Time-driven activity-based costing for supporting sustainability decisions in pig production

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Abstract

Current paper aims at supporting the choice of conversion to batch farrowing in pig production. This is a strategic decision that has to be evaluated from a corporate social responsibility (CSR) viewpoint, has a highly firm-dependent specificity of impacts and mostly occurs in low data circumstances.

Zooming from an overall CRS criteria framework into a concrete case study, the relevancy of criteria with respect to the particular conversion decision is derived. Important is labour productivity within the existing capacity (investment levels) and profit optimisation within existing production rights based on nutrient emissions, which constitute the main environmental externality in pig production. Other criteria are animal welfare, health and professional pride of the farmer.

In particular, a 4-weekly batch farrowing system is compared with the weekly farrowing, which is used here as the reference. Both systems are assumed to start with the same number of sows, these are the reproductive animals. First, the TD-ABC methodology of Kaplan and Anderson (2004) is adopted to estimate the labour hours needed, the floor space needed (investment levels), the nutrient emissions and the revenues for each of both systems. Second, qualitative evaluations are added. Finally, an integrated efficiency analysis, based on the non-parametric data envelopment analysis (DEA) technique, is used to benchmark the new production system against current practices.

Since sow productivity increases in the batch farrowing system, the number of finished pigs will grow with 10% and production rights have to rise with 3%. Results show that the investments are 5% higher, but that the labour hours needed is 6% lower in the four-week system. Moreover, labour input is more concentrated in time and can be easier scheduled, which is to be considered as an extra social advantage for the farm family, who provides the dominant part of labour. Profit will grow with 14.9 euro per hour labour in the four-week system under average price conditions, while in the meantime nutrient surplus only increases with 0.5 %. The DEA efficiency analysis shows a positive trade-off between economic and ecological performance.

Although the research is done with a specific conversion decision on a given case-study farm, conclusions may be generalised to a larger population of middle-size farrowing-to-finishing farms. The results also show that the TD-ABC approach is useful to quantify both the economic and ecological impacts of a strategic decision, and may even be extended to sociological features.

Key words: corporate social responsibility, batch farrowing, time-driven activity-based costing

1. Introduction

Society places new expectations on farming nowadays. Farmers have other responsibilities beyond simply making profit. From a *corporate social responsibility* (CSR) point of view, farming should also cope with social concerns, such as environmental issues and animal welfare aspects. In the last few years, a lot of these expectations are translated into norms, e.g. the more animal friendly group-housing for pig production will be obliged. As a consequence, management decisions in farming, in particular with respect to innovations (new technologies or farming systems), must not only take into account production improvements, but also social and environmental effects.

A recent innovation in pig production is *batch farrowing* (Armstrong, 2003), this is a way to organise the production flow of pigs from sows, the reproductive animals. The production process is partially biologically determined by the natural sow cycle, and partially managerial steerable. In contrast to the traditional pig production system, which delivers pigs on a continuous basis, batch farrowing groups the sows in order to obtain larger and more homogeneous batches of pigs to sell. Concentration of labour, health protection and a price premium for the homogeneous batches are the main incentives for adopting the innovative system. However, batch farrowing is not yet very common in Belgium. As a consequence, accounting data are poor. Moreover, existing literature is mainly based on *anecdotal evidence* and expert knowledge. Available information is mostly rather generic and doesn't sufficiently take farm specificity into account. Moreover, given the CRS framework, farmers need information on more criteria than the sole economic ones. On the other hand, expert knowledge is available, which is handsome to appropriately judge the available information and to transfer it to reasonably quantified managerial information. Uncertainty, multi criteria, low data availability, farm specificity and expert knowledge are the main features of the innovation decision problem.

Characteristic for batch farrowing is a fundamental change in labour organisation. The batch system enables the farmer to perform the main labour tasks (insemination, delivery, suckling control, weaning, cleaning farrowing room, etc.) more concentrated. An experienced farmer is familiar with these tasks, and so he can judge possible changes in organisation. However, given the complexity of the overall process, which is a combination of tasks, the evaluation of alternative farming systems has to rely on detailed system description and appropriate methods to integrate. One method that seems appropriate for this is time-driven activity-based costing, TDABC. In a business environment, TDABC has been described as a new management approach to guide decision making in complex and dynamic processes (Kaplan and Anderson, 2004). The breakthrough of TDABC lies in the estimations of labour time, based on real parameters. In particular, the time of performing an activity is estimated based upon different characteristics that influence each of the subtasks of the activity. TDABC has been successfully used to model labour and housing for logistics and service operations (e.g. Kaplan and Anderson, 2007; Everaert et al., 2008) and looks promising to be implemented in other labour intensive operations such as hospitals, education, but also farming. The question arises whether the method can also be applied for batch farrowing and, in particular, whether it can take account of the multi criteria nature of the CSR decision problem.

The objective of this paper is now to analyse whether pig farmers should switch from traditional pig production to batch farrowing, given the desire to combine profit maximization with sustainable production. TDABC is applied for the specific decision problem and adapted for multi criteria evaluation.

To obtain this objective, the traditional system will be compared with a four-week batch farrowing system, which seems currently the most promising batch system. The four-week alternative organises the production process in batches of 4 weeks, whereas other alternatives rely on 3 to 5 weeks batches. In order to account for farm-specificity, an *in-depth case study* is done on a single medium-size pig production farm, the Bryon Farm, where the owner-manager was considering the jump to a four week batch farrowing system. A detailed analysis of the main labour tasks is done to evaluate the impact on the work load for the farmer and his family. Based on the in-depth knowledge of the operations, the TD-ABC model was build using real life data and the actual strategic criteria of the farmer. The objective of this paper then turns, in practice, to investigate whether the Bryon Farm should switch from traditional to the four-week bath farrowing system. In particular, the following research questions are addressed:

(1) Can TD-ABC be used for guiding management with the decision problem of switching to batch farrowing?

(2) Can TD-ABC used to model the differences in labour and housing space, but also for nutrients production and other CSR criteria?

(3) Should the company switch to batch farrowing, given its desire for sustainable production?

