Total factor productivity change of Swiss dairy farms in the mountain region in the period 1999 to 2008

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Summary *– In the present contribution we assess the total factor productivity (TFP) change in the period 1999-2008 of Swiss dairy farms located in the mountain region using the Malmquist productivity index. We furthermore analyze the robustness of the results of this assessment to the effect of the type of panel used and to different modelling options regarding the inclusion of the ecological and ethological direct payments in the output set. The yearly TFP growth is shown to vary between +1.3% and +3.0% depending on the panel type and modelling option chosen. The results of our work suggest that the TFP growth rate of Swiss dairy farms in the mountain region is not lower than the levels observed in the dairy sector of other European countries. More generally, our investigation shows how sensitive the results of TFP change assessments are to data-related methodological choices and thus highlights the necessity of considering this issue when performing such assessments.*

Keywords*: Swiss dairy farming, mountain agriculture, Total Factor Productivity growth, Malmquist index, sensitivity analysis, agri-environmental direct payments*

Changement de la productivité totale des facteurs des exploitations laitières suisses en région de montagne sur la période 1999 à 2008

Résumé – Dans la présente contribution, nous quantifions le changement de la productivité totale des facteurs (PTF) des exploitations laitières suisses de la région de montagne sur la période 1999-2008 en utilisant l'indice de productivité de Malmquist. Nous analysons par ailleurs la robustesse des résultats de cette quantification à l'effet du type de panel utilisé et de différentes options de modélisation relatives à l'inclusion des paiements directs écologiques et éthologiques dans le set des outputs. La croissance annuelle de la PTF est montrée varier entre +1,3% et +3,0% selon le type de panel et l'option de modélisation choisis. Les résultats de notre travail suggèrent que le taux de croissance de la PTF des exploitations laitières suisses en région de montagne n'est pas inférieur aux niveaux observés dans le secteur laitier d'autres pays européens. D'une façon plus générale, notre étude montre combien les résultats de mesure du changement de la PTF sont sensibles aux choix méthodologiques associés aux données utilisées et souligne ainsi la nécessité de considérer ce problème lors de la conduite de telles analyses.

Mots-clés : production laitière suisse, agriculture de montagne, croissance de la Productivité Totale des Facteurs (PTF), indice de Malmquist, analyse de sensibilité, paiements directs agro-environnementaux

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1. Introduction

Swiss agriculture is characterized by the importance of its mountain agriculture. According to Swiss legislation on regional investment aid, the Swiss mountain area accounts for 66% of the Swiss national area (SAB, 2004). 34% of the Swiss mountain area is under agricultural use (SAB, 2004). This mountain agricultural production area represents in itself around 28% of the total agricultural production area of Switzerland (Stöcklin *et al.*, 2007). In 2008, 28% of Swiss farms were located in the mountain agricultural production area (FOAG, 2009), which includes mountain agricultural zones 2, 3 and 4 (FOAG, 2002) and which can be roughly defined as the agricultural production area located between 800 and 1500 meters above sea level. In 2007, 78% of the usable agricultural area of the mountain region [1] was cultivated by farms having a dairy production activity (Swiss Statistical Federal Office, Agricultural Census from the Swiss Federal Office for Agriculture).

Swiss dairy farms located in the mountain region are particularly important for the Swiss dairy sector as they account for one third of Swiss national milk production (Gazzarin *et al.*, 2007).

Furthermore these farms are of major relevance to the local economies of the remote regions they are located in and also play an important role for these regions in environmental terms. In cantons almost entirely mountainous, tourism represents an important economic sector. For example in the canton of Grisons, situated in the south-eastern part of Switzerland, or the canton of Valais, located in the south-western part of Switzerland, the proportion of GDP (Gross Domestic Product) coming directly or indirectly from tourism is equal to 30% and 25% respectively (Bühler and Minsch, 2004). Agriculture, and especially dairy farming, is indirectly of major relevance in economic terms for the local economies of these regions as it provides an important public good, the conservation of a mosaic rural landscape, which represents a crucial basis for the tourism activity on which the local economies of these peripheral mountain areas strongly rely. A general abandonment of agricultural land use leads to a loss of landscape heterogeneity and mosaic structure, which in turns represents a loss of unique cultural landscapes preserved by traditional agricultural cultivation forms (MacDonald *et al.*, 2000; Gellrich *et al.*, 2007).

Dairy farming is not only important for the local economies of these regions, but from an environmental perspective it also plays a crucial role in preventing natural hazards or negative spatial environmental externalities that would appear if abandonment of agricultural land was to occur (MacDonald *et al.*, 2000; Flury *et al.*, 2005). As

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[1] For the sake of conciseness we shall from now on use the term “mountain region” to refer to the mountain agricultural production area defined according to FOAG (2002).

shown by several investigations (refer for example to Poncet, 1971; Mössmer, 1985, Tasser *et al.*, 2005), agricultural land abandonment in mountain regions leads to a higher risk of landslides. Furthermore, unmown land resulting from agricultural land abandonment implies a higher risk of avalanches (Aulitzky, 1974; Tasser *et al.*, 2005). In addition, the abandonment of agricultural land use is also of major concern from an environmental perspective as it leads to natural forest re-growth, which is associated with a long term loss of habitats of high ecological value and thus biodiversity (Gellrich *et al.*, 2007).

Swiss dairy farming shows poor competitiveness in international comparison. The full costs of a typical dairy farm (20 cows) located in the hill region amounted to 1.73 CHF per kg milk in 2008 and thus exceeded the full costs of a similar typical German or Austrian farm by around 80% (Gazzarin, 2009 and Hemme *et al.*, 2009). The high general level of Swiss prices, especially the high level of prices for agricultural production factors (see for example Raaflaub and Genoni, 2005), and the general lower physical productivity of Swiss farms (refer for example to Schmid, 2009) are the two major factors accounting for this lower competitiveness. Since 1999 the Swiss agricultural sector has faced ongoing progressive liberalisation of its dairy market. In 2007, after a transition period of five years, the cheese trade between Switzerland and the European Union was fully liberalised as a consequence of the entry into force of bilateral agreements (Joerin *et al.*, 2006). Other dairy products such as liquid milk, cream or yoghurts were not covered by these bilateral agreements. Within the context of the ongoing economic integration between Switzerland and the European Union, a further market liberalisation has to be expected in the future. This probable further liberalisation is expected to put the Swiss dairy farms under pressure to increase their competitiveness.

There are two possibilities for a firm to improve its competitiveness (Oral *et al.*, 1999). It can either increase its TFP (Total Factor Productivity) growth more rapidly than the competitor or it can become a more cost effective purchaser of inputs, or both (Oral *et al.*, 1999). Even if a further liberalisation of the agricultural and food trade between Switzerland and the European Union were also probably to lead to a decrease in Swiss agricultural inputs prices, the Swiss dairy farms would however inevitably still have to drastically increase their physical productivity if they want to become competitive with their European counterparts on the liberalised dairy market.

