WORKING PAPER

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CH-FARMIS
An agricultural sector model for Swiss agriculture

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EXCELLENCE FOR SUSTAINABILITY

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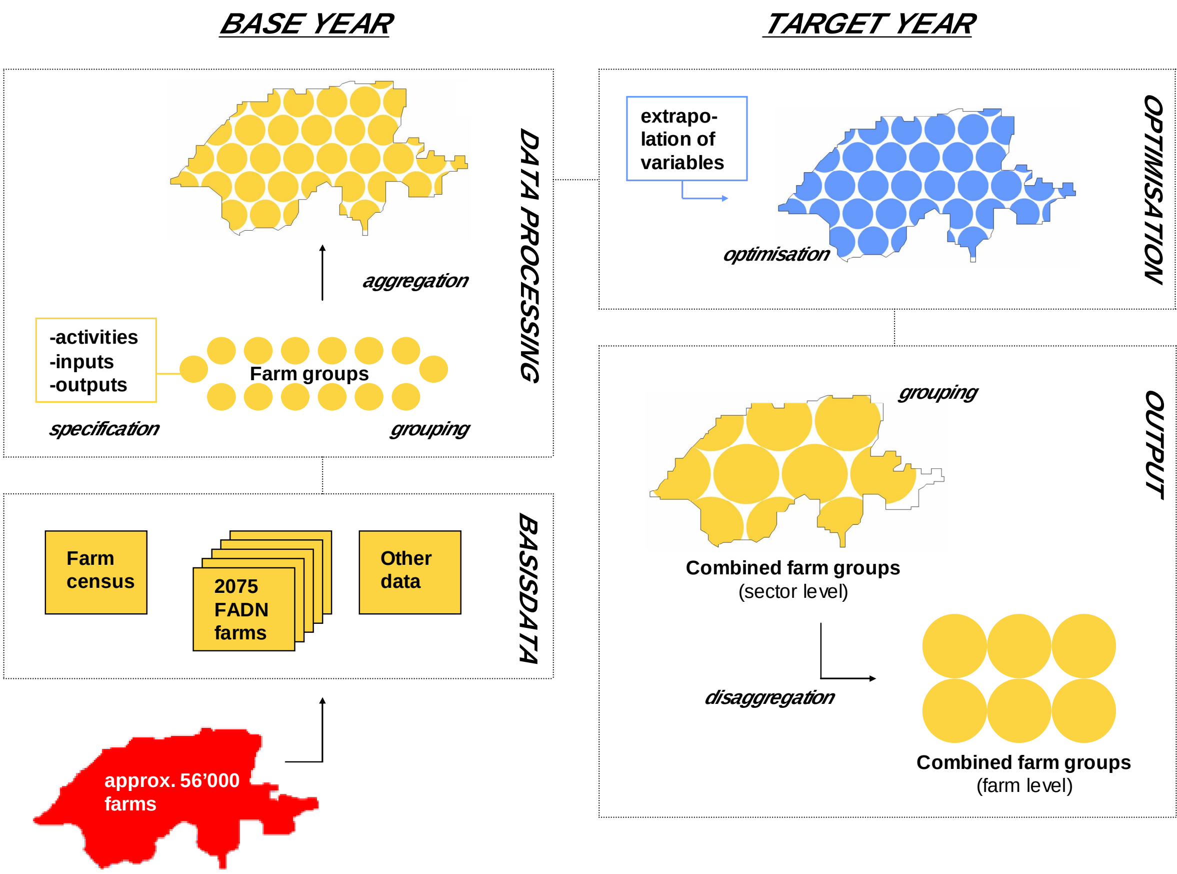
Overview of the model

This working paper gives an overview of the farm group model CH-FARMIS - a comparative static, process analytical, non-linear programming model that allows a separate assessment of the impacts of policies on organic and non-organic farming in Switzerland. Originally, FARMIS was developed by Jacobs (1998), Schleef (1999) and further enhanced by Bertelsmeier (2005) and Offermann ***et al.*** (2005) at the German Federal Research Centre (FAL) in Braunschweig for agricultural policy analysis, where it is used for within the FAL model group (Bertelsmeier ***et al.***, 2003) for agricultural policy analysis.

In CH-FARMIS, the agricultural sector is represented by thirty farm groups, which can be characterised by their farming system, farm type and geographic location. Book keeping data from the Swiss FADN was used as a primary source for the model. By applying farm-specific weighting factors, farm data were aggregated to sector accounts. The technical coefficients of the farm model were either taken directly from farm accounts or calculated on the basis of normative data. Agricultural production is represented by 29 crop activities and 15 livestock activities. The factor allocation and production of each farm group is optimised by maximising farm income under policy and management restrictions. The restrictions cover the area of land and labour use, livestock feeding, fertiliser balance, rearing of young stock, allocation of direct payments and requirements with respect to the organic production system. A positive mathematical programming approach (PMP) was used to calibrate the production activities in the base year to observed activity levels.

Figure 1 Structure of the CH-FARMIS model



In line with other sector programming models, CH-FARMIS can be divided into four parts (see Figure 1). The ***data unit*** comprises all the data needed to construct the model. The ***data processing unit*** includes all the stages involved in deriving complete input-output coefficients and other parameters for each farm group and in generating the weighting factors for the aggregation of farm data to sector accounts. The ***optimisation unit*** consists of an optimisation model for farm groups that is used, first, to generate PMP terms in order to specify a non-linear objective function and, second, to optimise factor allocation and production on the basis of a reference scenario and various alternative scenarios. Model results are further processed in the ***output unit***. Individual farm group results are first merged to combined farm groups. Finally, the results are presented either at sector level or disaggregated at farm level.

Data

Book keeping records from Swiss FADN farms are the primary source of data for the CH-FARMIS model. The base year period comprises the years 2000 and 2001. Using FADN farms for a farm group model has the advantage that the farms selected are already a representative sample of the farming sector (Meier, 2005). A further advantage of the Swiss FADN is that the proportion of organic farms in the sample is above average (Meier, 2004).

In 2000 and 2001, the Swiss agricultural sector consisted on average of 69,660 holdings, of which 13,456 farms can be characterised as small holdings or hobby farms. These farms were not included in the total population, because they do not contribute significantly to the sector output. In total, 3,000 - 3,500 farms are selected annually for a book keeping analysis by Agroscope Reckenholz-Tänikon (ART)[1]. The sampling scheme is based on three criteria: farm type, regional area and farm size. In contrast to the EU system, the Swiss farm typology (FAT99) is more differentiated and classification is carried out on the basis of land use and production characteristics rather than economic criteria (Meier, 1996).

Since the FADN sampling scheme has been demonstrated to be a suitable form of classification for portraying the Swiss agricultural sector in a representative manner (Meier, 2005), sample farms were clustered into farm groups according to the farm typology FAT99, geographical regions and the farming system. In line with the aggregation criteria proposed by Day (1963) it can be argued:

- pecunious proportionality is given through the distinction between organic and non-organic, as well as through the regional classification;
- institutional proportionality is given through the detailed farm typology, which distinguishes between specialised and mixed farm types as well as between farms types with generally high or low investment costs and generally high or low labour inputs;
- technical homogeneity is given through the geographical classification which takes account of similarities in slopes and in climatic and soil conditions.

