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Bio-economic modelling of decisions under yield and price risk for suckler cow farms

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Abstract

Applying a bio-economic whole farm model we assess the impact of price and weather risk as well as different risk management strategies on the variability of the income in Swiss suckler cow production. We consider different on-farm risk management strategies such as the flexible adjustment of herd size, fodder composition and feed stocks, as well as an income insurance. Our results show that without any risk-management income variability is rather high, with coefficient of variation (CV) of income ranging from 26% to 31%. Taking on-farm risk management strategies into account it is possible to reduce income variability significantly (CV 12-15%), but causes only low reductions of mean income levels. Our results also indicate that income insurance is not attractive for farmers Our results thus suggest that in particular promoting better access to markets for feed stuff provides an valuable opportunities for farmers to manage income risks.

Keywords: Weather risk, Bio-economic whole farm model, Suckler cow, Income insurance

JEL classification: Q12, Q18

1. INTRODUCTION

Agricultural production is facing several sources of risk and uncertainty that need to be taken into account by the farmer. In particular, variable weather conditions affecting crop and fodder production, fluctuating input and output prices as well as herd-health-problems and a subsequent decrease in the production capacity are main determinants of risks and uncertainties in agriculture (Moschini and Hennessy 2001, Hardaker et al. 1997). All these factors directly affect farmers' incomes and can critically affect the continuance of farms. In future, risks in agricultural production are even expected to increase due to climate change and increasing volatility on agricultural markets (Howden et al. 2007, Hardaker et al. 1997).

To cope with these risks, farmers can adapt their management plans. In the case of animal production that is addressed in this paper, an efficient and well-established risk-management strategy is for example to store fodder between years to survive unfavorable weather in a proceeding year (e.g. Mosnier et al. 2011, White et al. 2009). A further strategy to cope with risk is to choose herd sizes lower than in maximum possible which allows farmers to guarantee sufficient fodder production in bad years, and the selling of overproductions in good years (Parsch et al. 1997, Ritten et al. 2010). Beside such on-farm risk-management measures, there is also a possibility to reduce income risks for farmers using financial products such as insurances (see e.g. Bielza Diaz-Caneja et al., 2008, for an overview). In this paper, we particularly address an income insurance scheme, which is currently evolving in many countries (Turvey, 2011, Meuwissen et al., 2003). Some years with extremely unfavourable weather conditions in the last decade provoked a discussion if the government should provide such income insurance for farmers in Switzerland, as it is already planned in the European Union. Beside technical questions about the implementation of such an insurance scheme, it has to be assessed if these insurance schemes are more efficient to reduce the volatility of farmers' incomes and to prevent catastrophic income situations than are on-farm risk management strategies. In this paper, we address different risk management strategies in suckler cow farming, with an empirical application to Switzerland. Suckler farming has been chosen as example, because it is one of the most rapidly developing branches in Swiss agriculture. While in 1990 only very few suckler cows were held in Switzerland, this number increased to over 90'000 cows in 2010. And the prospects for suckler cow production are prosperous: Even though production in many branches of Switzerland is too high to sell products on domestic markets, which are still protected by relatively high tariffs ensuring high prices on domestic markets and therefore making an export of agricultural products unprofitable, there is still an unsatisfied demand for beef produced on suckler cow farms.

However, suckler cow producers face high risks because of weather and price uncertainty what has been shown in different studies (e.g. Payne et al. 2009). To mitigate negative impact of uncertainty Ritten et al. (2010) show that number of livestock has continuously to be adapted to current weather conditions to improve income and reduce risk. Applying a bio-economic model to simulate rangeland management in Namibia, Domptail and Nuppenau (2010) conclude that a good way to mitigate impact of weather risk is to minimize herd size adjustment costs and to expect low-rainfall when choosing the size of the herd. Applying a system dynamic model Payne et al. (2009) argue that beef cow operations in Texas face high uncertainties that can be reduced by changes in the calving season. Recent work of Mosnier et al. (2011) (using an example from France) has shown, that there are different possible on-farm risk-management strategies available that are especially suited for suckler cow farms. The most important strategy highlighted in their study is the ability of farmers to purchase additional fodder and adapt the number of animals. They also point out, that financial instruments as insurances could be an interesting tool for additional risk management. In contrary to these studies, Flaten and Lien (2007), who applied a bio-economic whole farm model to dairy farming in Norway, however, point out that farm plans do not differ if farmers' risk aversion changes.

Based on this background, the goal of our study is to analyse different risk management strategies in Swiss suckler cow production. For this purpose we use a bio economic whole-farm model to compare the impact of different risk management schemes on average farm income as well as standard deviation of the farm income. To this end, we expanded the INTSCOPT model that has been developed by Briner et al. (2012) with a stochastic production and price framework as well as by integrating farmers' decision making under risk. Applying this model we assess different on-farm risk management measures such as the adaptation of land-use, the adjustment of herd sizes and composition of the feed mix, the storage of roughage in the form of hay- or silage-bales and the use of maize as a switch crop. Finally, we compare these risk management measures with an income insurance scheme based on a fair premium approach. These risk management options are investigated for different scenarios on farmers' risk preferences. This modelling setup is used to answer the following research questions: 1) What is the mean and variance of farm-level income under the different assumptions for risk preferences, 2) Is an income insurance a more efficient measure to stabilize farmers income than on-farm measures? 3) What is the impact of an insurance scheme on optimal farm production plans?