This productivity increase is expected to be especially challenging for the dairy farms located in the mountain region as these farms show particularly low productivity due, amongst other things, to the difficult production conditions associated with their natural environment. There is therefore a growing concern about the future viability of dairy farming in the mountain region and especially about the ability of these farms to drastically increase their productivity in the event of a further liberalisation of the Swiss dairy market. It is especially feared that, in the absence of productivity growth possibilities, increasing market pressure on these farms might lead them to cease their agricultural production, which could lead to massive agricultural land use abandonment. This would then be associated with the negative spatial environmental externalities described previously.

The Swiss Confederation clearly stipulates that the Swiss agricultural sector should contribute by way of sustainable and market-orientated production to the secure provision of the population with food, to the conservation of natural resources, the upkeep of rural scenery and the decentralised inhabitation of the country (Swiss Federal Constitution, Article 104, S.R. 101). The policy-maker therefore has a strong interest in keeping dairy farming activity in the mountain region. In the context of probable further market liberalisation, the further supply of the positive externalities generated by these dairy farms can *ceteris paribus* only be guaranteed if these farms succeed in improving their productivity or if they are subsidised to remain in farming (e.g. subsidies for public good production).

Unfortunately no precise data on the recent productivity growth trends of these farms is available. In a previous study Ferjani (2006) used micro-data to measure the productivity growth of Swiss farms over the period 1990-2001. This study was not performed specifically for Swiss dairy farms in the mountain region.

More generally, from a data and methodological perspective, three major issues should be paid particular attention when performing a total factor productivity change assessment: (i) the sample or, more precisely, panel type, issue, (ii) the deflation issue and (iii) the direct payments issue. Regarding the sample on which a TFP change assessment is based, two types of panels may be used: balanced vs. unbalanced. Whereas a balanced panel has the advantage of providing data of better accuracy due to the possibility of checking the data consistency across time, the use of such a panel may be associated with some sample selection bias. The price correction (inflation or deflation correction) for outputs and inputs that are expressed in monetary terms is another central issue of any TFP change assessment as it might seriously affect the accuracy of the assessment. For that reason it should be carried out with special care. Last but not least, the issue of the consideration of direct payments in the productivity growth assessment should be addressed in detail. Since the fundamental reform of Swiss agricultural policy in 1992, support from a price and sales guarantee has been progressively shifted to direct payments (Joerin *et al.*, 2006). In addition, there has been a progressive "greening" of Swiss agricultural policy, an increasing part of the direct payments being allocated to the remuneration of ecological services provided by a farm voluntarily taking part in an agri-environmental scheme. As a consequence of this development, in any productivity change assessment a major emphasis should be placed on the inclusion and modelling of direct payments in the outputs. Furthermore, particular attention should be paid to how to deal with the increase in direct payment rates across time, as this increase very often results from the shift of government support from market support to direct payments.

The present article thus aims to assess the total factor productivity change of Swiss dairy farms located in the mountain region in the last decade and to decompose it into its components (technological change and change of technical efficiency). Particular attention is thereby paid to the methodological issues mentioned previously. The work especially focuses on the investigation of the robustness of the results of the TFP change assessment to the sample type used (balanced vs. unbalanced panel) as well as to different modelling options for the direct payments.

The rest of this paper is structured as follows. In section 2 we outline the method used to decompose total factor productivity change into its components. In section 3 we describe the data used and the six assessments carried out, paying particular attention (i) to the input/output set specification and especially to the consideration of the direct payments, (ii) to the description of the approach used for the deflation of monetary outputs and inputs and (iii) to the description of the two types of panel used. In section 4 the results of the six productivity growth assessments carried out are presented. Section 5 discusses the results of the investigation and their implications, draws conclusions and addresses the limits of the analysis performed.

2. Assessing TFP change

For the present investigation we shall use an input-orientated version of the Malmquist productivity index-based approach proposed by Färe *et al.* (1997)[2] to estimate and decompose the TFP change of the farms investigated. This approach makes use of the Malmquist TFP index originally proposed by Caves *et al.* (1982a; 1982b) and further developed by Färe *et al.* (1992, 1994a, 1994b). Following Färe *et al.* (1992), we estimate the distance functions that make up this index using the non-parametric Data Envelopment Analysis (DEA) approach originally developed by Charnes *et al.* (1978). We prefer a frontier approach over a non-frontier one as the assumption that the firms investigated are operating efficiently is particularly inappropriate in the present case. Within the frontier approaches we opt for the non-parametric DEA approach as it does not require any assumptions regarding the functional form of the production function and the distribution of the inefficiencies. Furthermore, the DEA approach is especially recommended if several input and/or output prices cannot be trusted to reveal the relative scarcity of resources and goods (Mußhoff *et al.*, 2009), which is very likely to be the case in the present study for both inputs (in particular land and labour) and outputs (in particular for the ecological services rendered by the farm to society).

2.1. The distance function notion

The input-based Malmquist productivity index relies on distance functions. The distance function concept was originally introduced by Shephard (1953). Before presenting in detail the way the Malmquist index is computed, it might be necessary to formally define the notion of distance function. For that purpose let us first of all define a technology set S as follows (Equation 1, based on Coelli *et al.*, 2005, p. 42).

$$S = \{(x, y) : x \text{ can produce } y\} \quad \text{(Eq. 1)}$$

with:

x a $N \times 1$ input vector of non-negative real numbers

y a $M \times 1$ output vector of non-negative real numbers

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[2] We opt for an input-based Malmquist index as the output of the farms investigated might be beyond the control of the farm manager due to the existence of raw milk quotas in the period under investigation.

The production technology defined by the set S may be equivalently defined using the input set L(y) representing the set of all input vectors, x, that can produce a given output vector y. The input set L(y) is defined as follows (Eq. 2, Coelli *et al.*, 2005, p. 43).

$$\mathrm{L}(y) = \{x : x \text{ can produce } y\} \quad \text{(Eq. 2)}$$

The input distance function involves the proportional contraction of the input vector given the output vector and can be defined as described in Eq. 3.

$$d(x, y) = \max\left\{\theta : \left(\frac{x}{\theta}\right) \in L(y)\right\} \quad \text{(Eq. 3)}$$

where θ is maximised and $\frac{x}{\theta}$ minimised. The distance input function is the reciprocal of the technical efficiency measure proposed by Farrell (1957).

2.2. Mathematical formulation of the input-oriented Malmquist index

The TFP change (TFPC) between period t and $t + 1$ using the input-oriented Malmquist index approach proposed by Färe *et al.* (1997)[3] is calculated as follows (Eq. 4 and Eq. 5).

$$\text{TFPC} = m^t(x^t, y^t, x^{t+1}, y^{t+1}) \quad \text{(Eq. 4)}$$

where:

$$m^t(x^t, y^t, x^{t+1}, y^{t+1}) = \frac{d^t_{\text{CRS}}(x^{t+1}, y^{t+1})}{d^t_{\text{CRS}}(x^t, y^t)} \quad \text{(Eq.5)}$$

with:

y^t the output vector in period t

y^{t+1} the output vector in period $t + 1$

x^t the input vector in period t

x^{t+1} the input vector in period $t + 1$

$m^t(x^t, y^t, x^{t+1}, y^{t+1})$ the input oriented Malmquist TFP index based on period t technology[4]

$d^t_{\text{CRS}}(x^t, y^t)$ the input distance function of the observation in period t in relation to the Constant Returns to Scale technology in period t

$d^t_{\text{CRS}}(x^{t+1}, y^{t+1})$ the input distance function of the observation in period $t + 1$ in relation to the Constant Returns to Scale technology in period t

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[3] The index proposed by Färe *et al.* (1997) originally adopts an output orientation. The formulae presented here have therefore been adapted for an input orientation.

