Valuation of Dairy Herd Health Management

PhD Thesis

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CONTENTS

Preface

Years ago in the western part of Jutland a veterinarian had a frustrating experience. Out of the blue came a moment of doubt in the shape of a question: 'To what extent does my services as a herd health management consultant add value to the dairy enterprise?'

The vet stopped his four-wheel drive and wondered but only for a few minutes because the next farmer anticipated our vet's arrival. That evening the vet had problems falling asleep. The question was confusing and discouraging. No obvious answers came to mind. From that day, the vet felt uneasy when taking the farmer's money in payment of an apparently unknown effect – or in plain language:
Was he selling 'hot air'?

A couple of years later this vet had the opportunity to do a PhD and he quickly decided for a quest; to search for answers to his own question(s) from the field.

This thesis is expected to fulfil the requirements for a PhD degree at the Faculty of Life Sciences (LIFE), University of Copenhagen, Denmark. The research presented was performed in 2006-2008. Inspired by my Supervisors I have tried to keep the thesis 'lean and mean' as academic writing was considered an important part of the educational process. I have focused my research towards applied science as it has been my ambition that any implications would be of value to possible end-users. The Readership must decide if this has been achieved.

The PhD project has been conducted within the framework of the Research School of Animal Production and Health (RAPH). Consequently, I was assigned to the special RAPH PhD program that requests PhD courses in statistics/epidemiology, project management, and ethics in science, biannual seminars and a compulsory interdisciplinary scientific approach. It follows that interdisciplinary research by itself is an important part of the identity of RAPH students and graduates. The different projects included in my thesis have followed the PhD plan as intended. The thesis draws from various scientific methods focusing on possible effects following management changes in dairy herds with the aim to provide insight into 'uncertainty' in areas like: Strategy; management; finances; value-added; measurements and evaluation; epidemiology; psychology and philosophy of life as became evident during my numerous hours of talking with and listening to relevant stakeholders.

I have studied these elements in detail to address the overall research question of my thesis and the inevitable question related to herd health management:

How to valuate dairy herd health management?

Along the way a number of people have participated in different parts of the project. They have all earned my gratitude and respect. However, my Supervisors deserve special recognition:

Your enthusiasm and concern for your PhD students are immensely inspiring. You have helped me further than I believed possible. You have challenged my beliefs and provoked me to think – and most importantly; this process has been a lot of fun.

I thank you for a mind-blowing experience!

Erling Lundager Kristensen
Ry, September 2008

Summary

Veterinary science has not provided convincing evidence that dairy herd health management programs are truly related to (any) measurable value beyond chance in applied settings. Consequently, farmers may be left with only their intuition to manage the dairy enterprise or they may perceive herd health management programs as 'hot air' or 'a matter of belief' because of the invisible and/or non-quantifiable value added to the dairy enterprise by management programs. This PhD thesis provides contributions to answer the overall research question:

How to valuate dairy herd health management?

The overall research question was addressed from a veterinary point of view focusing on the health promotion aspects in dairy herds. The contributions to an answer or answers are provided by four subprojects. Initially, available knowledge on herd dynamics, as synthesized in the SimHerd model, was used for deduction of the most important financial effects related to practically relevant management changes in dairy herds. This deduction was followed by the development of a metamodel, i.e. a condensation of a series of herd simulations with the SimHerd model that provided a more user-friendly and nevertheless valid tool for predicting the financial effect of the management adjustments in question. This approach contributed to circumventing some of the problems related to obtaining a large number of input variables needed for the complex SimHerd model. The SimHerd model was also used to estimate the random within-herd variation in financial performance between subsequent years following changes in selected technical key performance indicators assumed to mimic changes in herd management at herd level thereby illustrating the problems related to the commonly applied league-tables for motivating farmers.

If the input to the model (biological and technical associations at cow and herd level) is biased or imprecise the predictions of financial performance will also be biased or imprecise. Such input-parameters are usually estimated from observational field data. Consequently, we explored the validity of field data reported by veterinarians and utilized by modelers in dairy herd management research. Unfortunately, 'real life' is almost impossible to capture in multi-herd databases due to the different circumstances from which the data is collected and processed. Last, I inquired into dairy farmers' perceptions of herd health management. Clearly, financial performance and optimization of production was only a part of the whole picture. Apparently, farmers' expectations when participating in a herd health management program are more directed towards teamwork and animal welfare more than towards increased production and profit.

The following is a list of the most important conclusions from the thesis:

Potential financial effects of health related management changes

- A number of key performance indicators were identified and implemented in a mechanistic, dynamic and stochastic simulation model of a dairy herd (the SimHerd model)
- In a 10-year horizon the relative effects (percent of the long term effect on gross margin per cow) were: shape of lactation curve 53 (€ 227), reproduction efficiency 21 (€ 89), heifer management 8 (€ 34), dynamics of body condition score 6 (€ 25), mortality in cows 5 (€ 23), mortality in calves 4 (€ 18) and somatic cell counts 3 (€ 15)
- The results showed numerous significant interactions between the different combinations of key performance indicators. This implies that financial performance related to certain management strategies will depend significantly on the management level in other areas of herd management
- The standard deviation of the annual gross margin per cow year between subsequent years in the default herd with a constant production strategy and constant prices given the study context was € 26. In real life the standard deviation was € 248
- Approaches to implement the metamodel in veterinary cattle practice is outlined

Problems related to collection and analysis of health-related data

- This thesis supports previous findings that variability is high between veterinarians' procedures and criteria for decision making
- Semi-structured interviews of 20 veterinarians showed that even if a very detailed protocol was distributed to the veterinarians, validity of field data was problematic
- Estimates obtained from across-herd quantitative statistical analyses of large data files recorded in numerous herds may be misleading and very problematic as information for decision support systems to be used in individual herds
- Researchers are urged to increase their knowledge on the local context, i.e. the circumstances in which the data was constructed before inferring generalizations between cause and effect to the entire dairy population and the individual herd
- This thesis suggests that much research in herd health management will benefit substantially from a mixed methods research approach

Farmers’ perception of herd health management

- Farmers’ perception of herd health management programs could meaningfully be divided into four families of perspectives explaining 37, 12, 9 and 7 percent of variance, respectively, for families labeled: Teamwork, Animal welfare, Knowledge dissemination and Production
- Identical families of perspectives were identified among the affiliated veterinarians; however, veterinarians believed that farmers primarily were motivated by production (explaining 48 percent of variance)
- Farmers valued animal welfare for different reasons: 1) to please society; 2) because the farmers believed that increased animal welfare was a necessary prerequisite to increase production; 3) to increase the farmer’s subjective well-being
- Farmers apparently view veterinarians as largely incompetent when it comes to herd health economics, finances in general and strategy related to running a business

Sammenfatning (summary in Danish)

Veterinærvidenskaben har ikke fremskaffet overbevisende dokumentation for, at sundhedsrådgivning i malkekvægsbesætninger bidrager til nogen målbar værdiforøgelse i praksis. Kvægbrugerne risikerer derfor at måtte basere implementering af sundhedsrådgivning i kvægproduktionen på intuition alene. Alternativt kan opstå en opfattelse af, at sundhedsrådgivning er 'varm luft' eller 'et spørgsmål om tro' grundet den usynlige og/eller ikke-kvantificerbare værdiforøgelse, som (måske) tilgår bedriften. Denne ph.d.-afhandling bidrager til at besvare det overordnede forskningsspørgsmål:

Hvordan værdisættes sundhedsrådgivning i malkekvægsbesætninger?