2. METHODS

To assess the impact of different risk assessment strategies, we develop a bio-economic whole farm model for a suckler cow farm in the Swiss lowlands that is based on the INTSCOPT model that has been developed by Briner et al. (2012). This model assumes a representative specialized suckler cow production farm. In contrast to Briner et al. (2012), the here considered study region is located at the Swiss Plateau, where climatic conditions allow for intensive grassland as well as crop production but where climate conditions, especially precipitation, is more variable than in the Swiss pre-alps. More specifically, we use grass and maize production data that has been derived using weather information from an operational weather station (Wynau, 47°15'N, 7°47'E, 422 m a.s.l.), which is close to the experimental site Oensingen that has been subject to a large body of experimental and modeling studies (see e.g. Finger et al., 2010, for an overview). Since this location also allows the cultivation of grain maize, the income generating activities considered in Briner et al. (2012), production of meat and production of selling excess roughage on the market, are complemented by the production, on-farm use and the selling of grain maize.

The farm represented in our model is assumed to be specialized on suckler cow production. Thus, other types of animals are not considered and crop production plays a limited role in farming activities (only grain maize is considered). This type of specialized farm represents recent developments in Swiss agriculture where new farms often specialize solely on suckler cow farming to profit from the high economies of scale (Briner, 2008). Risks represented in the model, focus on weather risks (in form of volatile fodder and crop production) as well as on price risks (in form of volatile prices for meat). The here presented model does not simulate long-term changes in the farm type (e.g. a switch to crop farming), in land-use and livestock housing over time, but simulates an ex-ante five year farm plan. This farm plan has a time resolution of one month for decisions concerning livestock housing, i.e. number of livestock as well as feed mix, and one year for land-use decisions. To cover a whole production cycle of a suckler cow the farm plan has a time horizon of five years. This long time horizon also makes it possible to prevent that risk is shifted out of the modelled time frame. In addition, a time horizon of more than a year is necessary to represent decisions about storage of fodder across years. The monthly and annual time horizons considered in our model allows us to simulate tactical (within a year) and strategic (over a few years) adaptation responses to cope with weather and price risks.

The remainder of the methodology section is structured as follows: First, the goal function that represent farmers' decision making process is introduced. Second, the activities considered in our model are presented in detail. Third, agronomic and political restrictions in the model as well as data sources used are presented. Finally, the different scenarios with respect to weather and price risks as well as with regard to the risk aversion of the farmer are introduced.

2.1. Farmers decision making

Farmer's decision making is simulated applying a combined discrete stochastic programming (DSP) and safety first approach. DSP was introduced by Cocks (1968). It is a method that allows solving multi stage decision problems with uncertain outcomes. Applying this method brings the advantage that uncertainty can be introduced into coefficients of the objective function as well as into input-output coefficients or resource endowments. In this modelling approach, information about the exact distribution of random events is not necessary. It is sufficient to know the probability of realisation of different discrete states of nature. This enables an unbiased use of yield and price observations in our modelling approach. An additional advantage of DSP is that problems can be formulated in a linear programming framework for that powerful solving algorithms are available (Cocks 1968).

The here presented model uses a repeated two stage decision problem. In stage one the land-use activities are chosen. In stage two livestock activities including the number of different livestock and the feed-mix of the livestock is adapted. This procedure is repeated for every year in a temporal dynamic framework. The outcomes of the different years are linked with the feed stuff stored in the precedent year as well as with the number of animals that is transferred from year to year. In this framework, it is assumed that there is complete information about the outcome of the first stage decision (Appland and Hauer 1993), i.e. the farmer's decision on land use as well as the outcome of this land-use decision. In a simplified representation, the decision problem has the following form:

$$\max \quad = -\sum \qquad + \tag{1}$$

s.t.

$$+ \quad < \tag{2}$$

$$- \quad > 0 \tag{3}$$

$$=> 0, \quad => 0 \qquad (4)$$

Z is the farm gross margin per year, g is the gross margin of land-use activities. The modelling approach assumes that farmers maximize gross margins. Since all land-use activities primarily are dedicated primarily for (on-farm) feeding of animals, gross margins are negative because no revenues from these activities are considered at this stage. Note, however, that gross margin of selling feedstuff and maize that is not needed for feeding is calculated in stage 2. *X* is the decision vector for decisions in stage 1, i.e. land use. To ensure complete information in stage 1 the decision vector *X* must be the same in all states of nature *k*, i.e. once a land use decision is made for a specific year this decision is valid for the respective year in all states *k*. *m* are the gross margins and *Y* the decision vector of activities optimized in stage two. Decision vector *Y*, that is valid only for a specific combination of yields and prices, is different in all states of nature *k* as also are the gross margins *m* if price variability is taken into account. Whereas the decision vector *X*, chosen in stage 1, is optimal for every state of nature *k*, decisions made in the second stage are therefore only optimal for one specific state of nature. This means that the farmer has every month the possibility to adapt decisions made in stage 2 based on the outcome of the decisions made in stage 1. An additional important part of the optimization problem are the constraints (Eq. 2-4): *a* and *b* are vectors of resource needs of the different activities that may not exceed total available resources *r*. *c* are the yields of the different land-use activities *X* that are different in the states of nature *k*. Furthermore, aggregated yields of the different land-use activities must be higher than the need of feedstuff *d* of the activities of stage 2, i.e. yields must be higher than the amount of fodder that is fed or sold minus the amount of fodder that is purchased on the market.

