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Calculating full costs for Swiss dairy farms in the mountain region using a maximum entropy approach for joint-cost allocation

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ABSTRACT

Using data from the Swiss Farm Accountancy Data Network (FADN), this paper derives the full cost for all enterprises–also called 'activities' or 'production branches'–of a sample of 44 Swiss dairy farms in the mountain region. For the joint-cost assignment among enterprises, we apply an approach based on maximum entropy, leading to a disproportionate allocation. The costs per kilogram of milk are calculated on the basis of enterprises involved in dairy production such as roughage, dairy-cow husbandry and calf rearing. Said costs come to CHF 2.40 on average and CHF 2.13 for the median farm. Both results are over three times higher than the producer price, highlighting the significance of other income sources such as direct payments. Labour and machinery are the most important cost items, accounting for 62% and 14% of total costs, respectively. Furthermore, the analysis reveals significant negative correlations between the full costs for milk on the one hand, and farm size measured in livestock units and farm income per family annual labour unit on the other.

KEYWORDS: full costs; dairy; joint cost allocation; enterprise; Switzerland, FADN

1. Introduction

For years, the income of farms in the mountain regions has been modest compared to the income earned outside agriculture. For instance, in the years 2009 to 2011, a full-family workforce involved in mountain farming earned CHF 24,424 a year, while the comparable income in the industrial or service sector, CHF 62,617, was more than double that (Schmid and Roesch, 2012)[2].

Dairy farms–the main farm type found in the Swiss mountain region–contribute to important societal public goods such as grassland maintenance. How to increase income in the long run is therefore a political as well as a business-management question. Basically, there are three options: to increase producer milk prices; to increase direct payments; and lastly, to cut production costs. Owing to Swiss agricultural policy, the producer or farm-gate milk price in Switzerland is substantially higher than in neighbouring regions such as southern Germany or Austria. In 2010, for example, the average producer price for a kilogram of raw milk was CHF 0.62 (Federal Office for Agriculture, 2011), while prices in Bavaria and Austria were CHF 0.38 (€0.31; Agrarmarkt Austria, 2011). A potential free-trade agreement for agricultural commodities between Switzerland and the European Union as currently under discussion would lead to a substantial fall in the Swiss producer milk price, making the first option of increased producer prices less realistic. With the second option, it is important to note that direct payments are higher in Switzerland than in the European Union, averaging almost CHF 73,000 per dairy farm in the mountain region in 2010 (Hoop and Schmid, 2013). Recently passed in the Swiss national parliament, the agricultural policy for the years 2014 to 2017 retains the payment framework of the previous years (Lehmann and Lanz, 2012). To assess the third option of cost reduction, several questions suggest themselves. How high are full costs or full product costs per kilogram of milk? What does the cost structure look like? And finally, is there an economy-of-scale effect, i.e., a negative correlation between full costs and farm size?

Full-cost accounting is a suitable tool for answering these questions. For Swiss dairy production, the International Farm Comparison Network (IFCN) reports the full costs of typical farms (Hemme, 2012). Haas and Höltschi (2012) compile the full costs calculated by Swiss dairy-farm managers. Dorfner and Hofmann (2013) analyse the full costs of over 200 dairy farms in Bavaria. Based on Farm Accountancy Data Network (FADN) figures, the European Commission (2013) calculates full costs–also known as operating costs–for dairy farms in all

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[2] CHF = Swiss Franc. Exchange rates: CHF 1 = €0.81; CHF 1 = US$1.12 (http://fxtop.com, assessed 28 October 2013).

member countries. Using the full costs of several hundred dairy farms in the USA, MacDonald *et al.* (2007) analyse the influence of farm size on profitability.

The allocation of joint-cost items such as labour, machinery or buildings constitutes the main challenge for full-cost accounting. Such costs are normally reported at farm level. If a farm produces more than one output (e.g., milk and cereals), joint costs must be allocated to enterprises (also termed 'activities' or 'production branches'). For this, allocation factors such as working hours–available for all enterprises–are used. In the above-mentioned studies, allocation is performed in a proportional manner, which is a widely applied approach in the literature. Lips (2014) suggested an alternative approach based on maximum entropy. This allows us to discard the assumption of a proportional joint-cost allocation. In addition, as shown for arable crops, the choice of the allocation method is empirically relevant, since there were differences in a range of −16% to +18% between a proportional and a disproportionate allocation. For the full cost analysis of dairy farms, we take advantage of the new technique and apply the disproportionate joint-cost allocation. A proportional allocation is performed at the same time, offering the option of comparing allocation results, which is of interest from a methodological point of view.

