Joint Cost Allocation by Means of Maximum Entropy

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Abstract

The paper proposes an approach based on maximum entropy and reference values from farm management literature in order to allocate joint costs like labour or machinery use amongst multiple production branches at the farm level. The approach allows dropping the widely used assumption of a proportional allocation and enables to derive farm specific distribution keys. Based on a core model two extensions, a weighting according to production branches area as well as the introduction of inequality restrictions, are analysed, using accountancy data of arable crop farms from the Swiss Farm Accountancy Data Network (FADN). Both extensions are found to improve the meaningfulness of the approach's result.

Applying the extended core model, full costs are derived for five arable crops and compared to farm management literature. Total costs are met or exceeded up to around 20 %, in addition, cost structure clearly differs. The suggested approach shows substantially higher labour costs, indicating that arable crop farms utilize far more labour input than suggested in planning documentation. Conversely, derived costs for machinery are lower.

Key words: joint cost allocation, full cost, maximum entropy, FADN, arable crops, Switzerland

JEL codes: M41, Q12

1 Introduction

Full cost, also called full product costs (Horngreen et al. 2005) or cost price (Pearson Education 2007) is critical information for farming decisions and is of interest for three reasons. Firstly, profitability is determined by examining the difference between output price and full cost. Secondly, full cost provides the opportunity to calculate the cost shares of all inputs and give insight into the cost structure, important when costs need to be reduced. Finally, full cost is a useful tool for comparing different farms, also on a cross-country level. For example, the International Farm Comparison Network (IFCN) annually reports full cost of a litre of milk for dairy farms globally (Hemme 2010). Similarly, comparisons for crops (Agri Benchmark 2009) and beef (Deblitz 2010) are provided by the Agri Benchmark network.

When a farm produces only one output, full cost can be easily derived. Besides the evaluation of own factors, the farm accountancy can be transformed towards full cost. In the case of two or more outputs, which is the predominant case for Swiss farms, full costing denotes a definitely greater challenge since joint costs have to be allocated among production activities or production branches. Proceeding from accountancy data, there are, on principle, two possibilities to derive full cost. The so-called "analytical accountancy"[1] is a specific and highly detailed type of accountancy suggested by Ernst Laur (1930), which includes full cost for all production branches. Therefore, all inputs as well as all the physical flows of goods within the farm need to be documented in detail. In addition, it is necessary to evaluate all flows in monetary terms. As a consequence, a substantial effort is necessary for making this information available. Howald et al. (1971) estimate a time requirement of between 100 and 250 hours per farm for the accounts closing, which is far beyond a normal management effort.

As a second option, so called distribution keys for joint costs can be applied. As an example for crops, Agri Benchmark use machine runtime-hours for the allocation of both machinery and labour costs (Agri Benchmark 2009). The allocation itself is done in a proportional way. Moreover, all farms are typically treated in the same way. Although a proportional allocation symbolizes a very strong assumption, imposing that small as well as large cost items behave in exactly the same way, it is widely applied (e.g. DLG 2004, Hunger et al. 2006, Deblitz 2010, Hemme 2010).

When we allocate joint costs among production branches we normally struggle with incomplete data, or an underdetermined (cost) model, since the "true" distribution key as sketched above is not on hand due to a lack of available resources such as time or money. As a method to overcome data gaps and allowing information recovery, we find that maximum entropy addresses the joint cost allocation problem suitably due to two reasons. Firstly, maximum entropy allows dropping the assumption of a proportional distribution key. Secondly, the resulting distribution keys are farm specific.

The aim of the paper is to present an approach, which uses maximum entropy and reference values from farm management literature in order to derive a farm specific distribution key for joint costs. For a test application accountancy data of the Swiss Farm Accountancy Data Networks (FADN) is used.

The paper is organized as follows. The following methodological section describes the core maximum entropy model, the proposed extension of the core model as well as the criteria in order to compare the extensions. Section three presents the data used. The results are in shown in section four while conclusions are drawn in section five.

