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On the dynamics of agricultural labour input and their impact on productivity and income: an empirical study of Swiss family farms

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ABSTRACT
The labour employment trends of 2003 Swiss FADN farms between 2004 and 2009 are studied, differentiating between the use of on- and off-farm family labour, employees, and contracting services accomplished by and for third parties. By means of a correlation and data envelopment analysis, the relationships between changes in labour input, farm size, productivity and income are empirically explored. With the aid of a cluster analysis 7 major strategies to adjust labour input are revealed whereas slightly over half of the farms in the period under consideration leave labour input at a constant level. Although some of the clusters differ substantially in terms of growth in both labour productivity and income, differences in total factor productivity are not significant.

KEYWORDS: On-farm family labour; off-farm labour; employees; contractors; growth; cluster analysis; productivity; DEA

1. Introduction

Over the past few decades, the comparison of different forms of institutionalisation of labour has become a common field of research for agricultural economists, with particular attention being paid to the dichotomy between work performed on one's own farm and that performed off-farm as an employee (Huffman, 1980; Schmitt, 1989; Phimister And Roberts, 2006; Mann, 2007). Another topic that has been addressed is the decision to employ external labour on the farm (Van Zyl *et al.*, 1987; Preibisch, 2007). By contrast, studies on the dynamics of the use of contractors have been pursued less frequently (Krüsken, 1964; Franz *et al.*, 2010).

The three activity spheres involving the use of family labour (family members active on the farm), employees (non-family employees on the farm) and contractors (self-employed partners working on the farm) are naturally interdependent to a large extent, as already pointed out by Beckmann (1997) in a comprehensive paper using transaction-cost theory to deal with the determinants of these three variables on farms. The present article builds on this paper, but is more oriented towards observing empirically the relationship between changes in labour use, farm size, farm income, and productivity. Based on accountancy data from Swiss family farms between 2004 and 2009, it addresses the issue of what patterns are to be observed in the change in labour use over time. When we speak of the need to grow or give way, particularly in agricultural sectors with small-scale family farms (Weiss, 1999; Groier, 2004), this also raises the question of how the three forms of institutionalisation of labour are associated with one another in the growth process. In addition to this, the income and productivity growth that goes hand-in-hand with the individual patterns is considered.

As a general rule, when productivity remains constant, dynamic farm growth entails a dynamic growth in labour input, i.e. a change in farm size also entails a change in labour input. However, the theoretical possibility of leaving the ratio between the types of labour at a steady level is not always realistic in the case of growth and shrinkage processes. Reasons for a change in the composition of the types of labour accompanying farm growth might be that the family labour pool is already exhausted, or that the critical threshold for (additional) employees has not been reached. On the basis of differing flexibility, it is obvious that the variation in working-time requirement can be controlled to especial advantage via contracting services carried out on the own farm or for other farms, provided that there is a supply or demand for this. This assumption, however, requires empirical verification, which is the aim of this study. Although some parts of farming (Beckmann and Wesseler, 2003) or different farming systems (Buduru and Brem, 2007) have been

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looked at from this transaction cost perspective, a holistic view has not been covered yet for family farms.

To start with, the options for controlling the use of family and wage labour on the farm are described in somewhat greater detail in Section 2. Next, Section 3 outlines and substantiates the methodological approach. The results are set out in Section 4, followed by the drawing of conclusions–particularly with respect to the theoretical implications arising from the patterns observed–in Section 5.

2. Operationalisation of Family, Wage and Outsourced Labour

The term ‘family labour’ is derived directly from the concept of the family farm, and encompasses all the managerial and executive activities of all persons usually belonging to the farm manager’s family who do not receive a wage but participate from the family farm income (mainly farm manager, partner, other family members). For a number of reasons, family labour is considered to be particularly favourable: for one thing, family members are themselves interested in turning a profit, and do not incur supervisory charges (Hayami, 2010); for another, family members can be expected to work flexible hours, and because of their spatial proximity and familial closeness incur only minor coordination and adaptation costs (Beckmann, 1997). According to Beckmann (1997), family labour possesses obvious transaction-cost advantages over employees or contractors, particularly in the spheres of business management and animal husbandry, where managerial and executive activities are not readily separable.

Despite this, family labour in Switzerland is also increasingly being deployed off-farm (Lips and Schmid, 2012). This happens both because some family members have a preference for or are better qualified for non-agricultural work, and because the diminishing marginal benefits of employing labour on the family farm make off-farm work more profitable (Schmitt, 1989).

The labour performed on farms by (permanent or non-permanent) employees who regularly receive a wage is termed ‘wage labour’. Wage labour involves supervision and orientation costs, a fact which–according to Beckmann (1997)–has a negative impact on productivity (Eastwood, 2010). Moreover, wage labour is associated with a financial risk, since–seen from a short-term perspective–it constitutes a fixed-cost factor. It is therefore to be expected that family labour will be preferred to wage labour, and that wage labour will only be used when there is enough work to fully utilise the latter, or if the family workforce–owing to their high educational level–has markedly higher opportunity costs than wage labour. According to Beckmann (1997), wage labour is especially well suited to performing simple machine tasks, for straightforward manual animal-husbandry tasks, and for simple manual plant-production jobs.

The term ‘outsourced labour’ refers to those jobs outsourced by the farm to third parties (contractors and possibly also neighbour farms) that are normally invoiced on an area-related or hourly basis. Activities that are only performed occasionally, which can be measured relatively easily ex post in terms of their performance, and which require a high specific human capital (e.g. special machine tasks with a high service requirement and high risk of injury; Beckmann, 1997) are suited to contracting. Here, outsourced labour can take two possible forms for farmers: Either work on the own farm is outsourced, or the farm’s own workforce can be used for work on other farms.