Det overordnede forskningsspørgsmål tager afsæt i sundhedsfremmende aspekter i malkekvægs-besætninger. De tilvejebragte svar på spørgsmålet har form af fire delprojekter. Først blev den allerede tilgængelige viden om besætningsdynamik, som den er beskrevet i SimHerd modellen, brugt til at udlede de væsentligste økonomiske virkninger relateret til praktisk relevante ændringer i driftsledelsen af malkekvægsbesætninger. Herefter blev udviklet en 'metamodel', dvs. en kondensering af en serie af besætningssimuleringer med SimHerd modellen, hvilket resulterede i et mere brugervenligt og stadigt troværdigt værktøj til at forudsige de økonomiske konsekvenser af de aktuelle ændringer i driftsledelsen. Denne tilgang bidrog til at omgå nogle af de problemer, som følger af at skulle indhente flere forskellige typer af data til den betydeligt mere komplicerede SimHerd model. SimHerd modellen blev også brugt til at estimere den tilfældige variation på den økonomiske virkning af ændringer i specifikke besætningsnøgletal. Problemet med de ofte benyttede sammenligninger af ændringer i dækningsbidrag mellem besætninger blev dermed illustreret.

Hvis input til modellen (sammenhænge på ko- eller besætningsniveau) indeholder fejlskøn eller er upræcise, så vil forudsigelserne af økonomisk virkning tilsvarende indeholde fejlskøn eller være upræcise. Sådanne input-parametre estimeres normalt fra feltdata. Vi undersøgte derfor troværdigheden af feltdata rapporteret fra dyrlæger og brugt af forskere udi malkekvægsbesætningers driftsledelse. Desværre, så er det næsten umuligt at genfinde det 'virkelige liv' i databaser, som indeholder data fra mange besætninger. Det skyldes de forskellige omstændigheder, hvorfra data blev opsamlet og behandlet. Til slut undersøgte jeg kvægbrugernes forventninger til sundhedsrådgivningen. Det var tydeligt, at økonomisk virkning og produktionsoptimering kun var en del af det samlede billede.

Tilsyneladende retter kvægbrugernes forventninger sig mere mod følelsen af at være en del af et hold og forbedret dyrevelfærd end mod øget produktion og profit.

<u>Følgende er en liste over de væsentligste konklusioner fra afhandlingen:</u>

Mulige økonomiske virkninger af sundhedsrelatede ændringer i driftsledelse

- Et antal besætningsnøgletal blev identificeret og implementeret i en mekanistisk, dynamisk og stokastisk simuleringsmodel af en malkekvægsbesætning (SimHerd modellen)
- Efter en 10-årig periode var den relative virkning (procent af den langvarige virkning på dækningsbidrag per årsko) henholdsvis: Form på laktationskurven 53 (kr. 1.703), reproduktionseffektivitet 21 (kr. 668), kvie-management 8 (kr. 255), dynamik i huldvurderinger 6 (kr. 188), kodødelighed 5 (kr. 173), kalvedødelighed 4 (kr. 135) og celletal 3 (kr. 113)
- Resultaterne viste mange væsentlige vekselvirkninger mellem de forskellige kombinationer af besætningsnøgletal. Det fortæller, at den økonomiske virkning relateret til bestemte driftsledelsesstrategier vil afhænge betydeligt af driftsledelsesniveauet indenfor andre områder af driftsledelse
- Standardafvigelsen på det årlige dækningsbidrag per årsko mellem år i udgangsbesætningen med en fast produktionsstrategi og faste priser var kr. 195 givet det aktuelle forsøgsdesign. Beregnet på baggrund af virkelige tal er standardafvigelsen kr. 1.860
- Mulige metoder til at implementere metamodellen i veterinær kvægpraksis er beskrevet

Problemer relateret til indsamling og analyse af sundheds-relaterede data

- Afhandlingen bekræfter, at der er stor variation blandt dyrlæger mht. procedurer og kriterier for beslutningstagning
- Semi-strukturerede interviews af 20 dyrlæger viste, at selvom en meget detaljeret protokol blev uddelt til dyrlægerne, så var troværdigheden af feltdata problematisk
- Skøn fra kvantitative statistiske analyser på tværs af besætninger baseret på store datafiler fra mange besætninger kan være misvisende og meget problematiske som information til beslutningsstøttesystemer i den enkelte besætning
- Forskere opfordres indtrængende til at øge deres viden om den lokale kontekst, dvs. de omstændigheder under hvilke data blev konstrueret, før der drages konklusioner mellem årsag og virkning på såvel det overordnede niveau som i den enkelte besætning

- Denne afhandling foreslår, at forskningen i sundheds- og produktionsstyring vil opnå betydelige gevinster, såfremt synergien mellem kvantitative og kvalitative forskningsmetoder udnyttes

Kvægbrugernes forventninger til sundhedsrådgivning

- Kvægbrugernes forventninger til sundhedsrådgivning kunne meningsfuldt inddeles i fire familier, hvilket forklarede hhv. 37, 12, 9 og 7 procent af variationen blandt kvægbrugerne. Familierne blev navngivet Teamwork (holdfølelse), Animal welfare (dyrevelfærd), Knowledge dissemination (vidensdeling) and Production (produktion)
- Lignende familier blev identificeret blandt de tilknyttede dyrlæger, men dyrlægerne havde en forventning om, at kvægbrugernes primære motivation var produktion (hvilket forklarede 48 procent af variationen blandt dyrlægerne)
- Kvægbrugerne tillagde dyrevelfærd værdi af forskellige årsager: 1) for at tilfredsstille samfundets forventninger; 2) fordi kvægbrugerne mente, at øget dyrevelfærd er en nødvendighed for øget produktion; 3) fordi dyrevelfærd øger kvægbrugerens subjektive velbefindende
- Tilsyneladende opfatter kvægbrugerne dyrlæger som stort set inkompetente, hvis emnet er sundhedsøkonomi, driftsøkonomi eller forretningsstrategi

Chapter 1

GENERAL INTRODUCTION

From the point of view of a herd management scientist, the farmer is in focus and the purpose of the production is to provide the farmer (and maybe his family) with as much welfare as possible. In this connection welfare is regarded as a very subjective concept and has to be defined in each individual case. The only relevant source to be used in the determination of the definition is the farmer himself, Kristensen et al. (2007)

INTRODUCTION

In Denmark the majority of dairy farmers have implemented some sort of herd health management (**HHM**) program offered by the herd veterinarian. The framework with regular planned visits is usually based on requirements given by legislation related to use of antibiotics. However, to my knowledge veterinary science has not provided convincing evidence that implementation of such a HHM program is related to (any) measurable financial added value beyond chance. If this statement is true, veterinarians cannot provide valid answers when confronted by farmers or financial lenders and asked to justify farmers' allocation of resources to (expensive) management systems. Therefore, farmers may perceive HHM programs as 'hot air' or 'a matter of belief'. Why, then, is this evidence not available?

Obviously, one reason could be that HHM does not have any significant effect. Another reason could be that documentation of effects is lacking because estimation of such effects related to HHM is a very complex task for the following reasons: First, the dairy herd is a very complex system with numerous feed-back mechanisms (Enevoldsen et al., 1995; Østergaard et al., 2000) making it difficult to measure the effect of one or more changes in input factors (Dijkhuizen et al., 1995; Tauer and Mishra, 2006). Second, due to the long generation interval in cattle breeding, several years may pass before changes in individual animal performance affect the financial performance of the herd as a whole (Mourits, 1997). Third, during such a long time span, numerous other determinants of performance probably change as well, e.g. price level (Kristensen et al., 2008a) and farmer's goal(s) both on and off the farm (Black, 2006). This reflects that a dairy enterprise is dynamic by nature. Fourth, to obtain data valid for making such evaluations is very difficult (Kristensen et al., 2008c). Fifth, knowledge is lacking when it comes to the motivational explanations. What motivates farmers? - and why? (Bigras-Poulin et al., 1985b; Valeeva et al., 2007; Kristensen and Enevoldsen, 2008)

As indicated above the farmer's perception of value, success and subjective well-being may affect both implementation and evaluation of the HHM program. Such personal preferences are likely to change during time. To understand and meet the farmer's expectations the veterinarian must acknowledge the importance of personal preferences and the sometimes non-quantifiable nature of the term 'utility' (Kristensen et al., 2007). Additionally, the feeling of making a risky decision (generally speaking) evokes different feelings in different people (Hadar and Fischer, 2008). How do differences between farmer and veterinarian related to perceived risks associated with a certain management decision influence the consultancy process and consultant's proposed recommendations?