[1] in German: „Analytische Buchhaltung“

2 Method

2.1 Core Model

The allocation of joint costs is presented for a single farm, producing *k* arable crops. An arable crop is considered as a production branch or production activity (e.g. wheat). From the FADN data we know joint inputs *y* for several items such as labour input or machinery costs for the whole farm.
According to the notation used by Golan et al. (1996) joint cost allocation problem can be formulated as follows:

$$y = \sum_{k=1}^{K} x_k \beta_k \qquad (1)$$

x_k is the area of production branch *k* measured in hectares. The amount of cost of production branch *k* (β_k) is usually unknown (e.g. machinery cost per hectare of wheat). The variables β_k for all production branches *k* build together a farm specific distribution key.
We assume that β_k lies in a range, which is confined by two support points ($z_{k,i}$), both of which represent plausible extreme values for the upper and lower bounds. Each β_k can be formulated as a weighted sum of the two support points:

$$\beta_k = \sum_{i=1}^{2} z_{k,i} p_{k,i} \qquad (2)$$

$p_{k,i}$ represents the probability that support point *i* of production branch *k* is applied.
For each production branch *k* the probabilities *i* have to add up to 1:

$$\sum_{i=1}^{2} p_{k,i} = 1 \qquad (3)$$

Maximizing the Shannon entropy measure *H* allows determining the probabilities $p_{k,i}$ (Golan et al. 1996):

$$\max H = \left[-\sum_{k=1}^{K} \sum_{i=1}^{2} p_{k,i} \ln p_{k,i} \right] \qquad (4)$$

The function *H* reaches its maximum value when the distribution is uniform within all production branches *k* ($p_{k,1} = p_{k,2} = 0.5$).

Defining the support points ($z_{k,i}$) information outside the sample is necessary. Therefore, we refer to farm management literature, which supplies reference values μ_k for all cost items of production branch *k*. Reference values aim to assist farmers in their planning process. Furthermore, we consider two aspects. Firstly, since costs need to be positive we restrict the range between support points towards positive values. Second, following Heckelei and Wolff (2003) we apply a symmetric range around the reference value μ_k. Accordingly, we assume that the "true" value for β_k is within a range of +/-μ_k. For the first support point ($z_{k,1}$) we apply a value close to 0 (e.g. 0.001) instead of 0 avoiding that equation 2 collapses to: $\beta_k = z_{k,2} p_{k,2}$
For the second support point ($z_{k,2}$) we need to consider that some farms may have costs far beyond the farm management literature. In other words, it might be possible that no solution can be reached within the assumed range. Since the interval between support points should be wide enough to allow for a feasible solution to the maximization problem (Oude Lansink 1999), an enlargement is necessary. Therefore, we introduce the parameter θ, the multiplier for the second support point. The latter is defined as follows[2]:

[2] As a consequence, equation 2 is: $\beta_k = 0.001 * p_{k,1} + \theta \mu_k p_{k,2}$

$$z_{k,2} = \theta\mu_k \quad (5)$$

As a precondition to defining θ it is necessary to assess how much the total costs exceeds the values of the farm management literature. Therefore, the parameter alpha (α) is defined:

$$\alpha = \frac{y}{\sum_{k=1}^{K} x_k \mu_k} \quad (6)$$

α is the relation of the total costs related to the costs that we would expect from farm management literature for a farm with an identical structure. Based on α, we define θ:

$$\theta = \begin{cases} 2 \; if \;\; \alpha \leq 1 \\ 1 + \alpha \; if \;\; \alpha > 1 \end{cases} \quad (7)$$

For values of $\alpha \leq 1$ the upper support point is equal to $2\mu_k$ as described above. If $\alpha > 1$ we expand the second support point towards $(1+\alpha)*\mu_k$. The factor $(1+\alpha)$ ensures continuity with respect to values around 1 of α and allows the necessary enlargement of the solution space[3]. Accordingly, if $\alpha > 1$ only one of the two above mentioned aspects as regards the range between support points can be respected. While the range is still restricted on positive values, the symmetry around the reference value can no longer be maintained.