For several reasons, not all FADN farms were used for CH-FARMIS. First, in order to reduce the effects of potential yield variations, the arithmetic means of farm data from 2000 and 2001 were used. Consequently, all those farms were excluded that did not provide data for both

[1] Prior to 2004, ART was called the Federal Research Station for Agricultural Economics and Engineering (FAT).

years. In addition, farms were excluded that changed their farm type or their farming system during the base year period. Second, since the farming system is not taken into account when selecting farms for the Swiss FADN, some farm groups are represented by only a small number of farms. In order to avoid potential biases, only those farms were selected for which at least four farms were available to form a farm group[2].

As a consequence of these requirements, CH-FARMIS is based for the baseyear 2000/01 on book keeping data from 2,075 farms grouped into 30 farm groups. The selected groups are highlighted in Table 1. Although not all farm groups are currently included, CH-FARMIS represents the major part of the Swiss agricultural sector. In total, it covers 75% of all farms, 80% of total farmland and 80% of the sector net farm income. As indicated in Table 2, the organic sector is better represented than the non-organic sector; this is due to the relative higher number of non-organic farms excluded from the sample. A poor representation is mainly given for organic and non-organic arable crop production and pig/poultry production, respectively. This limited representation of parts of the farming sector needs to be taken into consideration when the model results of are interpreted and discussed.

Table 1 Average number of farms per farm group according to the farm census and in different farm samples[3] for the period 2000/2001

Regions	Data Source	Farm types										
		Arable crops	Special crops	Dairy cows	Suckler cows	Other cattle	Horses/ sheep/ goats	Pigs/ poultry	Comb. dairy / arable crops	Comb. suckler cows	Comb. pigs/ poultry	Comb. others
Organic farms												
Valley area	Farm census	12	184	252	62	26	55	7	69	56	85	235
	FADN	0	6	22	5	1	1	1	10	9	7	19
	CH-FARMIS	0	0	16	4	0	0	0	6	7	4	11
Hill area	Farm census	1	28	600	180	78	117	13	9	13	61	129
	FADN	0	1	62	8	3	0	3	1	0	6	6
	CH-FARMIS	0	0	46	5	0	0	0	0	0	3	3
Mountain area	Farm census	0	29	1298	482	391	492	5	0	2	23	184
	FADN	0	0	110	27	18	5	0	0	0	2	5
	CH-FARMIS	0	0	87	20	10	0	0	0	0	2	4
Non-organic farms												
Valley area	Farm census	3823	4683	3509	258	455	1559	1003	4974	381	3626	5808
	FADN	122	67	216	7	3	3	20	370	12	337	215
	CH-FARMIS	0	0	162	4	0	0	0	259	7	256	124
Hill area	Farm census	169	715	7188	461	1140	1551	720	649	107	2038	2807
	FADN	2	2	454	8	8	4	26	41	4	207	122
	CH-FARMIS	0	0	342	4	0	0	0	0	0	160	77
Mountain area	Farm census	2	998	7332	543	3756	2457	253	1	4	566	962
	FADN	0	2	455	16	120	16	8	0	0	35	30
	CH-FARMIS	0	0	319	10	90	0	0	0	0	20	13

Source: Own presentation based on data of Swiss FADN from ART and the farm censes of the Swiss FSO

[2] Organically managed combined pig/poultry farms located in the mountain region with only two sample farms pose an exception here. These farms have been included because there were only 23 corresponding farms in the total population.

[3] The FADN sample is a representative sample of the farm census carried out by the Swiss FSO. The CH-FARMIS sample is a sub-sample of the FADN sample.

Table 2 Representation (%) of the farming sector in CH-FARMIS

	Total sector	Organic sector	Non-organic sector
Number of farms	75.9	83.8	75.1
Sector net farm income (CHF)	77.9	86.5	76.8
UAA (ha)	80.8	87.5	80.2
Arable area (ha)	65.0	75.1	64.8
Grassland area (ha)	89.0	89.2	89.0
Total Livestock (LU)	81.2	86.5	80.7
Cattle (LU)	90.6	94.6	90.2
Pigs & Poultry (LU)	60.0	79.9	59.5

Source: Own calculations based on the 2006 farm census of the Swiss FSO

Generation of aggregation factors

As described in the previous section, CH-FARMIS is based on book keeping data from sample farms in the Swiss FADN. In order to relate the sample data to the total population (42,344 farms in 2001), a specific weight is assigned to each sample farm that corresponds to the number of farms out of the total population with similar characteristics (production patterns, size and geographic region, etc.).

For CH-FARMIS, the weighting of sample farms is done in two steps. First, the farm sample (i.e. the selected 2,075 FADN farms) and the corresponding total population are stratified according to the following four criteria: FAT-type99, region, farm size class and farming system. Based on the principle of "free expansion" , an individual weight is calculated for each holding. The weight for each sample farm is equal to the ratio between the numbers of holdings of the same stratum in the population and in the sample. Thus, the aggregation factor of each farm group is the sum of weights of all sample farms clustered into one group. However, for some parameters the application of “expansion weights” results in unsatisfactory deviations from the data of the total population (see Table 3). For this reason, in a second step, it is necessary to re-weight the weights of each sample farm.

Following the work of Deville and Särndal (1992), Jacobs (1998) and Meier (2005) a calibration model was developed for this purpose. The model is used to minimise a distance function which defines the differences between the new and initial weights. This is done under the constraint that the aggregated sample values of certain auxiliary variables are consistent with the statistical reference data of the total population. By calibrating the aggregated value of these auxiliary variables to the statistical reference data of the total population, it is possible to improve the representativeness of the sample. Given the aim to achieve an accurate representation of the agricultural sector in physical, structural and economic terms, the following auxiliary variables were selected for the calibration model[4]:

- area of organic and non-organic grassland, arable land, permanent crops, temporary ley, potatoes, sugar beet, maize, vineyard and total UAA at sector level;

[4] This selection is based, among other things, on research from Meier (2005) who, using a regression model, found that financial performance is determined mainly by farm type, region, farm size, age of the farmer, education, land use and number of livestock. The factor “education” was not selected because no statistical data were available for the total population.

- number of organic and non-organic dairy cows, fattening pigs, laying hens, fattening calves and total livestock units at sector level;
- number of organic farms per region (valley region, hill region, mountain region);
- number of farms per age class (age classes are defined as follows: <38, 38-44, 45-50, 51-56, above 56, specified for organic and non-organic farmers).