In contrast to other studies, e.g. Mosnier et al. (2011) and Dorward (1999), states of nature are not modelled in discrete classes, e.g. yields under favourable, average and unfavourable weather, but discrete sets of realized yields and prices (drawn randomly) were used (see also section 2.4). For each of the ten different states of nature *k* implemented in this model, sets of price and yields were randomly drawn for each of the five year. After the optimization process mean and standard deviation of the resulting 50 observations on incomes (5 years per state of nature) were calculated and analysed. Such an approach was chosen since the combination of two sources of uncertainty in two classes each for five years would have resulted in 1024 possible states of nature. In a model depicting all different compartments of the farm in enough detail, this amount of states of stages is not solvable even if we used a state of the art solver for linear problems CPLEX 11 (IBM 2011).

To optimize a five year farm plan, the framework presented in Equation 1 has to be expanded by a time dimension *t*. To do so, *X* and *Y* are now defined to be dependent to the time of the decision, and the objective function has thus the following form:

$$= \sum \quad \cdot \quad - \sum \quad + \quad , \quad , \qquad (5)$$

To take into account that parts of decisions made today are risky, i.e. their value is not know for sure, investments in the future production, which raise opportunity costs for the invested capital, future returns are discounted with a (risk-free) interest rate of 1%[1]. To avoid that initial resources would be simply exploited in the model during the 5 years considered, an additional constraint sets the number of livestock as well as the feed stored at the end of the 5 year farm plan to the initial level. To ensure that feedstuff is correctly transferred in-between the years, equation 6 has to be implemented in the model:

$$, \quad - \quad , + \quad - \quad = 0 \qquad (6)$$

In this equation, *s* denotes the stock size at the end and the beginning of the respective years. An equation similar to equation 6 is also necessary to ensure a correct transfer of the animals between years.

[1]Average yield of Swiss Confederation Bonds (6 years) in 2011 (SNB 2012)

In a subsequent step, we introduce risk aversion in this framework (Eq. 7). Thus we assume that farmers not only optimize gross margin but also consider the impact of risky events in their farm plan. In this study we assume that these are implemented in the optimization process using a "safety first" mechanism based on Roy (1952), which wasused in several other studies (e.g. Bigman 1996; Robison et al. 1984, Hailey 2011). Since we assume that farm goes bankruptcy if income falls under a certain level, this case must not occur, i.e. the probability that this happens is reduced to zero over constraints. In our study this means that farm plans are optimized in a way that gross margin also under very unfavourable weather or market conditions does not fall beyond a certain level. This "safety first" rule is implemented in the model using another constraint where *GM* is a predefined level of the gross margin that must be reached in every year *t*:

$$+ \quad _{,} \quad _{,} > \qquad (7)$$

This critical gross margin level is also employed to implement income insurance in the suckler cow production plan: Thus, in the scenarios assessing the use of income insurance, indemnity is paid if gross margin falls beyond the level specified for GM. The insurance premium is calculated model endogenously as a fair premium, i.e. it is calculated as the expected annual level of paid indemnities. If implementing the income insurance in the model, we assume that this premium has to be paid in every year.

2.2. Activities

In the first decision stage, land-use on the 30 ha that are assumed to be available in the here used exemplary farm is optimized. The model has the choice between 3 different types of grassland: Grazed grassland, mown grassland and mown grassland in crop rotation with maize. Each of the grassland types is available in three intensities differing in the intensity of fertilization: intensive (yield=100%), mid-intensive (yield=80%) and extensive (yield=30%). These types of grassland use and production intensity reflect the current conditions observed in Switzerland (Dütschler-Hermann et al. 2006). Beside grassland production the model (in some scenarios) also includes the possibility to grow maize for silage or grain maize. Since there are no other crops available crop rotation is limited to an alternation of grassland and maize.

Table 1: Description of the production system including Natura Beef and Feeder Cattle

	Production system	
	Natura Beef	Feeder Cattle
Weight of the cow [kg]	625	
Calves per year [1/year]	1	
Weight of calf at birth [kg]	36	
Milk production [kg/year]	2500	
Max. number of cows in stable house	70	
Age when leaving farm [months]	10	
Average growth per day [g/day]	1100	880
Live weight when leaving farm (LW) [kg]	364	300
Carcass weight (CW) [kg]	205	

Sources: Blum et al. (2009)

The main activity considered in the second stage of the decision problem is the production of animals. In the model three types of cattle are available: Suckler cows (mother cows) as well as Natura Beef and feeder cattle (for the calves). Natura Beef is a Swiss brand marketing young cattle from suckler cows that are slaughtered just after weaning (Mutterkuh 2012). Currently there is a high demand for Natura Beef because the meat is of good quality and the production system is perceived as animal friendly.