THE THESIS

THE RESEARCH QUESTION

The problems and questions raised above will be addressed in this PhD thesis. The overall research question is:

How to valuate dairy herd health management?

THE CONTEXTUAL FRAMEWORK OF THE THESIS

The overall research question is addressed from a veterinary point of view focusing on the health promotion aspects in dairy herds. Initially, available knowledge on herd dynamics, as synthesized in the SimHerd simulation model, is used for deduction of the financial effects related to practically relevant management changes. This deduction will be followed by the development of a 'metamodel', i.e. a simple and more user-friendly version of the SimHerd model. The SimHerd model is also used to estimate the random within-herd variation in financial performance between subsequent years following changes in selected technical key performance indicators assumed to mimic changes in herd management. Within-herd variation in financial performance may illustrate potential problems with the commonly applied league-tables with performance indicators used for motivating farmers. However, if the input to the model (biological and technical associations at cow and herd level) is biased or imprecise the predictions of financial performance will also be biased or imprecise. Such input-parameters are usually estimated from observational field data. We explored the validity of field data reported by veterinarians and subsequently utilized by modelers in dairy research. Last, I take a step back and inquire into the dairy farmers' perspectives on herd health management because financial performance and optimization of production probably are only parts of the whole picture. Farmers may attribute more value to other things like leisure time, animal welfare, prestige…

In summary, this approach led to four subprojects with the following objectives:

Subproject 1 To identify and rank technical key performance indicators that are useful to estimate effects on financial performance of interventions in the management of the dairy herd

Subproject 2 To estimate the random within-herd variation in financial performance between subsequent years including time to financial steady-state subsequent to changes in selected technical key performance indicators that are assumed to mimic changes in herd management. This knowledge is useful to illustrate the element of ‘financial randomness’.

Subproject 3 To discuss the importance of data validity and how this potentially may be improved by complementing the quantitative approach applied in most herd health management studies with qualitative research methodologies. Sufficient quality of data is a prerequisite for the simulation model and subsequently for valuating the effect of intervention

Subproject 4 To obtain knowledge about how farmers perceive and measure value (if any) added to the dairy farm by HHM programs and veterinarians contributions in general

OUTLINE OF THE THESIS

Chapter 2 provides a short general introduction to the research field and a description of the problems encountered when trying to estimate effect(s) of herd health management programs at farm level

Chapter 3 gives a thorough discussion of the methodological considerations and a short description of the applied study designs and data sources

Chapter 4 presents a summary of the results obtained in the subprojects

Chapter 5 presents a discussion of each subproject

Chapter 6 describes the competent herd health management consultant as viewed by dairy farmers and elaborates on the perception of risk related to the veterinarians contribution to decision making

Chapter 7 presents conclusions related to

- potential financial effects of health-related management changes
- problems related to collection and analysis of health related data
- farmers’ perception of herd health management and the veterinarians’ contribution
- implications and perspectives for research, consultancy and education

Publications present four papers published in peer-reviewed journals related to the subprojects

Chapter 2

HERD HEALTH MANAGEMENT

Consider the folktale of the czar who learned that the most disease-ridden province in his empire was also the province with the most doctors. His solution? He promptly ordered all the doctors shot dead, Levitt and Dubner (2005)

WHAT IS HERD HEALTH?

The concepts of health and disease are obviously essential in HHM. However, there are no explicit definitions of these concepts in veterinary textbooks (Gunnarsson, 2006). From my research and literature, ‘herd’ is defined within the current context as a dynamic and integrated system in which the individual parts are interrelated and function through predefined principles. The system includes the individual cow/calf but also the interaction between cows/calves and between cow(s) and the farmer, stable, feeding plan, veterinarian, weather etc. Further, I define ‘health’ as the absence of any state in which an animal cannot escape from or adapt to the internal or external stressors or conditions it may experience, resulting in negative effects on its normal functions and behavior, potential production (including actual production) and welfare. This definition is substantially broader than the traditional definition of health in veterinary science (Gunnarsson, 2006), i.e. absence of disease. I find support for this point of view in Green and Raeburn (1988) who suggest the following, even broader, definition to health promotion: ‘The combination of educational, organizational, economic and environmental support for action conducive to health’ and the view on animal health presented by the European Commission (2007) in the action plan for Animal Health Policy in the EU: ‘The concept of animal health covers not only the absence of disease in animals, but also the critical relationship between health of animals and their welfare’.

The objectives of HHM are somewhat more specific than the general definition of herd management: ’The purpose is concurrently to ensure that the welfare of the farmer is maximized subject to the constraints imposed on production’ (Kristensen et al., 2007). Brand and co-authors (2001) state that the primary objectives of HHM are to optimize:

- The health status of the herd, by prevention of health and (re)productive problems
- The productivity of the herd by improving management practices
- The production process in relation to animal welfare and ecological quality of the environment and the maintenance of a sustainable dairy industry

- The quality and safety of dairy and meat products
- The profitability of the dairy enterprise

I accept the definition by Kristensen et al. (2007); however, this thesis aim to provide knowledge on herd management in a veterinary context. Thus, I attribute more importance to the concept of health promotion than Kristensen and co-authors (2007). The issue of health promotion is also somewhat different from the production-oriented optimizing approach presented by Brand et al. (2001). This thesis provides several examples describing why it is essential to acknowledge and understand the unique nature of each farm and farmer and the complex combinations of factors contributing to herd health, animal welfare and farm performance (Barkema et al., 1998; de Kruif and Opsomer, 2004) including studies of farmers' subjective well-being.

HERD HEALTH ECONOMICS

When value judgments are involved, microeconomics cannot tell us what the best policy is, Pindyck and Rubinfeld (2005)

The manager of a dairy herd and the affiliated veterinarian constantly need to evaluate whether financial performance of the production system is satisfactory and whether there are real (systematic) effects of changes in management (Galligan et al., 1991). One major purpose is continuously to identify the most beneficial trade-off between input and output factors to increase profit (Kristensen et al., 2007). Such assessments (monitoring) requires 1) information about which performance indicators should be monitored; 2) information related to the magnitude of the random (within-herd) component of variation in the performance indicators of interest; 3) correctly recorded and processed data; 4) a valid prediction model (Dijkhuizen et al., 1995; Enevoldsen, 2006). However, due to the dynamic nature of herd health and the problems associated with collection of sufficient and necessary data it is practically impossible to collect empirical data at herd level from a sufficient number of herds and years to allow a valid comparison of financial performance within or between herds. Several simulation models intended for application at herd level have been developed to solve the problem of lack of sufficient and necessary data from the field (e.g. Ferguson et al., 2000; Shalloo et al., 2004). Simulation models makes it possible to keep all input factors and herd level constraints constant except for the input factor(s) of interest and repeat the process, i.e. cows and herds can be made to re-live their 'lives'. This provides the opportunity to explore the consequences of mutually exclusive management decisions, i.e. 'what-if' scenarios.

Stochastic, dynamic and mechanistic simulation models can provide the necessary estimates of random variation associated with technical and financial output variables. Such estimates are essential for planning interventions (Shalloo et al., 2004). It can be (and has been) argued that simulation models lack the creditability associated with empirical studies. If transparency in model design is not ensured it may be impossible to evaluate the consequences of the inherent trade-offs made by the modelers when constructing the model (Landry et al., 1983). This may explain why it has been difficult to develop a simulation model that provides estimates that are perceived as trustworthy by both farmers and veterinarians (Østergaard et al., 2000). The alternative to simulation models, however, would be to leave farmers with only their knowledge of the past to guide their financial dispositions. However, the need for formal prognostic models is questioned by Hoffmeyer (2008), the former CEO of The Danish National Bank, who stated: 'I have more trust in fundamental (human) attitudes than in prognosis – then you have to solve the problems as they emerge'. Personally, I believe that the most important mission of models (and simulation) is to illustrate the functions of the system. This increases my understanding of how the parameters interact and thus my possibilities to argue my case.