The remainder of the paper is organized as follows. Next section describes the overall research approach. This, first, implies a description of the innovator and the innovation (section 2.1 and 2.2), on the one hand the general criteria framework and system analysis, on the other hand, the particular case circumstances. System description and subsequent qualitative impact analysis is done based on a literature review and anecdotic evidence. Second (section 2.3 and 2.4), conventional techniques such as TDABC and productive efficiency analysis are discussed for quantifying impacts and trade-offs of the decision problem. Central is the adaptation of the Kaplan and Anderson (2004) TDABC method to the specific multi criteria information needs of our decision problem. Section 3 presents the results of the case study. Section 4 discusses the results, in particular their sensitivity with respect to farmer's criteria , trade-offs and generalisation. Section 5 concludes the paper.

2. Methods

2.1. The innovator: farm-specific features and objectives in a CRS framework

2.1.1. the case farm

The Bryon Firm approached the researchers, because the owner-manager was struggling with the decision whether or not to jump to batch farrowing. So, site selection was not random, but, it helped to overcome one of the main practical difficulties of conducting case study research: gaining access to field sites (Baxter and Gua, 1998). This farm was attractive on a priori, objective grounds, and would have been a top candidate in a purposive sampling approach. Furthermore, the daughter had an economic sciences background and was used to help on the farm. In that way, the researchers could access detailed knowledge on the different working procedures, which was absolutely necessary to develop a rigorous method to compare the two production systems.

The Bryon Farm owns 433 sows and 4500 pigs from 7 to 110 kg. It currently operates on a traditional one-week batch system. Average culling rate (number of culled sows divided by total sow herd number) is 45%. Per year, a sow has 2.3 litters with 11 piglets each. Pre-weaning mortality is 12.7%. Piglets are weaned at 23 days old. Sow productivity, expressed in number of weaned piglets per productive sow per year, is 23. After weaning, all piglets are reared on the farm and sold at 110 kg end weight. Finishing mortality is 6%. Daily live-weight gain (standardised to the 20-110 kg growth section) is 685 g/day. The time between 7 and 110 kg weight is 170 days. The feed conversion ratio is 3 kg of feed for a kg of weight gain.

There are 8 farrowing rooms with each 16 crates, so 128 crates are available. The insemination room has 23 boxes and 289 pregnant sows can be housed. The total number of places for sows is 456. As this farm has not enough places for pregnant sows, crates are used to house the sows a couple of weeks before they farrow. After weaning, piglets are housed in a weaner accommodation with a capacity of 1200 places until they are approximately 10 weeks, afterward the pigs move to a finishing room. The finishing rooms are on 4 locations. The capacity of the finishing rooms is 4140 pigs.

The labour on the farm is supplied by the farmer, his wife and his daughter. The woman on the farm takes care for the sows and piglets in the farrowing rooms and cleans the various rooms, the man does the other tasks. The daughter is responsible for farm accounting and is the author of the TD-ABC model. She also helps with the parents' tasks. The four-week system becomes an option: the farmer estimates that this system fits better in his current infrastructure than the three- and five-week system.

2.1.2. Situating the case farm

Data from the Farm Accountancy Data Network are used for benchmarking the farm. A sample of 70 Flemish pig farms this database considers only producers with more than 40 average present sows. Outliers are also removed and only farms that are present in the FADN dataset for three consecutive years (2001-2003) are retained. This allows for deriving more robust farm data as references (Van Meensel et al., 2008). Because not all data of the Bryon Farm were available, we selected a farm from the FADN data with the same technical results as the case study. This farm has 152 sows. This farm produces 941 499 kg meat per year, 2 245 560 kg feed for pigs and 654 322 kg feed for sows is needed, the variable costs are 72 497 EUR and the fixed costs are 164 548 EUR. As will be shown the farm is characterised with a high technical and ecological efficiency with respect to its peer farms.

2.1.3. Corporate social responsibility framework for pig production

Farmers are aware they have to produce according to social objectives. Within pig companies, lot show sustainable entrepreneurship. They are pro-active toward market and society and try to maximize positive impacts on their natural and social environment or to minimize negative effects, while keeping pace with economic growth (Lepoutre et al., 2005). Table 1 gives an overview of the elements that can be considered for CSR pig production. The economic aspect contains labour, housing (capital) and labour income. For the sociological aspect, professional pride and animal welfare and health can be included. Finally, for the ecological aspect, energy use and nutrient emissions are major attention points.

Table I: CSR Framework for Pig Production

Aspect:	**Topics**
economic	Labour Housing (capital) Labour income
sociological	Professional pride Animal welfare and health
ecological	Energy Nutrients Manure

Measurement of economic indicators usually do not face substantial problems. Other factors are less evident to measure. For example, professional pride is difficult to measure given its subjectivity and complexity with a lot of influencing factors (Steunpunt Duurzame Landbouw, 2006, p 113; Meul et al., 2008). Other difficult criteria are animal welfare and health, which are highly interlinked. Not only the latter is an important component of animal welfare – a sick animal has less welfare – also reduced welfare can lead to a larger susceptibility for sicknesses (Goossens et al., 2005). Although some measurements techniques exist, e.g. cough index, slaughter results, sneeze index, use of antibiotics and serology (Goossens et al., 2005), ex ante information of new production systems such as batch farrowing have to rely on more qualitative information. Finally, energy use implies indirect and direct energy use. The indirect energy input is higher than the direct energy input: indirect energy input represents about 71% of total energy use on pig farms. Direct energy input is mainly diesel use, indirect energy input is mainly the production of feed (Meul et al., 2008).

2.1.4. Sustainability criteria at stake in the case farm

Finally, farmer's decision will include self-interest. So, not every criterion will receive the same weight from the farmer. For the Bryon Farm scale enlargement is not an option, he just wants to optimise within the existing sow number. Normally the number of crates should be optimised because this is the largest cost for sows. Although there is no real restriction on labour - the family can always come to help-, the farmer wants to work efficient so attention is paid to labour productivity. Next, the farm family is convinced that the environment and animal welfare has to be taken into account. Avoiding negative impacts, e.g. nutrients emissions, is part of their professional pride. Running a farm is heavy, but as long as they love their job, they want to go further. In particular the farmer doesn't want to be embarrassed about the impact of his decisions. The farmer has not enough land for the manure of his pigs and he is not the only farm in his region with this problem. Also energy becomes an important criterion: not only the costs of energy are growing, they also have a negative impact on the environment.

We can conclude that the farmer pays most attention to the hours labour. Labour income will influence the decision as much as proud on profession, nutrients and animal welfare. Manure and energy will also influence the decision but to a lower extent. Investment costs intervene as a trade-off factor: what does it cost for improving the sustainability criteria.