[4] Note that, as outlined by Färe *et al.* (1997), by using period t technology as a reference against which to analyze performance, we adopt a backward-looking approach.

As is obvious from the formula introduced above, the input-orientated Malmquist productivity index defined here measures the TFP change as the relative input-orientated "move" of an observation between period *t* and period *t* + 1 in relation to a given technology frontier. This relative "move" is measured using period t technology. It is necessary to emphasize, as outlined by Boussemart *et al.* (2003), that values of the input-orientated Malmquist index below (above) unity reveal productivity growth (decline). This counterintuitive formulation results from the fact that the input-orientated Malmquist index was originally constructed exactly like the output-orientated Malmquist index. Due to the fact that the output distance function is equal to the Farrell output efficiency and that the input distance function is equal to the inverse of the Farrell input efficiency (Bjurek, 1996), the input-orientated Malmquist index thus has to be interpreted inversely to the output-orientated one[5].

2.3. Decomposition of the input-oriented Malmquist TFP index[6]

Following the approach proposed by Färe *et al.* (1997), the TFP change index is decomposed into Technical Efficiency Change (TEC) and Technical Change (TC) as formulated in equation 6.

$$\text{TFPC} = \text{TEC} \times \text{TC} \quad \text{(Eq. 6)}$$

where:

$$\text{TEC} = \frac{d_{\text{CRS}}^{t+1}(x^{t+1}, y^{t+1})}{d_{\text{CRS}}^{t}(x^{t}, y^{t})} \quad \text{(Eq. 7)}$$

$$\text{TC} = \frac{d_{\text{CRS}}^{t}(x^{t+1}, y^{t+1})}{d_{\text{CRS}}^{t+1}(x^{t+1}, y^{t+1})} \quad \text{(Eq. 8)}$$

with:

$d_{\text{CRS}}^{t+1}(x^{t+1}, y^{t+1})$ the input distance function of the observation in period *t* + 1 in relation to the Constant Returns to Scale technology in period *t* + 1

TEC (Technical Efficiency Change, Eq. 7) measures the change in the input-orientated measure of technical efficiency between period *t* and *t* + 1 and is also referred to as the "catch-up effect". It indicates how much closer (or further away) a farm moves to the CRS (Constant Returns to Scale) best-practice frontier between two successive time periods.

TC (Technical Change or Technological Change, Eq. 8) captures the shift in the frontier between period *t* and *t* + 1 measured at the period *t* + 1 observation. It shows whether the CRS best-practice frontier against which the firm is benchmarked is improving, stagnating or deteriorating.

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[5] Note that, for a more intuitive presentation, the productivity change rates presented in the section results have been converted so that a positive rate reflects productivity growth and a negative rate a decline in productivity.

[6] Based on Färe *et al.* (1992, 1997), Coelli *et al.* (2005) and Pantzios *et al.* (2011).

The Technical Efficiency Change (TEC) is for its part further decomposed into pure technical efficiency change (PTEC) and scale efficiency change (SEC) by introducing distance functions in relation to the VRS (Variable Returns to Scale) technology as proposed by Färe *et al.* (1994b) and as described in equation 9.

$$\mathrm{TEC} = \mathrm{PTEC} \times \mathrm{SEC} \quad (\mathrm{Eq.}\,9)$$

where:

$$\mathrm{PTEC} = \frac{d_{\mathrm{VRS}}^{t+1}(x^{t+1}, y^{t+1})}{d_{\mathrm{VRS}}^{t}(x^{t}, y^{t})} \quad (\mathrm{Eq.}\,10)$$

$$\mathrm{SEC} = \frac{d_{\mathrm{CRS}}^{t+1}(x^{t+1}, y^{t+1}) \big/ d_{\mathrm{VRS}}^{t+1}(x^{t+1}, y^{t+1})}{d_{\mathrm{CRS}}^{t}(x^{t}, y^{t}) \big/ d_{\mathrm{VRS}}^{t}(x^{t}, y^{t})} \quad (\mathrm{Eq.}\,11)$$

The Pure Technical Efficiency Change (Eq. 10) measures the change in the input-orientated measure of pure technical efficiency between period t and $t + 1$. It reflects how much closer (or further away) a firm gets to its peers on the VRS frontier ("best practice" firms of similar size) between period t and $t + 1$. PTEC results from changes in management practices.

In equation 11, the quotient of the two ratios measures the Scale Efficiency Change (SEC) between period t and $t + 1$. Scale efficiency is defined here as the ratio of the distance function relative to the CRS technology to the distance function relative to the VRS technology. The scale efficiency change represents the productivity gain due solely to modification of the scale of operation of the firm investigated. It indicates how much closer (or further away) a firm gets to the most productive scale size.

Following the approach developed by Färe *et al.* (1997), the technical change (Eq. 8) is further decomposed into a magnitude index (TCM) and a bias index (B) as expressed in equation 12.

$$\mathrm{TC} = \mathrm{TCM} \times \mathrm{B} \quad (\mathrm{Eq.}\,12)$$

where [7]:

$$\mathrm{TCM} = \frac{d_{\mathrm{CRS}}^{t}(x^{t}, y^{t})}{d_{\mathrm{CRS}}^{t+1}(x^{t}, y^{t})} \quad (\mathrm{Eq.}\,13)$$

The magnitude index (TCM) (Eq. 13) measures the shift in the frontier between period t and $t + 1$ measured at the period t observation. The bias index (B) (Eq. 12)

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[7] Based on Färe *et al.* (1997) and Pantzios *et al.* (2011). Please remember here that the input-orientated Malmquist index originally proposed by Färe *et al.* (1992) was constructed exactly like the output-orientated Malmquist index (for further details on this issue and on the interpretation of the index, refer to section 2.2.). This explains why our formulation differs from the one met in other contributions, such as Färe *et al.* (1997) or Pantzios *et al.* (2011), who have adapted the original formulation of the input-orientated Malmquist index proposed by Färe *et al.* (1992) to make its interpretation more intuitive.

compares the magnitude of technical change measured for the observation at $t + 1$ to the magnitude of the technical change measured for the observation at t. As explained by Färe *et al.* (1997), the "*bias index {equals 1 and thus} makes no contribution to productivity change if the magnitude of technical change is the same when measured along the two rays*". If the amplitude of technical change measured along a ray through period $t + 1$ data is higher (lower) than the height of technical change assessed along a ray through period t data, then the bias index makes a positive (negative) contribution to productivity change.