Both Natura Beef and feeder cattle are sold at the age of 10 months. The Natura Beef are sold for slaughtering. They reach live weights of 364 kg at the age of 10 months. Hence these animals need to be fattened rather intensive to reach daily gains in live weight of more than

1000g/day (Boessinger et al. 2010). In contrast, feeder cattle are sold to other farms where they are fattened intensively on a nutrient rich diet until they are slaughtered. In contrast to cattle sold as Natura Beef, daily gains in live weight are below 1000g/day thus they can be fed with less nutrient rich diets (Blum et al. 2010). There are no heifers on the farm since in Switzerland it is a common practice to purchase young cows just before first foaling. For more information about the production system see Table 1.

Further activities considered in the second stage of the decision problem are buying and selling different types of feedstuffs and the choice of the use of the grown maize (see subsequent points).

2.3. Balances

In the optimization process, the different activities are linked over three balances: Livestock balance, fodder balance and nutrient balance. These balances are described in more detail below.

2.3.1 Livestock balance

Livestock balance ensures that calves become one month older in each proceeding simulation period. Similarly, in each simulation period, suckler cows go one step further in their production cycle, which is implemented as follows: They foal in simulation period one, are with their calves until simulation period 10, and finally start a new cycle after simulation period 12 (Blum et al. 2010). Cows only can be purchased or sold just before foaling. Time of foaling is not predetermined but the model can choose this point in time endogenously. The decision if a calve is sold as Natura Beef or Feeder Cattle has to be made just after birth. This choice cannot be changed afterwards anymore. Additionally there is no possibility to buy additional calves.

2.3.2 Fodder balance

Following the procedure described in Briner et al. (2012), feed mix is calculated in the optimization process and can be adapted on a monthly base. Thereby for every single class of animals, i.e. for cows, Natura Beef and feeder cattle of each different age, a feed mix is calculated. The diet has to satisfy the needs of the animals for energy and protein. The demand for feed by the specific type of animals is calculated monthly using regressions provided by the Swiss research stations Agroscope (Arrigo et al. 1998). It considers the demand for preservation, milk production, gravidity and growth. Demand for preservation thereby is dependent on the average live weight of the animals in each month. Nutrient demand for growth is only considered in the case of the calves. Based on Boessinger et al. (2010) we assumed that growth curves of both feeder cattle and Natura Beef are linear (see also table 1). For the calculation of monthly milk production a regression based on Kwizda et al. (1956) has been used.

Beside nutrient demand, it is also considered that the amount of fodder fed has to be inside a certain band since the animals only can digest a certain amount of food but also need enough feed to be satisfied, i.e. the nutrient content of the feed mix only was allowed to deviate from the calculated value by +- 5%, allowing only a small amount of compensatory growth.

Fodder is supplied in different forms of roughage and concentrate. Grass can be fed by grazing pastures or it can be conserved as silage and ground dried hay. Grazing period is limited from April to October. Based on Arrigo et al. (1998), we assume that nutrient content of grass is higher when grassland is cultivated more intensively compared to the case if grassland is cultivated extensively. Maize only can be conserved in the form of silage. The use of concentrate is restricted to the feeding of calves that are older than 4 months. Beside hay and silage these calves also receive grain based concentrates.

Storage of feed in bulk is limited by barn capacities. Grass- and maize silage is stored in silos that have a total capacity of 100t DM. In addition, there is the possibility to store grass silage in bales. However, the production of these bales negatively affects farms gross margin since they are produced by a contractor, i.e. no on-farm resource of machinery and labour can be used to produce these bales (cp. Table 2). In contrast to storage of grass silage, storage of hay in bales is not limited because it requires no building for storage. Concentrate feed cannot be produced on-farm but has to be purchased at market prices. The farm has also the possibility to buy hay and grass silage from other farmers. Note that in contrast to other countries, there exists a market for basic fodder products that are exchanged between farmers (cp. agrigate 2012 for examples). If in one year grass production exceeds on-farm demand, farmers also have the possibility to sell hay and grass silage (see Table 2 for details). Trade with maize silage however is not possible.

2.3.3 Nutrient balance

A nutrient balance ensures that the modelled farm fulfils the cross compliance requirements (Proof of Ecological Performance (PEP), see El Benni and Lehmann (2010) for details), which represents a criteria that must be met to receive direct payments in Switzerland. In order to fulfil the PEP the amount of nutrients spread may not exceed 110% of the nutrient demand of crops and grassland. The calculation of this nutrient balance in the model was done according to the official calculation criteria (for details see Suisse-Bilanz, Amaudruz et al. 2003).

2.3.4 Calculation of gross margin

The calculation of the gross margin is based on price data of the year 2010 (See table 2 for details). Housing of animals causes fixed costs per animal such as for veterinary costs. Additionally there are costs for fodder that depend on the feed mix. Feed stuffs grown on the farm cause costs per hectare for machinery for cutting the grass. These costs are dependent on the intensity of the meadow since the intensity influences the number of cuts. Costs for the transport of hay to the barn are assumed to be dependent on the yield of the meadow. Additional costs are caused if a contractor has to make hay or silage bales. Additional costs need to be paid if artificial fertilizer needs to be purchased. All details on the calculation of the gross margin are presented in table 2.