3. Empirical Methods

The aim of this paper is to observe empirically the relationship between changes in labour input, farm size, farm income, and productivity growth. Therefore two statistical analyses are carried out. Firstly, a correlation analysis is conducted for estimating the relationships between the above mentioned farm characteristics. Because of non-normal distributions, the Spearman rank-correlations between the different types of labour, the workload on the farm and the turnover of the farm, the family farm income and the productivity growth are calculated. Secondly, farms whose on-farm and off-farm family labour, wage labour or outsourced labour (of and for third parties) changed according to the same pattern are allocated to groups by means of a cluster analysis. Cluster results are then further analysed.

For both statistical analyses a sample of 2003 Swiss family farms which made their data available to the Farm Accountancy Data Network[3] (FADN) in the year 2004 and 2009 (balanced panel) is used.

Measuring labour input, farm growth and farm income

The Swiss FADN system provides the number of family labour units and wage labour units employed on the farm, as well as the number of family labour units working off-farm, in annual working units[4] on a self-disclosure basis. Farm expenditure for labour and machine use by third parties as well as revenues for labour and machine use on neighbouring farms is also available in the FADN system (Table 1).

Furthermore the FADN-data base gives insight in farm income. Since the study is focused on agricultural labour input, the quantification of farm growth refers to the standardised workload on the farm. This indicator provides a suitable and comparable proxy for farm size and changes over time across all farms. The workload was calculated by including all agricultural production activities whose management requires work. Various production activities (e.g. ha wheat, LU dairy cows) were weighted with specific labour standard values (Table 2) and summed up to the farm’s total workload. Different standards of facilities or levels of mechanisation which influence the workload required were not taken into account for the above mentioned reason.

[3] Institution for summarizing and analyzing data from farm accountancy departments and supplementary surveys of various data processors for research, education, consultation, determination of the economic status of agriculture, agricultural-policy decision-making and evaluation, as well as agricultural valuation, including valuation for tax purposes.

[4] Both family and external labour units are generally recorded in working days, with an annual labour unit (AWU) corresponding to a fully efficient person working on the farm at least 280 working days per annum. A maximum of one annual labour unit can be credited per person. Part-time employees are converted pro rata on the basis of 280 normal working days per year.

Table 1: Measuring the five different categories of labour input in Swiss family farms

Type of labour input	Short description
On-farm family labour input (AWU)	Family members working on the farm and participating in the family farm income.
Off-farm family labour input (AWU)	Family members working off-farm. Usually as employees in the 2nd or 3rd sector.
Wage labour input (AWU)	Employees working on the farm (permanently or non-permanently).
Expenditure for outsourced work (CHF)	Outsourced work executed by contractors on the farm. Usually invoiced per hour or hectare.
Revenues for labour and machine use on neighbouring farms (CHF)	Work executed by the farm's workforce on neighbouring farms. Usually invoiced per hour or hectare.

Table 2: Labour standard values that were used to calculate the standardised workload on the farms

Husbandry	$h \cdot LU^{-1} \cdot a^{-1}$	Areas	$h \cdot ha^{-1} \cdot a^{-1}$
Dairy Cows*	128	Bread cereals**	43
Suckler Cows*	46	Fodder cereals**	41.8
Calf rearing*	57	Grain maize, pea, sunflowers, soya**	37.6
Fattening cattle*	74	Silage maize**	42
Other Calfs*	150	Sugar beets, fodder beets**	67.7
Horses*	105	Rape**	40.6
Sheep*	111	Potatoes**	150.5
Goats*	248	Grassland**	73.7
Other animals fed with roughage*	111	Fallow land****	11
Breeding sows*	308	Vegetables*	500
Fattening pigs*	38	Tobacco*	809
Broiler chicken*	34	Vineyards*	725
Laying hens*	42	Fruits*	705
		Berries*	2557
		Forest****	25
Additional workload		**Additional workload**	
Due to organic farming***	+20%	Due to organic farming***	+20%
		Due to hillsides***	$42\ h \cdot ha^{-1} \cdot a^{-1}$

Notes: ha: Hectare, LU: Lifestock Unit
***Source:** Deckungsbeitragskatalog 2009, Agridea.
****Source:** Arbeitsvoranschlag 2011 (V 1.1.8), ART.
*****Source:** Preiskatalog 2009, Agridea.
******Source:** Other.

Measuring labour productivity and productivity growth

Labour productivity relates farm turnover[5] to total labour input units (and therefore has the unit $\frac{CHF}{AWU}$) which includes family and wage labour units and expenses for outsourced work[6]. For calculating changes in labour productivity the farm turnover is being deflated on the minimum possible aggregation levels (e.g. revenues from bread wheat/milk/beef/eggs etc.) with price indices from the Swiss Federal Statistical Office in order to minimise the effects of price changes on productivity changes.