This paper is organised as follows: Section Two presents the data from the Swiss FADN as well as the allocation factors, while Section Three provides a brief summary of the disproportionate joint-cost allocation and explains the necessary extension when simultaneously analysing crops such as roughage and animal husbandry sectors. Furthermore, the conversion from enterprise costs to cost per kilogram of milk is presented in detail. Section Four comprises the results, while Sections Five and Six are devoted to the discussion and conclusion, respectively.

2. Data

Because of the focus on dairy production in the Swiss mountain region, we use the accounts of Swiss FADN specialist dairy farms in mountain zones 1 to 4 for the year 2010. There are two factors that lead us to select appropriate farms from the 507 available observations. Firstly, since we focus on agricultural activities, farms involved in agriculture-related activities of over CHF 5000 in value, such as direct sale or gastronomy, are excluded. Otherwise, a shortage of available data would make it impossible to allocate joint costs, especially joint labour costs. Secondly, we must exclude those farms using a substantial share of milk for the fattening of calves, an activity which, based on the available data, is difficult to distinguish from milk production. To this end, we define a maximum quantity of 5000 kg of milk which is not sold as raw milk, but consumed by the farmer's family or used on the farm (though not in the rearing of calves as replacements for the dairy herd[3]). This provides us with a sample of 44 dairy farms. Table 1 presents the characteristics of both the selected sample and the weighted average of all FADN dairy farms from the mountain region. Generally speaking, the selected farms are smaller in size and have lower incomes[4]. The 21.4 livestock units of the analysed sample comprise 15.2 dairy cows, 5.8 breeding animals and 0.4 'other' livestock such as sheep and goats. Seven farms out of the selected sample are run along organic lines.

Because the Swiss FADN provides highly detailed information for both cost items and enterprises, aggregations are necessary.

For dairy production, in order to correctly depict deliveries within the farm, it is essential to draw a distinction at enterprise level between fodder production and animal husbandry. To give an example, fodder produced on the farm can be used to feed dairy cows, or other ruminants such as sheep. Accordingly, we define roughage and silage maize as 'own fodder production' enterprises[5]. For dairy livestock, we distinguish between two enterprises: dairy-cow husbandry, including labour-intensive milking, and the calf rearing which serves as a dairy-herd replacement enterprise. This distinction is motivated by the organisational differences that exist between farms, with some outsourcing breeding, whilst others breed their own future dairy cows on-farm. All activities besides the four dairy-related enterprises are aggregated towards eight additional enterprises, three of which are concerned with plant production: cereals (wheat and barley), forestry, and 'other plant production' encompassing all other activities such as potatoes, peatland and specific ecological areas. Another five enterprises are devoted to animal husbandry: fattening cattle (including suckler cows but not calf fattening), sheep and goats; pork (pig fattening and pig breeding); poultry (poultry fattening and laying hens); and other animals (e.g., horses and donkeys).

Whilst the enterprises of roughage, dairy-cow husbandry and calf rearing are represented on all farms, the number of different enterprises on a farm varies between three and seven out of the 12 enterprises defined. In total, there are 189 enterprises.

With respect to full costs, three categories of cost items can be distinguished for the analysis (Table 2): direct costs, land costs and joint costs. The Swiss FADN includes these categories in different forms[6]:

- Direct costs are recorded at the enterprise level, and are aggregated towards three cost items: purchased feed (feed concentrates and purchased roughage), veterinary services and products (including insemination), and other direct costs (e.g. seeds, fertilisers, and purchase of livestock).
- For land, the FADN provides the total rent figure for leased land, while the opportunity costs of own land are derived by applying the interest rate of Swiss federal term bonds. The average costs per hectare are

[3] Given the limit of 5000 kg delivered milk, calf fattening – which forms part of the 'calf rearing' enterprise – can only take place on a limited basis.

[4] Farm income per family annual labour unit, both for selected samples and for all available dairy farms, is markedly higher than stated in the introduction. Whereas the values in Table 1 refer to the averages of the samples, the indications in of the comparison of income refer to the median, which – owing to cases with very high incomes – is lower than the average.