The suggested approach is formulated in the General Algebraic Modeling System (GAMS; Rosenthal, 2008). The above equations 1 to 4 together build the core model and relies on the model code of a cross entropy application for input output tables by Robinson et al. (1997). The model needs to be solved for each cost item such as labour or machinery use separately. When several farms are analysed, all expressions need to be expanded by the dimension farm. Consequently, the model is solved for every cost item of every farm. The sequential solving procedure is organized by the “loop” command of GAMS.

2.2 Extensions

The core model enables us to get results for all joint costs items on a production branch level. Furthermore, the maximum entropy approach provides a single and optimal solution. Nevertheless, in order to get meaningful results we have to look carefully at the applied mechanism of maximum entropy. As mentioned above the function H (equation 4) reaches its maximum value when the distribution is uniform, which is the case if the reference value from literature (μ_k) is applied. Accordingly, the approach minimizes the deviation from the reference values.

As a first implication, there is a tendency that production branches with larger reference values μ_k (or larger values for its second support point, respectively) will be adjusted in an over proportional way. Imagine a stylized allocation model. There are just two production branches with one hectare each, while the reference value of the first production branch is clearly larger. Assuming that the joint costs, which have to be allocated are smaller than the expected amount from farm management literature ($\alpha < 1$) an adjustment towards the lower support points takes place for both production branches ($p_{k,1} > p_{k,2}$). Due to different reference values (μ_k) an increase of the probability of the lower support point by one percent results in a larger impact for the first production branch

[3] As an alternative, to use $\alpha*\mu_k$ for the upper support point if $\alpha > 1$ would restrict the maximum entropy approach to one single solution: $\beta_k = \alpha\mu_k \;\; \forall \;\; k$

than for the second. Minimizing the deviation from an equal distribution, the model will adjust the first production branch in a stronger manner. This effect is welcomed since a relatively stronger adjustment of larger reference values takes account of the fact that the variety of input use increases with the absolute size of reference values.

As a second implication the number of hectares (x_k) matters in the allocation process. Let us assume another stylized allocation model with again two production branches. While the reference values are identical for both of them, there is a difference in terms of area. The first branch covers two hectares, while the second branch is represented by one hectare only. Again, the joint costs, which have to be allocated, are smaller than the expected amount from farm management literature ($\alpha < 1$). Increases of the lower support point's probabilities by one percent each have different impacts. Due to the larger area the effect on joint costs of the first production branch has twice the impact of the second production branch (equation 1). Minimizing the deviation from an equal distribution the model will end in a stronger adjustment of the first production branch. Since joint costs will be compared between farms, the number of hectare should not have such an influence in the allocation process. Accordingly, we have to define an alternative procedure. Therefore, we treat every hectare conceptually as an independent production branch. Due to the model specification all hectares of the same crop or rather the same reference values lead to the same results. As a consequence, we add up the hectares of the same crop, which yields x_k, the number of hectares of arable crop k. While the core model already includes the area in equation 2, we have to add x_k in the maximizing equation (4). Thinking hectare-wise the probabilities of crop k need to be multiplied by the area (x_k). Accordingly, we perform a weighting in order to treat every hectare identically. As weights the areas are applied.
The outcome of the weighting needs to be tested. Therefore, the maximum entropy approach is applied in different ways. The "*Core Model*" represents a straight forward application while "*Extension 1*" includes the suggested weighting.

