Synergies and trade-offs in the promotion of the economic and environmental performance of Swiss dairy farms in the mountain area

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Abstract
Promoting both the environmental and economic performance of Swiss agriculture is one of the core objectives of Swiss agricultural policy. In the present paper we identify the synergies and trade-offs in the promotion of these two dimensions of corporate sustainable performance for Swiss dairy farming in the mountain area. Performance is thereby defined as the efficiency of a farm in using its economic and environmental resources to produce agricultural goods or services. The results of our investigation show the existence of several synergies and rather few trade-offs. By increasing farm size, promoting full-time farming and decreasing the intensity of the use of concentrates, major enhancements in terms of both economic and environmental performance can be achieved. Only two variables are shown to present a trade-off in terms of promotion of farm economic and environmental performance: the production of silage-free milk intended for the manufacture of raw milk cheese and the stocking rate. The production of silage-free milk has a positive effect on farm economic performance but a negative one on farm environmental performance. Conversely, the stocking rate negatively impacts on the economic performance but seems to have a positive effect on the environmental one.

Keywords: *economic performance, environmental performance, dairy farming, Switzerland*

JEL classification: *Q12, Q15, Q57*

1. Introduction

Article 104 of the Federal Constitution of the Swiss Confederation clearly stipulates that the promotion of an environmentally-friendly agricultural sector should constitute a major goal of Swiss agricultural policy (FOAG 2004; FOAG 2010). At the same time, the improvement of the economic competitiveness of the Swiss agricultural sector is a core objective of Swiss agricultural government research (Agroscope and FOAG 2007). This second objective has recently gained importance within the context of a possible future free trade agreement in the agricultural and food sector to be concluded between Switzerland and the European Union (FOAG 2010; Integration Office FDFA/FDEA 2009).
The Swiss dairy sector located in the mountain area[1] is particularly affected by these two challenges. From an economic point of view the Swiss dairy farms located in the mountain area show a very low performance. Taking an average of the years 2007-2009, their median work income per family work unit (FWU) reached 46% of the comparative salary[2] in the mountain area and was 20% and 32%, respectively, lower than the average work income per FWU of dairy farms located in the hill and plain regions (own calculations based on the data of the Swiss Farm Accountancy Data Network and on Schmid and Roesch 2010). These figures clearly highlight the severity of the economic performance problem of the Swiss dairy sector in the mountain area. A detailed analysis of the distribution of the work income per family work unit (FWU) of these farms shows the presence of a substantial variability between farms and thus indicates that there is space for substantial improvement in this regard. In terms of environmental performance there has up to now been no large-scale study of the environmental performance of the Swiss dairy sector in the mountain region.

[1] The mountain area includes mountain zones 2, 3 and 4 as defined in FOAG (2002) and can be roughly defined as the agricultural production area located between 800 and 1'500 meters above sea level.

[2] The comparative salary is defined as the median gross salary of the employees in the secondary and tertiary sector and is made available by the Swiss Federal Statistical Office.

However, initial investigations on the environmental performance of Swiss dairy production[3] also indicate a high level of heterogeneity among farms (Rossier and Gaillard 2004).

It can be therefore expected that both the economic and environmental performance of the Swiss dairy farms located in the mountain region can be boosted. Improving these two dimensions of sustainable performance calls for identification at farm level of those characteristics that enable a simultaneous improvement in both components. The aim of the present work is therefore to investigate the determinants of the economic and environmental performance of Swiss dairy farms. Based on this investigation, we will determine the factors that positively or negatively affect both or only one of these two dimensions of the sustainable performance of a farm. We will thus be able to identify potential synergies and trade-offs in the development of an economically viable and environmentally-friendly dairy sector in the mountain area. In this sense the study will provide very valuable knowledge for farm managers, farm consultants and policy-makers by pointing out the key issues on which they should focus in order to positively influence both the economic and environmental dimensions of the sustainable performance of a farm.

The paper is set out as follows. Section 2 introduces the conceptual framework implemented in the study. Section 3 describes the data and approach used for the assessment of farm economic and environmental performance. In section 4 we focus on the models used for the analysis of the determinants of farm economic and environmental performance. Section 5 includes the results, while the discussion and the conclusions are presented in Section 6.

[3] These investigations have not been carried out on a specific basis, either for the mountain area or for dairy farming.

2. Conceptual framework

In view of the conceptual framework for investigating the synergies and trade-offs in the promotion of farm economic and environmental performance, it might be necessary first to briefly define these two notions[4]. By farm economic and environmental performance we mean the efficiency of a farm in using its economic and environmental resources to produce agricultural goods or services.

2.1. Analysis framework

Conceptually the potential common determinants of farm economic and environmental performance can be classified according to their simultaneous effect on the economic and environmental performance. A potential determinant can have either a significant or a non-significant effect on the performance indicator considered. In the case of a significant effect, it can be either positive or negative. In total, therefore, there are three possible outcomes for each potential determinant with regard to its effect on the performance indicator investigated. As we consider the simultaneous effect of a potential determinant on economic performance and environmental performance, the resulting classification of the potential common determinants is made up of a 3X3 matrix as illustrated in Table 1.