Total factor productivity (TFP) is more holistic than labour productivity and defines the ability to convert (possibly several) inputs into (possibly several) outputs. Stochastic Frontier Analysis (SFA) and Data Envelopment Analysis (DEA) are two widely used methods to quantify TFP. We favour DEA over SFA because the distance based non-parametric approach allows to estimate productivity without making assumptions of the production frontier which can crucially influence efficiency scores. The change in TFP was estimated with the aid of the Malmquist Index (MI; Malmquist, 1953; Färe *et al.*, 1992).

$$MI = \sqrt{\frac{d^t_{CRS}(x^{t+5}, y^{t+5})}{d^t_{CRS}(x^t, y^t)} \times \frac{d^{t+5}_{CRS}(x^{t+5}, y^{t+5})}{d^{t+5}_{CRS}(x^t, y^t)}} \quad (1)$$

Where:

in the following 't' is called current and 't+5' is called future

$d^t_{CRS}(x^t, y^t)$ DF[7] with current input-output set x^t, y^t relative to the current technology T^t

$d^t_{CRS}(x^{t+5}, y^{t+5})$ DF with future input-output set x^{t+5}, y^{t+5} relative to the current technology T^t

$d^{t+5}_{CRS}(x^t, y^t)$ DF with current input-output set x^t, y^t relative to the future technology T^{t+5}

$d^{t+5}_{CRS}(x^{t+5}, y^{t+5})$ DF with future input-output set x^{t+5}, y^{t+5} relative to the future technology T^{t+5}.

[5] For comparability with the output specification of the data envelopment analysis, which will be explained in more detail later, direct payments which are not related to ecological services or animal-friendly husbandry are excluded from the total farm turnover.

[6] The costs for on-farm contracting services were roughly converted to AWU by assuming an average price of 160 Swiss Francs per hour (including work and machinery costs), 10 working hours per day and 280 working days per year. The conversion factor from off-farm wage labour costs to AWU is therefore $\frac{1AWU}{448000\ CHF}$.

[7] Input distance function. Reciprocal of the technical efficiency measure proposed by Farrell (1957).

The four distance functions per farm are calculated by means of linear programming with the input-oriented (CCR) DEA model with constant returns to scale developed by Charnes, Cooper und Rhodes (1978). The distance function $d^t_{CRS}(x^{t+5}, y^{t+5})$ is calculated by the following linear program

$$
\begin{aligned}
&\left[d^t_{CRS}\left(x^{t+5}, y^{t+5}\right)\right]^{-1} = \min_{\theta,\lambda}\theta, \\
st \quad & -y_i^{t+5} + Y^t\lambda \geq 0, \\
& \theta x_i^{t+5} - X^t\lambda \geq 0, \\
& \lambda, \theta \geq 0,
\end{aligned}
\tag{2}
$$

presented in the so called multiplier form, where:

θ the efficiency of farm i,

λ a $I \times 1$ vector of constants,

x_i^{t+5}, y_i^{t+5} the future $N \times 1$ input vector and $M \times 1$ output vector of farm i,

X^t, Y^t the current $N \times I$ input set and $M \times I$ output set of all farms within the technology T^t and

I: the number of farms, N: the number of inputs, M: the number of outputs in the technology T^t.

As opposed to the original definition, we denote $MI<1$, $MI=1$, $MI>1$ as a decrease, stagnation and increase in productivity, respectively, and present the results as per cent deviation from 1.

The specification of the input-output set is based on Jan *et al.* (2012)[8], who developed an approach adapted to the conditions on Swiss farms. Four input categories (Intermediate consumptions [CHF[9]], Capital [CHF], Labour [AWU], Farm area [ha]), and two output categories (Output from agricultural production + Direct payments [CHF], and Output from agricultural related activities and services [CHF]) are specified. Intermediate consumptions include all direct costs like expenses for fuel, fertilisers, seeds and so forth. Capital costs include depreciation as well as expenses for interests[10]. Labour includes on-farm family and wage labour. The expenses for contractor services were allocated to intermediate consumptions, capital and labour according to an estimated average distribution key[11]. The farm area is made up of the usable agricultural area (UAA) in ha and the agricultural area outside the UAA. Output from agricultural production includes the turnover from selling agricultural products. Direct payments include all payments that are related to ecological or landscape preserving services of agricultural activity as well as payments for especially animal-friendly husbandry[12]. Output from agricultural related activities and services include revenues from the direct sale of products, tourist accommodation and activities but also the theoretical revenues from renting the farm house to the farm manager's family, because of the special accountancy guidelines in Swiss agriculture.

Before the accountancy data was aggregated to the specified inputs and outputs, monetary figures were deflated on the minimum possible aggregation levels (e.g. revenues from bread wheat/milk/beef/eggs or expenses for fuel/mineral fertilisers/seeds/interests etc.) in order to minimise the effect of price changes on productivity changes.

The accountancy sample contains 11 different farm types[13] which are divided among the plain, hill and mountain regions. This yields 33 so-called strata[14], for which the MI must be separately calculated, since the farms evaluated as part of a DEA should be similar (Dyson *et al.*, 2001). The MI calculated within the individual strata were then once again aggregated for the original overall sample.

A drawback of the deterministic DEA approach is that outliers influence the efficiency of other farms. For this reason, in addition to the MI, a 95% confidence interval was calculated for each farm via bootstrapping (Simar und Wilson, 1999; Hall, 1992).

Cluster analysis

A cluster analysis was carried out to identify a limited number of different labour-input strategies–specifically, the most common ones in Swiss agriculture in the past. The aim is to analyze whether these different labour input strategies influence the farms' productivity growth as well as their family farm income. A cluster analysis was favoured over a regression analysis, because the latter could only estimate global dependencies between variables but could not identify typical patterns of labour reallocation which was one of the main goals of this study.