[5] The storage costs for fodder produced on-farm are accounted for in the 'silage maize' and 'roughage' enterprises.

[6] The cost categories are not directly related to the terms 'variable costs' (varying in direct proportion to the volume of activity) and 'fixed costs' (remaining constant over wide ranges of activities) (Drury, 2004; p. 34). While direct costs belong to the 'variable costs' category, joint costs may belong to both categories. Machinery, for example, includes all costs related to machinery use. Depreciation and interest rates for the invested capital are fixed costs. By contrast, fuel is classified as a variable cost.

Table 1: Characteristic variables of dairy farms in the mountain region 2010

	Unit	Selected sample	Weighted average of all FADN observations
Sample size		44	507
Utilised agricultural area	ha	18.8	22.7
Livestock units	LU	21.4	24.7
Agricultural income	CHF	46,815	50,891
Farm income per family annual labour unit	CHF	30,583	32,216

Source: Hoop and Schmid (2013); Swiss FADN

Table 2: Cost categories and cost items

Total costs	Cost categories	Cost items
Full costs	Direct costs	Purchased feed Veterinary Other direct costs
	Land	Land
	Joint costs	Labour Machinery Buildings Other joint costs

Note: The shaded cost items include opportunity costs for remuneration of family-owned factors

calculated with the assumption of homogeneous land quality[7].

- All joint costs are provided by the Swiss FADN at farm level, and are aggregated towards four cost items: labour, machinery, buildings, and other joint costs (including energy, telephone, insurance, and further training). As regards labour, the FADN reports farm-level labour input measured in normal working days. The allocation is performed in the form of working days rather than labour costs. Working days are then rated with an opportunity cost of CHF 280 (10 hours per normal working day at CHF 28 per hour; Gazzarin, 2011). The machinery costs include depreciation and interest on invested capital, as well as repair, maintenance and fuel costs. Machines associated with animal husbandry such as milking parlours are also considered part of machinery costs. Building costs take account of depreciation, interest charges and maintenance. For both machinery and buildings, we apply the interest rate for foreign capital and opportunity costs (Swiss federal term bonds) for own capital.

The summary of the analysis contains the eight cost items listed in Table 2. All cost items are shaded, including opportunity costs for remuneration of factors owned by the farming family.

Allocation factors are necessary to enable the allocation of joint costs among enterprises. For this, standard costs from farm-management literature are used (Gazzarin *et al.*, 2013; Lips, 2014) or gauged, when no data was available. All values are reported in the Appendix.

3. Method

Joint-cost allocation

For joint-cost allocation, allocation factors or items available for all enterprises (e.g. area or working hours) are typically used (AAEA, 2000). In our case, standard costs (also called budgeted or forecast costs) from farm-management literature are applied. Taken together with enterprise-level information from the FADN, such as the number of hectares, these allow us to calculate the farm-level costs for joint-cost items such as buildings. In doing so, and assuming that the farm's costs are perfectly in line with the standard costs from the farm-management literature, we arrive at the building costs of a particular farm, which can be compared to the farm's actual building costs as reported by the FADN system. Based on these two figures, the deviation factor alpha can be calculated. In other words, alpha represents the ratio of observed farm-level costs (actual costs) to standard farm-level costs. Alpha is then multiplied by the standard costs of the enterprise, which yields the joint costs at the enterprise level we are seeking.

Because alpha is constant across all of a farm's enterprises, it corresponds to a proportional joint-cost allocation. Although widely applied, it represents a strong assumption, since all enterprises are adjusted in the exact same manner, regardless of whether the allocation factor is large or small. Furthermore, the ratios between enterprises (e.g. labour costs of 'forest' and 'dairy-cow husbandry') remain constant.

As an alternative, Lips (2014) suggested a disproportionate joint-cost allocation based on maximum entropy and the allocation factors mentioned above. This approach is based on the assumption that the resultant joint costs at enterprise level lie in an interval between zero and twice the standard costs from the literature[8].

[7] Homogeneous land quality is only assumed for plant enterprises (cereals, silage maize, roughage and other plant production). For forestry, a lower quality and hence a rental rate of CHF 72 per hectare (Albisser et al., 2009) is assumed.

