Total Factor Productivity change of the Swiss dairy sector for the mountain region in the period 1999 to 2008

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Abstract

In view of a probable free trade agreement between Switzerland and the European Union in the agricultural and food sector and as a consequence of their actual low competitiveness in international comparison, Swiss dairy farms are under pressure to increase their productivity. In the present contribution I assess the total factor productivity (TFP) change in the period 1999-2008 of a balanced panel of 118 dairy farms located in the mountain region using the Malmquist productivity index. Particular attention is paid thereby to the issue of deflation quality for monetary input and output variables, and to the consideration of direct payments.

The yearly average TFP growth rate of the sample of farms investigated amounts to 1% and is very close to the levels observed in European countries showing some similarities with Switzerland from an agricultural perspective. There seems thus 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 actual productivity gap existing between Swiss farms and their European counterparts, higher TFP growth would be necessary for the Swiss farms to increase their competitiveness in a European comparison.

1. Introduction

Swiss agriculture is characterized by the importance of its mountain agriculture. In 2008, 28% of Swiss farms were located in the mountain agricultural production area (FOAG, 2009, p. 10), 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.

Swiss dairy farming shows poor competitiveness by 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 (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.

In the context of ongoing progressive liberalisation of the Swiss dairy market and especially of a possible future free trade agreement with the EU in the agricultural and food sector (Integration Office FDFA/FEA, 2009), Swiss dairy farms are under pressure to increase their competitiveness and thus productivity. 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.

[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).

Unfortunately no precise data on the recent productivity growth trends of these farms is available. In a previous study Ferjani (2005) 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 of the mountain region.

More generally, from a data and methodological perspective, two major issues should be paid particular attention when performing a productivity change assessment: the deflation issue and the direct payments issue. The price correction (inflation correction) for outputs and inputs that are expressed in monetary terms might indeed affect the accuracy of the assessment and should thus be performed with care. Furthermore, 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 of direct payments in the outputs.

The present article 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 will thereby be paid to practical methodological issues such as the issue of deflation quality for monetary input and output variables and the consideration of direct payments.

The rest of this paper is structured as follows. In section 2 I outline the methodology used to assess Total Factor Productivity Change and decompose it into its components. In section 3 I describe the data used, paying particular attention here to the input/output set specification, to the deflation of monetary outputs and inputs and to the consideration of direct payments. In section 4 the results of the productivity growth assessment 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 using the input-based Malmquist productivity index

For the present investigation I shall use the input-based Malmquist productivity index developed by Färe et al. (1992)[2] to estimate the TFP change of the farms investigated. This approach makes use of the Malmquist TFP index originally developed by Caves et al. (1982a;b) and estimates the distance functions that make up this index using the non-parametric Data Envelopment Analysis (DEA) approach originally developed by Charnes et al. (1978).

[2] With the exception of the orientation, this index is identical to the output-oriented Malmquist index developed by Färe et al. (1994a; 1994b). For the present investigation we opted 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.

2.1. Mathematical formulation of the input-based Malmquist productivity index

The TFP change (TFPC) between period t and t+1 is measured in the input-oriented Malmquist index approach proposed by Färe et al. (1992). It is calculated as the geometric mean of two Malmquist indexes (Eq. 1 and Eq. 2).

$$m(y_t, y_{t+1}, x_t, x_{t+1}) = [m^t(y_t, y_{t+1}, x_t, x_{t+1}) \times m^{t+1}(y_t, y_{t+1}, x_t, x_{t+1})]^{0.5} \quad (Eq. 1)$$

$$m(y_t, y_{t+1}, x_t, x_{t+1}) = \left[\frac{d^t_{CRS}(x^{t+1}, y^{t+1})}{d^t_{CRS}(x^t, y^t)} \times \frac{d^{t+1}_{CRS}(x^{t+1}, y^{t+1})}{d^{t+1}_{CRS}(x^t, y^t)}\right]^{0.5} \quad (Eq. 2)$$

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

$m(y_t, y_{t+1}, x_t, x_{t+1})$ the input oriented Malmquist TFP index

$m^t(y_t, y_{t+1}, x_t, x_{t+1})$ the input oriented Malmquist TFP index based on period t technology

$m^{t+1}(y_t, y_{t+1}, x_t, x_{t+1})$ the input oriented Malmquist TFP index based on period t+1 technology

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

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

$d^{t+1}_{CRS}(x^t, y^t)$ the input distance function of the observation in period t in relation to the CRS technology in period t+1

$d^{t+1}_{CRS}(x^{t+1}, y^{t+1})$ the input distance function of the observation in period t+1 in relation to the CRS technology in period t+1