The identified clusters are analysed taking into account

- The clusters' structural features before the labour input change (in the year 2004)
- The clusters' farm size growth
- The clusters' labour productivity growth and the total factor productivity growth.
- The clusters' changes in the family farm income

Changes in how work is organised on Swiss family farms are being investigated with the sample of 2003 FADN farms. The five labour input categories (Table 1) in Swiss FADN-farms formed the underlying data for the cluster process, whose absolute changes from 2004 to 2009 were used as cluster-forming variables. The monetary variables were deflated over the period with the Swiss Federal Statistical Office's key figures. For reasons of data incommensurability (variables have different units of measurement or a mixed measurement level), the data were standardised so that the mean and the variance of each variable was 0 and 1, respectively

[8] For a comprehensive reasoning why this input-output specification was chosen we refer to Jan *et al.* (2012).

[9] In January 2004, 1 Swiss Franc (CHF) was approximately equivalent to €0.64, £0.44 and $0.81 (www.xe.com).

[10] The estimated capital costs for the farm's own land were subtracted in order to avoid a double-counting of the input 'land'. Furthermore, the costs for the leasing of land were not included into capital costs.

[11] The calculations where done according to Swiss farm management literature published by Gazzarin *et al.* (2012). The part that was allocated to labour was converted into AWU as described in footnote 4.

[12] Included are payments for the cultivation of slopes, for the so-called ecological compensation and for the so-called extenso production, for organic production, and for the husbandry according to the guidelines of BTS and RAUS.

[13] according to the FAT99 farm type definition that can be found in Hoop and Schmid, (2013: 11).

[14] Of these 33 strata, only 17 had enough observations to carry out a DEA. Here, the following applies: Minimum no. of observations ⩾ 2 x no. of inputs x no. of outputs (according to Dyson *et al.*, 2001). In order not to exclude too many observations from DEA we slightly changed the specification of the input output set as proposed by JAN *et al.* (2012) from original 4 inputs and 3 outputs to 4 inputs but only 2 outputs (we summed up the output from agricultural production and direct payments). Nevertheless, out of the original 2003 farms in the dataset, only 1912 farms could be analyzed for changes in their TFP.

Table 3: Spearman coefficients of the correlation analysis

changes in...	...labour input					
	Δ on-farm family labour	Δ off-farm family labour	Δ wage labour	Δ expenses for outsourced work	Δ revenues for work on neighbouring farms	Δ wage labour to total labour
Δ on-farm family labour		***−0.18	***−0.21	0	0.02	***−0.38
Δ off-farm family labour	***−0.18		−0.03	−0.03	0	0
Δ wage labour	***−0.21	−0.03		−0.01	0.01	***0.91
Δ expenses for outsourced work	0	−0.03	−0.01		−0.02	0
Δ revenues for work on neighbouring farms	0.02	0	0.01	−0.02		0
Δ wage labour to total Δ labour input	***−0.38	0	*** 0.91	0	0	
Δ workload	*** 0.1	***−0.09	*** 0.12	*** 0.15	−0.03	*** 0.08
Δ turnover[3]	** 0.06	***−0.11	*** 0.16	*** 0.18	*** 0.08	*** 0.12
Δ labour productivity	***−0.32	0.02	***−0.32	*** 0.15	0.03	***−0.23
Δ Malmquist Index	***−0.13	−0.03	−0.02	**0.07	0.04	0
Δ family farm income	*** 0.08	***−0.08	***−0.08	0	*** 0.11	***−0.1
Δ family farm income per Δ on-farm family labour	***−0.33	0.01	0.02	0	***0.08	***0.1

changes in...	...farm growth		...productivity		...income	
	Δ workload	Δ turnover[3]	Δ labour productivity	Δ Malmquist Index	Δ family farm income	Δ family farm income per on-farm family labour
Δ on-farm family labour	***0.1	**0.06	***−0.32	***−0.13	*** 0.08	***−0.33
Δ off-farm family labour	***−0.09	***−0.11	0.02	−0.03	***−0.08	0.01
Δ wage labour	*** 0.12	*** 0.16	***−0.32	−0.02	***−0.08	0.02
Δ expenses for outsourced work	0	*** 0.18	*** 0.15	** 0.07	0	0
Δ revenues for work on neighbouring farms	0.02	*** 0.08	0.03	0.04	*** 0.11	*** 0.08
Δ wage labour to total Δ labour input	*** 0.08	*** 0.12	***−0.23	0	***−0.1	***0.1
Δ workload		*** 0.42	*** 0.17	*** 0.16	*** 0.17	*** 0.1
Δ turnover[2]	*** 0.42		*** 0.59	*** 0.54	*** 0.43	*** 0.35
Δ labour productivity	*** 0.17	*** 0.59		*** 0.55	*** 0.37	*** 0.49
Δ Malmquist Index	*** 0.16	*** 0.54	*** 0.55		*** 0.62	*** 0.64
Δ family farm income	*** 0.17	*** 0.43	*** 0.37	*** 0.62		*** 0.84
Δ family farm income per Δ on-farm family labour	*** 0.1	*** 0.35	*** 0.49	*** 0.64	*** 0.84	

Note: *, ** and *** indicate P-values of 0.05, 0.01 and 0.001 respectively.

(using the 'scale' function of R; R Development Core Team, 2011).