The bias index can be further decomposed as the product of an output bias index (OB) and an input bias index (IB) as formulated in equation 14.

$$\mathrm{B} = \mathrm{OB} \times \mathrm{IB} \quad (\text{Eq. } 14)$$

where:

$$\mathrm{OB}(y^t, x^{t+1}, y^{t+1}) = \frac{d^t_{\mathrm{CRS}}(x^{t+1}, y^{t+1})}{d^{t+1}_{\mathrm{CRS}}(x^{t+1}, y^{t+1})} \Bigg/ \frac{d^t_{\mathrm{CRS}}(x^{t+1}, y^t)}{d^{t+1}_{\mathrm{CRS}}(x^{t+1}, y^t)} \quad (\text{Eq. } 15)$$

$$\mathrm{IB}(x^t, y^t, x^{t+1}) = \frac{d^t_{\mathrm{CRS}}(x^{t+1}, y^t)}{d^{t+1}_{\mathrm{CRS}}(x^{t+1}, y^t)} \Bigg/ \frac{d^t_{\mathrm{CRS}}(x^t, y^t)}{d^{t+1}_{\mathrm{CRS}}(x^t, y^t)} \quad (\text{Eq. } 16)$$

The output bias index (OB, Eq. 15) involves the input vector from period $t + 1$ and the output vectors from periods t and $t + 1$. Keeping the input vector constant at x^{t+1}, it measures the ratio between the magnitude of the technical change along a ray through y^{t+1} and the magnitude of the technical change along a ray through y^t. The input bias index (IB, Eq. 16) encompasses the input vectors from periods t and $t + 1$ and the output vector from period t. Holding the output vector constant at y^t, it compares the magnitude of the technical change along a ray through x^{t+1} to the technical change along a ray through x^t.

The output (input) bias index makes no contribution to productivity change if one of the two following conditions is met:

(i) temporal constancy of the output (input) mix implying that any bias that may exist has no opportunity to contribute to productivity change

(ii) absence of bias, i.e. presence of an output- (input-) neutral technical change.

2.4. Estimation of the distance functions using Data Envelopment Analysis

As is obvious from the formulae presented in the previous section, to measure and decompose the TFP change of the i-th firm (i = 1, ..., I) between two periods using the input based Malmquist index approach, we have to estimate 8 distance functions. For the present investigation these distance functions are estimated using DEA-like linear programs following Färe *et al.* (1992, 1994a, 1994b) as illustrated below (Eq. 17) for the distance function $d^{t+1}_{\mathrm{CRS}}(x_i^{t+1}, y_i^{t+1})$.

$$\left[d_{\text{CRS}}^{t+1}(x_i^{t+1},y_i^{t+1})\right]^{-1}=\min_{\theta,\lambda}\theta \quad \text{(Eq. 17)}$$

$$\begin{aligned} s.t. \quad & -y_i^{t+1}+Y^{t+1}\lambda \ge 0 \\ & \theta x_i^{t+1}-X^{t+1}\lambda \ge 0 \\ & \lambda \ge 0 \end{aligned}$$

with:

X^{t+1} is a N × I matrix representing the N inputs of all I observations for period $t + 1$

Y^{t+1} is a M × I matrix representing the M outputs of all I observations for period $t + 1$

λ being a I × 1 vector of constants representing the weights associated with each firm. If the weight is different from zero, then it means that the firm associated with this weight is used as peer for the assessment of the efficiency of firm *i*. A peer is a best-practice firm, i.e. a firm located on the production frontier. The projected point on the production frontier against which firm i is benchmarked is a linear combination of real "best-practice" firms, where λ represents the weight of each "best-practice" firm in this linear combination.

The present study uses the DEAP program developed by Coelli (1996) to estimate these distance functions and to assess the TFP change and its components of the farms investigated.

3. Data

3.1. Data source and entities analysed

The data on which the present investigation relies originate from the Swiss Farm Accountancy Data Network (FADN), which is managed by the Farm Economics Research Group of the Swiss Federal Research Station Agroscope Reckenholz-Tänikon ART. A specialised dairy farm is defined according to the farm typology of the Swiss Farm Accountancy Data Network. To be qualified as a dairy farm, a farm has to meet the following criteria (Roesch and Hausheer Schnider, 2009):

- the proportion of open arable area in the total usable agricultural area is below 25% ;
- the proportion of special crops (vineyard, market gardening, tobacco...) in the total usable agricultural area is below 25% ;
- the proportion of cattle in the total livestock units of the farm is higher than 75% ;
- the proportion of cows in the cattle livestock units is higher than 25% ;
- the proportion of suckler cows in the cattle livestock units is below 25%.

The data available relate to the period 1999 to 2008. In 2002 there were changes in the Swiss FADN method for the assessment of some accountancy variables that are of high relevance for the estimation of total factor productivity change. This has led to a data discontinuity that could not be corrected for. As a consequence, we decide not to consider the data of that year for the present TFP change assessment, i.e. we choose not to assess the productivity change between 2001 and 2002 on the one hand, and 2002 and 2003 on the other, as the method for the assessment of some FADN variables is not entirely comparable between these successive years[8]. The present work thus relies on two time spans: 1999-2001 and 2003-2008.

3.2. General specification of the output set

The output set is made up of three aggregate outputs, the output coming from agricultural activities, the output coming from para-agricultural activities and the environmental services produced by the farm, all expressed in Swiss Francs.

Output from agricultural activities

The output coming from agricultural activities includes the agricultural commodities produced by the farm. The agricultural commodities produced by the farm encompass both the outputs from animal production and plant production activities.

Output from para-agricultural and other activities

The aggregate output coming from para-agricultural activities is made up of three components: the output from para-agricultural activities, the profits from assets and any other miscellaneous outputs. Extraordinary profits and profits originating from the sale of non-activated milk quota are excluded from the output as they cannot be considered as outputs from regular farm activity. It is all the more necessary to exclude these output positions as, when they are not equal to zero, their value is extremely high, which would inevitably bias the results of the productivity change assessment.

Agri-environmental direct payments

The environmental services provided by the farm to society are those remunerated by ecological and ethological direct payments and by the direct payments for farming on steep slopes. Before motivating the inclusion of these direct payments in the output set, we shall give a brief overview of the Swiss agricultural direct payments system.

The Swiss agricultural direct payments system consists of two types of direct payments: general direct payments and agri-environmental direct payments (these latter being also called ecological and ethological direct payments). According to the Swiss Federal Office for Agriculture (FOAG, 2009) general direct payments "remunerate services provided by agriculture for the common good" and include the following payments based either on acreage or on number of livestock[9]: area payments, payments for holding roughage-consuming animals, payments for holding livestock under difficult conditions, payments for farming on steep slopes. The agri-environmental direct

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[8] The relative change in these variables due to methodological changes might be quite substantial. Due to the fact that TFP change assessment deals with very small relative changes, it is necessary to exclude the year 2002 from the assessment.

[9] Only the direct payments relevant to dairy farming are introduced here.

payments for their part remunerate concrete particular environmental services voluntarily provided by the farm to society, these services going far beyond the Swiss cross-compliance requirements[10] for the receipt of agricultural direct payments (FOAG, 2009). The environmental services compensated through ecological direct payments are of two types: they can consist either in a reduction of the environmental effects of agriculture and thus in protection of the soil, aquatic and atmospheric ecosystems (pollution reduction and protection of natural resources) or in the conservation of traditional landscapes. The Swiss agri-environmental direct payments scheme encompasses the following elements: payments for ecological compensation, payments for extensive cultivation, payments for organic farming, and payments for animal welfare measures. These direct payments are attributed only to farms voluntarily providing these additional environmental services, the provision of these services being controlled by the Swiss federal administration.