THE PROBLEM ENTITY

Value is not the same as profit. Profit is for countries, organizations and people what oxygen is to the organism – necessary to survive but not the meaning of life. Value (added) is defined and evaluated by the buyer and may be explored by studying the utility experienced by the buyer when acquiring a certain product or service, modified from Haagerup (2006)

Traditionally, HHM researchers and veterinarians have used neoclassical measures of financial performance to estimate value added to production following changes in management attributable to a specific HHM program (e.g. Dijkhuizen et al., 1995); however, this approach has its limitations (Kristensen et al., 2007) in terms of:

Certainty Neoclassical production theory assumes that all necessary knowledge on the relationship between input factors and outcome is available at all times. However, uncertainty is an inherent phenomenon in both biology and management

Dynamics Neoclassical production theory relies on static assumptions and models. Implicitly, production theory assumes that input factors are purchased, products produced and sold within the same time interval. Herd health is, as stated above, dynamic by definition

Adaption Any change in input factors is assumed to be followed by an immediate and full response in output level. Obviously, this is not the case in a dairy herd as cows may respond slowly to certain management changes, e.g. changes in feeding plan or heifer management

Two decades ago Bigras-Poulin et al. (1985a; 1985b) in two classic papers quantified the effects of the management factor in dairy herd management. The study included socio-demographic variables; psychological variables; management practice variables and farm performance variables from 102 farmers in Canada. Dependent variables were: Retained placenta, metritis, ovarian disorders, other reproductive disorders, calving interval, culling and breed class average for fat and milk. These authors obtained data by means of a questionnaire consisting of 4 parts. The first part included variables like age of the farmer, number of people depending on the farms outcome and farm size. The second part inquired into the farmers more personal views like the feeling of satisfaction associated with dairy farming and value orientations. The third part related to continuing education activities while the fourth part concerned the farmer’s HHM policies.

Socio-psychological variables mimicking the management factors were identified as even more important for profitability and efficiency at farm level (explaining between 11 percent and 25 percent of the variation in the dependent variables) than traditional herd level variables that explained between 0 percent and 16 percent of the variation. These authors concluded that farmers’ attitudes should be considered before proposing changes in management practices because interactions between attitudes and management practices acted as an effect modifier on the relationship between management practices and herd performance. The conclusion in the companion papers by Bigras-Poulin and co-authors was quite clear: ‘This study indicates the need for further research to better understand the mode of action of managers’ attitudes in the dairy farm system. Similar findings by other research groups would insure that the present findings are not time and/or sample related’.

Nonetheless, knowledge is still lacking in veterinary science when it comes to the motivational and behavioral side of farmers’ choices (Valeeva et al., 2007). A possible explanation to why this knowledge gap is still present may be that veterinary science is quite conservative and continue to use traditional quantitative research designs, even though these seem unfit to discover the impact of farmers’ values on farm performance, as discussed by Noe (1999). If provided, such knowledge might greatly improve the success of HHM programs (Bigras-Poulin et al., 1985a; Vaarst et al., 2002).

Chapter 3

MATERIALS AND METHODS

Audiences of all kinds most applaud what they like best...Ideas come to be organized around what the community as a whole or particular audiences find acceptable...perhaps most important of all, people approve most of what they best understand. Therefore, we adhere, as though to a raft, to those ideas which represent our understanding, Galbraith (1958)

METHODOLOGICAL CONSIDERATIONS

The PhD project was performed within the framework of Research School of Animal Production and Health (**RAPH**). Part of RAPH's mission is to promote interdisciplinary research. Thus, integrated research is an important part of the identity of RAPH students and graduates. This thesis includes a mixture of research methods to estimate possible effects following health-related management changes in dairy herds. Personally, I have perceived this as an excellent educational opportunity to get training in different research methodologies and disciplines.

Subprojects 1 and 2. The simulation model 'SimHerd' was chosen to estimate the financial value associated with specified technical key performance indicators (**KPI**). The objective was to describe possible financial consequences and uncertainty related to a number of health-related management changes at the individual herd level.

SimHerd is a dynamic, mechanistic, and stochastic model predicting the production and states of a herd in equidistant time steps (Sørensen et al., 1992; Østergaard et al., 2005). The states are characterized at the individual animal level by identification number, age, reproductive status, parity, days in milk, genetic milk yield level, lactation curve parameters, body weight, and body condition score, culling decision, health status on each simulated disease, milk withdrawal and somatic cell count. The state of the individual animal is updated, and the production and amount of input consumed by the herd are calculated for each simulation year. The drawing of random numbers using relevant probability distributions triggers variation between animals and discrete events like pregnancy and culling. In summary, the production and the development within the herd are determined indirectly by simulation of production and change in states of the individual animal that is constrained by herd factors like number of cows or milk quota (Kristensen et al., 2008a).

Subproject 3. If the input-parameters to the simulation model (biological and technical associations at cow and herd level) are biased or imprecise the predictions of financial performance will also be biased or imprecise. Such input-parameters are often estimated from observational field data. Fundamental problems with this type of data were indicated by Vaarst and co-authors (2002) who conducted a study on farmers' decisions to treat cows with mastitis or not. These authors stated: 'experience is gradually built up in collaboration between farmer and veterinarian, and both contribute to this common experience with their background and former experiences'. If farmers and veterinarians respond to their observations based on previous experiences and own beliefs this could potentially influence the validity of the input-parameters derived from data that are influenced by humans (e.g. culling, disease treatment and insemination). This can induce a serious bias in subsequent modeling. Consequently, we explored the validity of field data reported by veterinarians and subsequently utilized by modelers in dairy herd management research. The study was a combination of an observational quantitative approach utilizing data from the Danish Cattle Database and a qualitative approach inquiring into veterinarians' use of a clinical score system.

Subproject 4. Different farmers are motivated by different factors (Maybery, 2005; Valeeva et al., 2007). This implies that a 'one-size-fits-all' management approach from veterinarians or researchers to stimulate improvements of management is unlikely to succeed (Barkema et al., 1998). Likewise, conceptual models (i.e. economic models) or HHM programs that do not recognize the possible interaction between farmers' leisure concerns and income concerns probably will produce misleading results (Tversky and Fox, 1995; Pingle and Mitchell, 2002; Pindyck and Rubinfeld, 2005). Thus, studying farmers' choices may reveal differences between preferences and bring light to farmers' decision utility on such issues as overall farm performance, leisure time and expectations to HHM programs. However, as discussed by Greenwood and Levin (2005) and Onwuegbuzie and Leech (2007), it is important to acknowledge that because all qualitative findings are context-bound 1) any interpretations stemming from such findings should only be made after scrutinizing the context under which the findings were identified and 2) generalizations of any interpretations from the original study to other settings should be made only after adequately understanding the new context and how this new context differs from the original context.

STUDY DESIGN FOR SUBPROJECTS 1 AND 2

Subproject 1. From experience with herd management and modeling (Enevoldsen et al., 1996; Østergaard et al. 2000; Østergaard et al. 2005) and theoretical considerations (Kleijnen and Sargent, 2000; Shalloo et al., 2004) a number of herd level potential KPI were selected.

The following general criteria were used to select the potential KPI:

- The level of the variable describing the potential KPI had to be likely obtainable from data collected within a typical herd management program
- The level of the variable had to vary between herds
- The potential KPI had to describe a (technical) component of the production system that can be affected by the farmer or the advisor
- A cause-effect relation between the potential KPI and the financial performance had to be plausible

The potential KPI addressed were: Shape of the lactation curves; reproduction efficiency; heifer management; variation between cows in lactation curve persistency; mortality in cows; mortality in calves; dynamics of body condition and somatic cell counts.