[4] A precise definition of these notions and of the indicators used for their measurement will be provided in section 3.

Table 1: Classification scheme for potential determinants according to their simultaneous effect on the economic and environmental performance

			Economic performance		
			Significant		Non-significant
			+	-	
Environmental performance	Significant	+	① desirable positive synergy	③ trade-off	④ desirable unidimensional
		-	③ trade-off	② undesirable negative synergy	⑤ undesirable, unidimensional
	Non-significant		④ desirable unidimensional	⑤ undesirable, unidimensional	⑥ not relevant

Source: Own representation

2.2. Factors of farm performance: a classification

Most of the existing literature related to the assessment of farm performance and its determinants has focused on the performance of the use of economic resources, the environmental resources being thereby left unconsidered. Several classifications of the potential determinants of farm performance have been developed and proposed in the literature (refer for instance to Tian and Hua Wan 2000; Bezlepkina 2004; Van Passel et al. 2007; Lakner et al. 2009). The classifications proposed differ greatly, not only in the variables taken into account but also in their basic structure, and there does not seem to exist any broadly accepted consensus on a basic classification of potential farm performance determinants. This is probably due to the fact that the specification of the determinants set is contingent on the specific context of each investigation. Based on a literature review we define a classification of factors of farm performance. This classification is made up of two major groups of factors: those pertaining to the general environment of the farm and those that are related to the farm itself as economic agent.

The general environment of the farm as a potential factor affecting both farm economic and environmental performance can be divided into three major sub-groups: the legal/regulatory environment (environmental policies, agricul-

tural policy, labour legislation and food legislation), the socioeconomic environment (such as labour market, capital market, up- and downstream agro-food chain and its competitiveness, presence of institutions for agricultural knowledge transfer such as farm extension services) and the natural environment (climatic conditions, topographic conditions and soil characteristics).
The factors related to the economic agent can be split into three groups: the structural factors (farming type, farm size and ownership), the management factors (characteristics of the dairy production system, management of the dairy herd, inputs composition and capital structure, outputs composition and production orientation/form) and the human factors (age and education of the farm manager).

2.3. Hypothesis

We hypothesize that potential factors of farm performance affecting both economic and environmental resource use efficiency will affect these two dimensions in the same direction, i.e. we expect the presence of several synergies and few trade-offs in the promotion of farm economic and environmental performance. This hypothesis is motivated by the fact that environmental resources are incorporated in many economic resources. Thus factors positively and negatively affecting the efficiency of the use of economic resources are respectively most likely to indirectly positively and negatively affect environmental resource use efficiency.
Our hypothesis rests on the more general so-called «Porter hypothesis» (Porter and van der Linde 1995) according to which improvements in terms of environmental protection imply net benefits for private companies due to reduced costs. This is amongst others accounted for by the fact that «at the level of resource productivity, environmental performance and [economic] competitiveness come together» (Porter and van der Linde 1995). When using environmental resources inefficiently, companies bear pollution costs that correspond to the opportunity costs of wasted environmental resources. Porter and van der Linde (1995) documented their hypothesis with numerous examples of firms that reduced their pollution and costs at the same time by increasing the efficiency of their environmental resources use.

3. Assessing farm economic and environmental performance

In the present section we will describe the data used, the environmental issues considered and introduce the indicators used for the assessment of farm economic and environmental performance.

3.1. Data source

The data used for the present work originates from the Swiss Farm Accountancy Data Network (Swiss FADN) managed by the Farm Economics Research Group of the Swiss Federal Research Station Agroscope Reckenholz-Tänikon ART. The investigation is based on a sample of 480 dairy farms observed in 2006. A dairy farm is defined according to the typology of the Swiss FADN (ART 2006). The focus on the year 2006 is motivated by the availability of environmental data, as it is the only year for which environmental data are available for these farms.

3.2. Assessing the economic performance of a farm

As regards the present investigation, since we are only interested in the overall economic performance of a farm, we have opted for an indicator very widely used in the field of farm economic performance measurement in Switzerland, namely the work income per family work unit (FWU). This is defined as the agricultural income that remains available per family member working full-time on the farm after equity capital has been remunerated at its opportunity cost[5]. It would also have been possible to measure farm economic performance using a profitability ratio defined as the relationship between total farm revenues and total farm costs, equity capital and family labour force being thereby remunerated at their respective opportunity costs. However, we prefer the work income per family work unit indicator, as the Swiss legislator stipulates that this indicator should be used to assess the economic dimension of the sustainable performance of a farm (S.R. 919.118).

[5] The interest rate on ten-year Swiss government bonds is used as the rate of remuneration for equity capital and is taken from the official statistics of the Swiss National Bank.