[8] If alpha exceeds 1, the upper boundary is expanded towards 1 plus alpha. Out of the 44 dairy farms, such an adjustment is necessary for the joint-cost items of labour, machinery, buildings and other joint costs for 36, 32, 3 and 14 farms, respectively.

Table 3: Deviation factor alpha for all joint-cost items

	Labour	Machinery	Buildings	Other joint costs
Mean	1.61	1.28	0.52	0.87
Minimum	0.75	0.34	0.03	0.09
Median	1.55	1.18	0.48	0.86
Maximum	3.06	2.44	1.64	1.75

Source: Own calculation using data from the Swiss FADN

Both interval boundaries are assigned probabilities adding up to one–for instance, if both boundaries have a probability of 0.5, this yields the value from the literature. Assuming that a particular farm has lower building costs than suggested in the farm-management literature, the farm's alpha for buildings would be lower than 1, as is the case for the average of the selected sample, as we will see later on (Table 3). Consequently, the building costs fall short of the standard costs for all enterprises of the farm. As regards the above-mentioned interval, the probability of the lower boundary (0) is higher than 0.5, whilst the upper boundary (twice the standard costs) has a probability below 0.5. As a normative approach, the 'maximum entropy' application provides the single and optimal probability distribution for all boundaries subject to a total allocation of actual joint costs at farm level. This approach leads to a disproportionate allocation of joint costs among enterprises, meaning that enterprises with high standard costs undergo a more marked adjustment than those with low standard costs. Generally speaking, maximum entropy provides a probability distribution in which the adjustment of high standard costs is more likely than the adjustment of low costs. This closely corresponds to agricultural reality, in which the higher the standard costs, the higher the possibility of cost adjustment. In addition, since the disproportionate joint-cost approach is applied separately for each farm, a farm-specific joint-cost allocation is provided. In other words, the ratio of the labour costs of one enterprise to another–say, 'forest' to 'dairy-cow husbandry'–can vary between farms.

The method applied (Lips, 2014) represents a further development of a recent conference paper (Lips, 2012), and includes two main differences which are relevant for the present analysis. Firstly, the equation of the Shannon Entropy measure is supplemented with the number of enterprise reference units (e.g. hectares) as weighting factors. Given that the entropy model specification takes place at the reference-unit level, an enterprise of, say, two hectares is treated in principle as two separate enterprises. Since the boundaries are the same, the resultant probabilities are identical for both hectares. Accordingly, a weighting factor allows us to focus on enterprises rather than on individual reference units. Secondly, to ensure that findings from production-technology are borne in mind, inequality restrictions (Campbell and Hill, 2006) are added to the maximum entropy model. Given a clear rank order of an enterprise's standard costs, the inequality restrictions address the differences among said costs. Owing to the disproportional adjustment of maximum entropy, the differences among standard costs should increase steadily upwards. As a difference from the preliminary version, Lips (2014) suggested adding additional activities[9] in order to hone the differences if they are not steadily increasing.

Reference units of enterprises

For crop enterprises, one hectare of land is used as the reference unit (Lips, 2014)–but what reference unit is the most appropriate for animal-husbandry enterprises? Here, two requirements must be met. Firstly, the unit must be consistent within the sphere of animal husbandry–e.g. 'number of animals' would be misleading given the huge difference in the quantity of inputs required for laying hens on the one hand and dairy cows on the other. Secondly, the standard costs per unit should be in a similar range to the costs of plant-production enterprises–otherwise, the treatment of animal- and plant-production enterprises would differ owing to the disproportionate allocation of the maximum entropy approach. To give an example, if the allocation factors for all plant-production enterprises are lower than those of the animal-husbandry enterprises, the adjustment of the latter would be systematically greater. The livestock unit (LU) fulfils both requirements, which is why two reference units–hectares and LU–are applied for the joint-cost allocation (see also the Appendix).

Costs per kilogram of milk

Although the approach described above calculates the full costs for each enterprise, only four of these enterprises–silage maize, roughage, dairy-cow husbandry and calf rearing–are relevant to dairy production.

In order to derive the full cost per kilogram of milk–the core finding of this paper–several steps must be taken to transform these full costs. Here, we make use of additional data provided by the Swiss FADN, such as quantity of milk produced in kilograms.