The potential KPI were defined in the context of the SimHerd model described by Sørensen et al. (1992) and implemented into the modeling framework presented by Østergaard et al. (2005) with some model modifications to address the current research questions (for details about the modified SimHerd model and parameterization of the KPI, see Kristensen et al., 2008a). For each potential KPI the 75 percentile and the 25 percentile were calculated as found in various Danish standard protocols. The term 'High' (**H**) was defined as applicable to 'good farm management' and the term 'Low' (**L**) to 'pitiable farm management' and these corresponded with the 75 percentile and the 25 percentile. Because of the model design and to ease interpretation, the term 'Middle' (**M**) was calculated as the average of 'High' and 'Low' so that the numerical distance between 'Low' and 'Middle' was equal to the numerical distance between 'Middle' and 'High'. The selected scenarios represented practically relevant levels of management and associated performance (refer to details regarding the simulation context in Kristensen et al., 2008a).

This provided the model:
Gross margin = Shape of lactation curve (levels H, M, L) + reproduction efficiency (levels H, M, L) + heifer management (levels H, M, L) + variation between cows in lactation curve persistency (levels H, M) + mortality in cows (levels H, M) + mortality in calves (levels H, M) + dynamics of body condition (levels H, M) + somatic cell count (levels H, M) + all possible 2-factor interactions + the 3-factor interaction among shape of lactation curve, reproduction efficiency and heifer management.

The simulation experiment was conducted as follows:

- The choice of the potential KPI (e.g., lactation curves with different levels of peak-yield and persistency) was assumed to mimic effects of a systematic change of input factors in the herd management
- Simulated management changes (expressed as changes in KPI levels) were translated into changes in gross margins through the SimHerd model
- The simulation took place in a situation where the production was constrained by a maximum number of cows in the herd (see Kristensen et al., 2008a for a discussion of this constraint)
- Cows and heifers were fed TMR
- Prices were set according to typical prices in Denmark in 2006
- The output from the 10th simulation year was used for analysis, because initial exploration of the simulated data showed that in some scenarios, it took up to 9 years to obtain steady state, i.e. the 'burn in' period reflecting the initial bias (Abate and Whitt, 1987; Chen and Kelton, 2003)

Key characteristics of the default herd in the 10th simulation year after 200 independent replications are described in table 6 in Kristensen et al. (2008a). This herd was defined by having all the KPI placed at level 'Middle' (equal to the production level of an average Danish herd).

Subproject 2. The dataset and the simulation context in this study were identical to the raw data from subproject 1.

STATISTICAL ANALYSIS IN SUBPROJECTS 1 AND 2

If all else fails immortality can always be assured by adequate error, Galbraith (1975)

Subproject 1. The simulated results from the 10th simulation year were analyzed by means of an ANOVA using SAS PROC MIXED (Littell et al., 2006). The full model described above was reduced by backwards elimination of the KPI and their interactions until the p-values of all factors were highly significant ($P < 0.0001$). The level of financial significance was qualitatively defined at € 1.33 per cow per year. The 2- and 3-factor interactions were dissolved to study the differences between KPI and their relation to the gross margin when changing the KPI levels. To compare the KPI the differences from 'Low' to 'Middle' and from 'Middle' to 'High' were used making it possible to compare the 2 level KPI with the 3 level KPI.

That is, the unit of KPI change was largely 1 quartile within the interquartile range. The design provided a direct link to data from bench-marking facilities in herd management programs.

Subproject 2. Accumulation of net present value from years 1 to 10 from the default herd was selected as the measure of financial performance. To measure the magnitude of the random (within-herd) variation in KPI the variance components related to the default herd were estimated in a multilevel mixed model with repeated measurements using SAS PROC MIXED (Littell et al., 2006). Replications were specified as a random effect and year of simulation as a fixed effect. The intercept of the model was selected as the 10th year of simulation. It was expected that errors could be correlated because the gross margin per cow year was considered to be repeated measurements within each replication. Several different correlation structures were examined but the correlations were all very low (< 0.02 between years) and non-significant ($P > 0.5$) using the -2 log likelihood ratio test. Subsequently, gross margin per cow year was regarded to be independent within replication in the analysis. The use of independent replications allowed estimation of the variance within herds across time.

INTEGRATED RESEARCH

Declarations of uncertainty and openness to different ways of thinking require a degree of humility regarding one's own disciplinary authority that, if mutually achieved, can smooth the way towards better understanding, Marzano et al. (2006)

Increasing the relevance of HHM to the individual dairy farm(er) requires that the methodological approach includes both inductive and theoretical knowledge (Enevoldsen, 1993; Kristensen et al., 2008c) because individuals generally only understand generalizations through application to particular circumstances facing them (Tsoukas and Vladimirou, 2001). To reach a cow or herd level diagnosis the veterinarian will need to talk with the farmer and other stakeholders in order to collect and process all information available, i.e. a cow/herd/farmer anamnesis. This process aims at constructing (induce) an understanding (a theory) of the problem entity (Marzano et al., 2006) to be empirically tested against and combined with the veterinarian's own personal and professional experience (Markusfeld, 1993; Enevoldsen, 2006).

Accepting the individuality of dairy farms and farmers is important to any understanding of variation in performance between farms (Bigras-Poulin, 1985a) because 'in principle the outliers in any particular piece of research could be: the product of stochastic processes, the result of measurement error, the consequence of a variable that affects the outcome of the outlier case and also those other cases in the sample, or the consequence of a variable that is unique' (Bennett and Braumoeller, 2005). Consequently, skewed data may hide important knowledge that is lost if perceived outliers are removed from a dataset in an attempt to obtain a normal distribution. This essentially implies that if theories apply by analogy then it is up to the veterinarian and farmer to decide where they apply, where the analogy, by personal judgement, is sufficiently strong (Tsoukas and Vladimirou, 2001; Kristensen et al., 2007).

This view is coherent with the methodological approach found in evidence-based medicine. Consider the statement by Sackett and co-authors (1996): 'Good doctors' use both individual clinical expertise and the best available external evidence, and neither alone is enough. Without clinical expertise, practice risks becoming tyrannised by evidence, for even excellent external evidence may be inapplicable to or inappropriate for an individual patient. Without current best evidence, practice risks becoming rapidly out of date, to the detriment of patients. Evidence-based medicine is not "cookbook" medicine. Because it requires a bottom up approach (induction) that integrates the best external evidence with individual clinical expertise and patient´ choice, it cannot result in slavish, cookbook approaches to individual patient care. External clinical evidence can inform, but never replace, individual clinical expertise, and it is this expertise that decides whether the external evidence applies to the individual patient at all and, if so, how it should be integrated into a clinical decision'. Try to replace 'individual patient' with 'herd'…

Consequently, the iterative development of activities in the individual herd context provide new depths of knowledge due to the improvisational element and personal judgements involved when knowledge is put into action in the field (Ducrot et al., 1996).

MIXED METHODS RESEARCH

Mixed Methods Research (**MMR**) is defined as an intellectual and practical synthesis based on the combination of qualitative and quantitative research methodologies and results (Johnson et al., 2007). It recognizes the importance of both quantitative and qualitative research methods but offers a powerful third mixed methods approach that often will provide the most informative, complete, balanced, and useful research results (Kristensen et al., 2008c). Thus, MMR aims at linking theory and practice (Tashakkori and Teddlie, 1998). Kristensen and co-authors (2008c) argue that researchers with a need to understand a certain field of human action and the consequences and background of such actions may substantially increase their understanding of any data potentially influenced by human action by implementing the combined use of various scientific methodologies. This thesis applies three different qualitative methodologies (Caracelli and Greene, 1997; Shah and Corley, 2006): a) supplementary validation; b) triangulation and c) knowledge generation.

SUPPLEMENTARY VALIDATION

An important use of MMR is to expand qualitative (in particular) or quantitative studies by including other types of scientific methods and data in order to improve and justify inferences from the results of any single-method-study into a broader context. This approach has largely passed unnoticed by the HHM scientific community, which might be understandable, since most classical epidemiological and animal science studies do not include primary data collection of both qualitative and quantitative nature. Consequently, supplementary validation may often be regarded as 'extra work', i.e. visiting farms again. Subproject 3 is an example of supplementary validation.