3.3. Selection of the environmental issues to be considered

Prior to defining the indicators to be used to assess the environmental performance of a farm, it is necessary to identify the environmental issues to be considered. A core objective of Swiss agricultural policy is to increase the efficiency of the use of nitrogen, phosphorous, pesticides and energy (FOAG 2011; FOAG 2010). For the mountain region the pesticides issue is, however, irrelevant as Swiss mountain agricultural production systems almost never make use of pesticides. In the present investigation we focus on the fossil energy and nitrogen resources. This choice is motivated both by the fact that these two environmental issues are of high relevance for Swiss dairy farming and by data availability considerations. As the Swiss FADN does not contain any environmental data, the quantification of the amount of environmental resources used has to be performed indirectly on the basis of accountancy data. Such an assessment has been performed for fossil energy and nitrogen use for the Swiss FADN data of the year 2006.

3.4. Defining indicators measuring the environmental performance of a farm

Halberg et al. (2005) review the indicators proposed for the assessment of the environmental performance of European livestock production systems at farm level and formulate conclusions as to the indicators to be used. In accordance with Haas et al. (2000), Halberg et al. (2005) recommend selecting the indicator of environmental performance depending on the impact category type considered. For environmental issues with a local or regional geographical target (such as eutrophication or acidification), the indicator should be area-based, i.e. the area of the farm should be used as the basis for the indicator (Halberg et al., 2005). By contrast, for issues with a global focus (such as global warming or energy demand), the indicator should be product-based, i.e. expressed per unit of output produced (Halberg et al., 2005). For issues with both a local and a global dimension, both types of indicator should be used. As regards the present study, we shall be using a product-based indicator for measuring the environmental performance of a farm with regard to the energy issue, as this issue is of global relevance only. The nitrogen issue, for its part, has both a local and global dimension, which would advocate the use of both an area- and a product-based indicator. To calculate the area-based indicator for the environmental performance of a farm with regard to nitrogen, it would be necessary to estimate the amount of environmental impact generated locally per hectare of usable agricultural land, either by means of a rough approximation using the proxy variable «nitrogen surplus per hectare» or by means of a precise quantification (eutrophication potential generated by the use of the fertilizers estimated by means of a Life Cycle Assessment). As these variables are not quantifiable on the basis of the dataset used, we will consider the nitrogen issue from a global perspective only, i.e. using a product-based indicator.

The product-based indicator to which Halberg et al. (2005) refer is defined as the amount of environmental resource used or impact generated per physical unit of product (for example, kg) and is thus, in reference to the eco-efficiency typology proposed by Huppes and Ishikawa (2005), an indicator of environmental intensity, which is the inverse of the eco-efficiency ratio (Verfaillie and Bidwell 2000). For the present investigation we will be giving preference to the eco-efficiency indicator (also called environmental productivity) over the environmental intensity indicator, as it has a similar interpretation to the work income per family work unit indicator due to their analogous definition (output per unit of input).

When measuring eco-efficiency it is necessary to address the issue of the output measurement (monetary versus physical). Whereas Halberg et al. (2005) propose using an output expressed in physical terms, for the present investigation we shall be using an output expressed in monetary terms for the following reason. Due to the fact that our environmental assessment is conducted at farm level and not at product (or commodity) level, we need to aggregate several farm outputs into a single one to be able to estimate the eco-efficiency indicator. Using the total farm revenue from agricultural and para-agricultural activities[6] for calculating the eco-efficiency indicator enables the aggregation process to proceed in an objective manner using the market prices of the single agricultural commodities and para-agricultural services as weightings. Based on this monetary output figure and on the amount of fossil energy and nitrogen used, we will estimate the energy and nitrogen productivity levels for each farm.

[6] All direct payments have been excluded from the output figure as we are principally interested in the eco-efficiency of the production of marketed goods and services.

3.5. Assessing fossil energy use and nitrogen input on the basis of FADN data

For each environmental issue considered, the amount of environmental resource used is indirectly assessed on the basis of the farm accountancy data provided by the Swiss FADN.

The total fossil energy demand is assessed by means of Life Cycle Assessment. It includes preparation energy, process energy and intrinsic energy as defined by Gaillard et al. (1997). Both direct and indirect energy inputs are taken into account in the assessment. The direct energy input comprises the fossil energy demand associated with the use of diesel, electricity and other energy sources (such as heating material) that are used on the farm. The indirect energy input includes the fossil energy demand for the following items: mineral fertilizers, concentrates, minerals and salts for cattle, forage imported on to the farm, straw or litter material imported on to the farm, own machinery and seeds. By using the LCA technique as described previously for the assessment of fossil energy use, we ensure that the system boundaries of the environmental assessment are the same for all farms. By proceeding in this way we avoid farms that have outsourced their environmental «pollution» performing better in environmental terms than they really do[7].

The assessment of the fossil energy demand for each of the farm inputs listed previously consists of deriving the physical amount of farm input from the monetary variable available in the FADN data (cost position) and then multiplying this physical amount by the energy demand per physical unit of this input. The reference values used for the fossil energy demand for each farm input are available on request from the authors. Due to data availability, the following inputs cannot be considered in the assessment of the total fossil energy demand: farm buildings, field work through third parties (contractor, machinery ring), organic fertilizers imported on to the farm and heifers or cows imported on to the farm (i.e. which have grown up away from the farm).