As a first step, and based on the full costs per hectare of silage maize and roughage, we calculate total costs for on-farm fodder production by multiplying these values by the appropriate number of hectares. Next, we take the full-cost sum of both enterprises. Assuming that all ruminants require the same amount of fodder per livestock unit, we multiply these costs by the share of all ruminants livestock units devoted to dairy-cow husbandry and calf rearing.

Secondly, in order to obtain the total costs of the 'dairy-cow husbandry' and 'calf rearing' enterprises, we

[9] The additional enterprises are treated as additional crops without area, or additional animal-husbandry enterprises without livestock units.

Table 4: Full costs for all enterprises in CHF per hectare or livestock unit

Enterprise	Unit	Number of observations	Full costs in CHF per unit			
			Mean	**Minimum**	**Median**	**Maximum**
Cereals	ha	4	4240	2715	4468	5307
Silage maize	ha	2	8676	4283	8676	13070
Roughage	ha	44	4406	2446	4476	6250
Forestry	ha	28	1068	715	1076	1367
Other plant production	ha	7	16382	4809	14150	30664
Dairy-cow husbandry	LU	44	7992	3537	8211	12940
Calf rearing	LU	44	4658	2337	4783	8054
Fattening cattle	LU	1	6000	-	-	-
Sheep and goats	LU	6	4465	2076	4567	7004
Pork	LU	4	3621	2868	3485	4646
Poultry	LU	1	3650	-	-	-
Other animals	LU	4	3639	2473	3925	4233

Note: ha=hectare; LU=livestock unit
Source: Own calculation using data from the Swiss FADN

multiply the full costs per livestock unit by the corresponding number of livestock units. The resultant costs are then added to the costs from step one, yielding the total costs of all inputs used for milk production[10].

Thirdly, we must consider the by-products of milk production, such as old cows destined for slaughter, and breeding animals which can be sold to other dairy farmers. Assuming a joint production of milk and by-products, the total costs for milk production must be multiplied by the percentage of milk sales out of the total turnover for milk production. Finally, the resultant total costs of milk production are divided by the total number of kilograms of milk produced, less the milk fed to the calves reared for dairy-herd replacement, to obtain the full cost per kilogram.

4. Results

The deviation factor alpha presented in Table 3 gives an indication of the extent to which the farms' actual costs differ from those in the farm-management literature. A value of one would indicate that a farm is completely in line with standard cost. The mean values indicate that dairy farms of the selected sample use far more labour and machinery inputs than suggested. For buildings and other joint costs, inputs are below the level given in the farm-management literature. According to minimum and maximum values, there is substantial variance for all joint-cost items in the sample. The minimum values for machinery, buildings and other joint costs indicate that production at a very low cost is possible.

Table 4 reports the full costs per hectare or livestock unit for all enterprises. In addition to the mean full cost, minimum, median and maximum values are reported for all enterprises except fattening cattle and poultry, each of which is present on one farm only.

On average, the full costs of dairy-cow husbandry come to CHF 7992 per livestock unit. For roughage, dairy-cow husbandry and calf rearing, the minimum and maximum values fall in a range of at least $\pm$40% of the mean values, indicating a substantial variance between farms. The enterprise 'other plant production' exhibits the largest difference between farms, with a maximum value more than six times greater than the minimum value.

The full costs derived per kilogram of milk are depicted in Table 5. In the mean of the sample, costs come to CHF 2.40, of which CHF 1.48 or 61.5% relates to labour, the main cost item. The second-most important cost item is machinery costs, which accounts for CHF 0.35 per kilogram (14.5%). Cost items three and four, purchased feed and buildings, account for CHF 0.19 (7.8%) and CHF 0.14 (6%), respectively.

The average producer milk price realised for the farms analysed is CHF 0.68, with a range at the farm level between CHF 0.49 and CHF 1.03, respectively. The realised price is therefore markedly above the average milk price of CHF 0.62 (Federal Office for Agriculture, 2011), indicating that the milk is primarily made into cheese. Adding up the costs of machinery, purchased feed and buildings gives us CHF 0.68, which is equal to the average producer milk price. Consequently, no other cost item can be covered by the realised producer price.