For the study, the partitioning k-means method was chosen as an algorithm, since it generates homogeneous clusters with the smallest possible variation within the clusters on account of its optimality criteria. A disadvantage of this method, however, is that it does not permit us to make any assertions about the best possible number of clusters (Bacher *et al.*, 2010). In a first step, 29 cluster solutions with 2 to 30 clusters were generated using the k-means approach. From these, the best possible cluster solution in terms of degree of homogeneity within clusters (compactness) and heterogeneity between clusters (separation), data-assignment quality and reproducibility was selected. The ratio of compactness to separation of a cluster solution is measured on the one hand by the Average Silhouette Width index, and on the other by the Calinski-Harabasz index (Rousseeuw, 1987; Calinski and Harabasz, 1974). The normalised Hubert's correlation coefficient tests data-assignment quality by measuring the correlation between the cluster allocation and the original distance matrix (Halkidi *et al.*, 2001: 126ff). The larger the correlation coefficient, the better the cluster solution. The reproducibility of a cluster solution is checked with the aid of a bootstrapping method which slightly changes the entire dataset, generates new so-called bootstrap cluster solutions, and calculates the overlap between the original cluster solution and the bootstrap cluster solution with the help of the Jaccard coefficient (Hennig, 2007). As a final criterion, the number of farms per cluster was taken into account. Clusters with fewer than ten farms were excluded. There followed the content check to determine whether the clusters made sense and were plausible, and whether a name could be deduced for as many of them as possible (Bacher *et al.*, 2010). The 'k-means' function in the basic R-package was used for the cluster analysis. The starting centres were randomly set at 10,000 repetitions in each case in order to tackle the initial seed problem and to ensure the discovery of a globally optimal cluster solution. Cluster validation was performed with the 'cluster.stats' and 'clusterboot' functions from the fpc package in R (Hennig, 2010).

4. Results

Correlation analysis

The coefficients of the correlation analysis show the global interdependencies between shifts in the five distinguished types of labour input categories, farm growth, productivity growth, and income change (Table 3). Family labour input on-farm is negatively correlated with off-farm family labour and wage labour input, reflecting the substitutability of the different categories. Farm growth is accompanied by additional input of on-farm family and wage labour as well as on-farm contracting services. Off-farm family labour is reduced whereas off-farm contracting is not influenced by farm growth, meaning that the latter is not used in order to regulate farm labour capacities.

Naturally, labour productivity is negatively correlated with on-farm family and wage labour whereas the positive correlation with on-farm contracting indicates that labour productivity can be raised by employment of professional workforce with high specific human capital. Furthermore, the negative correlation between labour productivity and the share of wage labour at total on-farm labour supports the hypothesis that family labour is more efficient than wage labour.

Regarding TFP, a negative correlation with on-farm family labour and a positive correlation with on-farm contracting can be observed. Interestingly, the share of wage labour at the total labour input does not influence TFP. Focusing on the relationship between productivity and family farm income (per on-farm family labour) our results reveal that labour productivity–as part of TFP–does not influence income to the same extent as TFP does. The relationship between TFP and income, however, is impressively high, indicating that TFP is a key component of farm success.

Results of the Cluster Analysis

Selection of the cluster solution

Figure 1 demonstrates the approach for determining the best-possible number of clusters, showing the Average Silhouette Width and Calinski-Harabasz indices, Hubert's statistic, and the number of clusters with fewer than 10 members. At 9 to 11 clusters, both the Average Silhouette Width index and the Calinski-Harabasz index yield the best ratio between homogeneity and heterogeneity. The normalised Hubert's statistic is maximum in the same range. The contents check yielded 10 clusters, two of which nevertheless had too few cluster members, and were therefore excluded. According to the bootstrapping, clusters 1, 2, 3 and 7 are stable, cluster 6 is relatively stable, and clusters 4, 5 and 8 are fairly unstable (Table 4).

Cluster description

The eight identified clusters illustrate the typical changes in farm and family labour organisation that were observed in the sample (Table 5).

More than half of all the farms belong to cluster 1, for which family labour, number of employees and contracting services both on-farm and off-farm have hardly changed over 5 years. Owing to its relatively stable work organisation, it will hereinafter be referred to as the 'Stable' cluster.

In the second cluster, family members significantly restricted their off-farm labour, but only partially in favour of on-farm labour. This cluster, which contains only five per cent of the farms, is termed 'Sideline dropouts'. Compared to the overall sample, this cluster contains a higher-than-average number of younger farm managers under 35 years of age (28% as opposed to 13%). In 2004, the 'Sideline dropouts' were characterised by well-above-average family off-farm labour, including both the farm manager and his partner. Withdrawal from off-farm labour might therefore be because of the partner increasingly devoting herself to household, family and farm in the period under consideration.

By contrast, the defining characteristic of cluster 3 is that its family workforce was increasingly employed off-farm at the expense of on-farm activities. This cluster is downsizing its farm by 0.05 AWU, which distinguishes it significantly from clusters 1 and 2. Representing 8 per cent of all farms, cluster 3 is described as the 'Sideline-oriented' cluster. There are significantly more smaller farms with less than 20 ha farm area in the 'Sideline-oriented' group (72%) than in the overall survey (50%) making it harder for this cluster to substantially grow than to give way.

In 2009, the 'Family labour-focused' cluster 4 employed significantly more family members than it did in 2004, at the same time reducing its personnel expenditure. Since cluster 4 does not exhibit any special attributes, the reason for the increase in on-farm family labour remains unclear. We can only guess that there were redundant family workforce that were deployed at the cost of the employees.

Cluster 5, the 'Wage labour-focused' farms, increased significantly the number of employees between 2004 and 2009, both to cope with the above-average increase in workload and to take some of the pressure off of the family workforce. A defining characteristic of 'External labour-focused' farms is that they employed an above-average number of family labour units up to 2004. Taken altogether, they represent 9 per cent of all farms.