Within the scope of productivity change assessment, the question of the inclusion of direct payments in the outputs is of major relevance. A short review of the historical background of the emergence of direct payments in agriculture might be useful in determining the direct payments to be included in the productivity analysis. In the Swiss case, as is the case in the European Union, general direct payments originate in large part from a transfer of government support for agriculture from price and market support to farm income support. Against the background of the international negotiations on the liberalisation of trade[11], this transfer aimed to redirect agricultural support towards support forms having a more neutral effect on production and thus a lower trade-distorting effect, i.e. to shift this support from the amber box to the blue box and green box. Most of the actual direct payments paid to European farms were thus originally not tailored to the purpose of remunerating concrete environmental services provided on a voluntary basis by farms to society, but are a kind of historical residual of agricultural market support now aimed at remunerating the non-commodity outputs of the agricultural sector (such as landscape conservation or contribution to the vitality of rural communities), these outputs being jointly produced with the agricultural commodities to a greater or lesser degree of jointness.

The question of the inclusion of direct payments in the output set for the productivity change assessment refers to the more general question of the choice of non-commodity outputs to be included in the output set. For the present investigation we shall take into account only non-commodity outputs that require an additional input usage in comparison with the sole act of production of agricultural commodities. For that reason we shall consider only the agri-environmental services provided in addition to the basic non-commodity agricultural outputs jointly produced with agricultural commodities. We shall specifically include ecological and ethological direct payments in the output set. Contrariwise, all general direct payments, with the exception of direct

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[10] The Swiss cross-compliance requirements for eligibility for the receipt of direct payments are called "Proof of Ecological Performance" (PEP).

[11] Negotiations within the framework of the General Agreement on Tariffs and Trade (GATT), of the Uruguay Round, and since 1995, under the aegis of the World Trade Organisation (WTO).

payments for farming on steep slopes, shall be excluded from the output set, as these direct payments remunerate services which can be considered more or less as a simple by-product of the agricultural activity provided by all the farms investigated.

3.3. General specification of the input set

The input set is made up of four inputs: intermediate consumptions in Swiss Francs, capital costs in Swiss Francs, farm land area in ha and labour force in annual work units (AWU).

The farm area in ha is made up of the usable agricultural area (UAA) in ha and the agricultural area outside the UAA. The labour force measured in AWU includes both the hired labor force and the non-hired family labor force. One annual work unit corresponds to a person working full-time on the farm, a full-time occupation being thereby defined as 280 days of 10 hours work per year. Should a person work more than 2800 hours per year on the farm, then the additional working hours in excess of 2800 are not considered in the calculation to avoid a person accounting for more than one AWU. The capital costs are calculated as the sum of depreciation of fixed assets, interest on debts and on equity capital and rents (rents for land excluded). The use of capital costs instead of capital stock as an input variable is motivated by the fact that the first variable enables us to also take into account the capital costs of the farms whose buildings and machinery are rent/leased, whereas the second variable does not. If we had used the capital stock, then we would have omitted the capital input (in the form of buildings and machinery rents) of this type of farm. We are aware that the use of capital costs for a TFP change assessment may, depending on the type of accountancy data used, be inappropriate due to the fact that these costs are strongly dependent on the depreciation rates and interests rates. However, in the present case we do not have these problems owing to the fact that our FADN data do not come from financial accounting but from analytic accounting, which is done specifically for the Swiss FADN according to very strict rules/standards. These rules/standards are very comprehensive and pertain also to the depreciation rates of the assets. Contrary to financial accounting, where the depreciation rates are very often driven by the strategy of the farm regarding income taxation, in the case of analytic accountancy by the Swiss FADN such an adaptation is not possible. Regarding the interest rates, the very detailed price deflation we have performed (see section 3.4.) corrects for any increase or decrease in the interest rates across time.

When specifying the inputs, particular attention is paid to the avoidance of redundancy, especially with regard to land input. Indeed if one considers land as a separate input, then one should not forget to exclude the capital costs for land from the "capital costs" input to avoid any double-counting. Beyond the double counting issue, we take scrupulous care to ensure that the input set specified is consistent with the accountancy system boundaries. This has led us to consider the farm land area in ha instead of the usable agricultural area in ha as input. Indeed, the accountancy data on which the present investigation is based encompass the economic outputs and inputs associated with the use of the whole farm land area and not only of the usable agricultural area.

3.4. Outputs and inputs deflation

Method of deflation

Performing a productivity change analysis across time requires the creation of a quantity index [12] for each farm for each aggregate output and input that is expressed in monetary terms. This is done using the indirect method, which consists in deflating the monetary value of revenues and costs with corresponding price indices. In the present investigation, the price indices used originate from official Swiss agricultural statistics (SBV, 2000-2009). Deflation is performed at the level of each single position that makes up each aggregate output and input (i.e. at single revenues and costs positions) to ensure that the quantity index obtained reflects the reality as accurately as possible. Indeed a deflation performed at aggregate output or input level using aggregate price indices of the official Swiss agricultural statistics would inevitably have been inaccurate for the reasons exposed subsequently.

Any aggregate price index involves a weighting system for the aggregation of the price index of each single output or input that makes up this aggregate output or input. This weighting system is based on the quantitative composition of the aggregate output or input, i.e. on the quantitative importance of each output or input that makes it up. In the case of aggregate price indexes of official national statistics, the weighting system is based on the composition observed at national (macro) level. This latter will inevitably differ from the composition observed for a single farm of a particular farm type and region as illustrated in the subsequent example. We shall now consider the aggregate output "animal production". In the price index of the official Swiss Statistics for 2008 (SBV, 2009), the weighting of the single output "milk" in the aggregate output "animal production" is equal to 49%. In the sample of farms analysed within the present investigation, the weighting of milk in the aggregate output "animal production" amounts on average to 70% and varies between 46% and 97%. This example clearly demonstrates that performing deflation at aggregate output or input level using national aggregate price indexes is inappropriate for a farm-level investigation. In that case deflation should be done at the level of each single output or input position that makes up this aggregate output or input.

The direct payments deflation issue

As the output associated with the agri-environmental services voluntarily provided by the farm to society is measured by the amount of agri-environmental direct payments [13] received by the farm, the question of the deflation of this monetary output variable arises. Before choosing any price index, we should first of all conceptually analyse the price changes that should be corrected for and those that should not be. In the case of direct payments the nature of price changes can be of two types. An increase in the rate of a direct payment can either result from an increase in the environmental services

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[12] The quantity index created is often referred to as aggregate output or input at constant prices.

[13] In the present investigation the agri-environmental direct payments comprise the ecological and ethological direct payments and the direct payments for farming on steep slopes.

provided by the farm[14] (type 1) or can be motivated by a logic of inflation compensation or shift of government support from price support to income support (type 2). For the present investigation we should only correct for the second type of price change, as the first type reflects a real increase in the quantitative output produced by the farm. In concrete terms this implies that for each direct payment considered in the output, any increase in the direct payment rate not associated with an increase in the environmental services provided by the farm has to be corrected for. For that purpose, for each direct payment we have analysed in detail the evolution of its rate since 1999 using official documentation of the Swiss Federal Office for Agriculture and have developed a price index (direct payment deflator) to correct for type 2 price changes.