As is obvious from the formula introduced above, the input-oriented Malmquist productivity index measures the TFP change as the relative input-oriented “move” of an observation between period t and period t+1 in relation to a given technology frontier. Since this relative “move” can be measured using period t technology and period t+1 technology, the Malmquist index is defined as the geometric average of the two indices based on period-t and period-t+1 technologies. It is necessary to emphasize, as outlined by Boussemart et al. (2003), that values of the input-oriented Malmquist index below (above) unity reveal productivity growth (decline). This counterintuitive formulation results from the fact that the input-oriented Malmquist index has been constructed exactly like the output-oriented 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-oriented Malmquist index thus has to be interpreted inversely to the output-oriented one[3].

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

2.2. Decomposition of the input-oriented Malmquist TFP index

Färe et al. (1992) have shown that the TFP change index can be decomposed into Technical Efficiency Change (TEC) and Technical Change (TC) as formulated in equation 3.

$$TFPC = TEC \times TC \ \ (Eq.3)$$

<u>where:</u>

$$TFPC = m(y_t, y_{t+1}, x_t, x_{t+1}) \ (Eq.4)$$

$$TEC = \frac{d_{CRS}^{t+1}(x^{t+1}, y^{t+1})}{d_{CRS}^{t}(x^{t}, y^{t})} \ (Eq.5)$$

$$TC = \left[\frac{d_{CRS}^{t}(x^{t+1}, y^{t+1})}{d_{CRS}^{t+1}(x^{t+1} y^{t+1})} \times \frac{d_{CRS}^{t}(x^{t}, y^{t})}{d_{CRS}^{t+1}(x^{t}, y^{t})}\right]^{\frac{1}{2}} \ (Eq.6)$$

TEC (Technical Efficiency Change, Eq. 5) measures the change in the input-oriented 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 best-practice frontier between two successive time periods.

TC (Technical Change or Technological Change, Eq. 6) captures the shift in the frontier between period t and t+1 evaluated at y_t and y_{t+1}. It shows whether the CRS best-practice frontier against which the firm is benchmarked is improving, stagnating or deteriorating.

The Technical Efficiency Change (TEC) can for its part be further decomposed into pure technical efficiency change (PTEC) and scale efficiency change (SEC) by introducing distance functions in relation to the VRS technology as proposed by Färe et al. (1994b) and as described in equation 7.

$$TEC = PTEC\ X\ \ SEC \quad (Eq.7)$$

<u>where:</u>

$$PTEC = \frac{d_{VRS}^{t+1}(x^{t+1}, y^{t+1})}{d_{VRS}^{t}(x^{t}, y^{t})} \ (Eq.8)$$

$$SEC = \frac{d_{CRS}^{t+1}(x^{t+1}, y^{t+1}) / d_{VRS}^{t+1}(x^{t+1}, y^{t+1})}{d_{CRS}^{t}(x^{t}, y^{t}) / d_{VRS}^{t}(x^{t}, y^{t})} \ (Eq.9)$$

The Pure Technical Efficiency Change (Eq. 8) measures the change in the input-oriented 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 9, 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.

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. Our investigation relies on a balanced panel made up of 118 specialised dairy farms located in the Swiss mountain region. These farms have been observed over the period 1999-2008. A specialised dairy farm is defined according to the farm typology of the Swiss Farm Accountancy Data Network (Roesch and Hausheer Schnider, 2009).

The choice of a balanced panel is motivated by data quality considerations and in particular by the fact that the 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 Roesch (2011, forthcoming). For investigating economic developments across time, therefore, the use of a balanced panel is highly recommended despite its associated risk of sample selection bias.

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 lead to a data discontinuity that could not be corrected for. As a consequence, I decided not to consider the data of that year for the present TFP change assessment. The present work thus relies on two time spans: 1999-2001 and 2003-2008. For each of these two time spans I estimated for each year the TFP change of each farm relative to the previous year.

3.2. Outputs and Inputs specification

The first step of a TFP change assessment consists in specifying the inputs and outputs of the D.M.U observed. This step is of major relevance as it affects the results of the assessment.

3.2.1. Outputs specification

The output set is made of two aggregate outputs, the output coming from agricultural activities and the output coming from para-agricultural activities, both expressed in Swiss Francs.