[7] Such a situation might, for example, occur when farms make intensive use of concentrates produced outside the farm. If we were not to consider the fossil energy use for the production of those concentrates, then the environmental performance of these farms in terms of fossil energy use would seem better than it really is.

The quantification of the amount of nitrogen resource used has been carried out by assessing the nitrogen supply (in kg N) to the fields. This supply originates from two sources: the faeces of the farm animals and the use of inorganic fertilizers[8]. The nitrogen supply due to animal faeces is calculated on the basis of the inventory of animals held on the farm and on the basis of the reference values of the nitrogen provided by each category of animal (according to the species, sex and age). The reference values applied in the present work are those commonly used by the Swiss farm extension services and federal and cantonal administrations as specified in Agridea and FOAG (2006) and Walther et al. (2001). The nitrogen supply resulting from the use of mineral fertilizers is derived from the FADN cost position for mineral fertilizers, making assumptions about the type of mineral fertilizer used and assuming typical fertilizer prices (Agridea 2006).

4. Analysis of the determinants of farm economic and environmental performance

As mentioned previously, the aim of the present work is to identify the determinants of the economic and environmental performance of Swiss dairy farms located in the mountain region. For this purpose and for each of the three indicators introduced previously (work income per family work unit, energy productivity and nitrogen productivity) we shall be carrying out a multiple linear regression to investigate their potential determinants. Based on these three multiple linear regressions the determinants will be classified according to the classification scheme proposed in the conceptual framework (see Table 1). In the following we will first of all specify each of the three models to be estimated and then describe the approach used for their estimation.

[8] For the purposes of the present investigation, we have not considered the atmospheric nitrogen supply derived from precipitation or fixation as this is not quantifiable on the basis of FADN data. On the assumption that the rate of atmospheric nitrogen supply does not differ significantly between farms, the absence of any consideration of this nitrogen source should not represent a major problem for the present study aiming at investigating the factors that influence the environmental performance of a farm.

4.1. Choice of the dependent variables to be included in the model

The choice of the dependent variables to be included in the model is based on the classification outlined in the section «conceptual framework». The characteristics of the legal/regulatory environment and of the socioeconomic environment will not be considered as potential determinants of farm economic and environmental performance, as all farms operate under more or less similar conditions in this regard. The precise specification of the models is shown in Table 2 and has been made taking into account the data availability of the FADN database used. As will be evident from this table, some independent variables used in the regression model of the work income per family work unit are not included in the specification of the regression models of the two environmental indicators. This is due to the fact that these variables are relevant when it comes to explaining economic performance but are irrelevant as potential determinants of environmental performance.

Table 2: Specification of the regression models

(the names in the square brackets are the names given to the variables in the model)

INDEPENDENT VARIABLES: Category		Variables	DEPENDENT VARIABLES: Work income	Energy productivity	Nitrogen productivity
Natural environment of the farm		Agricultural production area ***[area]***: 0: mountain zone 2 1: mountain zones 3 and 4[1]	X	X	X
Structural characteristics of the farm		Farm size: economic output (farm revenue) in Swiss Francs ***[size]***	X	X	X
Structural characteristics of the farm		Type of farming: Part-time farming[2] 0: no – 1: yes ***[parttime]***	X	X	X
Structural characteristics of the farm		Proportion of farmland area rented in % ***[rent]***	X		
Characteristics of farm management	Dairy production system and dairy herd management indicators	Stocking rate (in livestock units per ha U.A.A.) ***[stockrate]***	X	X	X
Characteristics of farm management	Dairy production system and dairy herd management indicators	Intensity of the use of concentrates: Costs for concentrates for dairy cattle per kg milk (in Rappen[3]) ***[concuse]***	X	X	X
Characteristics of farm management	Dairy production system and dairy herd management indicators	Milk yield in kg per cow per year ***[milkyield]***	X	X	X
Characteristics of farm management	Dairy production system and dairy herd management indicators	Culling rate in % ***[cullrate]***	X	X	X
Characteristics of farm management	Dairy production system and dairy herd management indicators	Stable type ***[stable]:*** 0: tied stall barn 1: free stall barn	X	X	X
Characteristics of farm management	Dairy production system and dairy herd management indicators	Presence of own aestivation activity ***[aestiv]:*** 0: no 1: yes	X	X	X
Characteristics of farm management	Production orientation	Production form ***[organic]:*** 0: proof of ecological performance 1: organic farming	X	X	X
Characteristics of farm management	Production orientation	Milk utilization ***[cheese]:*** 0: industrial milk (silage milk) 1: cheese milk (silage-free milk)[4]	X	X	X
Characteristics of farm management	Production orientation	Importance of para-agricultural activity on the farm: Proportion of revenue coming from para-agricultural activities in the farm revenue (in %) ***[paraagr]***	X	X	X
Characteristics of farm management	Production orientation	Participation of the farms in agri-environmental and ethological governmental programs ***[ecolor]*** Ratio: direct payments for participation in environmental and ethological programs (without direct payments for organic farming) / farm revenue from agricultural and para-agricultural activities	X	X	X
Characteristics of farm management	Input composition and capital structure	Ratio debts to assets in % ***[debts]***	X		
Characteristics of farm management	Input composition and capital structure	Capital intensity: Ratio: capital[5] used in CHF / Normal Working Day ***[caplab]***	X	X	
Characteristics of farm management	Input composition and capital structure	Proportion of salaried labour in the total labour force of the farm ***[salarlabour]***	X		
Sociological characteristics of the farm manager		Age of the farm manager in years ***[age]***	X	X	X
Sociological characteristics of the farm manager		Agricultural education ***[agreduc1]***[6] 0: no - 1: yes	X	X	X
Sociological characteristics of the farm manager		Higher agricultural education ***[agreduc2]***[7] 0: no - 1: yes	X	X	X