Besides the reference values (μ_k) there are specific relationships between crops which should be reflected in results at the farm level. For instance labour and machinery input are typically larger for wheat than for barley in Swiss agriculture. Since the reference values show a similar magnitude, the core model cannot ensure that this relationship is reflected correctly in results. Technically spoken based on information outside the sample an inequality restriction like $\beta_{Wheat} > \beta_{Barley}$ needs to be considered. Campbell and Hill (2006) suggest the approach of imposing parameter inequality restrictions for maximum entropy models. Therefore, it is necessary to formulate equation 2 in a slightly different form:

$$\begin{bmatrix} \beta_1 \\ \beta_2 \\ \cdot \\ \beta_k \end{bmatrix} = \begin{bmatrix} \mathbf{z'}_1 & 0 & 0 & 0 \\ \mathbf{z'}_1 & \mathbf{z'}_2 & 0 & 0 \\ \cdot & \cdot & \cdot & \cdot \\ 0 & 0 & 0 & \mathbf{z'}_k \end{bmatrix} \cdot \begin{bmatrix} \mathbf{p}_1 \\ \mathbf{p}_2 \\ \cdot \\ \mathbf{p}_k \end{bmatrix} \tag{8}$$

While $\mathbf{z'}_k$ is a vector including both support points for crop k, $\mathbf{p}_k$ is the vector of the referring probabilities. An important detail is that the support matrix is not block diagonal as it is the case in the core model, since the vector of the support points of crop 1 is also considered for β_2. Following Campbell and Hill (2006), equation 8 includes the following inequality restriction $\beta_2 > \beta_1$[4]:

$$\beta_2 = z_{1,1}p_{1,1} + z_{1,2}p_{1,2} + z_{2,1}p_{2,1} + z_{2,2}p_{2,2} > \beta_1 = z_{1,1}p_{1,1} + z_{1,2}p_{1,2} \tag{9}$$

[4] As an important precondition of equation 9 both support points of crop 2 ($z_{2,1}$ and $z_{2,2}$) must have values greater than 0.

Accordingly, the support points for crop 2 can be interpreted as the sum of β_1 and the weighted sum of the support points for crop 2. Coming back to the relationship between wheat and barley, the support points of barley (say β_1) are also relevant for wheat (say β_2).
The Campbell/Hill approach requires a different treatment of support point values. Instead of applying directly reference values from farm management literature (μ_k) the differences are of importance. Accordingly, in the above example $z_{2,2}$ refers to the difference between wheat and barley.
As regards all arable crops in Swiss agriculture a strict rank order would not be appropriate. Instead we define groups of crops. While within a group there is no strict rank order, we impose inequality restrictions between groups. To illustrate those relationships a tree structure is appropriate (see Figure 1 in the appendix). Groups are depicted as branches belonging to the same nest.

An application of inequality restrictions is analysed in "*Extension 2*" ensuring that relationships between crops are depicted correctly in model results. "*Extension 3*" finally combines the weighting from *Extension 1* with the inequality restrictions from *Extension 2*. Due to the different specification of support points, the weights must also be adjusted.

2.3 Comparison of Model Versions

Since the "true" allocation of joint costs is not known, the results of the four applications (*Core Model* and *Extensions 1 to 3*) cannot be assessed about their accuracy. Furthermore, to our knowledge there exist no criterions in order to assess different cost allocation patterns.

For the *Core Model* and the *Extension 1* we test whether two specific relationships between crops are correctly depicted in results at the farm level. Firstly, for labour and machinery inputs we look at all farms growing wheat and barley, if the inputs for wheat are larger than for barley. As a second test a comparison again for labour and machinery inputs between potatoes and cereals is carried out. Typically for Swiss arable crops inputs for potatoes should exceed those for cereals, for which the maximum value of wheat and barley is applied.