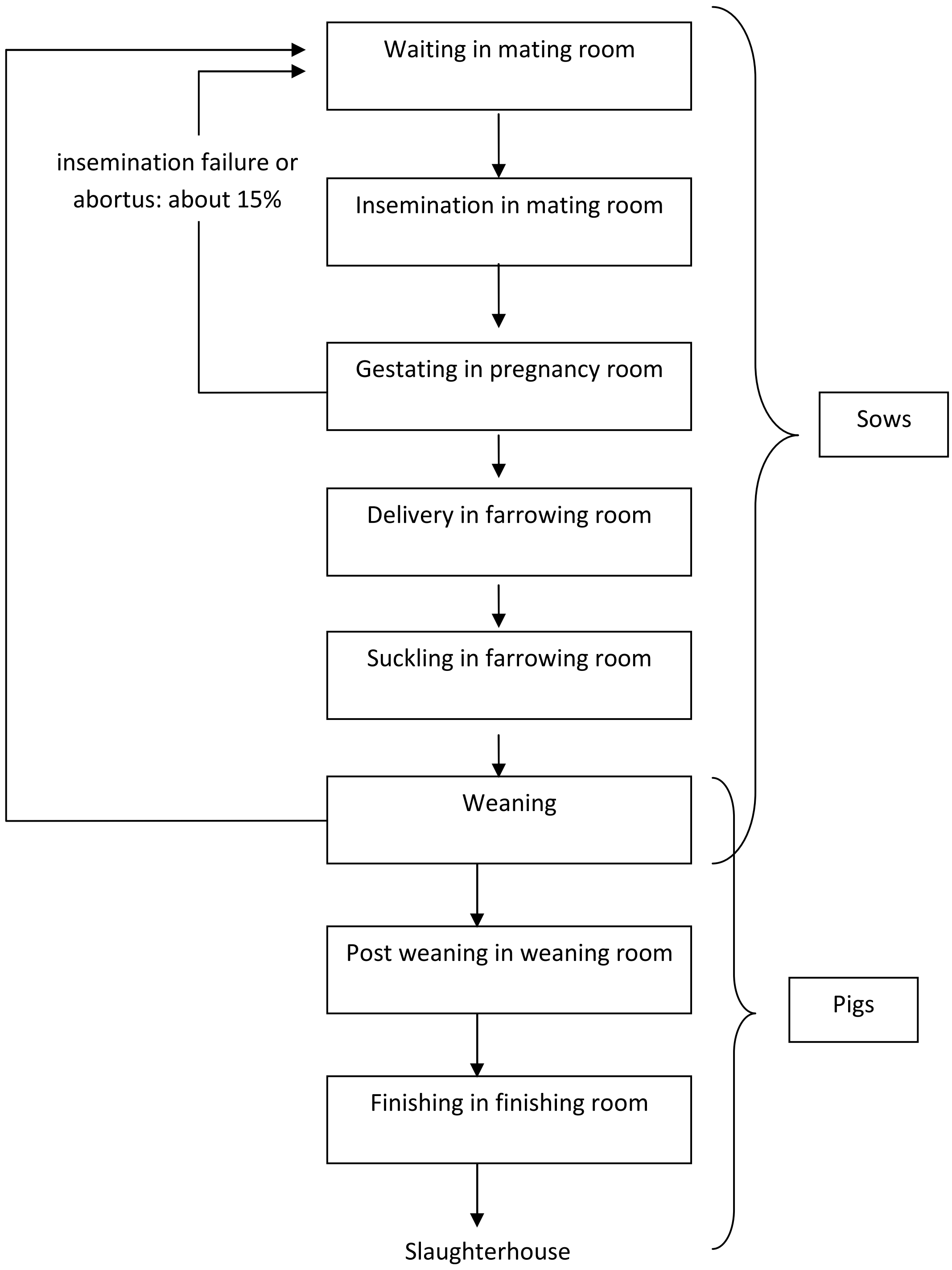
2.2. The innovation batch farrowing : system description and experts' evidence

In this paper the traditional system with a four-week batch farrowing system. First the production system and the 4-week batch-farrowing alternative will be analysed. Then, a literature review is done in order to collect quantifiable information for the CSR evaluation.

2.2.1. The pig production system and managerial decisions

Figure 1 gives a schematic representation of the pig production system, from insemination of sows to selling pigs to the slaughterhouse. The most important stages of the sow cycle are: waiting, mating (insemination), gestating and suckling. Waiting sows will turn to heat and are mated in the mating room. When pregnant, they are transferred to the places for gestating sows. One week before delivery, they are moved, for acclimatisation, to the farrowing room. After delivery, the sows are suckling their piglets during three weeks. Hence, the sows stay almost four weeks in the farrowing room. After weaning, the sows are moved to the waiting room, waiting for the next insemination. Cycle time is about 20 weeks from insemination to pig i.e. 4 weeks in insemination room, 12 weeks in pregnancy room and 4 weeks in farrowing room. The growth period for pigs, from birth to slaughtering, ranges between 24 and 27 weeks. The growth of pigs is divided into three stages, during the first two of them they are considered as piglets: suckling with the mother (3 weeks), post-weaning (8 weeks) and finishing (13 to 16 weeks). During suckling period, piglets stay in the farrowing room, in the post-weaning period piglets first go to the weaning accommodation, then to the finishing rooms (Lurette et al., 2007).

Figure 1: Flow diagram of the farrowing-to-finishing production system



Source: Adapted from Lurette et al., 2007

The main tasks for the farmer are stage related: mating (= insemination), farrowing (= delivery after gestating) and weaning (= taking away the piglets after suckling). These tasks are basic, regardless of the organisation. However, labour time needed and capital investments will differ and are at the core of the decision problem in this study. Still other tasks must be carried out, such as cleaning the farrowing room, weaner accommodation and finishing room after each group. The main managerial decisions are weaning age, culling rate (replacement of sows) and end weight of sold pigs.