[1] This zone classification is based on the following criteria: the climatic conditions (and especially the length of the growing season), the accessibility and the steepness of slopes. The degree of unfavourableness of the natural conditions increases with the zone number.
[2] A part-time farm is defined as one whose agricultural income accounts for less than 50% of the farm household income, the latter being defined as the sum of the agricultural and non-agricultural incomes.
[3] 1 Rappen = 0.01 Swiss Francs
[4] Milk used for the production of raw milk cheese.
[5] Capital is defined as the sum of amortizations, interest on debts and calculated interest on equity capital.
[6] Agricultural apprenticeship
[7] Master craftsman degree or higher agricultural education level

4.2. Mathematical specification of the models

The general specification of the three multiple linear regression models is given below.

$$Y_m = X_m \beta_m + \varepsilon_m \ (m = 1,2,3)$$

where:

- Y_1 is a (480 x 1) vector of observations on the work income per Family Work Unit
- Y_2 is a (480 x 1) vector of observations on the energy productivity
- Y_3 is a (480 x 1) vector of observations on the nitrogen productivity
- X_m is a (480 x K_m) matrix of observations on K_m-1 independent variables with $X_m 1 = 1$ for all m
- β_m is a (K_m x 1) vector of regression coefficients
- ε_m is a (480 x 1) vector of disturbances

It is at this stage important to note that the number of independent variables in each equation is not the same (K_1=21; K_2=18; K_3=17)

4.3. Estimation procedure

In a regression setting it is of central importance to remove or down-weight outliers that would distort estimates of regression coefficients. Standard procedures for detecting outliers (such as studentized residuals, Cook's distance measure, or DFITS statistics) suffer from a lack of robustness and might not be able to detect outliers, especially in a multidimensional setting as is the case in a multiple linear regression (Rousseeuw and Leroy 1987). For that reason Rousseeuw and Leroy (1987) and Maronna et al. (2006) advocate for the use of robust regression approaches to handling outliers in a regression setting. In the present work we make use of iteratively reweighted least squares (IRLS). The basic principle of this approach consists in attributing a weight to each observation according to its outlierness. The more extreme an outlier is, the less heavily it gets weighted in the minimization problem to be solved for estimating the beta parameters of interest. Extreme outliers are attributed a weight equal to zero and are thus not considered for the estimation of the model defined. In this study we use the rreg procedure of the Stata software package (Stata-

Corp. 2007a and 2007b) to estimate each model with IRLS. The weights calculated iteratively on the basis of the absolute residuals are derived from Huber and biweight functions tuned for 95% of the efficiency of OLS when applied to data with normally-distributed errors (Hamilton 1991). Once the IRLS approach has been performed, the weights generated are integrated into the subsequent step of the estimation procedure of the three models defined.

Due to the fact that the disturbances of the three equations are correlated (Breusch-Pagan for independent equations, $p < 0.001$), the three equations are estimated using the approach developed by Zellner (1962) for Seemingly Unrelated Regressions (the so-called SUR estimation procedure). In the presence of a contemporaneous correlation of the error terms, the regression coefficient estimators obtained by the approach proposed by Zellner (1962) are «at least asymptotically more efficient than those obtained by an equation-by-equation application of Ordinary Least Squares». Two approaches have been proposed by Zellner (1962) to estimate SUR equation systems: a two-stage procedure employing GLS (Generalized Least Squares) estimation and an iterative procedure based on the two-stage GLS procedure, this second procedure having been shown to yield maximum likelihood estimates (Felmlee and Hargens 1988). Felmlee and Hargens (1988) point out that there are no established statistical grounds for choosing one rather than the other estimator and find in their analysis no significant difference between the two methods. For the present investigation we use the two-stage GLS procedure for the SUR estimation of the three models defined.

5. Results

The results of the robust SUR estimation of the three linear regression models available in Table 3 will now be described and analysed in detail.