3.5. Description of the six assessments carried out

As mentioned in the introduction, two major data-related methodological choices may substantially affect the results of the TFP change assessment – the type of panel used (balanced vs. unbalanced panel) and the modelling of the direct payments in the output set. This calls for a sensitivity analysis aiming at testing the robustness of the results of the TFP change to these choices. In the following two sub-sections we address the two issues of panel type and direct payments modelling. In the third subsection we specify the six assessments carried out within the sensitivity analysis.

The sample issue: balanced vs. unbalanced panel

Basically, any TFP change assessment can be carried out on the basis of either balanced or unbalanced panel data. In the present case the use of a balanced panel may be preferable to the use of a non-balanced one for data accuracy reasons. Indeed, Swiss FADN sample is, like most FADN samples of European countries, not based on a random sampling procedure. As a consequence, the change in sample composition from year to year might have a substantial effect on the evolution of a variable between these two years. In the Swiss case this problem has been addressed in detail by Roesch (2011) and in the official reports referring to the accounting year 2009 (Schmid and Roesch, 2010; Dux and Schmid, 2010). The effect of the sample composition change on key economic variables, such as the work-income per family work unit, has been precisely quantified and it has turned out that for some layers this effect was quite substantial. For investigating economic developments across time, therefore, the use of a balanced panel is highly recommended despite its associated risk of sample selection bias. Using a balanced panel for a productivity change assessment makes all the more sense as, compared to an unbalanced panel, it enables a more precise check of the consistency of the outputs and inputs variables (and more particularly of the physical input variables) by analyzing their evolution from year to year. In the presence of an inconsistency, a correction can be made, or if a correction is not possible, the corresponding observation can be excluded from the sample. This should contribute to a substantial improvement of the TFP change estimation accuracy. However, as already

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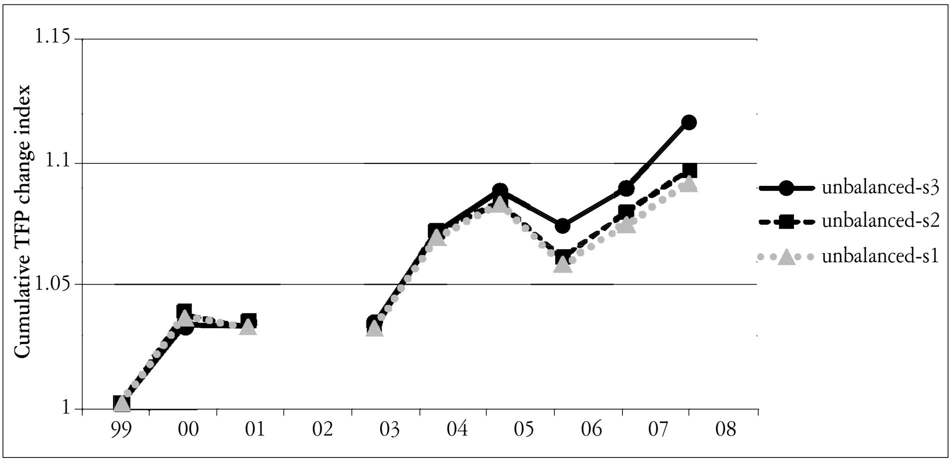
[14] i.e. from an increase in the environmental requirements to be complied with for the perception of this direct payment.

mentioned previously, the use of a balanced panel may lead to some sample selection bias. Depending on its magnitude, this problem may in turn question the appropriateness of the use of a balanced panel and argue for the use of an unbalanced one. For those reasons, the effect of the panel type (balanced vs. unbalanced) on the outcome of the TFP change assessment should be analyzed within a sensitivity analysis.

Figure 1. **Average cumulative index of TFP change (base year 1999) for the assessments relying on the unbalanced panel**



Source: Swiss FADN, unbalanced panel of dairy farms in the mountain region, years 1999 to 2008 (2002 excluded), own calculations

Nota bene: the TFP change between 2001 and 2003 has not been assessed (for further details on this issue, refer to section 3.1)

Legend: unbalanced-s3: unbalanced panel, output specification 3; unbalanced-s2: unbalanced panel, output specification 2; unbalanced-s1: unbalanced panel, output specification 1.

The number of observations available for each panel type is shown in table 1. Whereas the balanced panel is made up of 118 dairy farms observed over the whole period 1999-2008, the unbalanced panel comprises between 479 and 341 individuals, depending on the two year period considered.

Table 1. **Number of observations in the balanced and unbalanced panel from the Swiss FADN**

Time period	1999/ 2000	2000/ 2001	2003/ 2004	2004/ 2005	2005/ 2006	2006/ 2007	2007/ 2008
Balanced panel				118			
Unbalanced panel	479	435	341	380	369	391	416

Modelling options for the agri-environmental direct payments

Beyond the question of the direct payments to be included in the output set, which has been dealt with in section 3.2., the issue of how to model the direct payments as output arises. In any analysis conducted in the field of productivity measurement, it is important to control for output heterogeneity when defining the output set to make sure of comparing "like with like" within the benchmarking process. Whereas the definition of two separate outputs – agricultural output and para-agricultural output – seems quite straightforward, there may be different views on how to model the direct payments in the output set. While the fact that these direct payments are closely related to the agricultural activity may argue for their inclusion in the agricultural output, their service-orientated nature may advocate for including them in the para-agricultural output or modelling them as a separate output. The effect of these different modelling options on the outcome of the TFP change is the object of one part of the sensitivity analysis presented in the subsequent section.

Specification of the six assessments carried out

The specification of the six assessments carried out within the sensitivity analysis (an assessment being conducted for each possible combination panel type/output specification) is shown in table 2.

Table 2. **Description of the six simulations carried out**

Panel type	Output set specification
Balanced	Specification 1: two outputs Output 1: agricultural output + direct payments Output 2: para-agricultural output
Balanced	Specification 2: two outputs Output 1: agricultural output Output 2: para-agricultural output + direct payments
Balanced	Specification 3: three outputs Output 1: agricultural output Output 2: para-agricultural output Output 3: direct payments
Unbalanced	Specification 1: two outputs Output 1: agricultural output + direct payments Output 2: para-agricultural output
Unbalanced	Specification 2: two outputs Output 1: agricultural output Output 2: para-agricultural output + direct payments
Unbalanced	Specification 3: three outputs Output 1: agricultural output Output 2: para-agricultural output Output 3: direct payments

4. Results

The average annual rate of total factor productivity change (TFPC) and of its components – technical change (TC) (further decomposed into hicks-neutral technical change (TCM), output-biased technical change (OB) and input-biased technical change (IB)) and technical efficiency change (TEC) (further decomposed into scale efficiency change (SEC) and pure technical efficiency change (PTEC)) – for the six assessments carried out are presented in table 3. Before going into detail on the results, a reminder is necessary here that the data for 2002 could not be considered in this investigation (for further details on this issue, refer to section 3.1). As a consequence the TFP change between 2001 and 2002 on the one hand, and 2002 and 2003 on the other hand, has not been assessed.