Cluster 6, the 'Outsourcing-focused' cluster, exhibited above-average growth between 2004 and 2009, making increasing use of agricultural contractors. The 'Outsourcing-focused' cluster is characterised by a high percentage of lowland farms (68%). As early as 2004, both livestock numbers and the utilised agricultural area of these farms were higher than average. This, and the above-average percentage of farm managers who completed further training after their vocational education, points to a high degree of professionalisation, or to full-time farms. Six per cent of all farms belong to cluster 6.

Only three per cent of all farms belong to cluster 7. These farms perform significantly more contractor services for third parties, thereby achieving addition revenues of CHF 26,075 but on average also needing to invest another CHF 18,000 in machinery. As early as 2004, the 'Contractors' cluster showed a high use of on-farm family labour, as well as above-average revenue from contracting services. Thus, the agricultural related branch was not relaunched, but further expanded, whilst

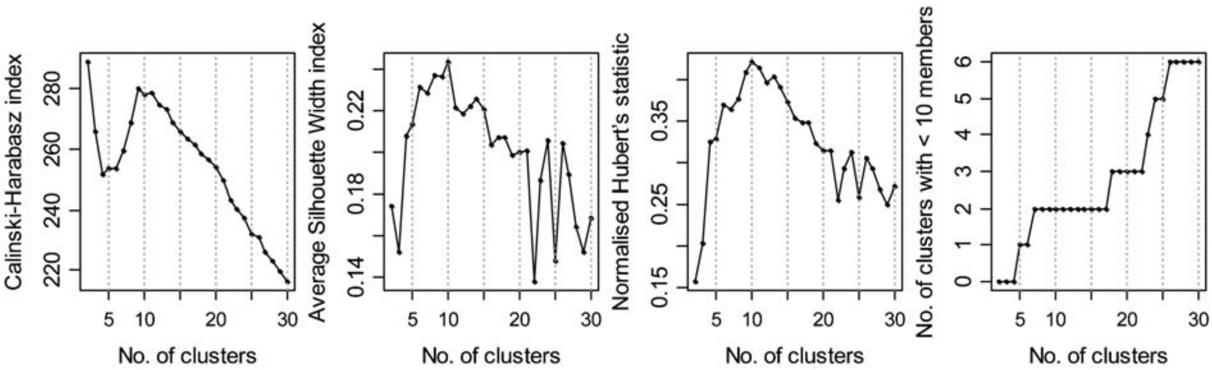

Figure 1: Results of the quantitative cluster validation. **Source**: Own calculations

Table 4: Results of the cluster bootstrapping

	Cluster							
	1	2	3	4	5	6	7	8
Average overlap[1)]	0.80	0.90	0.77	0.68	0.65	0.74	0.82	0.54
	No. of repetitions with…							
Overlap >75%	79	96	67	41	22	53	73	47
Overlap <50%	0	0	2	16	13	4	2	40

[1)]Arithmetic mean of the Jaccard index for 100 repetitions.
Source: Own calculations.

the size of other branches was steadily increased. Unused capacity reserves, e.g. where the farms have limited growth opportunities, are thus turned to good account.

In Cluster 8, on the other hand, the agricultural related branch of contracting services is curtailed in favour of other branches. This cluster therefore unites the 'Contractor dropouts'. In 2004, the 'Contractor dropouts' cluster was characterised by comparatively high revenues from contracting, plenty of land, relatively high number of employees, and an above-average agricultural income. This indicates that at the start of the period under investigation, these farms were faced with an impending decision regarding growth. Utilisation of the available labour and machine capacity now takes place on their own farm.

Productivity and income comparison

On average, labour productivity across all 1912 Swiss farms rose by approx. 9% in 5 years (Table 6). The annual growth of 1.5% is rather low compared to the literature (for example 2.1% p.a. in Kansas from 1996 to 2005 [Mugera *et al.*, 2012] or 2.5% p.a. in the European Union from 1993 to 2007 [Ciaian *et al.*, 2010]).

With a 32% rise[15], the 'Outsourcing-focused' cluster 6 achieved the highest average labour productivity increase by a significant margin. The 'Contractors' and the 'Sideline entrants' (cluster 7 and 3) improved their labour productivity by an average of 15% due to increases in turnover in the agriculture related sector and reduction of labour input, respectively. Although the 'Stable' cluster 1 achieved a below-average growth in turnover, they did on the other hand employ fewer labour units. The labour productivity of this cluster grew by around 11% in 5 years. The 'Wage labour-focused' cluster only slightly improved its labour productivity (+4%), since significantly more labour units were employed to expand production. At around 4% and 5%, the increase in labour productivity of the 'Contractor dropouts' and the 'Sideline dropouts' (cluster 8 and 2) was likewise below average. Only the 'family labour-focused' cluster 4 did not manage to improve its labour productivity over the course of time, employing significantly more family labour units without increasing its turnover accordingly. The result was a decline in labour productivity of approx. 8%.

A measure of total factor productivity (TFP), the MI is increasing across all farms by an average of approx. 2%. Although some of the mean TFPs differ significantly from one another, the differences are not statistically significant because of the overlapping confidence intervals between the clusters[16].

If we compare the mean TFP in Table 6 with the mean income growth in Table 7, it becomes clear that high productivity increases do not, per se, mean high income increases. To give an example, the 'Outsourcing-focused' Cluster 6 boosted its productivity more than all

[15] Comparing the different clusters by mean values in the following lines it is important to keep in mind that the standard deviations within the clusters (Table 6) are quite large meaning that all clusters have members with declining (increasing) labour productivity although the cluster mean is positive (negative).