Figure 1 illustrates the variance while depicting the full costs for a kilogram of milk in an ordered array for all farms. Whereas the lowest total costs stand at CHF 1.23, the highest are CHF 5.73. Between these totals is a factor of more than 4. There is also a group of five farms where full costs of CHF 3.00 are clearly exceeded, an obvious sign that a minority of dairy farms are either subject to specific circumstances (e.g. an extreme event) or have production systems that do not accurately reflect economic realities. The discussion section provides a number of arguments as to why full costs may exceed producer prices.

Table 5 includes the cost structure of the farms with the lowest and highest total costs, as well as the median farm. The main differences are attributable to labour. Furthermore, a comparison of the cost item 'buildings' between the median and the best farm reveals that the farm with lowest total costs does not have the lowest values for all cost items. The farm with the highest total costs also has extremely high values for the cost items 'purchased feed', 'other direct costs' and 'machinery'.

[10] 'Milk production' is used as an umbrella term for the major share of the enterprises 'silage maize' and 'roughage', as well as the full share of the 'dairy-cow husbandry' and 'calf rearing' enterprises.

Table 5: Full costs in CHF per kilogram of milk

Cost item	Mean		Farm with lowest total costs	Median farm	Farm with highest total costs
	CHF	In %			
Purchased feed	0.19	7.8	0.20	0.28	0.41
Veterinary	0.05	2.1	0.04	0.03	0.17
Other direct costs	0.07	2.8	0.02	0.05	0.31
Land	0.04	1.5	0.03	0	0.05
Labour	1.48	61.5	0.55	1.45	3.37
Machinery	0.35	14.5	0.19	0.19	0.99
Buildings	0.14	6.0	0.15	0.03	0.16
Other joint costs	0.10	4.2	0.05	0.11	0.28
Total	2.40	100.0	1.23	2.13	5.73

Source: Own calculation using data from the Swiss FADN

The correlations between full costs and structural and economic indicators presented in the data section are shown in Table 6. As expected, all correlations are negative. For livestock units and farm income per family annual labour unit, the Pearson correlations differ significantly from zero at the 1% level.

5. Discussion

Our results can be compared with two analyses from the literature of Swiss dairy farms in the mountain region. A typical Swiss dairy farm with 18 cows is included in the annual dairy report of the International Farm Comparison Network (IFCN; Hemme, 2012) quoting costs of USD 2.42 per kilogram (approx. CHF 2.16), which are close to those of our median farm. Analysing the full costs of 26 dairy farms in the mountain region for the year 2010, Haas and Höltschi (2012) found that the average full costs came to CHF 1.54 per kilogram of milk. Two factors may be responsible for the differences between their full costs on the one hand and those of our study on the other. Firstly, the dairy farms of the sample they investigated are markedly larger than ours (22 cows on average as compared to 15 cows in our sample). Secondly, the full costs in the Haas and Höltschi sample derive from three subgroups: dairy farmers calculating their full costs as a case study within the framework of their higher vocational education in agriculture; dairy farmers attending a full-cost course or consultation; and dairy farmers organised into working groups, calculating and comparing their full costs. For the second and third subgroups at least, a specific interest in production costs can be assumed. It is therefore likely that these dairy farmers are considering implementing cost-reducing measures, or have even done so already. Consequently, their full costs are markedly lower than those of the FADN sample.

The negative correlation found between number of livestock units and full costs per kilogram bears out Gazzarin *et al.* (2005), showing the gradual decrease in cost as the number of cows increases by means of full-cost calculation for dairy production. Similarly, Jan *et al.* (2011) point out that for dairy farms in the mountain region, farm size has a positive influence on the work income per family annual labour unit.

In addition to the joint-cost allocation by maximum entropy, a proportional joint-cost allocation was also performed as a sort of sensitivity analysis, using the same standard costs as allocation factors. At the enterprise level, the largest differences can be observed for activities which are rarely represented in the sample. Compared to the results set out in Table 4, a proportional joint-cost allocation would lead to deviations for silage maize, other plant production and poultry of +10%, −9% and +13%, respectively. For roughage, dairy-cow husbandry and calf rearing, the differences are much smaller (+1%, −1% and +2%). With regard to the full costs of a kilogram of milk, the deviations at single-farm level between a disproportionate joint-cost allocation and a proportional one fall within the range of CHF −0.01 and CHF +0.05. For the average of all 44 farms, the full cost would be CHF 0.001 lower under a proportional allocation. An important reason for this very slight difference is the fact that the farms in this sample specialise in dairy production. Whatever type of joint-cost allocation is applied, the bulk of it is devoted to milk production.