Table 3 Representation (%) of sector data on the basis of different weighting factors

	Sector data	Aggregation using simple weights	Aggregation using calibrated weights
Land use (ha)			
Total UAA	100.0	99.2	100.0
Total grassland	100.0	101.5	100.0
Temporary ley	100.0	99.4	100.7
Total arable land	100.0	92.3	101.1
Wheat	100.0	86.9	98.1
Fodder Maize	100.0	105.3	100.8
Potatoes	100.0	116.8	105.0
Total permanent crop area	100.0	126.4	106.1
Vineyard	100.0	47.1	90.0
Livestock (LU)			
Dairy cows	100.0	102.4	101.8
Fattening pigs	100.0	91.2	97.6
Table birds	100.0	92.6	96.4
Laying hens	100.0	82.0	95.3

Source: Own calculations based on data of Swiss FADN from ART and the 2006 farm census of the Swiss FSO

The equation for the calibration model can be formulated as follows:

$$\sum_{n} (w_n - MW)^2 = \min! \qquad \textbf{(1)}$$

subject to

$$\sum_{n_s i} (w_{n_s} * y_{n_s i}) > Y_i * \alpha_i \qquad \forall\, ni \qquad \textbf{(2)}$$

$$\sum_{n_s i} (w_{n_s} * y_{n_s i}) < Y_i * \beta_i \qquad \forall\, ni \qquad \textbf{(3)}$$

where:

n = index for farms in the farm sample

i	=	index for production activities
s	=	index for farming systems

w_n	=	new weight
y_{ni}	=	auxiliary variable
MW	=	mean weight
Y_i	=	reference value of the total population
α_i	=	coefficient defining the lower level of a solution corridor
β_i	=	coefficient defining the upper level of a solution corridor

The objective function is defined as the sum of least squares of individual farm weights from mean weight (equation 1). With 2,075 sample farms and 42,344 farms in the total population, the mean weight used in the calibration model is 42,344/2,075 = 20.4, rounded down to 20. By minimising the distance to the mean weight, all auxiliary variables, including the stratification criteria, are given the same importance (Meier, 2005). The model constraints are specified for organic and non-organic farms. The coefficients α and β (equation 2 and 3) define a solution corridor for the aggregated sample data. In order to increase the solubility of the model, the aggregated sample data are not required to be exactly equal to the reference data of the total population. Taking into account the fact that the farm census and FADN use partially different measuring concepts in terms of date of measurement and definition of livestock category (Meier, 2005), an exact congruence is not desirable. The results of the calibration are shown in the right-hand column of Table 3. Through the calibration process, the aggregated sample values of the auxiliary variables were approximated to the reference data of the total population.

Generation of input-output coefficients

CH-FARMIS represents 15 livestock and 29 crop activities, producing 32 main or intermediate products. Table 4 shows the livestock production activities that are represented in CH-FARMIS. All livestock activities produce more than one output. For practical reasons[5], the following production activities have no physical output but a monetary main output: “Horses”, “Sheep”, “Goats”, “Other grazing livestock”, “Other livestock”. The level of livestock activities is measured in livestock housing units (LHUs), which are defined as the number of farm animals kept per available housing space per year. For example, if a farm animal is kept for more than 365 days (e.g. dairy cows), the number of LHUs corresponds to the number of farm animals kept on the farm. In the case of a shorter production period, e.g. table birds, the number of LHUs corre-

[5] Since book keeping data provide no information about physical outputs for the above stated production activities and all of them usually produce a range of different products, output coefficients cannot be directly specified from the FADN data. One possibility would be to use an econometric estimator for the specification. However, in view of the minimal importance of these production activities for the selected farm groups, this approach was regarded as too time-consuming.

sponds to the number of farm animals kept on the farm per year divided by the number of rotations per year.

Table 4 Overview of livestock activities

Livestock activities	Description	Outputs
Unit: Livestock Housing Unit		
Dairy cows	Dairy cow	Milk, Beef from slaughtered dairy cows, Calves (1 month old), Others (cow hide, natural service, etc.), Manure
Suckler cows	Suckler cow with calf	Milk, Beef from slaughtered suckling cows, Beef from slaughtered calves (12month), Others (cow hide, natural service, etc.), Manure
Breeding heifers	Breeding heifer (4-32 months old)	Heifers for replacement, Others (cow hide, natural service, etc.), Manure
Calves	Calves (1-4 month old)	Male and female calves for breeding and fattening, Manure
Fattening cattle	Fattening cattle (4-24 months)	Beef from fattening cattle, others (cow hide, natural service, etc.), manure
Fattening calves	Fattening calve	Veal, Manure
Horses	Horse	Monetary output, Manure
Sheep	Sheep with lamb	Monetary output, Manure
Goats	Goat with goatling	Monetary output, Manure
Other grazing livestock	Deer, Lama, Alpaca, Bison	Monetary output, Manure
Breeding sows	Breeding sow	Piglets, Manure
Pork	Fattening pig	Pork meat, Manure
Table birds	Table bird	Poultry meat, Manure
Laying hens	Laying hen	Eggs, Slaughtered laying hens
Other livestock	Duck, Rabbit, Geese	Monetary output

Source: Own description

Apart from cereals, all crop activities produce one specific output (Table 5). Again for practical reasons, the production activities “Vegetables”, “Fruit plantations”, “Vineyard”, “Berries”, “Other crops” and “Wood” produce no physical output but a monetary output, which is derived from the revenues per production activity unit shown in the farm accountancy data. Furthermore, both types of fallow land have no output sales but do receive direct payments.

The production activities of each farm group are described by input-output coefficients (defining the relation between factor inputs and outputs) as well as by other farm group-specific parameters (such as prices, available resources, etc.). These parameters are generated in a two-stage approach. First, parameters are calculated for each individual sample farm. This is done in the following way:

Table 5 Overview of land use activities

Land use activities	Description	Output
Unit: Hectare		
Wheat	Winter wheat, Summer wheat	Wheat, Straw
Rye	Rye	Rye, Straw
Other cereals	Spelt, Emmer	Spelt, Straw
Oats	Oat	Oat, Straw
Barley	Winter barley, Summer barley	Barley, Straw
Triticale	Triticale	Triticale, Straw
Grain maize	Grain maize	Grain maize
Fodder maize	Green and silage maize	Fodder maize
Potatoes	Potatoes	Potatoes
Sugar beet	Sugar beet	Sugar beets
Rape	Rape	Rape
Vegetables	Carrots, Leak, Celery, Onion, Tomatoes, White cabbage, Iceberg lettuce, Butterhead lettuce	Monetary output
Fodder root crops	Fodder root crops	Fodder root crops
Pulses	Field bean, Pea	Horse bean
Tobacco	Tobacco	Tobacco
Other oilseeds	Sun flower, Soya	Sun flower
Mixed fallow land	Mixed fallow land	-
Rotational fallow land	Rotational fallow land	-
Temporary ley	Temporary ley	Grass
Extensively-used meadows	Extensively-used meadows	Grass
Less-intensively used meadows	Less-intensively used meadows	Grass
Intensively used meadows	Intensively used meadows	Grass
Permanent pasture	Permanent pasture	Grass
Alpine meadow	Alpine meadow	Grass
Vineyards	Vineyards	Monetary output
Fruit plantations	Apple, Pear, Cherry, Plum	Monetary output
Berries	Strawberry, Raspberry	Monetary output
Other crops	Other permanent crops, Greenhouse production, Others	Monetary output
Wood	Wood	Monetary output

Source: Own description

The book keeping records of the sample farms provide activity-specific data about resource endowment, expenditure for variable inputs, physical yields and output prices. The corresponding parameter values can therefore be derived directly from farm accounts.