TRIANGULATION

The classical definition of triangulation requires that identical findings are reported from separate studies, preferably through different scientific methods (Denzin, 1978), see Vaarst et al. (2006) for an example. Research projects using multiple methods for the purpose of triangulation are characterised by two factors:

- The emphasis on testing the same hypothesis multiple times, using different methods in each iteration
- The focus on aggregating knowledge, rather than on discovering new relationships

That is, each component of a triangulation research project independently illustrates the central argument of the research (Caracelli and Greene, 1997). The relationship between the component studies is one of joint reinforcement; each component can stand alone, but make a stronger argument in combination. Essentially, this is what happens in the 'Discussion' section of most papers when the (experimental) results from quantitative research are (qualitatively) compared by the authors to previous results reported in literature.

KNOWLEDGE GENERATION

Herd health management programs are characterized by an iterative process of refinement of concepts and propositions and an initial inductive approach to formulate questions (Kristensen et al., 2008c). Next, the inductive and deductive analyses are mixed. If an epidemiological pattern can be identified from observations, a hypothesis can be deduced and submitted to testing. The aim of this test would be to reject or accept the generated knowledge situated within the hypothesis. Consequently, the iterative processes provide new research questions and strengthen conclusions related to the involvement of stakeholders.

The multiple stages of inquiry aiming at reframing questions, reconstructing instruments, reanalyzing data and refining interpretations and conclusions all form part of this iterative process as illustrated in figure 1.

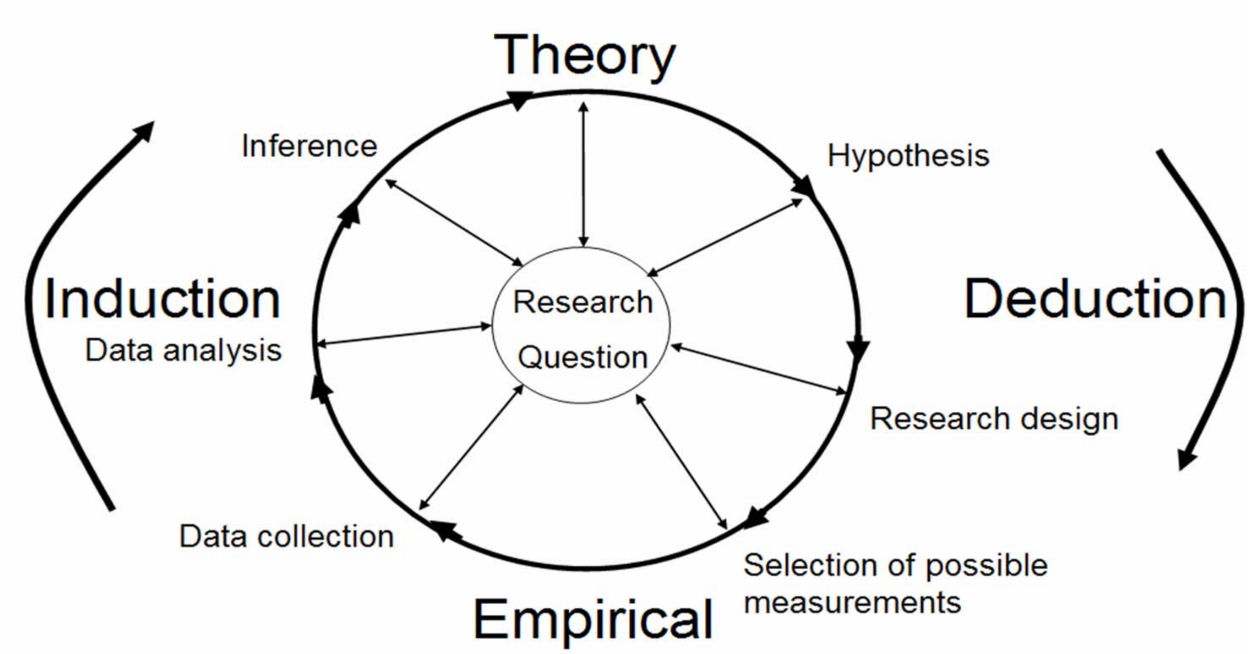

Figure 1. From Kristensen et al., 2008c. Conceptual model of the iterative process of induction and deduction in herd health management and research.

With a mixed design, the different research methods are combined into a coherent whole making the evaluation of results a synthesis of all the study data and less a report of findings from each method separately. As such, mixed designs are generative and yield new insight, or they may redirect research questions (Greene et al., 2001).

STUDY DESIGN FOR SUBPROJECTS 3 AND 4

Subproject 3. The empirical part of subproject 3 consisted of two separate research projects. The first project was a classical observational study on risk factors for metritis in Danish cattle. The second project was of a qualitative nature and consisted of a series of semi-structured interviews with a number of veterinarians about a widely applied Danish metritis scoring system to provide deeper insight into the veterinarians' decision making when collecting and processing data that would eventually enter the simulation model. Obviously, increasing quality of the data used for estimating model parameters increases the trustworthiness of financial predictions.

Subproject 4. This study combined two different research methodologies in an iterative manner: Factor analysis and a series of semi-structured qualitative interviews (see details below).

DATA SOURCES FOR SUBPROJECTS 3 AND 4

Subproject 3. In Denmark, there is a legal requirement for all practicing veterinarians to record the treatments they conduct (cow identification, date of treatment and diagnosis) whenever drugs regulated by law, e.g. antibiotics or prostaglandins, are administered. All treatments of metritis were therefore assumed recorded, and this study aimed at identifying risk factors for cases of metritis treated by a veterinarian. Based on various sources in literature, potential risk factors for metritis were identified, i.e. milk yield, herd size, parity, calving season, breed, reproductive diseases, digestive diseases, metabolic diseases, nutrition, and age. The objective was to estimate effects of important diseases and other risk factors on the risk of being treated for metritis in the period from calving until 21 days post partum utilizing data from the Danish Cattle Database (refer to Kristensen et al., 2008c for details on selection criteria, disease registrations etc.).

From a database containing records from routine clinical examinations of fresh cows (Enevoldsen, 2006), 71 veterinarians with experience in collecting and processing data according to the HHM program named 'The Danish Concept' were identified. In this concept fresh cows are systematically screened, uterine discharge is scored (0-9) and cows are treated for metritis if they meet the criteria decided upon at the individual herd. Twenty veterinarians were interviewed. Refer to Kristensen et al. (2008c) for a detailed description of the applied criteria for selection of respondents, i.e. veterinarians. The interviews focused on the application of criteria for metritis treatment and the metritis scoring system as defined by the management concept.

Subproject 4. In this study the objective was to address the dairy farmers' subjective points of view. What do dairy farmers expect to gain from entering a herd health management program? The core research tool of this study was Q-methodology, which was first described by Stephenson (1935) and provides a foundation for the systematic study of subjectivity, that is, 'a person's viewpoint, opinion, beliefs, attitude, and the like' (Brown, 1993). Consequently, Q-methodology does not aim at estimating proportions of different views held by the 'farmer population' (this would require a survey). Rather, Q identifies qualitative categories of thought shared by groups of respondents, i.e. farmers.

The study was conducted according to the guidelines described by van Exel and de Graaf (2005), who divide the approach into the following steps:

1. **Construction of the concourse**
2. **Development of the Q-set**
3. **Selection of the P-set**
4. **Q-sorting**
5. **Q-factor analysis**

1. Construction of the concourse. In Q-methodology a ‘concourse’ refers to ‘the flow of communicability surrounding any topic’ (Brown, 1993). The concourse is a technical concept for a contextual structure of all the possible statements that respondents might make about their personal views on the research question. In this study, the concourse was constructed by the authors’ reflections on viewpoints in literature, our experience, and previous interviews and discussions with dairy farmers, veterinarians and researchers. These reflections were condensed into statements, i.e. the concourse. This concourse supposedly contains the relevant aspects of all the discourses and thus forms the raw material for Q-methodology.