As a more quantitative indicator, the allocation at the farm level should be analysed. In a proportional allocation all crops of a farm are treated similarly. Accordingly, all production branches are adjusted by the same factor (α). By contrast, the maximum entropy approach allows variation between crops. In order to get an idea of the present diversity we define ψ_k, which indicates the adjustment of crop *k*:

$$\psi_k = \frac{\beta_k}{\alpha \mu_k} \tag{10}$$

The joint cost item β_k is divided by both, the reference value μ_k as well as α, the parameter, which represents the relation between total costs and the costs expected from farm management literature. In the case of a proportional allocation ψ_k is equal to one for all crops *k*. Applying the maximum entropy approach ψ_k varies around 1 while the weighted (area) farm average would also be equal to one.
In order to illustrate the variability of ψ_k we report the standard deviation across all crops and farms for all joint cost items. Furthermore, we identify the maximal differences of ψ_k at the farm level (crop with the highest ψ minus crop with the lowest ψ) and take the average out of it over all farms.

In respect of the mechanism of the entropy approach we expect the largest standard deviation of ψ_k as well as the largest differences within farm for the *Core Model*. The weighting limits the tendency that large areas lead to extreme joint cost allocation results. Accordingly, we expect in *Extension 1* smaller values for both standard deviation and differences within farms. Similarly, the inequality restrictions also limit the variability within farms due to the application of differences instead of absolute reference values (*Extension 2*). Finally *Extension 3*, which combines weighting and inequality restrictions, should show the lowest value for standard deviation and differences within farms.

3 Database

To test the suggested approach we use data from the Swiss Farm Accountancy Data Network (FADN). In order to reduce complexity, we focus on farms of the arable crop farm type. Based on all available observations of the accountancy years 2007 and 2008 we exclude farms practicing animal husbandry as well as farms, which are involved in agricultural-related activities such as agritourism or direct sales[5]. Finally, 36 farm observations remain[6]. With an average area of 22.3 ha, the farms investigated are below the average size of the crop farms of the Swiss FADN, whose area accounts for 25.8 ha (Roesch and Hausheer 2009). We aggregate all activities from the accountancies into 12 production branches with a total of 235 production branch cases[7]: Wheat (33 cases also include rye or spelt), barley (22 cases also cover oats as well as other grains for animal feed), corn/maize grain (15 cases), silage maize (15 cases), potatoes (7 cases), sugar beet (23 cases), oilseeds (31 cases comprise rapeseed, sunflower and soybean), field beans (13 cases also include peas and field peas), grassland (36 cases, pasture and/or temporary ley), fallow land (13 cases cover wildflower strips, rotational fallow, hedgerows as well as field- and riparian coppices), forest (20 cases) as well as other activities (7 cases include highly labour intensive activities such as vine plants, fruit production, outdoor vegetables and tobacco).

As regards the allocation of joint costs we concentrate on three cost items, which are available at the farm level:

- **Labour:** We refer to total working days, whereby the Swiss FADN provides the number of working days for both hired workers as well as family members. After the allocation working days are valued, whereas we assume a remuneration of CHF 250.- per day (10 working hours at CHF 25.-). For potatoes a slightly lower value is applied (CHF 200.-) due to lower qualified labour forces for harvest activities.
- For **machinery costs** we summarize three accountancy items: costs of farm-owned machines (interest, depreciation, fuel and services), costs of machinery services contracted from other farmers or companies (e.g. combine harvesters for cereal harvest), as well as a share of the farmer's car.
- **Other joint costs** include depreciation of farm buildings, installed equipment, land improvements and plants (perennial cultures). Additional costs are insurance premiums,

[5] In detail farms with a return from agricultural-related activities above a limit of 2000.- Swiss Franc (CHF) are excluded. As an exception farm involved in renting out buildings are not excluded. For those farms a correction of capital costs is necessary in order to ensure that capital costs of the rented buildings are not considered for the joint cost allocation. Therefore, we assume in accordance with interest rates and gross return on buildings that half of returns are necessary to cover the capital costs of the buildings hired out.

[6] The sample consist of 20 farms for the year 2007 and 16 farms for the year 2008. 12 farms contributed data for both years. For 2007 131 cases and for 2008 104 cases are available.

[7] In order to distinguish between farm and production branch level we use the expressions observation and case, respectively.

energy, water, telephone, overheads as well as interest rates on debts and remuneration of private capital. Therefore, the interest rate of Swiss Federal Term Bonds is applied as opportunity costs.