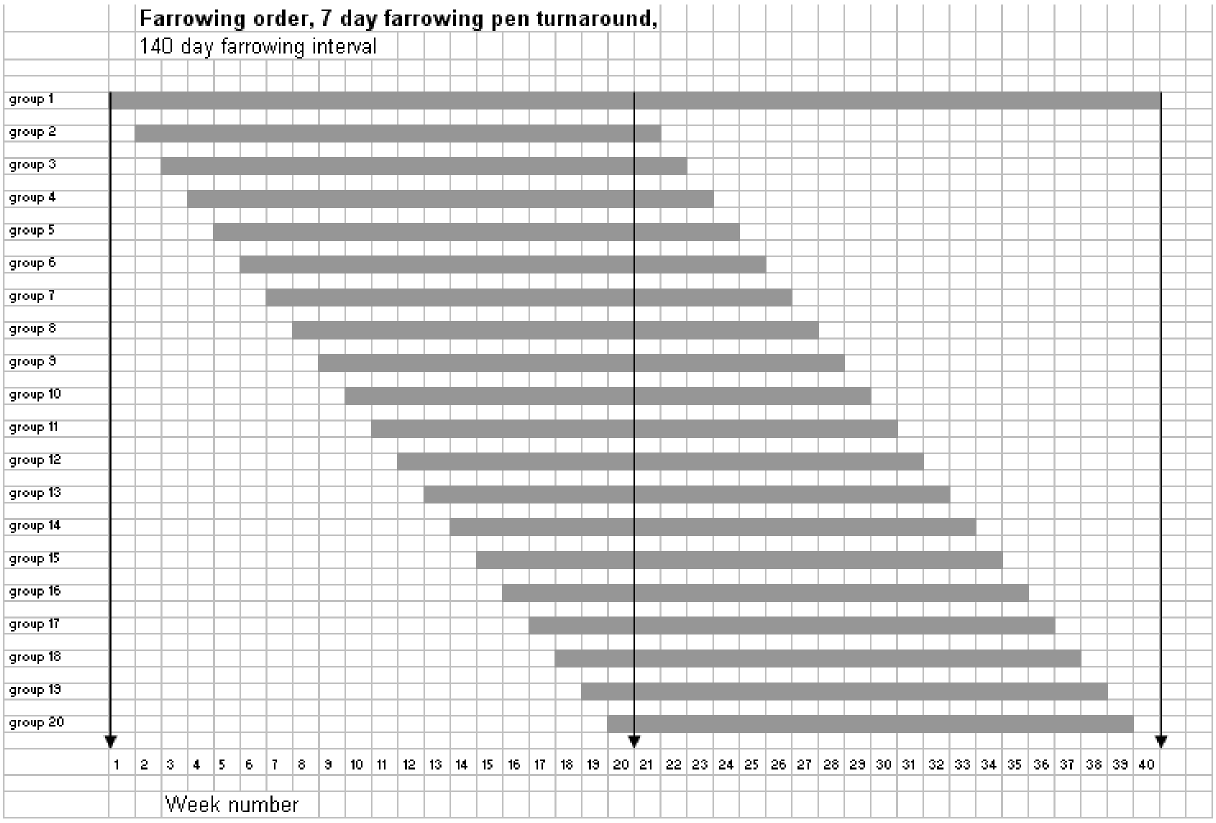
2.2.2. The batch farrowing alternative

Traditionally, pig producers have used a continuous flow production method, which usually involves weekly mating, farrowing and weaning. In batch farrowing, the herd is divided into several groups of sows in the same reproductive stage and of similarly aged pigs. Each group will be at various stages of production depending on the batch interval. Batch farrowing allows for mating and farrowing at a fixed interval and leads to an all-in/all-out (AIAO) management of pigs. Typically, this management allows for an age segregated rearing and so, pigs coming from different batches are housed in different rooms and have no direct contact.

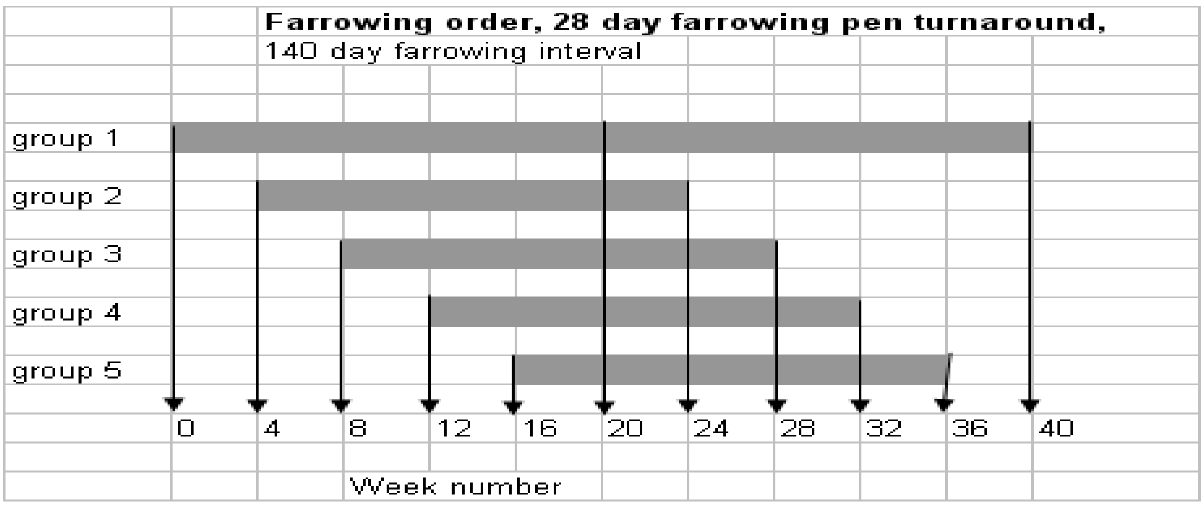
In this study, the consequences of a traditional system (weaning every week) are compared with a four week batch system. The 4-week system means that the farmer has to perform the main labour tasks (insemination, delivery, suckling control, weaning, cleaning farrowing room, etc.) every four weeks. Also a two, three and five week system exists, but the paper focuses on the four-week batch farrowing, because of farmer's preferences and advisors' recommendation. Hence, in a four-week batch farrowing, the farmer is weaning every four weeks, i.e. in the 1st, 5th, 9th, 13th and 17th week, which allows for making less, but bigger groups of sows, as shown in Figure 2.

Figure 2: Traditional system, compared with a four week batch system.

Panel A: Traditional pig production



Panel B: Four weeks batch farrowing



Source: Based on Moore and Cargill, 2005

2.2.3. Literature review

Previous studies on the comparison, are mainly based on qualitative expressions of experts or farmers. We shortly summarize this stream of literature according to the components of sustainability outcomes.