2.4. Yield data

For each of the 10 possible states of nature k (causing different yield levels), grass and maize yield data were calculated for five years (see table 2 for average and standard deviation). Yield data for grassland in this work is based on a study of Finger and Calanca (2011) and observations are drawn randomly from the yield data reported there. Grassland yield observations in this study were derived for an intensive grassland for the here considered study region, under current climatic conditions. In this work, also information on distributions of grassland yields under different nitrogen fertilization regimes are provided. A similar procedure was employed to derive statistical information on maize yield distributions. We use data provided by Lehmann et al. (2012), assuming weather information from the Wynau station and taking the same setup as in Finger and Calanca (2011). This procedure ensures that yield distributions of grassland and maize refer to the same study region as well as to the same time horizon (details on the employed yield distributions are available upon request from the authors). Since we assumed that maize and grassland yields are correlated with each other, yields of maize were ranked in the same order than yield for grassland. Thus, high and low yield events, respectively, for grass and maize production are assumed to occur jointly.

2.5. Uncertain price data

As noted in Table 2, price date for the year 2010 was taken from Boessinger et al. (2010). In our analysis, we focus on the influence of output price volatility on optimal farm-decisions. Thus, the prices of meat of calves were assumed to be uncertain. Information on price distributions was derived from price statistics published by the Federal Office for Agriculture of Switzerland (FOAG 2011). Intra-annual price development for Suckler beef in Switzerland follows a regular pattern with low prices in spring and fall and higher prices in winter and summer. This was considered in the model by setting the base for prices for meat using monthly average prices of the years 2004 to 2009. The same data were used to calculate the inter-annual variation of the prices that was estimated as standard deviation. Using this data 10 sets of 5 years of deviations from the average meat price were drawn randomly from a normal distribution using the information on price distributions that were then added to the average monthly prices. (Details on the employed price distributions are available upon request from the authors)

Table 2: Input parameter

Parameter		Amount	Unit	Reference for data
Returns				
Meat Calve	Average	10	CHF/kg CW	See section 2.5
	Standard deviation	0.47	CHF/kg CW	
Meat Cow		7.9	CHF/kg CW	Blum et al. 2010
Grain maize		350	CHF/t	
Hay		300	CHF/t DM	Agrigate 2012
Grassilage		270	CHF/t DM	
Subsidies(general and ecological direct payments)				
Grassland intensive		1040	CHF/ha	Swiss Federal Council 1998
Grassland mid-intensive		1040	CHF/ha	
Grassland extensive		2540	CHF/ha	
Maize		1680	CHF/ha	
Cows		960	CHF/LU	
Costs				
Young cow		3500	CHF/cow	Schoch 2010
General costs husbandry		300	CHF/cow	Boessinger et al. 2010
Concentrate feedstuff		700	CHF/t	
Hay		420	CHF/t	Agrigate 2012
Grass silage		440	CHF/t	
Fertilizer				
Fertilizer Urea		636	CHF/t	Schoch 2010
Fertilizer Ammonium Nitrate		385	CHF/t	
Fertilizer Triple Super Phosphate		680	CHF/t	
Fertilizer Potash		640	CHF/t	
Assignable costs land cultivation (excl. fertilizer and harvest costs)				
Meadow and pasture		0	CHF/ha	Blum et al. 2010
Meadow in crop rotation		276	CHF/ha	
Maize		797	CHF/ha	
Harvest cost				
Hay and silage conservation (excl. bailing)		106	CHF/ha/Cut	Gazzarin and Albisser 2010, SVLT 2011
Bailing	Silage	143	CHF/t DM	
	Hay	98	CHF/t DM	
Grass silage conservation in silo		497	CHF/ha/Cut	
Maize silage harvest		1200	CHF/ha	
Maize grain harvest		510	CHF/ha	
Drying grains		145	CHF/t	Blum et al. 2010
Yields				
Grassland	intensive	100	% intensive	Blum et al. 2010
	mid-intensive	78	% intensive	
	extensive	28	% intensive	
Intensive Grassland	Average	10.8	t DM/ha	see section 2.4
	Standard deviation	1.3	t DM/ha	
Grain Maize	Average	10.8	t DM/ha	
	Standard deviation	1.1	t DM/ha	
Conversion factor grain/silage maize		1.8		Blum et al. 2010

2.6. Scenarios

Using the above presented modelling setup, three different scenarios were calculated and average and standard deviation of the income compared. (1) In the baseline scenario income was calculated for a farm that has the possibility neither to buy roughage on a market nor to grow maize on a farm. Therefore risk management strategies on this farm are limited to the adjustment of the number of animals, the size of the feed stock and the composition of the diet. (2) In the second scenario, the farm has the additional possibility to buy roughage on a market. This gives the farmer the possibility to bridge a gap in fodder production in years with unfavourable weather conditions. (3) In the third scenario, the use of maize was allowed as an on-farm risk-management measure: More specifically, maize can either be harvested as silage and then used as feed stuff if yields on grassland are too low to feed the animals, or it can be sold as grain maize at the end of the year. The advantage of the cultivation of maize is that the decision of whether maize is harvested as silage or corn can be delayed until 90% of the grass is harvested.

Farm income was maximized for these three scenarios under four different constraints: (1) First, assuming no risk-aversion, i.e. farm income was maximized without the implementation of the safety first rule.(2) A moderate risk-averse decision maker was assumed, a safety first-rule was implemented on a level of 80% of the average income. Thus, income in each year must never fall below this threshold. (3) A highly risk-averse decision maker was assumed by setting this threshold on 90% of the average income. (4) In a fourth step, farm income is maximized if the farmer has the possibility to sign an income that guarantees him 90% of the average income, i.e. assumption 3 (high risk aversion) is extended with the option to buy income insurance.