Since even the best farm has full costs of almost twice the producer milk price, the question arises as to how these farms can continue to operate. Three possible explanations suggest themselves. Firstly, the actual hourly wage rate is lower than the presumed CHF 28. Assuming 280 normal working days of 10 working hours each (see also data section) for a family annual labour unit yields an average hourly wage rate of CHF 10.92 for the 44 farms in question[11]. Secondly, the direct payments must be taken into consideration. Finally, there might be an additional income from off-farm activities at the household level.

6. Conclusions

In this paper, the full costs or full product costs of the enterprises of 44 Swiss dairy farms in the mountain region were derived from accounting data from the Swiss Farm Accountancy Data Network (FADN) using a maximum entropy approach, which provides a disproportionate joint-cost allocation. Because several enterprises such as roughage, dairy-cow husbandry and calf rearing contribute to dairy production, full costs are deduced per kilogram of milk in a subsequent step. The

[11] On-farm income per family annual labour unit of CHF 30,583 (see Table 1) divided by 2800 hours per year

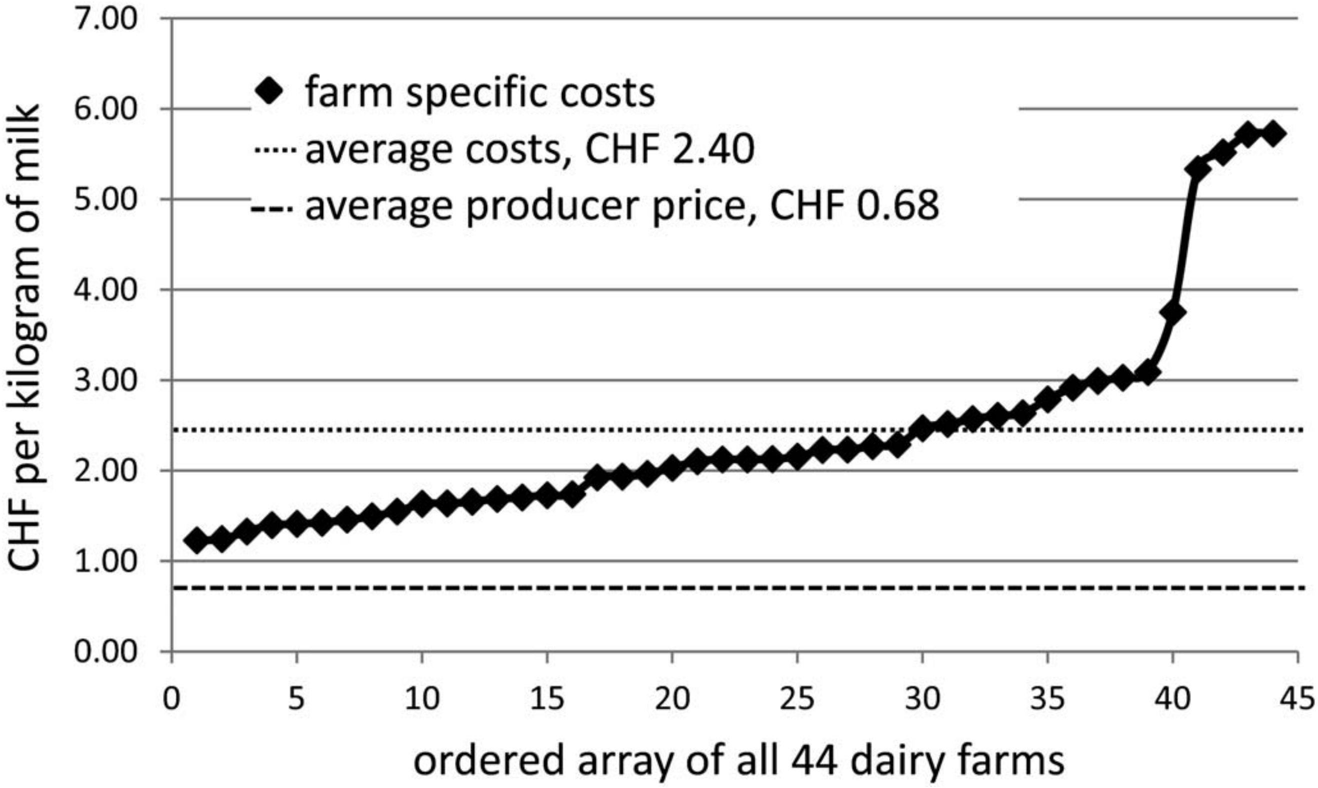

Figure 1: Distribution of full costs for a kilogram of milk

resulting average full costs of CHF 2.40 per kilogram milk are more than three times as high as the realised milk producer price of CHF 0.68. Accordingly, milk production does not even come close to covering costs, and falls far short of the assumed hourly wage rate of CHF 28. Milk production is therefore only modestly profitable, which goes some way towards explaining the chronically low incomes for dairy farmers in the mountain region. Furthermore, the significant negative correlation between full cost per kilogram and farm income per family annual labour unit shows the importance of a cost cut for an increase in income.

The cost structure reveals labour as the main cost driver, responsible for around 60% of full costs. A reduction of labour input per kilogram of milk is therefore a must for dairy production in the mountain region. In other words, a dramatic increase in labour efficiency is needed to cut the cost per kilogram and to increase income per family labour unit. Looking at the dairy farm with the lowest costs in the sample, achieving this objective would appear to be possible. Moreover, an increase in farm size allows advantage to be taken of economies-of-scale effects, and can be achieved e.g. by cooperating with other farmers. The highly significant negative correlation between number of livestock units and full costs per kilogram of milk underscores the promise of such a strategy, and is in line with the literature.