Economic outcomes

Positive effects of the batch system are the more efficient labour input, higher output prices and improved productivity. Some major tasks, such as farrowing, insemination, weaning can be done for larger groups. Management tasks can be concentrated in time. There are regular periods of less work during which maintenance, holidays or field work can be scheduled (Brown, 2006; Kains, 1998). Larger groups of pigs of the same age mean more homogeneous supply, which leads to a higher price (Kains, 1998). Pigs show a better heath (see also further), which leads to an increased productivity (Armstrong, 2003). Productivity gains are possible in the reproduction as well as in the finishing stage: up to one piglet more per litter, less mortality, a better feed conversion and daily weight gain (table 2).

Table 2: Improvements by 4-week system (Suls, 2008; Scheidt et al, 1995)

	improvements with respect to the 1-week system
Piglets weaned per sow	+1 piglet
Average daily gain	10%
Feed conversation	- 5%
Mortality	-1%

At the reverse side are the possible increase of culling rate, need for extra investments and cash flow problems during transition period. In order to cope with the biological constraints, mating targets must be achieved. So, gilt (young sow) cycling becomes important: both gilts and sows may fail to cycle within the required period, in which case extra females need to be mated to avoid empty crates (Brown, 2006). So more gilts are needed and the culling rate will go up. Batch farrowing also requires additional capital expenditure (Brown, 2006) but according to Van den Plas (2007) the number of crates won't differ between the one- and four-week system. Finally, there may be an initial period of low production with knock-on effects for the cash flow of the business when changing over from a continuous flow system (Brown, 2006*)*.

Sociological outcomes

Positive is the better management of labour scheduling, in particular with respect to leisure, but on the other hand, some farmers see the times of peak work as overwhelming (Kains, 1998). Risk for mismanagement of large numbers of sows during the service period is the main problem. Both over- and under-stimulation can result in poor conception rates. With substantial numbers of sows to be inseminated on one day, it is important that the last sow is inseminated as carefully and diligently as the first (Brown, 2006). But also more generally, it remains a challenge to keep the sows on the chosen schedule. Another positive effect is the improved animal health, because of less different groups and because batch farrowing systems enable all-in all-out procedures. Better animal health leads to improved daily life-weight gain, improved feed efficiency, lower mortality and a reduction in medication costs (Armstrong, 2003; Brown, 2006; Jansen Animal Health, 2006; Scheidt et al, 1995). Finally, given the challenge to keep the sows on the chosen schedule and to introduce the gilts into a batch, hormones (such as progesterone) may prove necessary to keep the sows in batches (Kains, 1998), but it remains unclear what social reaction might be (acceptance, reluctance).

Ecological outcomes

Larger group of pigs with similar age incite adopting more efficient feeding technologies, such as phase feeding (Brown, 2006*).* Phase feeding involves adjustments of successive diets to the varying needs of the pig during growing stages. This enables 9% reduction in nitrogen intake and a 15% reduction in nitrogen output compared with the original diets (Willis, 2004). Although no references are found, we can estimate that similar efficiency gains can be reached for other resource use, such as better water and energy use. Better heath would also means economising on veterinary costs.

2.3. TD-ABC : description plus possibilities for an enlarged CSR evaluation (or accounting)

2.3.1. A powerful management accounting technique

Given the specificities of the decision problem in this paper, time-driven activity-based costing (TD-ABC) will be used for evaluating the innovation. TD-ABC is a modelling technique in management accounting, recently developed by Kaplan and Anderson (2004, 2007). Basically, it was invented because normal costing methods, such as activity-based costing, had difficulties with modelling complex activities and variability in working methods (Varilla et al, 2007). The time-driven approach requires the estimation of only two parameters: the unit cost of the capacity and the number of units required of the capacity to perform an activity, or a subtask within the activity. In TD-ABC capacity stands for “time spent by employees” (e.g. for manual operations) or “space needed” (e.g. for housing activities). The breakthrough of time-driven ABC lies in the capacity estimation (time or space). The time required for performing an activity is modelled, based on all possible variants of the activity. The characteristics that drive the variants of the activity are called time-drivers, because they “drive” the time spent for a particular case. Time equations model how time drivers drive the time spent for an activity. In complex environments where the time needed to perform an activity is driven by many drivers, TDABC can include multiple drivers for each activity.

Consider an example of the example of the sales order processing. Assume now a total resource cost of €57.600 (payroll, depreciation, other supplies) per week related to a practical time capacity of 5.760 minutes (80 per cent of the theoretical capacity of 40 hours per week for 3 employees). So, the cost per minute for this resource group is 10 Euros. The time required to process a standard order is estimated to be three minutes. Order processing for new customers requires a registration, taking an additional 15 minutes. So the event of order processing for a new customer takes 18 minutes, while the event of order processing for an existing customer takes three minutes. Hence, in the time-driven approach, the cost per order equals €30 for existing customers and €180 for new customers. The time equation for this simple example is given as:

Order processing time per order = 3 + 15, if new customer

2.3.2. Some applications

The aim of this subsection is to examine, from literature, whether TD-ABC might be an appropriate technique for our evaluating our decision problem, given its complexity, low data availability, multi criteria. Through the inclusion of multiple time drivers, complex activities can be modelled without expanding the number of activities (Kaplan & Anderson, 2004). Hence, TDABC provides apparently many opportunities to design cost models in environments with complex activities and dynamic processes, such as in logistics and distribution companies, hospitals, and servicing companies in general, e.g. Everaert et al. (2008), Pernot et al. (2007). So far, no applications has been developed for the farming industry.

The problem of low data availability is treated by Kaplan and Anderson (2004) themselves. In fact, their method is based on, what they call well-informed managerial estimates. Possible extensions of the primarily labour-based method are already announced in the original Kaplan and Anderson (2004) paper.

2.3.3. Enlarged, multi criteria, use of TD-ABC

The above cited references deal with capacity needs, where capacity stands for labour or space spent on a activity. In current study, we want to use the TD-ABC method in a somewhat different way. We continue to look primarily to time-drivers and the unit labour needed per activity. But instead of looking to the labour costs, factors that finally influence the remuneration of labour will be analysed. Indeed, it's common business in agricultural economics to use labour income as indicator for economic performance. Labour income is then obtained by deducing non-labour costs from revenues. As differences in non-labour costs need to be captured, also drivers for this variation need to be taken into account, e.g. feed uptake. This adapted approach enables us to obtain the labour income per unit labour needed to perform the activity.