Table 3. **Annual average rate of the TFP change and of its components**

Simulation	TFPC	TC	TCM	OB	IB	TEC	PTEC	SEC
Balanced panel Output specification 1	+2.0	+1.9	+0.1	+0.6	+1.3	0.0	0.0	+0.1
Balanced panel Output specification 2	+2.1	+2.0	+0.1	+0.5	+1.3	+0.1	0.0	0.0
Balanced panel Output specification 3	+3.0	+2.9	–1.0	+1.6	+2.3	+0.1	+0.1	0.0
Unbalanced panel Output specification 1	+1.3	–0.6	–1.8	+0.3	+0.9	+1.9	+1.2	+0.7
Unbalanced panel Output specification 2	+1.3	–0.3	–1.5	+0.3	+0.9	+1.6	+1.1	+0.5
Unbalanced panel Output specification 3	+1.6	–0.4	–2.3	+0.6	+1.4	+2.0	+1.4	+0.6

Source: Swiss FADN, data of dairy farms in the mountain region, years 1999 to 2008 (2002 excluded), own calculations

The average total factor productivity change of Swiss dairy farms in the mountain region varies between +1.3% and +3.0% per year depending on the type of panel used and on the option chosen regarding the modelling of the direct payments.

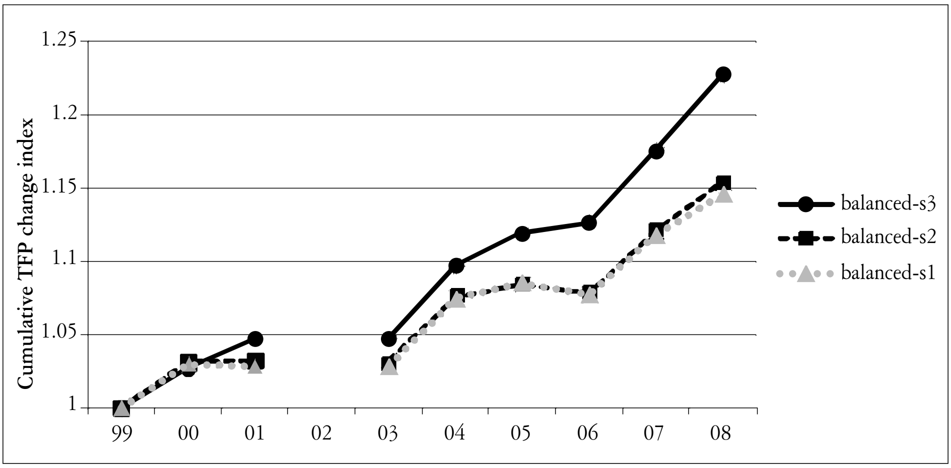
The type of sample used (balanced vs. unbalanced panel) substantially impacts on the outcome of the TFP change assessment and, more precisely, on both the absolute height of the TFP growth and its sources. TFP change assessments relying on the balanced panel of farms lead to a higher productivity growth compared to assessments relying on the unbalanced panel (between +2.0 and +3.0% per year vs. between +1.3 and +1.6% per year). Furthermore, whereas in the assessments based on the balanced panel the productivity growth is entirely attributable to technical change, in those performed using unbalanced panel data, this growth is exclusively due to an improvement in technical efficiency.

In the case of the assessments relying on the balanced panel, the technical change is not hicks-neutral and emerges from both an input-biased and output-biased technical change, which amount respectively to between +1.3 and +2.3% and between +0.6 and +1.6% per year. The fact that the technical efficiency remains constant when using the balanced panel is due to the fact that the two components of technical efficiency – pure technical efficiency and scale efficiency – remain constant across time.

The improvement in technical efficiency observed for the assessments performed using unbalanced panel data is ascribable firstly to an increase in pure technical efficiency (between +1.1 and +1.4% per year) and secondly to a rise in scale efficiency (between +0.5 and +0.7% per year). Part of the substantial gain in technical efficiency is however annihilated by a productivity decline due to technical regress (between –0.3 and –0.6% per year). This technical regress results from a strong hicks-neutral technical regress (between –1.8 and –2.3% per annum) partially compensated, however, by input- and output-biased technical progress (respectively between +0.9 and +1.4% and +0.3 and +0.6% per year).

The option chosen for modelling the direct payments in the output set also affects the outcome of the TFP change assessment, however to a lesser extent than the type of sample used. Whereas the outcome of the TFP change assessment is almost similar whether the direct payments are included in the agricultural output or in the para-agricultural output, modelling the direct payments as a separate output leads to higher productivity growth compared with the two previous modelling options. This is especially true for the assessment performed on the basis of the balanced panel. Indeed, for this type of panel, modelling the direct payments as a separate output is associated with a higher output-biased and input-biased technical change (+1% for each component) and a lower hicks-neutral technical change (–1%) compared to output specifications 1 and 2.

Figure 2. **Average cumulative index of TFP change (base year 1999) for the assessments relying on the balanced panel**



Source: Swiss FADN, balanced panel of dairy farms in the mountain region, years 1999 to 2008 (2002 excluded), own calculations

Nota bene: the TFP change between 2001 and 2003 has not been assessed (for further details on this issue, refer to section 3.1)

Legend: balanced-s3: balanced panel, output specification 3; balanced-s2: balanced panel, output specification 2; balanced-s1: balanced panel, output specification 1.

As it is obvious from figures 1 and 2, the total factor productivity change is subject to fluctuations over the period under investigation. Quite interestingly, even if the rate of total factor productivity change substantially varies between the six simulations carried out, the pattern of the productivity change direction across time is quite similar between the simulations. In this regard four main periods can be distinguished. In the period 1999-2001 TFP increases in the first year and then stagnates or even decreases in the second one. Between 2003 and 2005 substantial productivity growth can be observed for all simulations. Subsequently a decline or stagnation of TFP is experienced between 2005 and 2006 for all simulations. In the last period from 2006 to 2008 the TFP of the farms investigated registers considerable growth.

5. Discussion and conclusions

In the present section we shall in a first part summarize and discuss the main findings of the TFP change assessment. In a second part we shall discuss the average TFP growth performance of the Swiss dairy sector in the mountain region in an international comparison in the context of a possible further liberalisation of the Swiss dairy market. Finally, in part 3, the limits of the present investigation are addressed and the outlook for future research work discussed.

5.1. Summary and discussion of the main findings of the TFPC assessment

The present work assesses the total factor productivity change of Swiss dairy farms in the mountain region in the period 1999 to 2008 and tests the robustness of the results of this assessment to different data-related methodological choices regarding (i) the type of sample used (balanced vs. unbalanced) and (ii) the modelling option chosen for the direct payments.

As there is no compelling argument either in favor of one of the two types of panel used or in favor of one of the three output specifications tested, it is not possible to give preference to one of the six assessments over the others (i.e. to consider one assessment more reliable than the others). In lieu thereof, we prefer to draw conclusions taking into account the uncertainty in terms of TFP change assessment results that arises from the different possible data-related methodological options. The yearly TFP growth is shown to vary between +1.3% and +3.0% depending on the methodological options chosen. With respect to the source of productivity growth, no homogeneous trend emerges across all simulations. Whereas in investigations based on balanced panel data, productivity growth seems to be driven by technical change, in those relying on unbalanced panel data technical efficiency improvement is the main driver of productivity growth. A result which is constant across all simulations is that if technical change occurs, it is not entirely hicks-neutral but also results from output-biased and input-biased technical change. This indicates thus that technical change is associated with a particular production structure both on the output and input side. Additional analyses would be necessary to identify the detailed patterns of the output- and input-biased technical change with respect to each output and input.