Coefficients related to fixed costs, labour inputs and direct payments were calculated on the basis of a simple adjustment procedure. In a first step, data from management handbooks and other statistical sources (FAT, 1996; LBL, 2001a; LBL, 2001b; SBV, 2001; SBV, 2002; LBL, 2004) were used to calculate farm group-specific, normative coefficients for each activity. Different standard data were used for organic and conventional farming. For the calculation of labour coefficients, a distinction was made between the valley, hill and mountain region. In a second step, the normative coefficients were adjusted according to the corresponding monetary accounts in the book keeping records of each sample farm.

This approach is only possible, however, if the farm data are related to a single input or output (e.g. specific direct payment). The consistency problem becomes more complex in the case of fertilisers and purchased feedstuffs, since the corresponding expenditures are an aggregate of different input elements. In addition, it is necessary to calculate the coefficients in physical units, whereas data in the farm accounts are given in monetary terms. Because of these problems, input coefficients for feedstuffs and fertilisers are estimated using a Generalised Cross Entropy (GCE) Estimator (Golan ***et al.***, 1996), which allows the inclusion of prior information about the unknown parameter[6]. The GCE Estimator is based on support points for each parameter centred around specific expectation values. The expected values are calculated with the help of farm account statistics and normative data. The spread of support points restricts the results to plausible values. The ratio of estimated and expected parameter values is subsequently used to correct the normative data in order to obtain consistent price and activity input-output coefficients for feedstuffs and fertilisers.

In a second step, the parameters of individual sample farms are weighted by means of aggregation factors. Representative farm group parameters are an output of this procedure. A consistency check was carried out for prices and yields using a data corridor based on normative data, in order to correct non-plausible parameter values.

The temporal validity of farm group-specific parameters is limited and needs to be adapted for the target year. On the one hand, this concerns parameters for prices and direct payments. On the other hand, it concerns input-output parameters, which are affected by technical progress and structural changes in rural areas. The projection of these parameters is based on previous research results and is briefly described below. The corresponding trend coefficients are either specified as annual rates of change or else they refer to the target year (2013) of the model analysis.

Ferjani and Messerli (2006) estimated the impact of technical progress on yield growth for various arable crops. The average increase in yield was estimated using a linear regression model, containing information on input factors, weather, location and type of farming. For the projection of yields in CH-FARMIS, annual yield growth data from this study were applied; these are shown in Table 6.

[6] A detailed description of the GCE application in FARMIS is given by Offermann ***et al.*** (2005).

Table 6 Assumed annual yield growth (%)

Crop	Annual yield growth
Triticale	1.95
Barley	1.01
Oats	0.93
Rye	0.82
Wheat	0.65
Sugar beet	0.53
Grain maize	0.50
Fodder maize	0.50
Potatoes	0.50
Rape	0.50
Other oilseeds	0.50
Pulses	0.50

Source: Messerli and Ferjani (2006)

Yield trends in livestock production are based on expert knowledge and were taken from Mack and Flury (2006). They assumed that milk performance increases by 70 kg per cow per year. An annual increase in slaughter weight of 0.1% is assumed for beef and pork production. Input coefficients for feed, fertiliser and monetary inputs are adapted according to changes in yields.

The development of yields in organic farming has been discussed widely in the literature, in terms of both absolute changes and relative changes compared to non-organic farming. As mentioned there, different studies provide evidence for constant (Mühlebach and Mühlebach, 1994; Offermann and Nieberg, 2000; FiBL, 2005; Mäder et al., 2006) or increasing (Padel and Lampkin, 1994; Offermann, 2003) relative yield differences in organic farming. Changes in the relative differences in yields are due mainly to increasing or decreasing incentives for non-organic farmers to intensify their farming system, as well as due to advances in organic research. Future liberalisation policies – as currently discussed in Switzerland - could provide an incentive for further intensification of non-organic production (due to lower input prices) or an extensification of non-organic production (due to lower commodity prices). In view of this uncertainty, it is assumed that yield growth in organic farming is similar to the expected growth in non-organic farming.

In addition to changes in yields, technical progress usually leads to increasing labour efficiency. In order to estimate labour requirements in the target year, trend coefficients from ART were used (Schick, 2003), which were derived from the farm census 1990 and 1996 as well as from expert knowledge (Table 7). No distinctions were made between organic and non-organic farms.

Table 7 Assumed changes (%) in labour requirements

Activity	Base year 2001	Target year 2013
Dairy cows	100.0	85.0
Other livestock	100.0	90.0
Cereals	100.0	94.0
Rape	100.0	94.0
Potatoes	100.0	88.0
Other arable crops	100.0	100.0
Permanent crops	100.0	95.0
Forage production	100.0	94.0

Source: Schlick (2003)

Because CH-FARMIS is not able to take into account structural changes in rural areas endogenously, it is necessary to determine exogenously the available family labour resources for the target year. For this study, results from Mann (2003) were used, who employed a regression model to project the future development of Swiss agricultural structures by 2008. According to this projection, family labour resources will decline in the range of 0.9-1.2% per year, subject to the geographical area (Table 8).

Table 8 Changes (%) in family labour resources

Region	Base year 2001	Target year 2013
Valley region	100.0	87.5
Hill region	100.0	90.5
Mountain region	100.0	90.0

Source: Mann (2003b)

Model specification

A mathematical programming model optimises an objective function subject to a number of constraints. The objective function can be specified as either a primal or a dual problem. In the primal case, the decision problem is defined as a profit or output maximisation problem subject to a given production technology (fixed input level). Alternatively, it can be specified as a dual problem, where the decision problem is defined as a problem of cost or input minimisation subject to equilibrium (fixed output level) conditions. The optimisation problem, objective function and model restrictions of CH-FARMIS are described in the following.

Optimisation problem / Objective function

The objective function of CH-FARMIS is expressed as a primal problem based on the assumption that farmers aim to maximise their income. The agricultural income is calculated in the model as the sum of revenues from agricultural production, direct payments and other revenues minus variable and fixed production costs. Two additional cost terms have been added to the objective function to ensure that the activity levels of the base year are exactly reproduced without calibration constraints. The complete non-linear programming problem can be formulated as followed:

$$MaxZ_n = \overbrace{\sum_j p_{nj} Y_{nj}}^{1} - \overbrace{\sum_i c_{ni} X_{ni}}^{2} + \overbrace{\sum_i dp_{ni} PX_{ni}}^{3} - \overbrace{\sum_u r_{nu} U_{nu}}^{4} \qquad \textbf{(4)}$$

$$- \overbrace{\sum_v r_{nv} V_{nv}}^{5} - \overbrace{\sum_l r_{nl} LAND_{nl}}^{6} - \overbrace{\sum_i \delta_{ni} X_{ni}}^{7} - \overbrace{0.5 \sum_i \omega_{ni} X_{ni}^2}^{8} \qquad \forall n$$

$$X_{ni}, PX_{ni}, U_{nu}, V_{nv} > 0$$

where:

n	=	index for farm groups
i	=	index for production activities
j	=	index for output products
l	=	index for land type
u	=	index for labour
v	=	index for fertilisers
Z_n	=	objective function
Y_{nj}	=	sales of agricultural products (t or CHF)
X_{ni}	=	level of activities (ha or LHU)
PX_{ni}	=	level of activities eligible for direct payments (ha or LHU)
U_{nu}	=	level of labour input/requirements (in 1,000 h)
V_{nv}	=	level of fertiliser input/requirements (in t)
$LAND_{nl}$	=	level of rented UAA (in ha)
p_{nj}	=	prices for agricultural products (in kCHF/output unit)
c_{ni}	=	activity-specific costs (in kCHF/ha or LHU)
dp_{ni}	=	activity-specific direct payments (in kCHF/ha or LHU)
r_{nu}	=	labour costs (in CHF/AWU)
r_{nv}	=	expenditures for fertilisers (in kCHF/t)
r_{nl}	=	rental costs for UAA (in kCHF/ha)
δ_{ni}	=	parameter associated with the linear PMP term
ω_{ni}	=	parameter associated with the non-linear PMP term

The first term of equation 4 comprises sales of agricultural products generated through the various production activities less expenditure for purchased feedstuffs.