3. RESULTS

Results are presented in table 3. It shows that in all three scenarios there is a high variability of income if no risk aversion is assumed (First column of each scenario in table 3). More specifically, coefficients of variation range from 26% (if trade of roughage is allowed, scenario 2) to 31% (if maize production is allowed, scenario 3) if the farmer is assumed to be risk neutral.

Furthermore, we find that the possibility to produce maize enables the farm to generate, on average, higher incomes. This is due to the fact that in good years, where fodder production exceeds on-farm demand, the farmer can profit from selling grain maize. This is also underlined if comparing the maximum incomes observed (not shown): In scenario 3, the maximum income level is 219 kCHF, whereas the maximum income in the Baseline scenario 1 was found to be 211 kCHF. However, maize production also causes higher risks. Since in the maize scenario more land is dedicated to crop production the number of animals has to be reduced in years with unfavourable weather conditions since the increase of the maize silage fraction is limited. Thus, scenario 3 leads also to the lowest observed states of income (not shown).

In contrast, scenario 2 (where roughage trade is allowed) shows the smallest variability of the income. In this scenario the farmer, independently from the assumed risk aversion, equals his fodder balance over the market for feed-stuff. This is possible since the cost of production of fodder and the fodder purchase costs do not differ to a large extent. However, the option to purchase fodder on the market allows the farmer a slightly higher number of cows compared to the baseline scenario what provides, on average, a higher income.

Comparing the outcomes with regard to the different levels of risk aversion assumed, the implementation of the safety first rule (i.e. risk aversion) significantly reduces the variability of the income in all scenarios. The highest reduction can be seen in scenario 3. In this scenario variability is highest if risk aversion is not considered in the optimization of the farm-plan, and the safety first rule thus has its highest risk reduction potential. In contrast, the reduction of income variability is lowest in scenario 2. In this scenario it is, even without assuming risk aversion, profitable to buy feed stuff in years with unfavourable weather conditions, a management strategy that reduces income variability.

Comparing the different levels of risk aversion we assumed in our analysis, it shows that income variability reductions are largest for highly risk averse decision makers. For instance, the coefficient of variation decreases form 18% for the moderate risk averse farmer to 12% if high risk aversion is assumed. Thus, the specific risk preferences assumed have an impact on optimal production plans.

Our results show that the reduction of income variability comes at low costs, i.e. the implementation of the safety-first rule in planning, does not reduce average income significantly. In all scenarios the reduction of the average income is below 1% of average income. Reduction of income variability is most expensive in scenario 3 (assuming high risk aversion). In this scenario average income is reduced by 0.8% compared to 0.58% in scenario 2 (again, assuming high risk aversion). The low influence of risk-mitigation behaviour is due to the fact that we consider a large set of potential risk mitigation options. Thus, risk mitigation is made in cost efficient combinations of different measures. In contrast, to single activity investigations, this is known to clearly reduce the influence of changing risk preferences and risk sources on whole-farm income (cp. e.g. Lehmann and Finger, 2012).

In the following, we discuss in more detail which risk reduction strategies have been chosen in the model for the different scenarios. To reduce income variability in the scenarios 1 (Baseline) and 2 (including trade of roughage), the average number of cows is slightly increased and land-use is intensified if risk aversion is assumed. This intensification of production guarantees a minimum income in years with unfavourable weather conditions. Thus, cows are sold in bad years – generating additional returns- to stabilize income levels in these scenarios. This strategy, however, leads to a lower average income due to difference in price between sold and purchased cows. Furthermore, fodder stocks are chosen in the model as risk management option to reduce variability of income in scenarios 1 and 2. In these scenarios, average fodder stock per head is increased if risk aversion is assumed. The resulting need for more intensive grass land use to fill the stocks as well as the discounting of the value of the fodder stocks, however, cause opportunity costs that reduce average incomes.

The results for scenario 3 (where maize production is allowed) contrast the findings of the scenarios 1 and 2. More specifically, the number of cows is reduced to decrease variability of income if risk aversion is assumed. This measure is used to increase the area cultivated with maize per head giving farmers the option to increase the amount of maize in the feed mix in years when grass yields are low. Even though the production of corn is not as profitable (on a per hectare basis) as meat production (particularly due to high costs for drying the grains, cp. Table 2), this management measure only causes low opportunity costs – because it replaces grass. However, the use of this option is limited due to the fact that maize silage is rich in energy, and its fraction of the diet is thus limited by the maximum energy content of the feed mix.

In the fourth assumption on risk aversion, we allowed the highly risk averse decision maker to also buy an income insurance that protects him against income levels that fall below 90% of the average income. Our results show that in none of the assessed scenarios the farmer is willing to buy this income insurance, even though a fair premium was assumed. This is due to the fact that the reduction of the income variability by applying on-farm risk management strategies is cheaper than the premium he had to pay because these on-farm measures can also lead to higher income levels. For instance, if an additional stock for fodder has the same stabilizing impact on the income than an insurance but the expansion of the fodder stock can provide to increase income by adjusting herd size, the insurance is not the primary risk mitigation option taken by the farmer. Again, this highlights the usefulness of whole-farm approaches where adjustments in the entire animal production system can be represented.