The reference values (μ_k) for joint cost items labour (in working days), machinery use and "other joint costs" (both in CHF) come from farm management literature and are defined as target values, which can be reached by conventional production techniques. For wheat, barley, potatoes, sugar beet and oilseeds (rapeseed) we use the costs reported by Lips and Ammann (2006) as the reference values. Albisser and Gazzarin (2010) calculate labour and machinery costs for maize, field beans, grassland, fallow land and forest applying a standard costing approach. They also deliver a value for "other joint costs" for forest. For the production branch, "other activities" values are derived from a report by Agridea and FiBL (2008), which includes working time and machinery costs for all relevant activities in Swiss agriculture based on standard costing. For some production branches no value for the "other joint costs" is available from literature. Referring to the most similar production branch, we gauge those values. All reference values are included in Table 4 in the appendix.

4 Results

In the result section we focus on three aspects: parameter alpha, comparison of model extensions as well as full cost for production branches applying *Extension 3*.

4.1 Results for Parameter Alpha

The parameter alpha offers the opportunity to compare at the farm level actual costs with the costs we would expect from farm management literature for a farm with an identical production structure. Accordingly, it can be considered as a rough efficiency indicator. The mean value of labour inputs for all 36 farm observations indicates that analysed farms utilize 160 % more labour than suggested in farm management literature (Table 1). As regards machinery use, the actual costs are 20 % lower than suggested in literature. Also the "other joint costs" exceed clearly the targeted values. Looking at extreme values (minimum and maximum), a huge variability can be observed. There are farms with very low costs, while the most labour-intensive farm reaches a value beyond 9.

Table 1: Parameter alpha for all joint cost items

	Labour	Machinery use	Other joint costs
Mean	2.6	0.8	1.7
Minimum	1.1	0.3	0.2
Maximum	9.6	1.5	5.3

4.2 Comparison of Core Model Extensions

For the applications *Core Model* and *Extension 1* the relationships between wheat and barley on the one hand and potatoes and cereals on the other hand are analysed for labour and machinery costs. In total 19 farms produce both wheat and barley. In the *Core Model* wheat shows more input than barely for labour and machinery use in 18 and 8 cases, respectively. In *Extension 1* all relationships are correct depicted.

The potatoes-cereals comparison is related to seven farms producing both crops. Here the picture is slightly different. While the relation is always correct depicted for labour, the machine input for cereals exceeds the input for potatoes in three cases for the *Core Model* and four cases for *Extension 1*, respectively.

Table 2: Standard deviation and average maximal difference at farm level of ψ_k

Indicator	*Version*	Labour	Machinery use	Other joint Costs
Standard deviation of ψ_k	*Core model*	0.118	0.401	0.456
	Extension 1	0.106	0.302	0.091
	Extension 2	0.063	0.176	0.089
	Extension 3	0.084	0.170	0.045
Average of maximal difference of ψ_k at farm level	*Core model*	0.304	0.710	0.584
	Extension 1	0.259	0.615	0.166
	Extension 2	0.162	0.373	0.148
	Extension 3	0.158	0.312	0.084

ψ_k: indicator of the adjustment of crop *k*

Table 2 illustrates that the standard deviation of ψ_k is continuously decreasing from the *Core Model* to Extension *3*. The additional adjustments taken in *Extensions 1 to 3* lead to a lower variety within the allocation process of joint cost items. The average maximal difference of ψ_k highlights the variation between crops at the farm level in the *Core Model*. The additional adjustments result in at least halving the differences at the farm level for all three joint cost items in *Extension 3*.