[16] In order to calculate the average MI of each cluster, the MI that were calculated within each individual strata were aggregated for the original overall sample and analysed in terms of their membership of a cluster. This procedure implicates that the average change in productivity in each cluster only reflects the average change of cluster members relative to their strata but not relative to the whole sample. According to Latruffe *et al.* (2012: 271) confidence intervals of clusters were estimated by calculating the arithmetic mean of the cluster members' confindence intervals. The MI and the confidence intervals (for 2000 repetitions) were calculated with the functions 'malmquist.components' and 'malmquist' in the FEAR package in R (WILSON, 2008).

Table 5: Results of the cluster analysis

		Cluster 1 Stable	Cluster 2 Sideline dropout	Cluster 3 Sideline-oriented	Cluster 4 Family labour-focused	Cluster 5 Wage labour-focused	Cluster 6 Outsourcing-focused	Cluster 7 Contractor	Cluster 8 Contractor dropout	All farms Mean	All farms Standard dev.
No. offarms	No.	1035	104	160	297	175	124	60	45	2000	2000
Distribution	%	52%	5%	8%	15%	9%	6%	3%	2%	100%	100%
Clustervariables (mean absolute deviation 2004–2009)											
Family-labour on farm	AWU	−0.03	0.20	−0.22	0.44	−0.37	−0.01	−0.08	0.10	0.01	0.32
Wage labour on farm	AWU	−0.03	−0.06	0.01	−0.19	0.67	−0.09	0.09	−0.07	0.01	0.37
Expenses for outsourced work	CHF	307	1748	491	46	810	13789	1354	816	1281	5229
Revenues for work on neighbouring farms	CHF	451	735	315	569	−152	490	26075	−20417	721	7018
Family-labour off farm	AWU	−0.01	−0.54	0.38	−0.03	−0.02	0.01	0.01	0.05	−0.01	0.21
Descriptive variables (mean absolute deviation 2004–2009)											
Livestock population	LU	1.6	3.5	1.4	2.6	3.8	7.6	1.9	4.5	2.5	8.6
	SG[3)]	cd	bod	d	bc	ab	a	abcd	abcd		
Area	UAA	0.3	1.3	−0.1	0.8	1.2	3.1	0.3	1.9	0.7	3.4
	SG[3)]	b	ab	b	b	ab	a	ab	ab		
Workload[4)]	AWU	0.05	0.17	−0.05	0.11	0.24	0.34	0.08	0.18	0.10	0.48
	SG[3)]	c	bc	d	b	ab	a	abcd	abcd		
Labour input[5)]	AWU	−0.06	0.14	−0.21	0.25	0.31	−0.06	−0.05	0.09	0.02	0.42
	SG[3)]	d	bc	e	a	ab	d	d	cd		
Labour balance[6)]	AWU	−0.11	−0.03	−0.16	0.14	0.07	−0.40	−0.13	−0.09	−0.08	0.57
	SG[3)]	b	bc	b	d	cd	a	abc	bc		
Structural features (mean 2004)											
Family-labour on farm	AWU	1.28	1.01	1.29	1.17	1.56	1.26	1.40	1.28	1.28	0.37
Wage labour on farm	AWU	0.29	0.44	0.28	0.46	0.37	0.62	0.42	0.52	0.36	0.48
Expenses for outsourced work	CHF	6857	8420	7260	7478	10511	10936	9302	14264	7875	8221
Revenues for work on neighbouring farms	CHF	3653	4358	2837	3486	5185	6392	12477	35113	4876	11297
Family-labour off farm	AWU	0.17	0.68	0.20	0.20	0.17	0.11	0.17	0.16	0.20	0.26
Livestock population	LU	25.25	23.5	25.2	26.7	30.3	34.9	25.5	32.2	26.6	15.8
Area	UAA	19.44	21.0	18.3	20.1	23.8	24.4	22.6	25.2	20.4	9.4
Open arable land	UAA	4.09	6.1	3.6	4.1	6.4	7.9	6.0	9.3	4.8	6.7

Source: wn calculations

Notes:

[1]. lds highlighted in grey: The mean of the cluster deviates more than **one** cluster standard deviation from the mean of all farms (positive/negative).

[2]. Underlined digits: The mean of the cluster deviates more than **one-half** cluster standard deviation from the mean of all farms (positive/negative).

[3)]. Significance group (SG). According to the pairwise Kruskal-Wallis test (1952), if two clusters do not have the same letters in their group name, there exists a significant difference between these clusters (P<0.05, P-value adjustment according to Holm, 1979).

[4)]. The farm's total workload is arrived at by multiplying all farm production activities in 2004 and 2009 by their corresponding, yet constant-over-time, working-time requirement coefficients.

[5)]. Labour input for farm = family labour on farm + wage labour + labour share of contracting services on farm.

[6)]. Labour balance for farm = workload–labour input.