Table 3: robust SUR estimation of the three linear regression models

	work income per FWU (in Swiss Francs)		fossil energy productivity (in Swiss Francs per 10'000 MJ fossil energy)		nitrogen productivity (in Swiss Francs per kg N)	
Variable	Coefficient	P>|z|	Coefficient	P>|z|	Coefficient	P>|z|
area	-1'619	0.206	-13.1	0.018	2.8	0.003
size	0.12089	0.000	0.000196	0.000	0.00006	0.000
parttime	-16'736	0.000	-34.8	0.000	-0.5	0.579
rent	-4.35	0.810				
stockrate	-7'304	0.000	16.1	0.034	0.38	0.76
concuse	-313.4	0.000	-1.5	0.000	0.01	0.775
milkyield	-0.2818	0.583	-0.0067	0.002	-0.0002	0.673
cullrate	-29.37	0.236	-0.009	0.921	-0.03	0.135
stable	-1'164	0.487	-8.5	0.213	0.6	0.571
aestiv	1'056	0.394	4.7	0.379	-3.2	0.000
organic	2'439	0.060	15.3	0.006	7.0	0.000
cheese	2'322	0.066	-10.7	0.031	-2.4	0.004
paraagr	-10.05	0.813	0.92	0.000	0.54	0.000
ecolor	237.25	0.358	-1.4	0.198	-1.16	0.000
debts	-18.57	0.404				
caplab	-18.76	0.208	0.108	0.029		
salarlabour	14.66	0.702				
age	-357	0.000	-0.24	0.402	-0.05	0.258
agreduc1	1'126	0.470	8.8	0.187	1.8	0.089
agreduc2	2'045	0.327	16.6	0.060	-0.9	0.525
R^2	0.521		0.392		0.626	
p	0.000		0.000		0.000	

Source: Own calculations based on data from the Swiss FADN

5.1. Determinants of work income per family work unit

The coefficient of determination of the model is equal to 0.52, which means that the model explains 52% of the variance of the dependent variable.
Among the seven independent variables that are found to have a significant effect on work income per FWU, only three have a positive effect: farm size, organic farming and silage-free milk production. An increase in farm size (farm output produced) by 10'000 Swiss Francs leads – ceteris paribus – to an increase in work income per FWU of 1'209 Swiss Francs ($p<0.001$). Organic farms show a work income that is higher by 2'439 Swiss Francs than the work income of similar non-organic farms ($p=0.060$). Silage-free milk production, i.e. the production of milk for the manufacture of raw milk cheese, leads – ceteris paribus – to an increase in work income of 2'322 Swiss Francs ($p=0.066$).
The variables that have a negative effect on the economic performance indicator are the following: part-time farming, stocking rate, intensity of the use of concentrates and farm manager age. Ceteris paribus, part-time farms show a work income per FWU that is lower by 16'736 Swiss Francs than non part-time farms ($p<0.001$). An increase in stocking rate by 0.1 Livestock Unit per hectare causes – ceteris paribus – a decrease in work income per FWU of 730 Swiss Francs ($p<0.001$). One extra Rappen added to the cost of concentrates per kg milk leads – ceteris paribus – to a decrease in work income per FWU of 313 Swiss Francs ($p<0.001$). Adding ten years to the age of the farm manager is associated with a decrease in work income per FWU of 3'566 Swiss Francs ($p<0.001$).

5.2. Determinants of the productivity of fossil energy use

The coefficient of determination of the model specified is equal to 0.39. Eleven of the sixteen predictors included in the model are found to have a significant effect on energy productivity.
The farm size, the stocking rate, the production form, the importance of para-agricultural activity on the farm, the capital intensity and a higher agricultural education have a positive effect on the dependent variable.
The predictors of agricultural production area, part-time farming, intensity of the use of concentrates, milk yield and silage-free milk production have a negative impact on energy productivity.

5.3. Determinants of the productivity of nitrogen use

The coefficient of determination of the model explaining the eco-efficiency of nitrogen use is equal to 0.63. Eight variables can be shown to have a significant effect on the nitrogen productivity of the farms investigated.

The variables of agricultural production area, farm size, organic farming, importance of para-agricultural activity and agricultural education are found to have a positive effect on the productivity of nitrogen use.

Three variables are found to have a negative impact on nitrogen productivity: presence of a farm's own aestivation activity, silage-free milk production, ecological orientation.

5.4. Classification of the determinants of economic and environmental performance

On the basis of the results of the multiple linear regression analyses performed previously, the independent variables are now grouped according to the classification scheme proposed in Section 2.1. The results are presented in Table 4 for the energy issue and in Table 5 for the nitrogen issue.