The value added of the present work is threefold. First, it addresses the issue of the inclusion of agri-environmental services voluntarily provided by farms to society and remunerated through direct payments in a total factor productivity change assessment. Until now, to our knowledge, despite the omnipresence of the multifunctionality issue in the field of agricultural economics, very little attention has been paid to the consideration of this question in productivity change assessments. Secondly, the present contribution shows that the rate of total factor productivity change and the sources of this change are highly contingent on the data-related methodological choices made. It provides thus the evidence of the necessity of accounting for the uncertainty arising from these choices when performing TFP change assessments. Providing results based on a sensitivity analysis considering the different possible options regarding data-related methodological issues seems definitely more appropriate than providing TFP change figures based on a single assessment. Thirdly, the sensitivity analysis performed here gives the evidence that there has been productivity growth in Swiss dairy farming in the mountain region in the decade 1999 to 2008. Even if there exist uncertainties on the exact magnitude of this growth, we can ascertain that it amounts to between +1% and +3% per year. The present study cannot, however, answer the question of whether this growth is due to technical progress or to an improvement in technical efficiency.

5.2. Average TFP growth of the Swiss dairy sector in the mountain region by international comparison

As there are no similar studies for dairy farms located in European alpine regions such as the German, Austrian or French Alps, it is impossible to compare the TFP growth of the Swiss dairy farms in the mountain region with that of farms operating under similar natural production conditions. More generally, comparisons with other studies assessing total factor productivity change in agriculture have to be made cautiously, as the periods under investigation and the specification of input and output sets differ significantly between studies. Furthermore, when performing comparisons with other European countries, the fact that the Swiss dairy farms are operating under a different agricultural policy framework should be kept in mind as it might impact productivity change. Despite these challenges we shall, however, venture to attempt to compare this performance with results found in the literature for the total world and European agricultural sectors, and especially the European dairy sector.

The TFP change of the farms investigated is similar to the +2.1% average yearly TFP growth rate of the top 93 world agricultural producers (countries)[15] reported by Coelli and Rao (2005) for the period 1980-2000. Even if such a comparison might at first glance not make much sense, as the productivity growth rate of agriculture in developed countries is inevitably going to differ from the one observed in developing countries, this comparison does, however, give a first indication of the evolution of the competitiveness of the sector analyzed. In the present case this comparison indicates that the relative competitiveness of the Swiss dairy sector located in the mountain region has remained quite constant in international comparison.

If we restrict the comparison to the European agricultural sector, then the TFP growth performance of the Swiss dairy farms in the mountain region, despite their particularly difficult natural production conditions, remains in the same order of magnitude as the performance of the European agricultural sector over the period 1980 to 2000 (+1.4% yearly productivity growth; Coelli and Rao, 2005). Compared to European dairy farms, the farms investigated present a yearly productivity growth rate

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[15] These 93 producers account for roughly 97 percent of the world's agricultural output.

which seems in the same range as the levels observed in European countries either showing some similarities in the characteristics of their dairy production systems (grassland based production systems like in Ireland), or being quite similar with respect to the climatic and topographic production conditions (like Finland)[16]. For example, for the period 1995-2000, Newman and Matthews (2006) reported a +0.9% TFP growth for Irish specialist dairy farms and a +1.4% TFP growth for all Irish dairy farms (specialist and other dairy farms). In a similar investigation, Carroll *et al.* (2009) also reported a TFP growth of +1.4% in the Irish dairy sector for the period 1996 to 2006. For Finnish dairy farms, Sipiläinen (2007) found a yearly TFP growth of +0.94% over the period 1990 to 2000.

There thus seems to be some initial evidence that Swiss dairy farms located in the mountain region can keep up with their European counterparts in terms of TFP growth. However due to the existing productivity gap between Swiss dairy farms and their European counterparts, a higher TFP change would be necessary if Swiss dairy farms want to increase their competitiveness, especially with the prospect of future possible further trade liberalisation. It can, however, be questioned whether higher TFP growth would be attainable as these farms are producing under particularly difficult natural production conditions, which might be a major hindering factor in terms of productivity growth. Investigations carried out for Austria by Ortner *et al.* (2006) and for Switzerland by Jan *et al.* (2010) have clearly shown that difficult natural production conditions negatively impact technical efficiency. It might therefore be expected that technical efficiency change, technological change and thus TFP growth are also affected by the farm's natural environment. Therefore, despite their significant productivity growth, these farms would not likely be able to compete with their European counterparts on an entirely liberalised dairy market without a high level of public support in the form of direct payments, as is already the case today (Kirner and Gazzarin, 2007).

Furthermore, more generally, within the context of the improvement in the competitiveness of the Swiss dairy sector, we should not forget that beyond TFP change, the change in the prices of production factors also plays a major role in the evolution of the competitiveness of a sector as outlined by Oral *et al.* (1999). In Switzerland the prices of the agricultural production factors have traditionally been significantly higher than in the neighboring EU countries (refer for example to Raaflaub and Genoni, 2005). This higher general input price level is the second factor that explains the lower competitiveness of Swiss dairy farms compared to their European counterparts. In the event of a free-trade agreement in the agricultural and food sector between Switzerland and the European Union, Swiss farms would have to face much lower output prices but would also be expected to benefit from much lower prices for several production factors. This would have a major positive effect in terms of improved competitiveness.

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[16] Remember that no result on the TFP growth of dairy farms in other European alpine regions could be found in the literature. As a consequence, the «benchmarking» has been done with countries presenting similarities either regarding the dairy production system (high proportion of grassland) or the climatic and topographic conditions.

5.3. Limits of the present investigation and outlook

In the present investigation we have focussed on productivity change due to technical efficiency change and technological change. Placed in a more general framework of assessment of the competitiveness of a sector in international comparison, the present work addresses only part of the competitiveness issue. Indeed, if we want to analyse competitiveness between two or more competitors in a comprehensive way, then we should consider that the competitive differences between competitors can be due either to productivity differences or to differences in the absolute level of production factor prices (Oral *et al.*, 1999). The differences in productivity for their part can result from differences in the technology used, in pure technical efficiency, in scale efficiency and in allocative efficiency. To assess the competitive differences between competitors we should assess these components from a static (absolute levels for a given time period) and from a dynamic (change across time) perspective. In the present investigation we have only focussed on the productivity change across time due to technical change and changes in technical efficiency. This restriction should therefore be kept in mind when drawing conclusions regarding an international comparison of the competitiveness of Swiss dairy farming in the mountain region on the basis of the results of the present work. In the context of a possible further liberalisation of the agricultural trade between Switzerland and the European Union, a precise and comprehensive quantification of the sources of competitive differences between Swiss dairy farms and their European counterparts is of high relevance. Until now no investigation has dealt with this issue in such a comprehensive way.

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[17] Systematische Rechtssammlung (systematic collection of law).