This way of doing also make it possible to enlarge to set of possible outcomes of the TD-ABC evaluation. First, of all labour, housing (capital invested) and labour income will be gratified through TD-ABC. The scope of labour, will be captured by estimating the needed time for every activity through the variables that influence the duration of the different activities. The scope of the investment will be influenced by the number of places for the sows, especially by the number of crates. The labour income will be expressed by the income that the farmer gets, expressed per unit labour that is needed, but also given the farmer's criteria by sow or by production right. Next, given the fact that supplementary drivers need to be assessed, some joint products, interesting from ecological side, can be derived. The most apparent is the nutrient emission which can be derived as the balancing item of outputs and inputs. Similar derivation are possible for energy and water use. Lacking accurate data forces us to analyse these impacts more qualitatively. Finally, there are more complex to measure outcomes, such professional pride, animal welfare and health. However, also here, the decomposition of the complex decision problem into drivers allows us to perform some estimations in a more qualitative way.

In sum, the TD-ABC approach will be used in a slightly adapted form to compare batch farrowing with the traditional production method, on:

- the labour hours needed;

- space needed, in particular for insemination, pre-nursery, nursery, farrowing and finishing;
- the livestock capital needed;
- revenues and non-labour costs;
- labour income;
- nutrients.

2.3.4. Data collection

Data were collected from a variety of sources, and included literature information, quantitative and qualitative farm data and secondary data from the Belgian farm accountancy data network. Some of the literature is given above, the same for the specific farm data. The traditional pig production system at the Bryon Farm has been described up in consecutive phases, according to the phases in the sow cycle and pig growth. This enabled to describe the time-drivers and time equations for both the traditional and the batch system.

The TDABC system has been elaborated by the daughter of the farm family, checked by the other co-authors. A farm visit together with a veterinarian-consultant with profound expertise in batch farrowing took place to cross-check findings. The meeting was also helpful to further unravel the decision criteria that are at stake within the Bryon family, and to validate some of the necessary extensions, such as the operational costs.

2.4. Integrating the CSR outcomes (reports) in a frontier analysis framework

In order to benchmark the farm to its peers, a non-parametric efficiency analysis technique based on DEA, data envelopment analysis, is used. DEA models are linear programming methods that calculate the frontier production function of a set of decision-making units and evaluate the relative efficiency of each unit. Those identified as best practice units, determine the frontier.

Technical efficiency (TE) will be calculated assuming constant returns to scale. TE for a unit that produces k-outputs using m different inputs is obtained by solving the following model:

$$\begin{aligned} &\text{Min}_{\theta,\lambda}\theta \\ &\text{subject to} \quad y_i \leqslant Y\lambda, \\ &\qquad\qquad\quad \theta x_i \geqslant X\lambda, \\ &\qquad\qquad\quad \lambda \geqslant 0, \end{aligned} \tag{1}$$

y_i is the (k · 1) vector of the value of outputs produced

x_i is the (m · 1)vector of the value of inputs used for unit i.

Y is the (k · n) vector of outputs and

X is the (m · n) vector of inputs of all n units included in the sample.

λ is a (n · 1) vector of weights and

θ is a scalar with boundaries of one and zero that determines the efficiency score of each DMU (Galanopoulus et al, 2004).

The value of θ will be the efficiency score for the i-th DMU. It will satisfy $\theta \leq 1$, with a value of 1 indicating a point on the frontier and hence a technically efficient DMU. We consider an average present sow as production unit. The main inputs are feed for pigs as from 20 kilogram's, feed for sows and for piglets, fixed costs and other variable costs. Output consists of kg marketable pigs.

Given the production technology, there is not only an input proportion that minimizes costs, but also an input proportion that minimizes nutrient balance. An ecological efficiency measurement that can be decomposed into input oriented technical and ecological allocative efficiency measurements. Note the difference between ecological efficiency and eco-efficiency. While eco-efficiency is defined as a ratio-indicator between an economic outcome and an ecological outcome, ecological efficiency compares the actual ecological performance to an optimal level.

In this research, average price from FADN data are used and nitrogen content data come from literature.

Cost efficiency for the i^{th} case is the ratio of minimum costs to observed costs. Ecological efficiency equals the ratio of minimum nitrogen uptake to observed nitrogen uptake. Dividing cost and input oriented technical efficiency yields the cost allocative efficiency (CAE). In a similar way, ecological allocative efficiency (EAE) is calculated by dividing ecological and input oriented technical efficiency.

3. Results

3.1. Farm-specific features and assumptions

For comparison of both two systems, the biological parameters of pig production and most managerial decisions that don't intervene with the batch choice are kept the same. First, and most important, the weaning age is set at 3 weeks. So, this means that cycle, together with the pregnancy of 115 days and acclimatisation, lasts 20 weeks. Second, piglets are transferred to finishing at 8 weeks and finally finished at the age of 24 weeks. Third, we assume that 85 percent of sows will give birth after insemination. Finally, although culling rate can be influenced by batch choice, here we assume, however, that it remains the same in both systems. This is reasonable because of the farmer already obtains a high culling rate, comparable to those necessary for batch systems.

Since the farmer doesn't want to keep more than 433 sows, we start from this number of sows. This results in groups of 20 sows in the one-week system and of 80 sows in the four-week system. To optimize the one-week system, the farmer needs 23 insemination places, 306 places for pregnant sows and 20 parking places. In the four-week system, this is 92, 245 and 80, respectively. The farmer needs both in the one-week system and the four-week system 80 crates for farrowing and suckling. The farmer determines also the amount of places for the piglets and pigs based on the batch system (Janssen Animal Health, 2006). The number of places in the nursery and finishing rooms depends on the number of batches and the number of pigs in these batches, which depends on sow productivity. According to what is found in literature, we count with 10.5 weaned pigs/sow in an one-week system and with 11.5 weaned pigs/sow in a four-week system. The piglets remain almost 8 weeks in the weaner accommodation, so the needed number of nursery places is 1680 in the one-week system and 1840 in the four-week system. The pigs are kept almost 17 weeks in the finishing room in a one-week system. So, 17 groups must be housed, which results in a minimum of 3570 places. As pig grow faster in a four-week system, we assume they are kept almost 16 weeks in the finishing room, so we need at least 3680 places.