Table 4: Classification of the independent variables according to their simultaneous effect on work income per family work unit and productivity of fossil energy use

<table>
<tr><td colspan="3" rowspan="3"></td><th colspan="3">Work income per FWU</th></tr>
<tr><th colspan="2">Significant</th><th rowspan="2">Non-significant</th></tr>
<tr><th>+</th><th>-</th></tr>
<tr><th rowspan="3">Productivity of fossil energy demand</th><th rowspan="2">Significant</th><th>+</th><td>1 desirable positive synergy
size
organic</td><td>3 trade-off
stockrate</td><td>4 desirable unidimensional
paraagr
caplab
agreduc2</td></tr>
<tr><th>-</th><td>3 trade-off
cheese</td><td>2 undesirable negative synergy
parttime
concuse</td><td>5 undesirable, unidimensional
area
milkyield</td></tr>
<tr><th colspan="2">Non-significant</th><td>4 desirable, unidimensional</td><td>5 undesirable, unidimensional
age</td><td>6 not relevant
cullrate
stable, aestiv
ecolor
agreduc1</td></tr>
</table>

Source: Own representation

Table 5: Classification of the independent variables according to their simultaneous effect on work income per family work unit and productivity of nitrogen use

			Work income per FWU		
			Significant		**Non-significant**
			+	**-**	
Productivity of nitrogen use	**Significant**	**+**	① desirable, positive synergy **size** **organic**	③ trade-off	④ desirable, unidimensional **area** **paraagr** **agreduc1**
	Significant	**-**	③ trade-off **cheese**	② undesirable negative synergy	⑤ undesirable, unidimensional **aestiv** **ecolor**
	Non-significant		④ desirable, unidimensional	⑤ undesirable, unidimensional **parttime, stockrate** **concuse, age**	⑥ not relevant **milkyield** **cullrate** **stable** **agreduc2**

Source: Own representation

6. Discussion and Conclusions

In this section it is our intention first of all to summarize the main findings of the investigation carried out. In a second part we will discuss selected results and outline the limits of the approach and data used. Finally, the implications of the present study for all stakeholders involved (farmers, consultants and policy makers) will be extrapolated.

6.1. Main findings of the investigation

Overall, the data suggests the existence of several synergies and rather few trade-offs in the promotion of an economically viable and environmentally-friendly dairy sector in the Swiss mountain region and thus confirms the hypothesis formulated in section 2.3. Organic farming and an increase in farm size on the positive side, part-time farming and an increase in the intensity of the concentrates use on the negative side are the four variables that influence in the same direction both the economic and environmental performance of the farms studied. The two single farm characteristics that are shown as presenting a trade-off in terms of enhancement of the economic and environmental performance of the Swiss dairy sector in the mountain area are the production of silage-free milk destined for the manufacture of raw-milk cheese and the stocking rate. Silage-free milk production positively affects economic performance but negatively impacts on the two dimensions of environmental performance under consideration. The stocking rate negatively impacts on the work income per FWU but positively influences energy productivity

The other potential determinants of the economic and environmental performance of a farm that are taken into account in the regression analyses exhibit neither synergies nor trade-offs with respect to the improvement of farm economic and environmental performance. Most of them impact either on economic performance or environmental performance. A few have no effect either on the economic or on the environmental performance of a farm.

6.2. Discussion of the results and limits of the investigation

In the current section we shall be discussing selected results of the study and addressing its limits. Due to the fact that no similar study has been performed either in Switzerland or in comparable agricultural mountain regions within the European Union (such as the Austrian, French and German Alps), the results of our investigation cannot be compared with those derived from similar studies. As explained in section 3.4., we decided to perform the assessment at farm level because an economic and environmental performance assessment at product group level would have not been possible due to a lack of data. This choice has led us to consider a monetary output instead of a physical one as numerator for the calculation of the two environmental productivity indicators, since a monetary output enables us to solve the aggregation problem of the single outputs produced by a farm. This choice is, however, associated with two major drawbacks for the measurement of environmental performance.

First of all, we acknowledge by virtue of this choice that higher market prices for commodities generate an improvement in environmental performance. This presents a problem, as an environmental performance assessment is primarily interested in what we would call the «physical productivity» emanating from the use of environmental resources, i.e. in the physical quantity of resources used to produce a given physical quantity of output (for example, kilograms of milk). In this regard, the strongly positive effect of organic farming has to be to a certain extent relativised as it results mostly from the higher market prices organic farms obtain for their agricultural commodities compared to non-organic farms. In the sample investigated, the average price for organic milk was 11.1% higher than the average price for non-organic milk. If we were to consider this market price effect, then the positive effect of organic farming in environmental terms (+7.4% on energy productivity and +13.0% on nitrogen productivity) would remain very limited if not non-existent. Analogous considerations apply to the effect of the variable cheese on the two environmental performance indicators defined. The average milk price for farms producing silage-free milk is 7.4% higher than the average milk price for silage milk. If we were to take into account this higher market price, then the negative effect of the production of silage-free milk on energy and nitrogen productivity (respectively -5.2% and -4.0%) would become more marked.

The second problem leading on from the choice made to perform an assessment at farm level lies in the heterogeneity of the output composition. Even if all the farms analysed primarily produce milk, the output composition may vary significantly from farm to farm, albeit to a restricted extent. Since one precept of environmental performance assessment should be to «compare things that are comparable», carrying out the assessment at farm level might to a certain extent have brought about some bias in the results in terms of environmental performance due to the different output mix between the farms studied. This was the rationale which motivated us to introduce the variable «proportion of para-agricultural activities in the farm output» as a potential determinant for both environmental performance indicators. Indeed, compared to agricultural activities para-agricultural activities are more service- and less «manufacturing-» oriented. As the provision of services is less intensive in terms of consumption of environmental resources than the production of agricultural commodities, we expected the increase in the proportion of para-agricultural activities to be associated with better environmental productivity. Our expectations have been confirmed by the results of the regression analysis testifying to the positive effect of the variable «proportion of para-agricultural activities in total farm revenue» on both environmental performance indicators used.