3.2.1.1. Output coming from agricultural activities

The output coming from agricultural activities includes the agricultural commodities produced by the farm and the environmental services provided by the farm to society. The agricultural commodities produced by the farm encompass both the outputs from animal production and plant production activities. The environmental services provided by the farm to society are those remunerated by ecological and ethological direct payments and by direct payments for farming on steep slopes. Before motivating the inclusion of these direct payments in agricultural output, I shall give a brief overview of the Swiss agricultural direct payments system.

The Swiss agricultural direct payments system consists of two types of direct payment: general direct payments and agri-environmental direct payments. According to the Swiss Federal Office for Agriculture (FOAG, 2009, p. 184) 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 [4]: 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 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 [5] for the receipt of agricultural direct payments (FOAG, 2009, p. 184). The ecological 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 to the emergence of direct payments in agriculture might be useful in determining how to include direct payments in a 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 liberalization of trade [6], this transfer aimed to redirect

[4] Only the direct payments relevant for dairy farming are introduced here.
[5] The Swiss cross compliance requirements for the eligibility for the receipt of direct payments are called "Proof of Ecological Performance" (PEP).
[6] 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).

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 output for the productivity change assessment refers to the more general question of the choice of non-commodity outputs to be included in output. For the present investigation I shall base this choice on production theory considerations. I 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 I shall consider only the agri-environmental services provided in addition to the basic non-commodity agricultural outputs jointly produced with agricultural commodities. I shall specifically include ecological and ethological direct payments in output. Contrariwise, all general direct payments, with the exception of direct payments for farming on steep slopes, will be excluded from output, 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.

3.2.1.2. <u>Output coming from para-agricultural and other activities</u>

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 have been excluded from 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.

3.2.2. Inputs specification

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 labour force and the non hired family labour 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.

When specifying the inputs, particular attention has been 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 problem. Beyond the double counting issue, I 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.

3.3. Outputs and inputs deflation

3.3.1. Method of deflation

Performing a productivity change analysis across time requires the creation of a quantity index[7] 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 to ensure that the quantity index obtained reflects 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 single 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. I 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 118 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.

3.3.2. 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[8] received by the farm, the question of the deflation of this monetary output variable arises. Before choosing

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

[8] 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.

any price index, one 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 provided by the farm[9] (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 one 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, any increase in the direct payment rate not associated with an increase in the ecological services provided by the farm has to be corrected for. For that purpose, for each direct payment I 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 to correct for type 2 price changes.

4. Results

Before presenting the results of the TFPC assessment, 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.
Over the 1999-2008 period the total factor productivity of the 118 farms investigated increased by +7.3%. This corresponds to an annual TFP growth rate of +1%. This improvement is exclusively ascribable to technical progress (+1% per year). Indeed technical efficiency has on average remained constant. This is due to the fact that both pure technical efficiency and scale efficiency have remained almost constant in the period under investigation (+0.4% versus -0.2% for the whole period).

As is obvious from the box-plot in figure 1 in the Appendix, the farms investigated show a high heterogeneity with regard to their TFP change. Whereas 25% of the farms show a TFP decrease lower than -0.6% per year, 25% of them exhibit a yearly TFP growth rate higher than +3.0%.

5. Discussion and conclusions

In the present section I shall in a first part discuss the average TFP growth performance of the Swiss dairy sector in the mountain region in an international comparison in the context of a probable future free trade agreement between Switzerland and the European Union in the agricultural and food sector. In a second part I shall briefly address the heterogeneity issue with regard to TFP change and its implications. In part 3 the approach used for the present investigation will be briefly discussed. Finally, the limits of the present investigation will be addressed and the outlook for future research work discussed.

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

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

In the period investigated Swiss dairy farms in the mountain region registered an average TFP growth of 1% per year. 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 this performance with that of farms operating under similar natural production conditions. More generally, comparisons with other studies assessing total factor productivity change in agricultural holdings have to be made cautiously, as the periods under investigation and the specification of input and output sets differ significantly between studies. Despite these challenges I 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 of the farms investigated remains lower than the +2.1% average yearly TFP growth rate of the top 93 world agricultural producers (countries)[10] reported by Coelli and Rao (2005b) 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 analysed. In the present case this lower rate clearly indicates that the relative competitiveness of the Swiss dairy sector located in the mountain region has decreased in international comparison.