3.2. Time equations for labour

For every activity, an equation is established. This equation exists out of a time that is determined by starting up a sort of activity and a time that depends on a variable. When for example sows are cleaned, it takes 15 minutes to start and stop cleaning and 3 minutes are needed per sow. The parameters for the four-week will differ, the batches will be four times bigger. Some equations will differ according to the productivity changes, we assume productivity gains as indicated in table 2 (Suls, 2008; Scheidt et al, 1995), e.g. the number of weeks in the finishing places goes down with one week.

The various activities of pig production are given in Table 3. Before going into detail on results , we can see that farrowing and the subsequent feeding of piglets that still are with the sow are the major process compounds that will be influenced by the new system , so we can use these to illustrate the TD-ABC principle.

When sows are farrowing it's better to attend because mortality rates will decrease. In the case, sows farrowing are attended, mortality could decrease 44%, which is equivalent to about one piglet extra per litter (White et al., 1996). The duration of labour at farrowing does not much depend on the number of sows farrowing, so the more sows, the more efficient the work will be. Attending the farrowing sows takes 120 minutes per day per batch. Mostly, the sows don't need help. When help is required, 120 minutes have to be spend on one sow. We assume that 10% of the sows need help. During attending, the teeth of the piglets are clipped.

Piglets at the sow are fed twice a day. It takes 5 minutes to prepare the feed for the piglets. Here we have to take into account that piglets in the four-week system are only 3 of the 4 weeks present in the farrowing room. This results in the following formula: 5*365*X14-X17*X18*5*X14, where X14, X17 and X18 are the number of times in a day the pigs get feed during suckling period, number of days that there are no piglets in the farrowing room and number of farrowings per crate per year, respectively.

The duration of the feeding of the piglets at the sow depends also on the number of litters. 1 minute is needed for one litter. The number of litters is the multiplication of the number of sows per group and the number of groups in the farrowing room. The occupancy is (1-X16*X18/365) and the complete formula is then 0,5*365*X14*X3*X5*(1-X16*X18/365), where X3, X5, X14, X16 and X18 are the number of sows per group, number of groups in the farrowing rooms the number of times in a day the pigs get feed during suckling period, number of days that there are completely no piglets in the farrowing room and number of farrowings per crate per year, respectively. The difference between X16 and X17 depends on management decisions. During the feeding session, piglets are controlled.

All other activities are analysed in a similar manner. For more details, we refer to the original research report (Bryon et al., 2008). Attention points are:

- Slack time between two batches may occur, e.g. in farrowings places, this parameter is decide by the farmer;
- Although labour is better organised, some activities turns out to be more labour consuming. This is a result of the increased productivity.
- Slight differences in dominantly biological determined parameters, according to some managerial decisions (see above remark on X16 and X17);
- Existence of pragmatic linking of activities clipping teeth and controlling respectively.

For the case farm, the shift to a 4-week system would turn out to be 385 hours, which is about one hour per sow per year, or 6,38% (table 8). This is mainly caused by the decreased amounts of starting up an activity. In a 1-week system, every activity has to be carried out every week, every activity happens 52 times in one year, whereas at 4-weeksystem the activities take place 13 times in one year. The activities which differ the most are farrowing, feeding piglets at sow, feeding and controlling pigs, moving sows, insemination and treating piglets. We notice that the needed hours labour increases in the four-week system for feeding and controlling pigs. This is the consequence of the higher number of pigs in the four-week system.

Table 3: Labour need for the different systems (in minutes/year)

	1-week system	4-week system	Difference
Activities (Labour)	total minutes per year	total minutes per year	total minutes per year
Feeding sows	28991	28861	-130
Controlling sows	35259	35259	0
Feeding piglets at sow	32850	24635	-8215
Feeding and controlling pigs	109099	113706	4607
Insemination	14638	13078	-1560
pregnancy diagnosis	1976	1391	-585
Vaccination of sows	8190	8190	0
Vaccination of pigs	4160	4377	217
Moving sows	16744	14404	-2340
Cleaning sows	3900	3315	-585
Farrowing	24960	15600	-9360
Cross-fostering piglets	1820	1625	-195
Treating piglets	16120	14950	-1170
Cleaning and disinfecting the farrowing room	16276	15379	-897
Cleaning the places	1040	1430	390
Weaning	15059	14680	-380
Cleaning and disinfecting weaner accommodation	4628	3887	-741
Move to finishing room	10400	10010	-390
Cleaning and disinfecting finishing room	8320	7540	-780
Departure to slaughterhouse	7228	6253	-975
Total (minutes)	361658	338569	-23090
Total (hours)	6028	5643	-385

3.3. Resource equations for housing and livestock

Capital input mainly concern housing and livestock. As shown in the farm-specific results the number of place to house sows at various stages will change. To calculate the housing cost, the prices for new places are used (for details, see Bryon et al. 2008) and multiplied with the number of needed places (see 3.1.) Livestock capital will also change, given the productivity increases. Number of animals are multiplied with the value of the animals. The numbers of pigs are found through the following formulas:

Pigs < 20 kg: X6/X0*7*(X38*X0*7-X50)/(7*X38*X0)*(1-X31/4/100)

Pigs > 20 kg: X6/X0*((X39+X38)*X0-7)*(1-X31/4/100)*(1-X31/2/100)*(X39*X0*7-X51)/(X39*7*X0))

Where X0, X6, X31, X38 and X39 are the number of weeks (batch system), number of weaned piglets in one batch, mortality rate of pigs, number of batches in the nursery rooms and number of batches in finishing rooms, respectively.

Capital costs are calculated, assuming 5% as interest rate and depreciation of investments in buildings over 20 years. More capital is needed in the four-week system than in the one-week system. Costs of capital are 14017 euro higher, or 32 euro per sow per year.

3.4.Equations for balancing labour income

Contrarily to the original TD-ABC objective of allocating overall labour costs to specific activities, in current study we are interested in the remaining remuneration of labour after subtracting non-labour costs from revenues. For each of the labour income balancing item, revenues, operational costs, capital costs, equations are established. For revenues, average prices (obtained from the FADN data) and the amount of sold kg pig are use. Conservatory, we didn't differentiate for prices in the four-week system, the size of the delivered batches in the one-week system is already large (approximately 200 pigs), so it is less probable to obtain a price premium for the larger batches. Batch system dependant changes in revenues are caused by productivity differences. Also operational cost, which are mainly determined by the input feed, are influenced by productivity changes: the more pigs are produced, the more feed is needed. Nevertheless, the link is not linear because also feed conversion improves. Other important operational costs are energy costs, veterinarian and artificial insemination costs. Because these latter also imply labour costs paid to thirds, one has to be cautious not to double-count labour gains. Again, some costs will raise due to productivity, but, due to better health, the per animal costs will decrease .