4.3 Full Cost for Production Branches with Comparison to Literature

In order to evaluate the proposed joint cost allocation, we want to look at the whole picture, say the full cost of arable corps. Based on the data of the 36 arable crop farms totally eight cost items are considered. Swiss FADN provides four cost items at the production branch level: seed, fertilizer and plant protection as well as "other direct costs". The latter is an aggregate of costs for cleaning, drying, hail insurance and other direct costs of plant production. For the costs of land a farm specific mix of opportunity costs for own land and the real costs for rented land from the FADN data base is calculated[8]. Finally the three joint cost items labour, machinery use and other joint costs are considered, which are derived by *Extension 3*, the application with the highest meaningfulness[9].

For five crops (wheat, barley, potatoes, sugar beet and oilseeds) a comparison with farm management literature is provided in Table 3. The result from farm management literature are denoted as FML and are based on Lips and Ammann (2006), while the results of the presented approach are denoted as ME (maximum entropy). Full Cost of the remaining production branches are reported in the appendix (Table 5).

Looking at the total costs, the ME approach shows higher values for all crops except oilseeds. Barley and sugar beets exceed clearly the values reported in farm management literature.

Since most of the direct cost items in the FML are also based on accountancy data it is not surprising, that both approaches show the same magnitude for all production branches.

[8] In detail, based on accountancy data we can derive the average rental rate per hectare of land. For private land we apply a value of CHF 688.- per hectare, the average rental rate of crop farms for the years 2006-2008. Taking account of the shares of own and rented land we calculate farm specific weighted averages. Due to the crop rotation we do not differentiate land quality between production branches. Thereby forest is treated as an exception since it is not involved in the crop rotation. In addition, due to a lower soil quality a reduced rental rate (CHF 72.- per hectare, Albisser et al. 2009) is assumed.

[9] Therefore, all production branch results are weighted with reference to the area at the farm level.

Land costs are lower compared to FML. The reason is that the farms under consideration pay low rents, in some cases even nothing, for rented land.
The three joint cost items labour, machinery use and other joint costs show considerable differences. While labour costs and other joints costs show larger values under the ME approach, machinery costs are lower. When comparing results of machinery use and other joints costs for wheat and barley under the ME approach it is important to note that these are supported by different farm observations.

Table 3: Full cost for five arable crops in CHF per hectare

Production Branch	Wheat		Barley		Potatoes		Sugar Beet		Oilseeds	
Method	FML	ME	FML	ME	FML	ME	FML	ME	FML	ME
Seed	307	267	203	197	2430	2179	393	402	154	159
Fertilizer	382	321	379	302	621	668	730	483	552	387
Plant Protection	239	210	222	189	870	716	634	620	401	375
Other Direct Costs	254	291	225	264	401	423	141	248	355	323
Total Direct Costs	1182	1089	1029	952	4322	3987	1898	1753	1462	1243
Land	718	499	718	497	718	632	718	503	718	471
Labour	825	1812	810	1717	3543	6963	1602	3743	696	1421
Machinery use	1591	1107	1506	1263	4553	2742	2839	2214	1366	886
Other Joint Costs	791	943	779	1526	982	1360	879	1205	784	901
Total Costs	5107	5450	4842	5954	14118	15683	7936	9418	5026	4923
in %	100	107	100	123	100	111	100	119	100	98

Note: FML = farm management literature, i.e. cost calculations by Lips and Ammann (2006)
ME = maximum entropy results, i.e. full cost approach applying maximum entropy for the allocation of joint cost items

5 Conclusions and Outlook

The paper proposes an approach to allocate joint costs among production branches. Based on maximum entropy and reference values from farm management literature the approach helps to overcome the frequently applied procedure of a proportional allocation. Furthermore, the approach allows deriving a farm specific distribution key for joint costs.
Using accountancies of arable crop farms of the Swiss Farm Accountancy Data Network (FADN) besides the suggested core model three model extensions including a weighting according to production branches area and inequality restrictions are proposed, which address the specific mechanism of the maximum entropy approach.