The sum of production costs is expressed in the second term, with costs per activity unit multiplied by the activity level. This includes variable costs (expenditure for seeds, plant protection, veterinary services and medicines, energy, insurance, expenditure for contract work and others) as well as activity-related fixed costs (depreciation, interest rates, machinery costs).

The third term describes revenues from direct payments. These revenues comprise:

- area payments
- contributions for keeping grazing livestock
- contributions for animal husbandry under adverse production conditions
- contributions for hillsides
- contributions for ecologically-oriented and animal-friendly farming practices
- contributions for alpine summer grazing
- cantonal or private payments.

The variable PX_{ni} indicates the level of activities that is eligible for premiums. Apart from payments for keeping grazing livestock and payments for animal husbandry under adverse production conditions, the level of PX_{ni} is equal to X_{ni}.

The fourth term indicates expenditure for employed labour less contract work. Employed labour can either be regular or seasonal workers. The labour input is determined by equations 8 to 10 (see Table 9). The different costs per working hour are defined exogenously and adjusted according to the labour costs of the aggregated farm accounts.

Similarly, costs for fertilisers (N, P, K, Mg) are calculated in the fifth term of the objective function. The level of purchased mineral fertiliser inputs results from the nutrient requirements of the crops, less nutrients coming from livestock manure and nitrogen–input coming from temporary leys.

The sixth term describes expenditure or revenues related to the leasing of agricultural land. A distinction is made between grassland, arable land and land for permanent crops. The term is generally negative but may also be positive if revenues from leased-out land are higher than expenditures for leased-in land.

The two last terms refer to the so-called “hidden” costs; these are used to reproduce exactly the activity levels of the base year.

Constraints

CH-FARMIS consists of seventeen blocks of restrictions which are related to balancing the use of land, labour, fertiliser, production outputs, young stock, feeding and the fulfilment of certain policy and management restrictions. The model constraints are briefly described below. All relevant equations are listed in Table 9.

Table 9 List of model restrictions

Restriction related to:	Nr.	Equation	
Land	**(5)**	$\sum_{l} X_{nl} - LAND_{nl} \leq b_{nl}$	$\forall n$
	(6)	$\sum_{n} X_{n_r l} \leq rx_{rl}$	$\forall n$
	(7)	$\sum_{n} LAND_{nlBASYR} + \sum LAND_{nlTGYR} > 0$	$\forall n$
Labour	**(8)**	$\sum_{i} (X_{ni} * (\sum_{c} \varphi_{nit} + \varsigma_{ni})) - \sum_{u} U_{nu} \leq 0$	$\forall n$
	(9)	$\sum_{i} (X_{ni} * \varphi_{nit}) - \sum_{u} T_{ntu} \leq 0$	$\forall n, u, c$
	(10)	$T_{ntu_{nop}} - \eta_t * \sum_{i} (X_{ni} * (\varphi_{nit} + \varsigma_{ni} * \eta_t)) \leq 0$	$\forall n, u, c$
Feeding	**(11)**	$(F_{nif} * \chi_{fm_{'drymat'}}) \geq (X_{ni} * DM_{ni} * \tau_{\min})$	$\forall n, i, f$
	(12)	$(F_{nif} * \chi_{fm_{'drymat'}}) \leq (X_{ni} * DM_{ni} * \tau_{\max})$	$\forall n, i, f$
	(13)	$\sum_{m} (F_{nif} * \chi_{fm}) \geq (X_{ni} * \upsilon_{nim})$	$\forall n, i, f$
Fertilizer	**(14)**	$(\sum_{i_{cro}} X_{ni_{cro}} * \vartheta_{nvi_{cro}}) - (\sum_{i_{liv}} X_{ni_{liv}} * \mu_{nvi_{liv}}) - V_{nv} \leq 0$	$\forall n, v$
Young stock	**(15)**	$\sum_{i_{liv}} (X_{ni_{liv}} * \psi_{ni_{liv}}) = 0$	$\forall n$
Production	**(16)**	$\sum_{i} (X_{ni} * o_{nij}) - W_{nj} - Y_{nj} = 0$	$\forall n, i, j$
Direct payment	**(17)**	$PX_{ni} - X_{ni} \leq 0$	$\forall n, i$
	(18)	$(X_{n_r i_{gras}} * \kappa_r) - PX_{n_r i_{liv}} \geq 0$	$\forall n, i$
ECA	**(19)**	$\sum_{i_{eca}} X_{ni_{eca}} * \sigma_{i_{eca}} \geq \sum_{i} X_{ni}$	$\forall n, i$
Organic farming	**(20)**	$V_{n_{org}\, v_{'nitr'}} = 0$	$\forall n$
	(21)	$(F_{nif} * \chi_{fm_{'drymat'}}) * 0.5 \geq (X_{ni_{cro}} * o_{ni_{cro}} * \chi_{fm_{'drymat'}})$	$\forall n, i$

where:

f	=	index for feedstuffs
i_{cro}	=	index for crop activities
i_{eca}	=	index for crop activities defined as ECA
i_{gras}	=	index for grassland activities
i_{liv}	=	index for livestock activities
m	=	index for the nutritional value of feedstuffs
n_{org}	=	index for organic farms
r	=	index for regions
t	=	index for time periods
u	=	index for labour
u_{nop}	=	index for non-permanent labour
v	=	index for different types of fertiliser
DM_{ni}	=	dry matter consumption of livestock (in t)
F_{nif}	=	used feedstuffs (in t)
$PX_{ni_{liv}}$	=	number of livestock eligible for direct payments (in LHU)
T_{ntu}	=	labour input for different time periods (in 1,000 h)
U_{nu}	=	labour requirements (in 1,000h)
W_{nj}	=	home-produced feedstuffs used on the farm (in t)
X_{nl}	=	level of production activities (in ha/LHU)
X_{ns}	=	level of production activities (in ha/LHU)
b_{nl}	=	available land resources (in 1,000 ha)
b_{nu}	=	available labour resources (in 1,000 h)
rx_{rl}	=	total regional land area (1,000 ha)
ς_{ni}	=	labour requirements related to no specific seasonal period (in 1,000 h)
$\imath_{t}$	=	proportion of work that needs to be done by permanent labour (in %)
$\vartheta_{nvi_{cro}}$	=	nutrient requirements of crops (in t)
κ_{r}	=	maximum stocking rate (LU/ha)
$\mu_{nvi_{liv}}$	=	nutrient content of manure (in t)

o_{nij} = marketable output of each production activity (in 1000 CHF / t)