Total costs will raise (table 4), but proportionally to a lesser extent than revenues, so labour income over the existing sow capacity increases. The higher productivity in the four-week system leads to 175 euro extra labour income per sow, or 75 622 euro at farm level. This is an increase of 58 %.

Together with the gains on labour input (6%), this means that two factors interfere and finally leads to an improved labour remuneration of more than 70%: from 21 to 36 euro per hour labour.

Table 1: Labour income

	1-week system	4-week system	Difference
Turnover	1318716	1441524	122808
- Feed	707622	731830	24208
- Other operational costs	204600	213561	8961
- Costs of capital	276995	291012	14017
Labour income	129498	205121	75622
Labour income/labour hour	21	36	15
Labour income/sow	299	474	175

3.5. Equations for sustainability criteria

The nutrient surplus is calculated as follows:

$NS = \sum NC_{Xi} * X_i - NC_Y * Y$ (3)

With NC, nutrient content information of sow feed (24.3 grammes per kg) piglet feed (28.8 grammes per kg) finishers feed (24.7 grammes per kg) and pig meat (26 grammes per kg) (CAE, 1998).

Given the productivity gains, nutrient surplus raise from 59 411 kg in the one-week system to 59701 kg in the four-week system. Difference is, however, moderate, because of a better feed conversation rate. So the nutrient surplus/finished pig declines in the four-week system.

So far the outcomes could be quantitatively derived from equations. Other sustainability but their derivation can be facilitated through the explicit decomposition of the production process into activities. Animal health and welfare has been qualitatively assessed according to the activities enumerated in table 2. For all activities, the 4-week system has been estimated beneficial, some activities such as feeding and controlling pigs received an extra positive evaluation.

Another values surplus of the 4-week system is the better scheduling of leisure time within the farm family. This information can be directly derived from the labour equations. Two busy weeks alternate with two less busy weeks, In these weeks, it becomes possible to do a trip or to spend more time with family. Moreover, given the work load concentration, it becomes easier to hire someone to perform specific tasks.

The improvement of animal welfare, animal health and a declined nutrient surplus per finished pig will improve pride on profession.

3.6. The economic-ecological efficiency trade-offs

Table 5 presents the efficiency scores, varying between 0 and below 1. 0 being inefficient and 1 being fully efficient. The effects of the four-week system are obtained by applying the results of our model on the data of the farm selected from the FADN-sample. With the four-week system, the cost allocative and ecological allocative efficiency increase. The technical efficiency even increases until full efficiency is reached compared to the other farms in the FADN-sample. There is a positive trade-off between economic and ecological performance.

Table 2: Efficiency scores for the case

	one-week system	four-week system
Technical efficiency	0,952	1,000
Cost allocative	0,829	0,855
Ecological allocative	0,966	0,971
Cost	0,789	0,855
Ecological	0,919	0,971

4. Discussions

By introducing the four-week system on the case farm, with the same reproductive capacity, labour input can be reduced with 385 hours per year 6%. This could also incite the farmer to grow while maintain the labour input. In the Bryon Farm, the farmer prefers not to increase the business scale. If he would like to extend his farm, he could keep 693 sows with his number of crates in the one and four-week system (number of crates/number of groups in the farrowing rooms*number of groups*52/number of litters/sow/year). For this number of sows, he has to invest in insemination places, places for pregnant sows, parking places, nursery places and finishing places. Through changing the number of sows as input, the model could calculate the opportunity cost of this choice.

Nevertheless, even with the same sow capacity, more investments are needed in the four-week system because sow productivity increases. Compared to total investments, they are minor and only 5 % compared with a one-week system. In current study , we used costs for new places, in really converting farms have already places. The extra investments turns out to be 394 893 EUR in the four-week system if the farmer takes into account the investments in the past. On the other hand, the opportunity exists to give one kind of place another destination, e.g. places for pregnant sows can be used as insemination places. Finally, new legislation may change costs comparisons. For example, the obliged shift to group housing in near future will also cause extra investments in the traditional system. Probably the cost to adapt will be lower in the four-week system because of the bigger batches.

Labour income has been calculated with averages figures of the past (averages over the period 2001-2003, which may be seen as representative for a longer period). Pig prices, however, fluctuate and also feed prices vary. A sensitivity analysis to fluctuating prices is performed. The difference between the systems keeps positive, so labour income in the four-week system surpasses each time those of the one-week system. When looking to future, prices of pig meat are probably declining, while intermediates prices are rising. In recession times, however, farmers in the four-week system will face more difficulties to pay back debts and interests, because they had to invest more.

5. Conclusions

The experiences with current study show that TD-ABC can be used for guiding management with the decision problem of switching to batch farrowing. Because it is more common to use labour income as profitability in agriculture, the method needed to be adapted. Only differences in labour time are calculated, and remuneration of this input is calculated as a balancing item of revenues minus non – labour costs. Focus on labour time gives the opportunity to give different weights to the activities. Some activities like castrating are worse and will have more weight than other activities like moving sows.

Moreover, TD-ABC is not only used to model the differences in labour and housing space, but also for nutrients production and other CSR criteria. This allows for deriving trade-offs between economic and ecological criteria. Outcomes of TD-ABC can be used for integrative analyses such as DEA which allows the benchmark the individual farm outcomes and progress.

Finally, based on our results, we advice the farmer to switch to the four-week system from a corporate social responsibility viewpoint. The economic and ecological efficiency will be better, labour income will increase and both decrease and concentration of labour input will satisfy private requirements for more leisure time. Next to this, he can be proud on his farm because the welfare of the animals will better and the nutrient surplus per finished pig will decline. As all these sustainability criteria improve, the extra needed investment is acceptable.

The added value of his paper with regard to the original work of Kaplan & Anderson is the use of TD-ABC to test a new production system. Moreover this is used to draw up a model that encloses the different costs and this model can be generalized to other farrowing-to-finishing farms. Whether all these farms would take profit from a conversion to batch farrowing is another question of which the results would depend on the actual simulation on each farm. There may also be remaining bottlenecks for adopting batch farrowing. Some farmers can't stand the labour peaks or they don't have enough labour capacity in the busy days, because they don't find or don't want to hire other people. Next to this, in some cases, the adaptation of the infrastructure of the farm to the four-week system can be tough.

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