The core model leads to substantial relative differences among production branches within a farm. Furthermore, typical relations among crops such as higher labour and machinery input for wheat than for barley are not correctly depicted in all cases. Accordingly, the introduction of inequality restrictions as a core model extension is necessary, which guaranties that a rough rank order between production branches is complied with. Furthermore, both inequality restrictions and weighting contribute substantially in order to reduce the spread within farms. Accordingly, we recommend the application of the core model with both extensions weighting and inequality restrictions.

For five out of twelve production branches comparisons to the farm management literature are possible, focusing on both total costs and cost structure. We find that total costs from farm management literature are met or exceeded up to around 20 %. Furthermore, there are substantial

differences for the joint cost items labour and machinery use. Labour shows higher, machinery use lower values than those found in literature.
The higher costs on labour are caused by a sharply higher labour input than suggested in planning documentation. Accordingly, the efficiency of labour input for crop farms could be substantially improved.
Lower costs of machinery are in line with a recent revision of machinery cost planning material. Revising prices and the degree of utilization, Gazzarin and Albisser (2009) suggest lower costs for machinery typically used by farms with arable crops. For example, costs for ploughs, which are measured per hectare are reduced around 20 %. In addition, the analysed farms may use less machinery input than assumed in farm management literature.
It is important to note that the above mentioned costs for labour and machinery from farm management literature refer to standard costing, which has usually a normative character. Conversely the full costs derived in the paper are based on accountancies and rely on actual or historical inputs. As a conclusion, for labour and machinery costs of wheat, barley, potatoes, sugar beet and oilseeds we observe substantial differences between standard costing in farm management literature and actual costing. Consequently, we derive either suggestions to improve efficiency (e.g. reduce input of labour) or a need of revision of the assumption for standard costing (e.g. reduction of machinery costs). For farm consultants it is essential to be aware of both the current status and potentially existing gaps between standard costing and the current status of the industry. Otherwise suggestions towards farmers run into the risk that they are far from reality. Furthermore, an improvement in efficiency is hardly achievable.

Looking at the limited number of cases (especially potatoes with 7 cases), it is important to enlarge sample sizes in future. An expansion towards other farm types (e.g. mixed dairy crop farms) is intended as a next step. At the same time, the suggested approach needs to be expanded towards production branches with animal husbandry.
The suggested approach allows a high degree of automation and is suited to process large data samples. Accordingly, given that FADN data are available for several thousand farms in Switzerland, the approach offers manifold opportunities such as for the analysis of productivity or economies of scale at production branch level. Furthermore, since returns are available on a production branch level, detailed analyses of profitability can be carried out.

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Appendix

Table 4: Reference Values for all crops per hectare

Joint cost item	Labour in working days	Machinery costs in CHF	Other joint costs in CHF
Wheat	3.3	1591	791
Barley	3.2	1506	779
Corn	3.6	1338	800
Silage Maize	3.7	2629	800
Potatoes	14.2	4553	982
Sugar Beet	6.4	2839	879
Oilseeds	2.8	1366	784
Field Beans	4.3	1632	800
Grassland	3.7	2221	850
Fallow Land	3.3	542	700
Forest	1.0	352	445
Other Activities	64.0	4000	1400

Table 5: Full cost for corn, silage maize, field beans, grassland, fallow land, forest and other activities in CHF per hectare

Production Branch	Corn	Silage Maize	Field Beans	Grassland	Fallow Land	Forest	Other Activities
Seed	314	336	360	65	99	10	817
Fertilizer	360	347	107	38	14	0	279
Plant Protection	262	302	213	10	8	0	1728
Other Direct Costs	940	62	199	7	0	9	2191
Total Direct Costs	1877	1046	879	119	121	19	5015
Land	605	497	516	502	545	72	562
Labour	2232	1979	1896	1984	1560	470	27410
Machinery use	1179	1842	918	1601	471	313	2361
Other Joint Costs	1505	1691	1049	1270	546	908	1956
Total Costs	7168	7256	5465	5748	3277	2033	40161

Figure 1: Tree structure among production branches in respect of joint cost items