If I restrict the comparison to the European agricultural sector, then the performance of the Swiss dairy farms in the mountain region, despite their particularly difficult natural production conditions, remains very close to the performance of the European agricultural sector over the period 1980 to 2000 (+1.4% yearly productivity growth; Coelli and Rao, 2005b). Compared to European dairy farms, the farms investigated present a yearly productivity growth rate which seems very close to 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)[11]. 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, to a certain extent, keep up with their European counterparts in terms of TFP growth. However due to the existing productivity gap between Swiss farms and their European counterparts, a higher TFP change would be necessary if Swiss farms want to increase their competitiveness, especially with the prospect of future probable further trade liberalization. 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

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

[11] Remember that no results on the TFP growth of dairy farms of 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.

hindering factor in terms of productivity growth. Investigations carried out for Austria by Ortner et al. (2006) have clearly shown that difficult natural production conditions negatively impact technical efficiency. It might therefore be expected that technical efficiency changes and thus TFP growth is also affected by the farm's natural environment.

5.2. The heterogeneity issue and its implications

A major finding of the present study is the substantial heterogeneity existing within the sample of farms investigated with regard to TFP change. This finding highlights the need for further investigations on this issue in order to try to better understand the reasons behind this heterogeneity.

5.3. Discussion of the approach used

From a methodological perspective the present contribution addresses the issue of the inclusion of agri-environmental services provided by farms to society and the issue of the consideration of direct payments in a total factor productivity change assessment. Until now, 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. In the present investigation I develop an approach to consider this issue in our assessment. Beyond this novelty, this analysis pays heed to the quality of the data used and especially to the quality of the deflation of monetary variables to make sure that the result in terms of TFP change is as accurate as possible. Simulations that have been performed employing the data used for the present investigation and that will be the object of a future article have shown that the deflation quality issue is of crucial importance in terms of the accuracy of the productivity change assessment.

5.4. Limits of the present investigation and outlook

The fact that the present investigation relies on a sample comprising only 118 farms should be kept in mind when interpreting the results. The choice of a balanced panel, which in the present case was motivated by the objective of eliminating the effect on the results of the sample composition change between years, might have happened at the expense of representativeness as it might have induced some selection bias, a problem typically met in analyses based on balanced panel data. One might wonder to which extent this choice might have affected the results of the TFPC assessment. Indeed the probability of the presence in the balanced panel of a farm initially showing low technical efficiency might be expected to be lower for a farm that has not succeeded in improving its productivity than for a farm that has increased its productivity.

In the present investigation I 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 one wants to analyse competitiveness between two or more competitors in a comprehensive way, then one 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 one 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 I have only focussed on the productivity change across time due to technical change and changes in technical efficiency (both pure technical efficiency and scale efficiency). This restriction should therefore be kept in mind when drawing conclusions regarding an international comparison of the competitiveness of the Swiss dairy sector in the mountain region on the basis of the results of the present work. In the context of a probable free trade agreement between Switzerland and the European Union in the food and agricultural sector, 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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8. Appendix

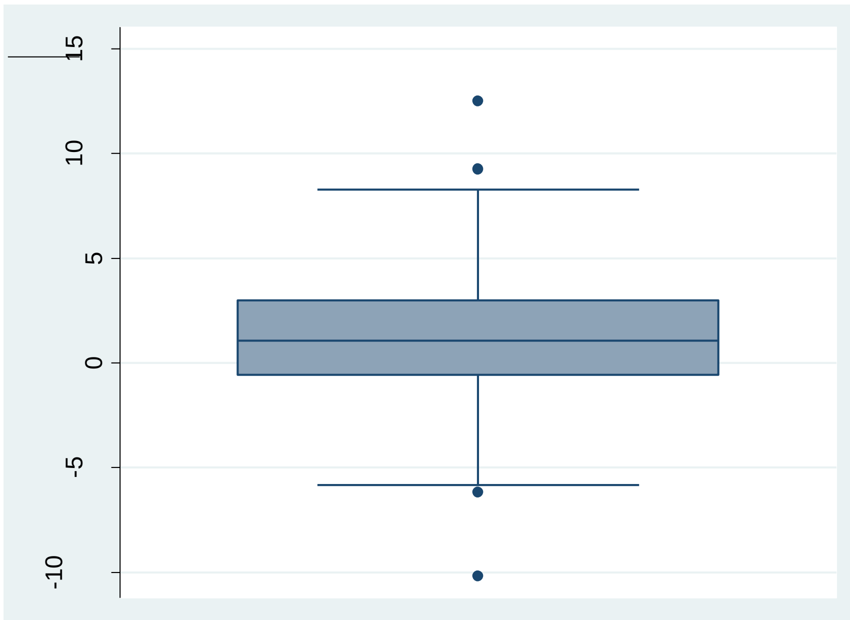

Figure 1: Variability of the yearly TFP change rate of the farms investigated
Source: Swiss FADN, balanced panel of 118 dairy farms in the mountain region, years 1999 to 2008 (year 2002 excluded), own calculations