Table 6: Growth of turnover, labour input, labour productivity and total factor productivity from 2004 to 2009

	Δ Deflated Turnover [1000 CHF] M[1)]	Δ Labour Input [AWU] M	Labour Productivity Change			Malmquist Index Total Factor Productivity Change			
						95% Confidence Interval			Interval Overlap
			M	SD[2)]	SG[3)]	Lower boundary	M[1)]	Upper boundary	
All Farms	14.9	0.02	8.7%	36.7%		−3.0%	+1.8%	+6.5%	
Cluster 1	8.3	−0.06	10.6%	34.4%	b	−2.1%	+2.5%	+6.9%	a
Cluster 2	19.6	0.13	4.5%	30.9%	bc	−1.0%	+3.5%	+9.3%	a
Cluster 3	−2.1	−0.20	14.9%	40.9%	b	−6.0%	−1.1%	+3.8%	a
Cluster 4	11.8	0.25	−7.5%	31.1%	d	−7.5%	−3.2%	+1.7%	a
Cluster 5	33.2	0.30	4.3%	38.6%	cd	−1.0%	+3.7%	+8.4%	a
Cluster 6	60.7	−0.09	31.7%	47.3%	a	+1.1%	+6.7%	+11.6%	a
Cluster 7	23.8	0.02	15.3%	34.2%	b	−4.3%	+3.5%	+8.7%	a
Cluster 8	28.2	0.04	4.2%	35.2%	bcd	−4.6%	+0.8%	+7.4%	a

Source: Own calculations.
Notes:
1). M: Arithmetic mean.
2). SD: Standard deviation.
3). SG: Significance group. If two clusters do not have the same letter in their group name, according to a multiple Kruskal-Wallis test (Conover, 1999), a significant difference exists between these clusters ($P<0.05$, P-value adjustment according to Holm, 1979).

the others whilst experiencing an average change in income. The reason for this is that the use of the contractor results in additional third-party costs. By contrast, the 'Family labour-focused' Cluster 4 managed to keep its agricultural income despite declining productivity, since it was able to expand its employment of labour on the farm without incurring additional costs. In terms of the organisation of labour use, the only crucial factor for the farming household is ultimately how household income changes in relation to the family workforce deployed on- and off-farm. The 'Wage labour-focused' and the 'Contractor' clusters 5 and 7 contrast significantly positively with the 'Stable', 'Sideline-oriented' and 'Family labour-focused' clusters 1, 3 and 4, with the 'Contractor' cluster benefiting in particular from increases in turnover in an agricultural related market with relatively stable prices compared to the actual agricultural market.

5. Conclusions

This paper investigated the relationship between changes in labour use, farm size, farm income, and productivity. We approved the intuitive interdependencies between the different types of labour except for the off-farm contracting services that obviously do not contribute to the regulation of farm labour capacities. In general, higher labour productivity and TFP lead to higher family farm incomes (per on-farm family labour).

By means of a cluster analysis we identified 7 major strategies to adjust labour input. Between 2004 and 2009, just over half of the sample–the cluster of the 'Stable' farms–kept their inputs constant, and did not achieve the worst operating results by doing so. A further eight per cent of the farms–the sideline-oriented ones–decided to embark on a process of contraction of the farm in favour of stronger off-farm commitments.

Table 7: Average growth in agricultural income [AI] and household income [HI]

	Income in 2004 [1000 CHF]				Nominal mean absolute change 2004–2009 [1000 CHF]							
	AI	HI	AI per FAWU[1)]	HI per FAWU[2)]	AI	SG[3)]	HI	SG	AI per FAWU[1)]	SG	HI per FAWU[2)]	SG
All Farms	66.6	85.5	54.9	61.3	−3.2		1.7		−4.1		0.8	
Cluster 1	65.1	83.2	52.7	60.1	−3.2	a	0	bcd	−2.1	ab	1.3	b
Cluster 2	59.3	91.7	59.3	56.8	3.3	a	−8.6	d	−9.3	bc	11.3	ab
Cluster 3	58.1	80.9	50.4	58.6	−11.3	b	12.4	a	−5.3	b	−0.8	b
Cluster 4	62.9	82.4	57.5	64.1	0.1	a	2.5	abc	−16.7	c	−13.8	c
Cluster 5	74.9	93.4	51.3	58.5	−10.7	b	−4.7	cd	2.6	ab	11.1	a
Cluster 6	84.9	95.9	68.8	71.7	−1.4	a	7.4	abc	−0.3	ab	6	ab
Cluster 7	73.9	89.3	56.2	61.4	11.9	a	18.4	ab	12.5	a	15.2	a
Cluster 8	81.3	97.5	67.3	72.2	−3.9	ab	6.6	abcd	−8.9	bc	−3.4	abc

Source: Own calculations
Notes:
1). FAWU: Family annual working units, farm
2). FAWU: Family annual working units, farm and sideline
3). SG: Significance group. If two clusters do not have the same letter in their group name, according to a multiple Kruskal-Wallis test (Conover, 1999), a significant difference exists between these clusters ($P<0.05$, P-value adjustment according to Holm, 1979).

Likewise interesting is the heterogeneity of the 40 per cent of farms in the sample under consideration that are growing. The six different patterns indicate that simple categorisations of the three types of labour–family and wage labour as well as contracting services–evidently fall short of the mark, and that differentiated theories on their use must be developed. This, for example, holds true for the phenomenon of one cluster substituting work on their own farm for contracting services on neighbouring farms, whilst a similarly-sized cluster decides on the reverse substitution process. The fact that these two clusters (7 and 8) from the outset exhibit high expenditure for contracting services points to the great importance of the concept of path dependencies in such a theoretical approach. Moreover, the fact that, as part of the growth process, both clusters virtually change places on the income ladder, indicates that purely economic explanatory approaches fall short of the mark here, and that social factors will also be playing an important role.

Since forecasts for the agricultural sector are also increasingly based on the simulation of individual farms (Kleinhanss *et al.*, 2002; Möhring *et al.*, 2011), it makes sense to integrate the existence of the different growth patterns in the modelling of growth processes too. A challenge faced here is to link the structural features of the modelled farms with the allocation of specific types of growth. Further empirical analyses of growth processes in different historical and socioeconomic contexts will help us cope with this challenge as realistically as possible.

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