Apart from the importance of labour, the analysis highlights the significance of the three cost items 'purchased feed', 'machinery' and 'buildings'. Taken together, their costs equal average producer price of farms analysed, indicating a clear and immediate need for cost reductions in dairy production. Without a change, the current unbalanced situation requiring additional revenue such as direct payments to cover these expenses in full could be expected to continue. Given the importance of dairy farms for grassland maintenance in the mountain region, the government could support such a process by supplying more information and advice about full costs at the enterprise level for dairy farmers.

Our results are higher than those of the full-cost analysis literature. In addition to farm size, the attitude of the dairy-farm manager might be of importance, given that the study by Haas and Höltschi (2012) is based on the full-cost calculations of dairy farmers, at least some of whom might have an above-average interest in production costs. Accordingly, a selection bias might also be responsible for the differences. The possibility that the farms in our analysis are markedly above-average in terms of full costs cannot be ruled out.

Table 6: Pearson correlations between full costs and characteristic variables of dairy farms

Variable	Unit	Correlation	P-Value
Utilised agricultural area	ha	−0.18	0.239
Livestock units	LU	−0.40	0.007
Agricultural income	CHF	−0.30	0.049
Farm income per family annual labour unit	CHF	−0.40	0.008

In order to clarify these aspects, the analysis must be expanded for all dairy farms from the mountain region in the Swiss FADN. As a precondition it is essential that approaches be developed to cope with both large agriculture-related activities and calf fattening in addition to dairy production.

The present analysis makes use of a disproportionate joint-cost allocation via maximum entropy. The sensitivity analysis, which consists in also running a proportional allocation, reveals substantial differences at the enterprise level. The results for full cost per kilogram of milk are the same, indicating that the type of joint-cost allocation is only of minor importance for the present analysis. Owing to the high degree of specialisation, most costs are assigned to dairy production by whatever means is used to perform the joint-cost allocation.

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Appendix A: Standard costs from farm-management literature

Enterprise	Unit	Labour in normal working days	Machinery costs in CHF	Buildings in CHF	Other joint costs in CHF
Cereals	ha	3.3	1549	160	130
Silage maize	ha	3.7	2629	2509	140
Roughage	ha	5.3	1036	648	150
Forestry	ha	1.0	352	100	100
Other plant production	ha	18.3	4553	310	320
Dairy-cow husbandry	ha	10.5	440	670	400
Calf rearing	LU	8.5	80	933	380
Fattening cattle	LU	14.7	70	827	360
Sheep and goats	LU	6.8	30	676	350
Pork	LU	5.5	15	835	250
Poultry	LU	4.5	10	1104	260
Other animals	LU	6.0	25	600	300

Note: ha=hectare; LU=livestock unit; CHF=Swiss Franc
Sources: Gazzarin *et al.* 2013, Lips 2014, own estimates