2. Development of the Q-set. The concourse is subsequently broken down into answers or statements that potentially could answer the research question. Next, a subset of statements is drawn from the concourse (labeled the Q-set). The selection may be based on existing hypotheses or theory. The Q-set should include statements that are contextually different from one another in order to ensure a broad representation of points of view in the Q-set (Brown, 1991). In this study all the 46 statements derived from the concourse were included in the Q-set to keep as broad a representation of points of view as possible.

3. Selection of the P-set. The P-set is a sample of respondents, which is theoretically relevant to the research question, i.e. it represents persons who probably will have clear and distinct viewpoints on the subject and, because of that quality, may define a factor (van Exel and de Graaf, 2005). Sixteen farmers were selected from a group of Danish dairy farmers managing conventional dairy enterprises and being clients in a single large nationwide cattle practice and participating in a recently developed intensive HHM program. Farmers were selected that we expected would provide breath and comprehensiveness to the P-set thereby acknowledging that the P-set is not supposed to be random (Brouwer, 1999). The selected farmers (the P-set) were invited to participate in the study by a covering letter, an additional page describing the ‘conditions of instruction’ (Brown, 1993), an empty layout guide and a stamped envelope for the returning of the layout guide. Farmers did not receive any compensation for their participation.

4. Q-sorting. Respondents (P-set) were asked to rank (Q-sort) the statements (Q-set) according to their own point of view with minimum interference from our part. The fact, that the farmers ranked the statements from their own point of view and not according to ‘facts’, is what brings the subjectivity into the study. The statements were sorted on the layout guide along a quasi-normal distribution (mean 0, SD 2.67) ranging from ‘agree mostly’ (+5) to ‘disagree mostly’ (-5). Each of the statements was typed on a separate card and marked with a random number for identification.

Table 1. An example of a Q-sorting on the layout guide. Numbers refer to the statements presented in Kristensen and Enevoldsen (2008), table 1.

Disagree										Agree
-5	-4	-3	- 2	-1	0	1	2	3	4	5
24	30	5	7	3	8	2	1	10	19	41
25	31	6	13	4	14	11	26	38	23	42
	34	9	15	12	20	18	32	40	39	
		33	17	16	21	28	44	43		
			46	22	27	29	45			
				35	36	37				

During a continuing education course in November 2007, 18 veterinarians associated with the abovementioned cattle practice sorted the same statements in a similar manner as the farmers. Here, the ‘conditions of instructions’ were delivered in a short oral presentation.

5. Q-factor analysis. The returned Q-sortings from the farmers and veterinarians were analyzed separately by means of the PC-program ’PQMethod’ (Schmolck, 2007) that is tailored to the requirements of Q-methodology. Specifically, ‘PQMethod’ allows easy entering of data the way it was obtained, i.e. as ‘piles’ of statement numbers. ‘PQMethod’ computes correlations among the respondents (the variables or columns in the data matrix) that were characterized by the Q-sorting. That is, each of the 46 statements was represented by one row in the matrix. This is equivalent to reversing the correlation matrix used in traditional ‘R-factor analysis’, which is based on correlations between variables characterizing respondents. Respondents, who are highly correlated with respect to their ranking of statements, are considered to have a ‘familiar’ resemblance, i.e. those statements belonging to one family being less correlated with statements of other families. A principal component analysis was chosen in ‘PQMethod’ to estimate the total explained variance and the variance attributable to each identified factor (family of perspective). Following a commonly applied rule for including number of factors, factors with eigenvalues smaller than 1.00 were disregarded. A factor loading was determined for each respondent as an expression of which respondents were associated with each factor and to what degree. Loadings are correlation coefficients between respondents and factors. The remaining factors were subjected to a varimax (orthogonal) rotation to provide the rotated factor loadings.

The final step before describing and interpreting the factors was the estimation of factor scores and difference scores. A statement’s factor score is the normalized weighted average statement score of respondents that define that factor. The weight (w) is based on the respondent’s factor loading (f) and is calculated as: $w = f / (1-f^2)$. The weighted average statement score is then normalized (with a mean of 0.00 and SD = 1.00) to remove the effect of differences in number of defining respondents per factor thereby making the statements’ factor scores comparable across factors. Thus, we take into account that some respondents are closer associated with the factor than others by constructing an idealized Q-sorting for each factor. The idealized Q-sorting of a factor may consequently be viewed as how a hypothetical respondent with a 100 percent loading on that factor would have ranked all the statements on the layout guide. The idealized layout guides for each family of farmers’ perspectives are provided in Kristensen and Enevoldsen (2008), table 1. The difference score is the magnitude of difference between a statement’s score on any two factors that is required for it to be statistically significant. ‘PQMethod’ offers the possibility to identify the most distinguishing statements for each family of perspectives, i.e. when a respondent’s factor loading exceeds a certain limit (often based on $P < 0.05$) and consensus statements between the families of perspectives, i.e. those that do not distinguish between any pair of families (van Exel and de Graaf, 2005). The limit for statistical significance of a factor loading is calculated as: Factor loading / (1 divided by the square root of the number of statements in the Q-set). If this ratio exceeds 1.96, the loading was regarded as statistically significant ($P < 0.05$). The idealized Q-sortings were assigned with informative names (labels) with input from both the most distinguishing statements for family of perspective and the consensus statements. The process of giving names to the idealized Q-sortings according to its characteristics may serve to facilitate the discussion and communication of the findings (Kiernan and Heinrichs, 1994).

INTEGRATED RESEARCH ANALYSIS IN SUBPROJECTS 3 AND 4

An elephant looks very different when seen from above or below, Malterud (2001)

Subproject 3. This analysis was an example of 'supplementary validation' as defined by Kristensen et al. (2008c).

Subproject 4. All farmers in the P-set were invited to participate in an interview to elaborate on their preferences as expressed by the placing of the statements on the layout guide and 12 farmers accepted the invitation. All farmers were men and managed conventional farms, all free-stalls. Additional herd characteristics are listed in Kristensen and Enevoldsen (2008), table 2. Veterinarians were not interviewed due to budget and time constraints. The first farmer accepting the invitation was defined to serve as a pre-test for the interview approach (leading to minor adjustments). This interview was eliminated from the data. The qualitative study therefore consisted of 11 interviews. Consequently, the entire data collection process was as follows: First, veterinarians face-validated the contextual structure of the concourse during the common Q-sorting session. Second, pre-testing was performed. Third, farmers sorted the Q-set and returned the layout guides. Fourth, the contextual structure of the concourse and the results from the individual Q-sortings were face-validated by the farmers during the interviews. Further, the interviews offered an opportunity to confirm farmers' understanding of the sorting technique and correct any misunderstandings. No misunderstandings were identified. Fifth, following the face-validation of the concourse each interview session with the 11 farmers included three thematic questions:

- What about animal welfare and herd health?
- Assume that you have an extra hour every day (i.e. the 25th hour) what would you do? – Increase the herd size, improve management or increase leisure time?
- Assuming you have a farm board: Would your practicing veterinarian be a member? – why (not)?

The interviews followed the approach described by Vaarst et al. (2002) and lasted between 65 and 80 minutes. Interviews were digitally recorded and I conducted all the interviews (January to March, 2008). The interviews were analyzed according to the inductive approach recommended in Kristensen et al. (2008c) for HHM research with inspiration from Stake (2005) on how to interpret a series of interviews with the intent to provide insight into a phenomenon of more general interest, e.g. to facilitate 'multivoices' (Guba and Lincoln, 2005).

Chapter 4

RESULTS FROM SUBPROJECTS

We are not in the cow business serving farmers. We are in the farmer business serving herds, modified from Haagerup (2006)

SUBPROJECT 1: TECHNICAL INDICATORS OF FINANCIAL PERFORMANCE…

This study indicated that improving the shape of the herd level lactation curve in the default herd (with a production level equal to an average Danish herd) with one quartile was associated with an increase in gross margin of € 227 per cow per year. This represented 53 percent of the potential increase in gross margin associated with all the management changes included in the study. Other results were: Reproduction efficiency, heifer management, dynamics of body condition, cow mortality, calf mortality and somatic cell count explaining; 21, 8, 6, 5, 3, and 3 percent, respectively. Variation between cows in lactation curve persistency was not significant in the metamodel.