In addition to the presented changes, a wide range of other, but less relevant, on-farm adjustments have been taken into account that are, however, linked to the other risk-management strategies. Among others, we found risk aversion to lead to changes in the fodder composition, grassland production intensity, differentiation between two main products Natura Beef and feeder cattle, and the receipt of ecological direct payments for grassland production. For instance in scenario 1 the area of extensively used meadows, which are subsidized with the highest amount of direct payments, are slightly increased under the assumption of risk aversion. Thus, risk averse farmers tend to rely more on direct payments as risk management option. Furthermore, we find that in this scenario grazing is slightly reduced under the assumption of risk aversion since loss in fodder is higher when grazing than when cutting the grass.

Table 3: Key figures of the results of the different scenarios including mean and standard deviation of the income.

Scenario	Scenario 1 Baseline				Scenario 2 Allowing roughage trade				Scenario 3 Allowing maize production			
Applied Goal Function	NRA	MRA	HRA	Ins	NRA	MRA	HRA	Ins	NRA	MRA	HRA	Ins
Standard deviation of gross margin [kCHF]	42	25	19	19	37	24	17	17	44	30	21	21
Average yearly gross margin [kCHF]	141	140	140	140	141	141	140	140	143	143	142	142
Coefficient of variation [%]	30	18	14	14	26	17	12	12	31	21	15	15
Average number of cows [head]	61.5	61.6	61.7	61.7	62.6	62.9	63	63.3	61.8	61.8	61.5	61.5
Premium paid [CHF]	-	-	-	0	-	-	-	0	-	-	-	0
Silage stock at end of the year [dt DM]	650	654	663	659	666	669	703	704	707	700	699	699
Hay in stock at end of the year [dt DM]	496	489	492	497	480	472	473	473	548	517	479	479
Total fodder in stock at end of the year [dt DM]	1146	1143	1155	1156	1146	1141	1176	1177	1255	1217	1178	1178
Fodder in stock per head [dt DM/head]	18.64	18.57	18.71	18.72	18.29	18.15	18.67	18.59	20.32	19.71	19.15	19.15

NRA: No risk aversion; MRA: Moderate risk aversion; HRA: High risk aversion;
Ins: High risk aversion and income insurance

4. DISCUSSION

Compared to other studies that investigate income risks in suckler cow production systems, the income variability found for the here analyzed Swiss suckler cow farm is rather high. For instance, Mosnier et al. (2011) find a farm profit coefficient of variation of 13% for French suckler cow production and Payne et al. (1997) showed that the variation of the income in different beef cattle production systems in the US ranges between 13% and 32%. This contrasting result is caused by the (additional) consideration of volatile meat prices in our study. The impact of price volatility is even amplified because the here simulated farmer is assumed to have information about the (long-term) development of prices. Hence most animals are sold at a price peak, which leads to an amplification of the income in years with high prices at the expense of income in years with lower prices for meat. This results in an increasing variance of incomes.

Our results show that income variability can be substantially reduced by on-farm risk management schemes. Even if the farmer does not have the possibility to purchase roughage at the market, what is known to be one of the best measures to mitigate variability of the income (e.g., Mosnier et al. 2011, Kobayashi et al. 2007) they still have the possibility to adjust the number of animals or to adjust feed stocks. In contrast to the results of Mosnier et al. (2011), our model suggests that an increase of the stocking rate coupled with more intensive use of the grassland is an efficient strategy to reduce income variability. An increase in stocking rate is reducing the probability to generate income beyond a certain limit, because more animals can be sold if meat prices are low to keep the revenue at a constant level. In addition, livestock is a financial reserve and cows thus can be sold in years with unfavourable weather conditions (i.e. low levels of fodder production). The more intensive use of grasslands has been found to clearly reduce risks of shortfalls in fodder production and thus is a valuable risk management strategy in suckler cow production. This contrasts the result if risk considerations focus only on grassland production and do not consider further on-farm use: Finger et al. (2010), for instance, show that optimal grassland production intensities decrease with increasing risk aversion. These contrasting results highlight the relevance of whole-farm perspectives if modelling decisions under risk in agricultural systems.

Moreover, increasing feed stocks reduces income variability. If risk aversion was assumed, the amount of roughage that is stored per animal has been increased in our model. Thereby, the stocks need to be higher if the possibility of trading roughage is limited. Stocks also need to be higher if it is profitable to reduce the fraction of land dedicated to fodder production to increase crop production. This is mainly an option if costs for storing roughage are low as it was assumed in our analysis where fodder can be stored in bales, which does not demand for high investments in buildings. If, however, more expensive possibilities of taking fodder stocks have to be considered (e.g. investments in new buildings), this may change the results in favour of other risk management options.

We are aware that the role of the fodder market could be overestimated in our analysis because the natural hedge was not considered. If yields, in a specific region, are low this causes usually higher prices (e.g. Finger, 2012), which is particularly driven by high transportation costs for fodder. Thus, the possibility to buy fodder in cases where on-farm yield levels are low would be more expensive if such correlation would have been taken into account. However, note that since prices for roughage in Switzerland always are higher than in the neighbouring countries import of feed stuff still will be a possibility to satisfy demand. Thus, our approach is expected to overestimate the risk mitigation potential of markets only slightly. Still, the implementation of price-yield correlations should be addressed in future research.

