	0.22	0.45	0.42	0.36	0.26	0.10	0.05
Fertilizer/pesticides	-0.09	0.44	0.43	0.79	0.98	1.11	-0.06	0.19
No. of obs.	395	659	451	454	147	363	401	348

Values in bold show if either yield 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 normalized 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. Normalized 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 intensive wheat producing farms is significantly more affected by price than by yield variability. Thus, the price effect significantly dominates the yield-risk effect. In contrast, corn and barley production are particularly affected by yield variability. No significant differences between the direct effects of yields and prices could be observed for extensive 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 from 2.4% (sugar beet) to 12.2% (intensively produced barley)[6]. For all crops considered but potatoes, fertilizer and pesticide costs contribute much more to net revenue variability than seed costs. For instance, for barley, rapeseed and intensive wheat production, fertilizer and pesticide costs contribute with 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 fertilizer and pesticide costs are negligible.

The results for the first-order interaction effects (lower panel of Table 2) show negative (normalized) 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 et al., 2010). The negative covariance between yields and prices indicate 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 strongest for sugar beet (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 intensive 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 normalized covariance terms between gross revenues and costs have positive signs. Also 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) to 98% (sugar beet) of the variability in net revenues. Hence, an optimal portfolio of risk management strategies should address both, yield and price risk. Furthermore, farms may ask for different risk management tools dependent on the crops produced. The net revenue variability of sugar beet and intensive 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. In general, natural hedge plays a substantial role in reducing revenue risk at farm level (reducing net revenue variance by between 6-36%). 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 analyze 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 is formed by 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

[6]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).

variability is mainly dependent on yield risk, 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.

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

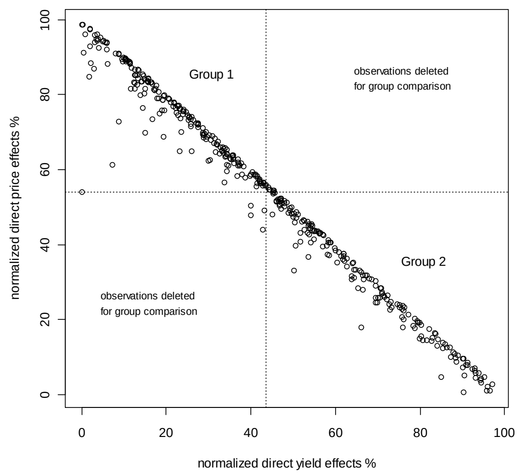


Table 3 shows the results of the group comparisons. Not surprisingly, the coefficients of variation for yields (prices) are significantly lower for farms facing higher than average price (yield) risk than for those facing higher than average yield (price) risk. The differences in the coefficients of variation of price and yield variability, respectively, are significant for all of the crops considered. For farms facing higher price than yield risk (group 1) the coefficients of variation for prices range between 0.16 for intensive 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 on the crops they produce. For instance, while net revenue variability of intensive 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, barley producing farms facing high yield risk does not differ from barley farms facing high price risk. For both groups, the variation coefficient is about 0.30 for net revenues. 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 significant lower net revenue risk.

In general, Table 3 shows, that farms facing higher yield than price risk (Group 2) have lower yields than farms facing higher price than yield risk (Group 1). The differences in yields are significant for all crops but corn and sugar beet. We compared groups also with respect to other proxies for intensity, i.e. fertilizer and pesticide expenditures. We find that farms facing high yield risk produce less intensively than farms facing high price risk. The results are however, 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 but extensive wheat and potatoes. Thus, producers generating higher price levels (due to higher quality levels) tend to face higher price than yield risks. For 5 of the 8 considered crops, farm-level crop acreage is – on average - larger for those farms where price risks are dominating. Differences are significant for extensive and intensive wheat as well as for rapeseed. This finding underlines our expectation that farms with a larger crop acreage face lower production risks, and thus rather price variability is the important factor for these farms.

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

	Wheat intensive		Wheat extensive		Barley intensive		Barley extensive		Corn		Rapeseed		Sugar beet		Potato	
Group	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**
Ouput																
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)																
Fertilizer	**335.94**	**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 ha	**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
No % of all	178 51%	170 49%	304 50%	307 50%	174 44%	220 56%	153 39%	237 61%	56 42%	77 58%	167 53%	149 47%	206 53%	184 47%	161 50%	158 50%

Values in bond 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 yield effects than average direct price effects, i.e. yield risk dominates) at the 10% level.

To analyze the influence of 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 fertilizer 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 ratio with values above 1 indicating a positive and values below 1 a negative relationship to the odd of being exposed to higher price than yield risk. For instance, in the case of intensive wheat production, 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 than to yield risk.

The results of the regression models show that for most of the crops considered, the level of crop prices significantly affect the odds of a farm being more exposed to price than to yield risk. This is in accordance to the group comparison results. For instance, a 1 CHF higher price per dt of intensively produced wheat increases the odds that a farm is more exposed to price than to yield risk by a factor of 1.11. The effect of the price level is found to be also significant for barley (intensive and extensive) and sugar beet production as well as for corn production (however, for the latter only at the 10% significance level). Furthermore, also higher yields increase the odds of being more exposed to price than to yield risk (the odd rations of yields for all crops have values higher than 1). The effect is significant for extensive barley, wheat, and rapeseed and potato production. The crop acreage is only significant for wheat production and shows 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 intensive barley, intensive wheat production as well as corn and rapeseed production. Spatial heterogeneity has thus no influence on farms' risk profiles for extensively produced wheat and barley as well as potato and sugar beet production.

Table 4. Regression results explaining higher than average price risk

	Wheat intensive	Wheat extensive	Barley intensive	Barley extensive	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
Canton (no)	0.489* (12)	0.477 (17)	5.234*** (14)	0.846 (16)	8.381* (11)	0.651** (15)	0.328 (12)	2.720 (11)
AIC	396.56	748.9	455.33	473.31	164.61	359.76	480.55	408.25
Pseudo R-squared	0.13	0.08	0.10	0.10	0.17	0.18	0.07	0.05
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.

5. Summary and Conclusion

The aim of this paper was to assess what types of risk management is required to reduce the income risk of Swiss crop producers. Therefore, we quantified the variability in net revenues due to prices, yields and costs for the six major crops produced in Switzerland. To this end, a variance decomposition approach was applied to FADN data of more than 3000 farms over the period 2005 to 2009.

We find that input costs, such as fertilizer, pesticides and seed costs, 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 with 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 and price risk are dominant in Swiss crop production, management tools to address them seem to be most 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 or yield risks management strategies depends on the specific crop produced. For instance, sugar beet and intensive 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. The results are in line with those of e.g. Mahul (2003) and might be explained by the fact that boarder protections measures make Switzerland to a rather closed economy for agricultural goods and that most of the crops produced in Switzerland are concentrated on a small area at 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 and prices are thus directly influenced by supply and demand at harvesting (Pavlista and Feuz, 2005).

The observed correlations between prices and yields for the different crops considered have implications on 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, 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.

To investigate if farm characteristics can be used to classify for a specific crop if price or yield risks are more important, we used group comparisons and logistic regressions. It shows that more intensively producing farms 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. For some crops, also regional differences in the exposure to either price or yield risk was observed which should be analyzed in more detail in further research.

More general, 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 significant lower net revenue risk. These results suggest, that risk analysis in agriculture should not be focused on either price, yield or revenue risk alone but should consider the dependence 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 risk farmers' face. Results from such kind of studies can be furthermore used as basis for further analysis such as the viability of different risk management instruments, including price and yield risk management tools as well as e.g. on-farm diversification.

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