$c_{i_{eca}}$ = proportion of ECA (in %)

$\tau_{\max}$ = coefficient defining the upper level of the feed ration (in %)

$\tau_{\min}$ = coefficient defining the lower level of the feed ration (in %)

υ_{nim} = nutritional requirements of farm animals (in t)

φ_{nit} = labour requirements related to specific seasonal periods (in 1,000 h)

χ_{fm} = nutritional value of feedstuff (in t)

$\psi_{ni_{liv}}$ = output and input of young stock (in numbers)

Land use: The agricultural land balance says that the sum of all grassland, arable and permanent crop activities does not exceed the resource endowment of each farm group (equation 5). Equation 6 requires that the sum of grassland and crop activities for all farm groups in each region be equal to or lower than the available grassland and arable land resources in each region (valley, hill, mountain). Thus, farm groups can lease-in additional farm land if other farm groups from that region lease-out farm land. Furthermore, farm groups can also take land out of production. However, this is restricted to the amount of land that was leased-in during the base year period (equation 7). Technically, this is ensured by Equation 7, which requires that the total area of rented farm land of the base year ($LAND_{nlBASYR}$) and the target year ($LAND_{nlTGYR}$) is positive.

Labour: Where appropriate, labour requirements for each activity were specified for different seasonal periods (expressed through the coefficient φ_{nit}): spring, early summer, summer, autumn and winter. Equation 8 ensures that labour requirements for all periods plus labour needs that are not allocated to a certain period are covered by the total available labour inputs of each farm group. Labour requirements related to tasks that do not need to be done in a certain period are expressed by the coefficient ς_{ni}. Equation 9 specifies that the labour requirements of each time period need to be covered by labour resources available in the corresponding period. Certain tasks are restricted to permanent labour (e.g. accounting and billing). This requirement is ensured through equation 10, where the coefficient $\imath_t$ indicates the proportion of work that cannot be done by non-permanent labour. The values for $\imath_t$ were defined on the basis of expert opinion and vary between 0-20%, depending on the time period.

Feeding: The feeding rations for livestock were calculated for the base year with the help of a GCE Estimator, as described earlier. Equations 11 and 12 determine for the ex-ante period that the ration may differ from the proportions originally calculated, but only within a predetermined corridor expressed by the coefficient τ, which is defined on the basis of expert opinion. A second feeding constraint is related to the nutritional requirements of the diet (expressed by the coefficient υ_{nim} multiplied by X_{ni}). Equation 13 ensures that the required energy, protein, dry matter and proportion of crude fibre are covered by the available feedstuffs.

Fertiliser: The equation for balancing fertiliser inputs (equation 14) can be divided into three parts. The first part defines the total fertiliser needs. The second part describes the amount of fertiliser coming from livestock manures and nitrogen-fixing crops. The difference between both terms is covered by purchased fertiliser (defined as variable V_{nv}).

Young stock: With regard to replacement stock, livestock activities can be divided into two groups. For cattle and pig activities, the production of and requirements for young stock are represented in physical terms (described using the coefficient $\psi_{ni_{liv}}$). The balance of internal transactions must be zero, which is ensured through equation 15. For all other activities, the cost for replacement is already included in the output coefficient.

Sales: The balancing of physical outputs for all production activities is achieved by equation 16. The physical output is described by the activity level multiplied by the output coefficient. Products can either be sold or, in the case feedstuffs, used as input for other activities within a farm group. The proportion of feedstuffs used on the farm depends on the farm group-specific feeding rations and, in the case of organically managed farm groups, on equation 21.

Direct payments: While the eligible level for most direct payment measures is not specifically restricted, this is not the case for payments related to grazing livestock and animal husbandry under adverse production conditions. The eligible number of livestock is limited for these two payment measures by the coefficient κ_r, which is different for each region (equation 18). Equation 17 simply ensures that the number of farm animals eligible for direct payments is equal to or less than the number of animals kept on the farm..

Ecological compensation area: According to the direct payment regulation (SR 910.13), a certain proportion of farm land must be managed as ecological compensation area (ECA)[7]. This requirement is ensured through equation 19, where the coefficient $c_{i_{eca}}$ defines the minimum proportion of ECA (currently 7%).

Organic farming: There are two additional constraints that are applied only to organic farm groups. Firstly, equation 20 specifies that organic farms are not allowed to buy mineral N fertiliser. Secondly, equation 21 defines that organic farms must produce at least 50% of their required feedstuffs on the farm.

Model calibration

Because the number of binding constraints is usually lower than the number of observed activities, programming models tend to have over-specialised solutions by design. This problem is frequently even more severe in sector models, as Heckelei (1997) pointed out, due to the smaller number of empirically justified constraints relative to the number of observed production activities, as well as due to the difficulty of specifying non-linearity in aggregate technology. In order to ensure that the calculated activity levels are equal to those that can be observed in the base year, it is common to calibrate programming models. Traditionally, this is achieved by adding either rotational constraints and/or production activities (Hazell and Norton, 1986) or by using a quadratic form of the objective function (Bauer and Kasnakoglu, 1990). Both approaches are associated with considerable problems, however. Since calibration constraints are only valid in the base year, they restrict the solution corridor for the ex-ante period as well and may consequently lead to biased results (Howitt, 1995). The use of a non-linear term in the objective function may reduce the specialisation errors in optimising models without using inflexible cali-

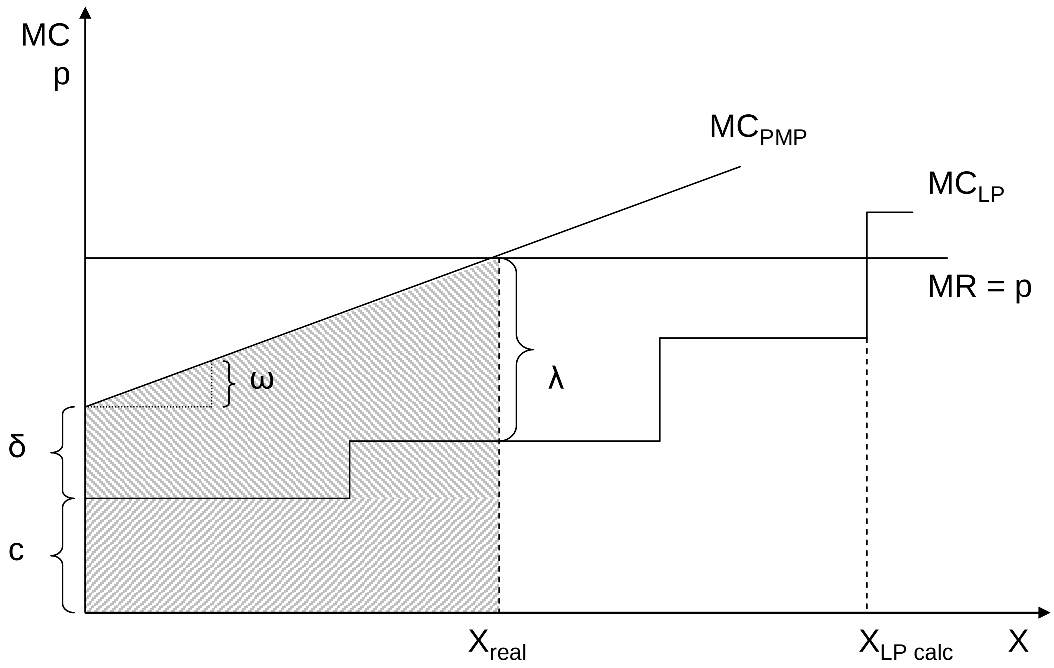
[7] ECA comprises the following model activities: extensively-used meadows, less intensively-used meadows, mixed fallow land, rotational fallow land.

bration constraints. However, this is done at the expense of a perfect calibration, as Meister ***et al.*** (1978) reported, because the observed base year activity levels are not explicitly taken into account.