Nevertheless, the risk mitigating role of fodder markets that was indicated by our results has clear-cut policy implications: Instead of subsidizing other risk management strategies the improvement of market facilities (e.g. by creating better, e.g. online, market places) should be fostered. Furthermore, the results of Mosnier et al. (2011) show that lower prices for purchased feedstuff results in a decrease in income variability. An additional strategy to reduce income variability in Swiss suckler cow production could therefore be to reduce tariffs (and taxes) on imported roughage if weather conditions are unfavourable and therefore not enough feedstuff is available inside the country. This practice was already applied during the drought and heatwave of 2003 (ProClim, 2005)

The risk management strategies considered in our analysis cause trade-offs, i.e. lower income variability is accompanied with lower average income. These trade-offs for example are caused by discounting the value of the hay that is stored in the barn. Additional trade-offs occur in the form of opportunity costs if land-use needs to be adapted either because the share of grassland needs to be increased or if the area used as extensive meadows needs to be decreased what causes a loss of subsidies. However trade-offs on the here presented case-study farm are rather small. Mosnier et al. (2011) show that a reduction of the coefficient of profit on French suckler cow farms by 56% or 73% -depending on the scenario- causes a loss in average income of 2%. Our study indicates lower costs of risk reduction, i.e. a reduction of the standard deviation by 52% to 54% costs less than 1% reduction in income. The lower risk mitigation costs indicated by our analysis are caused by the consideration of a large set of risk management options. Furthermore, the income variability in our model is clearly buffered by taking direct payments into account. The high levels of direct payments in Swiss agriculture stabilize income levels and thus have an insurance like effect (cp. Finger and Lehmann, 2012).

Our results show that on-farm risk management schemes are more efficient than income insurance to reduce income variability. In none of the described scenarios, the income insurance is cheaper for the reduction of the variability than on-farm risk management measures. Since the gross margin is maximized, only variable costs are calculated for storage of the fodder. Storing bales for hay or silage does not require high investments in buildings but this simplification is expected to underestimate real world costs, if at all, only slightly. Furthermore, we assumed that there is no correlation between production costs (i.e. costs for fodder production and fodder buying) as well as levels of fodder production with the price of meat. In reality, though, prices for slaughter cows are expected to decrease if a large share of farmers reduces their herd due to low grass yields. Taken this relationship into account, reduction of income variability would become more expensive. Furthermore we did not take into account shocks (i.e. abrupt regime shifts) in prices or yields, but rather focussed on the price and yield variability observed in the last decades and years. Schaufele et al. 2010 show that an income insurance for suckler cow producers in Canada only is a considerable risk management tool, and not only an instrument for subsidizing farms, if such shocks are taken into account.

Our results show that the degree of risk aversion has an impact on the farm plan. These findings are in opposite to Flaten and Lien (2007) who found that risk aversion has no impact on the farm plan of a Norwegian organic dairy farm. This difference however could be explained by the different goal functions used: utility efficient programming by Flaten and Lien (2007) and a safety first mechanism in this study. Levy and Levy (2009) as well as Arriaza and Gómez-Limón (2003) found that when using only the safety first mechanism, the implications of risk aversion on behaviour are overestimated. Levy and Levy therefore suggest combining the safety first approach with an expected utility approach in a weighted goal function. Such an approach however would demand more information about farmers' risk aversion, and therefore neglect one of the main advantages of the approach applied in this study. Nevertheless it should be considered in future research.

The here employed model is expected to overestimate the knowledge of the farmer about future conditions because we assumed that the farmer has knowledge on short-term developments of prices for meat. This overestimates the forecast potential of farmers and offers potential for the calculation of different scenarios on the value of information in future research. Inter-year variability of meat prices in Switzerland however is smaller than intra-year variability of prices and these developments are well known by the farmer. We therefore assume that a perfect knowledge about inter-year price development does not bring a large bias into our results. More general, we assume that farmers have knowledge on income risks and potential pitfalls in fodder production. But, assuming good knowledge on risks and developments is based on the findings that subjective probabilities exist in many cases – so that the decision maker has an (empirical) intuition on the probability distribution of the random variable (LeRoy and Singell, 1987, Holton, 2004). This means that even though farmers may not have specific distribution families and distribution parameters at hand for decision making, it is assumed that they are aware of probabilities for specific states of crop yields or prices (Musshoff and Hirschauer, 2011).

5. CONLUSIONS

Even though producing suckler cows is risky due to volatile fodder production and meat prices, several on-farm risk management strategies are available to reduce the resulting income risks. Our results show that a mixture of these strategies is applied to adjust production plans to risk averse decision making. The most important options indicated in our results are the possibility to adjust the number of animals and the size of the feedstock. If these management strategies are applied to reduce income variability this causes trade-offs in terms of lower average incomes. However, these income reductions were found to be small. Our model results show that income insurance would not be used by farmers since the premium would be higher than the opportunity costs of on-farm risk management options are. Based on this study, we therefore suggest that improving the access to fodder markets and to make import restrictions for fodder more flexible are the primary paths to improve the ability of farmers to withstand unfavourable weather conditions.

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