We will now discuss two selected results that might at first glance appear somewhat counter-intuitive or not self-evident: the positive effect of the variable «agricultural production area» on nitrogen productivity and the negative effect of the predictor «ecological orientation» on nitrogen productivity.
One possible explanation for the positive effect of a location in mountain zones 3 and 4 in terms of nitrogen productivity may lie in the fact that dairy farms located in these zones make use almost exclusively of organic fertilizers, which may be more efficiently utilised than mineral fertilizers. Further investigations would however be required to verify the validity of this hypothesis.
The mechanisms behind the negative effect on nitrogen productivity of participating in governmental agri-environmental and ethological programmes could not be clearly elucidated. It may be assumed that the extensification brought about by participating in environmental programmes and the production restrictions associated with both environmental and ethological programmes could be responsible for the decrease in nitrogen productivity. This does not mean, however, that these programmes are entirely detrimental to the environment. Indeed, they probably promote other dimensions of environmental performance and especially the local one. For example, they could contribute to reducing the environmental impact generated at the level of the local ecosystem or to an improvement in biodiversity.
Above and beyond the limits mentioned previously, the following restrictions should be borne in mind when interpreting the results.
First of all, the environmental performance assessment carried out here only takes into account two environmental issues: the energy and nitrogen issues. Many other relevant environmental issues could not be considered for reasons of data availability (for example, soil erosion, biodiversity...).
Secondly, the assessment has only been performed from a global perspective, i.e. using the so-called product-based indicators. When performing an assessment of farm environmental performance both perspectives (global and local) should be taken into account to avoid an improvement of one dimension happening at the expense of the other. In the present case we were unfortunately not able to consider the local dimension for reasons of data availability. This restriction should be paid a particular attention especially as the positive impact of the stocking rate on the productivity of fossil energy use indicates that there could be a trade-off in the promotion of the local and global environmental

performance of a farm. Indeed, high stocking-rates are generally associated with an increased environmental pressure on the local ecosystem (refer for example to Monaghan et al. 2005).

Thirdly, a major restriction in terms of the accuracy of the assessment performed lies in the type of database used to perform the assessment. As previously mentioned, the investigation relies on accountancy data. The quantification of the use of environmental resources (fossil energy demand and nitrogen input) has been made on the basis of this data, thus making assumptions as regards the composition of inputs. Furthermore, due to a lack of data, some inputs could not be considered for the assessment of fossil energy demand.

Last but not least it should be remembered that the present study focuses on only two dimensions of farm sustainable performance, the social dimension not being addressed here. Even if one can argue that the indicator used to measure economic performance is also at the same time an indicator of social performance – the generation of a sufficient income for the farmer family is one of the basic requirements for a farm to be socially sustainable – we are aware that additional aspects of the social dimension of sustainability, such as the livelihood of the countryside, should also be taken into account if we aim at performing a holistic sustainable performance assessment.

6.3. Implications for stakeholders

In the present section, we will discuss the implications of our study for stakeholders. First of all, we must again stress that the results and conclusions of the present study should be considered with a certain degree of caution, due to the limitations of the environmental assessment performed both in terms of accuracy and number of issues examined. This study should therefore be considered as paving the way for further joint economic and environmental performance investigations at farm level.

The results of our investigation provide initial evidence that the promotion of an economically viable agricultural system as well as the enhancement of one which – from a global perspective – is environmentally friendly is not agonistic but highly synergetic. By increasing farm size, i.e. through economies of scale, by promoting full-time farming and therefore advising young farmers not to take on a farm if it can only be run as a part-time enterprise, and by highlighting the great relevance of an appropriate feeding system made up of rough

forage of high nutritional quality and of a low intensity of concentrate usage, major enhancements in terms of both economic and environmental performance could be achieved.
Only two variables present a trade-off in terms of the simultaneous promotion of economic and environmental performance: the production of silage-free milk intended for the fabrication of raw-milk cheese and the stocking rate. The fact that only two variables present a trade-off is good news. However, the fact that one of the variables for which this trade-off occurs is the variable «production of silage-free milk» is particularly unfavourable and challenging. Indeed, in the context of a possible future free trade agreement in the agricultural and food sector between Switzerland and the European Union, the Swiss Confederation aims to develop and implement a quality strategy for Swiss agriculture so that it can more easily compete with its European counterparts in the liberalized market which is likely to emerge in the future. The promotion of raw-milk cheese is part of this quality strategy. The policy-makers should therefore be aware at that stage that this could present a conflict in terms of economic and environmental performance, at least when environmental performance is considered from a global perspective.

Acknowledgements

The authors would like to thank two anonymous reviewers as well as the editor for their helpful and valuable suggestions and comments on the earlier version of this manuscript.

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