In light of these difficulties, positive mathematical programming (PMP) appears to be a more convincing approach. The basic idea of PMP is to use information contained in the opportunity costs of each activity to specify a non-linear objective function so that observed activity levels can be reproduced without inflexible constraints (Howitt, 1995). Calibration constraints are used only to calculate two additional cost parameters which later form the additional non-linear cost term of the objective function.

The basic approach of PMP is illustrated graphically in Figure 2. Assuming a marginal revenue function MR and a marginal cost function MC_{LP}[8] of an LP model, the optimal level of activity X would be X_{LPcalc} , where MC_{LP} intersects MR. Beyond this level, every additional unit of X would lead to higher marginal costs than revenues. In reality, however, activity X has only the extent X_{real}. Since profit maximising behaviour is assumed, there must be a reason for this difference. One explanation is that MC_{LP} is not correctly specified because not all costs are taken into consideration. These so-called "hidden costs" can be attributed, for example, to differences in soil quality, risk aversion or expected decline in prices. The hidden costs are equal to the dual value λ, which can be obtained from a linear programming model that is constrained to observed activity levels. In order to reproduce the exact activity level, a linear and a non-linear term are added to the existing cost function, such that MC_{PMP} is equal to MR exactly at X_{real}. In Figure 2, δ represents a vector of parameters associated with the linear cost term and ω

Figure 2 Model calibration based on the PMP approach



Source: Adopted from Bertelsmeier (2005)

[8] The run of the MC_{LP} curve is due to the erratic changes in marginal opportunity costs of fixed production factors. For the sake of clarity MC_{PMP} has been shown as a straight line.

represents a symmetric, positive (semi-) definite matrix of parameters associated with the non-linear cost term. Due to the new, non-linear cost function, and based on the assumption that X_{real} expresses the optimal level of X in the base year, there is no longer any incentive to extend the activity beyond $X_{real.}$ Consequently, the model reproduces the observed activity level without calibration constraints.

Since the publication of a comprehensive paper on PMP in agricultural policy models by Howitt (1995), this calibration approach has become a standard methodology and has been employed in various models at farm, regional, and sector level[9].

Although PMP provides an elegant approach for improving the validity of sector models, it has been criticised as a calibration approach that results in arbitrary simulation behaviours (see Heckelei (2002), for example). This is mainly caused by the thin information base which is taken into account for the calibration. A single observation is certainly a very limited basis for the specification of the PMP terms – particularly if the economic conditions are expected to change considerably. Using only a single observation for the parameter specification implies, first, that any activity with X equal zero in the base year period cannot be included in the solution of the target year, because there are no PMP terms for these activities. Second, there is an infinite number of parameter sets which lead to a perfect calibration in the base year and each set implies a different response behaviour in the scenario analysis. Third, no information is provided to specify the diagonal elements of the cost matrix ω Finally, fourth, the PMP approach overestimates the dual values for new and less common activities in the base year (e.g. because a decline in risk costs is not taken into consideration). For this reason Umstätter (1999) concluded that the PMP standard approach is less appropriate for innovative or alternative production activities. A similar observation was also made by Offermann (2003) with respect to organic farming activities in a regionalised sector model.

To limit the problem of the thin information base, Helming ***et al.*** (2001) proposed using the calibration method in combination with supply elasticities. By using this prior information, programming models are generally better able to capture the behavioural responses of farmers to changing economic conditions (Gocht, 2005). This approach was also implemented in the German FARMIS model (Bertelsmeier, 2005) and has been adopted for the Swiss FARMIS version as well[10]. The approach adopted can be divided into three different steps, as described in the following paragraphs[11].

In the first step, calibration constraints are used in a primal LP model (equation 22) to guarantee that the activity levels can not exceed the observed levels of the base year plus a very small perturbation factor, which is included to distinguish between binding and slack resource constraints and to ensure that the first one remains binding (equation 23 and 24).

[9] See, for example, farm level applications in: Arfini and Paris (1995), Judez ***et al.*** (2001); regional applications in: Barkaoui and Butault (1999), Umstätter (1999), Barkaoui ***et al.*** (2001), Graindorge ***et al.*** (2001), Helming ***et al.*** (2001), Paris (2001); Röhm (2001); and sector applications in: Jacobs (1998); Cypris (2000), Malitious ***et al.*** (2000), Heckelei and Britz (2001), Helming (2005).

[10] Due to a lack of time, other methods that also address the above-mentioned shortcomings of PMP have not been taken into consideration yet. For example, Paris and Howitt (1998) as well as Heckelei and Britz (2000) proposed the application of a Generalized Maximum Entropy (GME) estimator to specify the diagonal elements of the cost matrix ω and to increase the number of observations. A general alternative approach to PMP has been proposed by Heckelei and Britz (2005) as well as Heckelei and Wolff (2003); this approach is based on the direct use of the first order condition of the assumed optimisation model to estimate the shadow values of resource constraints simultaneously with the other parameters of the model.

[11] The description of the calibration process in this section is based on Bertelsmeier (2005).

$$\max Z = \sum_i p_i x_i - c_i x_i \quad (22)$$

subject to

$$\sum_i a_{ik} x_i \leq b_k \qquad \forall k \qquad [\pi_k] \quad (23)$$

$$x_i \leq x_i^* + \varepsilon \qquad \forall i \qquad [\lambda_i] \quad (24)$$

$$x_i \geq 0 \qquad \forall i \quad (25)$$

where

i	=	index for activities
m	=	index for marginal activities
p	=	index for preferential activities
k	=	index for inputs

Z	=	farm income
p_i	=	product price
c_i	=	product costs per activity unit
b_k	=	total inputs
a_{ik}	=	required amount of inputs per activity level
x_i^*	=	observed activity level in the base year
ε	=	perturbation factor
π_k	=	dual values of the resource constraints
λ_i	=	dual values of the calibration constraints

Following Heckelei (1997) the set of production activities S^i can be divided into two subsets. One subset contains the "preferential activities" x_p ($S^p \subset S^i$), which are restricted by the calibration constraints from which dual values (shadow prices of the calibration constraints) can be derived. The other subset contains the marginal activities x_m that are not restricted ($S^m \subset S^i$). Assuming that xi does not equal zero and all constraints are binding, the dual values can be calculated according to the Kuhn-Tucker-Condition (Chiang, 1984) as follows:

$$\lambda_p = p_p - c_p - \sum_k a_{p,k} \pi_k \quad (26)$$

$$\lambda_m = 0 \qquad \textbf{(27)}$$

$$\pi_k = (p_m - c_m)(a_{mk})^{-1} \qquad \textbf{(28)}$$

In a second step, the linear cost function $c_i x_i$ is changed to a non-linear function by adding a non-linear cost term with the two parameters δ and ω As in most other PMP models, a quadratic cost function is assumed, which has the advantage that the model is easier to solve. The new cost function has the following form:

$$C_i = c_i x_i + \delta_i x_i + 0.5\,\omega_i x_i^2 \qquad \textbf{(29)}$$

where:

δ	=	parameter associated with the linear PMP term
ω	=	parameter associated with the non-linear PMP term

In order to obtain an exact reproduction of the base year behaviour, the two parameters δ and ω must be specified under the condition

$$\frac{\partial C_i(x_i^*)}{\partial x_i} = \frac{\partial R_i(x_i^*)}{\delta x_i} \qquad \Leftrightarrow MC_i\,(x_i^*) = MR_i\,(x_i^*) \qquad \textbf{(30)}$$

where:

R_i	=	total revenues of activity x_i
C_i	=	total costs of activity x_i
MR_i	=	marginal revenues of activity x_i
MC_i	=	marginal costs of activity x_i

For activities with marketable outputs (i.e. activities with production revenues), the parameter ω can be calculated using the supply elasticity of revenues[12]. The supply elasticity of revenues of x_i^* can be written as:

[12] Referring to Figure 2, this approach assumes that $MR_i = p_i$, (which simply says that the producer's decisions will have no effect on the price of the product). An increase in marginal revenues would therefore result in a parallel upward shift of the MR curve so that the slope of the MC_{PMP} curve would always be the same in relation to the MR curve.

$$\varepsilon_i^{x,MR} = \frac{\dfrac{\partial x_i^*}{x_i^*}}{\dfrac{\partial MR_i}{MR_i}} \qquad \Leftrightarrow \qquad \varepsilon_i^{x,MR} = \frac{\partial x_i^*}{\partial MR_i} \frac{MR_i}{x_i^*} \qquad \textbf{(31)}$$

The gradient of the marginal cost function is now equated with the gradient term of the elasticity equation at level x_i^* so that the supply elasticity can be formulated as:

$$\varepsilon_i^{x,MR} = \frac{1}{\omega_i} \frac{MR_i}{x_i^*} = \frac{p_i y_i + prem_i}{\omega_i x_i} \qquad \textbf{(32)}$$

where:

y_i	=	physical output
$prem_i$	=	activity-related direct payments

By transforming equation 32, one obtains the final term that can be used to calculate the non-linear cost parameter ω

$$\omega_i = \frac{p_i y_i + prem_i}{\varepsilon_i^{x,MR} x_i^*} \qquad \textbf{(33)}$$

The parameter δ_i is derived from the difference between the dual value λ and the non-linear cost term $\omega_i x_i^*$ as shown in equation 34:

$$\delta_i = \lambda_i - \omega_i x_i^* \qquad \textbf{(34)}$$

It is apparent that this approach can not be applied for activities that have no direct revenues (e.g. grassland). Therefore, parameter a_i is alternatively derived using equation 35, which specifies that a_i results from the sum of variable costs and dual values λ divided by the activity level of the base year period.

$$\omega_i = \frac{(\lambda_i + c_i)}{x_i^*} \qquad \textbf{(35)}$$

Having fully specified the cost function using an additional linear term ($\delta_i x_i$) and non-linear term ($0.5 a_i x_i^2$), it is now possible, in a third step, to formulate the non-linear optimisation problem of the PMP model, which is able to reproduce exactly the activity level of the base year without any calibration constraints:

$$\max Z = \sum_i p_i x_i - c_i x_i - \delta_i x_i - 0.5 \alpha_i x_i^2 \qquad \textbf{(36)}$$

subject to

$$\sum_i a_{ik} x_i \leq b_k \qquad \forall k \qquad [\pi_k] \qquad \textbf{(37)}$$

$$x_i \geq 0 \qquad \forall i \qquad \textbf{(38)}$$

Model validation

It is obvious that the usefulness of agricultural policy models is closely related to their ability to project correctly the impact of policy changes – irrespective of whether these changes are implemented in reality or not. In order to test the projection quality of CH-FARMIS (calibrated for the base year period 2000/2001), a validation scenario has been specified using price data and direct payment rates from the year 2005. In Table 10, the results of the validation scenario are compared with the data from the Swiss FADN and the Swiss farm census for the year 2005.

Table 10 Validation results

	Unit	Organic ALL			Non-Organic ALL		
		Model projection	FADN / FC data	Deviation (%)	Model projection	FADN / FC data	Deviation (%)
Agricultural income [1]	CHF	56.60	58.06	*-2.51*	55.10	54.63	*0.86*
Grassland [2]	ha	17.90	19.38	*-7.66*	14.52	15.44	*-5.91*
Arable land [2]	ha	1.43	1.38	*3.58*	4.66	4.95	*-5.69*
Total livestock units [2]	LU	22.48	22.01	*2.12*	28.22	27.24	*3.59*

[1] FADN data
[2] Farm census data

Source: Own calculations based on data of Swiss FADN from ART and the farm census of the FSO for the year 2005

The comparison shows that the CH-FARMIS model is able (on the basis of 2000/2001 data) to project, within a certain range of tolerance, the agricultural income, land use and total livestock units of organic and non-organic farming for the year 2005. When comparing the model results with the FADN and farm census data, it is important to take into account that complete consistency can not be expected for the following reasons[13]:

Though the FADN results claim to be representative for the whole farming sector they are also subject to a certain standard error. For example, the standard error of estimate of agricultural income for the non-organic farm group amounts to CHF 663 for the year 2005. Since the number of organic farms per farm group is considerably smaller, the standard error of estimate is larger and amounts to CHF 1,663. This means that the real average agricultural income of non-organic and organic farms can be expected to be within a range of +/- CHF 1,200 (non-organic

[13] For the same reasons, it appears to be less useful to validate the results of each of the 30 farm groups, since the negative effects of the limitations described are even greater for farm groups represented by a small number of farms.

farms) and +/- CHF 3,300 (organic farms) around the estimated average mean of CHF 54,630 (non-organic farms) and CHF 58,060 (organic farms) respectively. Thus, the average agricultural income projected by CH-FARMIS is within the estimated range of real average income.

Average farm size increases by approximately 0.4 ha per year in Switzerland (Mann, 2003b). This increase is mainly a result of cessation of farming. Since the current model version of CH-FARMIS is not able to consider endogenously a decline in the number of agricultural holdings, an increase in farm size cannot properly be represented. This limitation may explain why the amount of grassland of the organic and the non-organic farm group is slightly lower in the validation scenario compared to the farm census data. The overestimation of the organic arable area can be explained mainly by the very small absolute amount of arable land.

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