The metamodel – an illustration: A farmer owns a herd identical to the default herd (herd characteristics in Kristensen et al., 2008a) and asks about the expected financial performance if all the KPI change from 'Middle' to 'High'. The answer is € 291 with a 95 percent confidence-interval for financial performance of € 235 to € 349 given the specified changes in KPI (based on the root mean standard error, refer to table 7 in Kristensen et al. (2008a) for more details). In the simulation contexts the default herd consisted of 248 cows with a mean gross margin per cow per year equal to € 1579. Thus, the total gross margin for the default herd equaled € 391,344. The best-case scenario equaled an improvement of the gross margin by almost 20 percent. This value takes into account important interactions between KPI and prevents double counting because of the simulation design. The financial performance associated with changes in herd management did not include labor and management costs or costs associated with needs for improved feed quality which may be important costs in a real herd decision problem. In that case these costs must be estimated and subtracted from the gross margin estimated with the metamodel.

SUBPROJECT 2: RANDOM WITHIN-HERD VARIATION IN FINANCIAL PERFORMANCE…

The main effects of KPI could be divided into two different groups with respect to time to steady state: The default herd, high reproduction efficiency, heifer management, variation between cows in lactation curve persistency, mortality in cows, mortality in calves, dynamics of body condition and somatic cell count reached steady state in less than 5 years whereas low reproduction efficiency and shape of lactation curve needed more than 5 years to reach steady state. Scenarios, which included changing the level of lactation curve, did not reach financial steady state within the simulated time span and reducing the level of variation on slope between cows only shortened time to steady state with 1 year. If steady state was declared by means of a qualitative approach (set at € 5), then the scenarios including a high level of heifer management and a high level of mortality in cows would reach steady state 1 year earlier.

If the standard deviation of an annual gross margin in an average Danish herd with no missing information (a simulation study) in Denmark with a constant production strategy and constant prices is € 26 per cow year between subsequent years, as indicated by the simulation model, it follows that a systematic financial effect associated with a change in management at the individual herd level must exceed 2 × € 26 to be statistically significant at the 5 percent level. However, Kristensen et al. (2008b) refers to an unpublished observational longitudinal study (Østergaard and Krogh, 2007) including 77 typical Danish herds (each with 2 or 3 years of well-verified production and accounting data). In this study the within-herd standard deviation of gross margin between subsequent years was € 248 per cow year. This estimate of within-herd variation from the field included unknown systematic effects like changes in prices, quality of silage production, management strategies, errors in data management etc.

SUBPROJECT 3: A MIXED METHODS INQUIRY INTO THE VALIDITY OF DATA

The relations between risk factors and metritis estimated in the quantitative research project supported the findings in several other observational quantitative studies (Curtis et al., 1985; Markusfeld, 1987; Fleischer et al., 2001). Risk factors identified in the final model, as significantly associated with metritis were: Energy corrected milk, herd size, parity, breed, assisted calving, stillbirth, twins, retained placenta, vaginitis, prolapsed uterus, milk fever, ketosis, displaced abomasum, indigestion, traumatic reticuloperitonitis, foot disorder and diarrhoea (refer to Jensen (2007) for details regarding the quantitative project). Important differences identified between veterinarians in the qualitative part of the study were (Kristensen et al., 2008c, table 1):

- Scoring system. Nineteen veterinarians used the metritis scoring system defined by ‘The Danish Concept’. One veterinarian used his own scoring system despite the presence of very explicit guidelines
- Time of clinical examination (required to be in the interval 5-12 days post partum): Fifteen veterinarians performed the clinical examination between 5-12 days post partum. Two veterinarians examined 4-12 days post partum and three veterinarians 5-19 days post partum

- Exploration method (not defined in the manual). Sixteen veterinarians used vaginal exploration by hand; two used rectal exploration and two veterinarians used both vaginal and rectal exploration
- Body temperature (not a parameter included in the manual). Three veterinarians consistently included temperature as a diagnostic tool. Ten veterinarians included temperature on indication (e.g. depression or anorexia). Seven veterinarians never used the thermometer; however, one of these veterinarians explained that he believed he could feel the temperature of the cow during the examination procedures
- Threshold for treatment. One veterinarian stated that elevated temperature would always lead to a medical treatment. Nineteen veterinarians used metritis score 5 as an indicator of clinical metritis and thus indicative of medical treatment. During the interviews ten veterinarians retrospectively realized that various cow and herd factors (e.g. ketosis, mastitis, reduced milk production, changes in cow behavior as reported by the farmer, knowledge on metritis problems in the herd or knowledge on a difficult calving) changed their treatment threshold from 5 to one of the following: 4 (three veterinarians), 6 (six veterinarians) and 7 (one veterinarian) for treatment to be initiated
- Data processing. Twelve veterinarians would record a smelly placenta not expelled 4-5 days post partum as 'retained placenta' in the Danish Cattle Database. Two veterinarians were motivated by the price difference (treatment costs) between a case of metritis and a case of retained placenta (+ 25 %) to record it as the latter, and charge for this. One veterinarian explained that it was time-consuming to enter two diagnoses into the database, so he would only record the retained placenta. The remaining six veterinarians normally recorded these findings as a metritis

The herd incidence risk of metritis was highly skewed (Kristensen et al., 2008c). Similar skewed distributions were found in studies of clinical mastitis (Schukken et al., 1991; Bartlett et al., 2001). This 'problem' was handled statistically by selecting a distribution that fitted the data (Schukken et al., 1991) or by cutting off the extreme values due to suspected non-compliance 'based on the subjective opinion of the investigators during the data collection phase' (Bartlett et al., 2001). In the quantitative study described here, herds with very low incidence risks were also excluded. However, there may be simple practical reasons for the skewed distribution like underreporting in many herds (Enevoldsen, 1993; Bartlett et al., 2001) or significant differences in veterinarians' beliefs in the use of diagnostic tools and in thresholds for treatment, i.e. misclassification errors, as discussed in Kristensen et al. (2008c). The results of the semi-structured qualitative interviews also indicated potential biases regarding data collection and analyzing data both in purposive sampling and sampling related to routine screenings:

- The veterinarian may examine the cow more carefully if called to attend a ‘sick’ cow
- The risk of many diseases is higher in early lactation. Consequently, it is likely that more than one disease can be diagnosed. Potential statistical associations may not reflect a biological association between diseases but rather between e.g. lactation stage and disease detection, and therefore reflect bias due to human decision making
- A veterinarian may initiate medical treatment on basis of an observed predisposing factor such as retained placenta, without actually observing the disease in focus, as indicated in the semi-structured qualitative interview study

These types of problems are very unlikely be identified in analyses of large databases like the Danish Cattle Database, where medical treatments are recorded irrespective of the farmers’ and veterinarians’ motivation for treatment and recording. The associations derived from the statistical analyses may therefore reflect not only biological relations but also be heavily influenced by decisions taken by the farmer or the veterinarian. The interview results furthermore indicated the presence of herd specific decision making, because most veterinarians included local conditions connected to cow, herd and farmer factors in their decision process. This raises the important issue about what data included in an observational quantitative study actually represents, and it suggests that ‘the general population of dairy herds’ consist of widely different herds, all subject to individual decision making in their own context. It also demonstrates the important differences between data collected in situations where the veterinarian monitors the health status of all cows through a predefined protocol and data collected when the farmer calls the veterinarian to attend a ‘sick’ animal.

The interview study showed that none of the abovementioned situations will create uniform data, because perceptions and disease treatment decisions are related to the involved persons. Bartlett and co-authors (2001) suggest that there is a high variability between veterinarians’ diagnostic ability and there is often lack of standardized case definitions (without explicitly studying the question). The qualitative research project strongly supports this, and vividly illustrates existing discrepancies in data related to screening of risk animals, also in cases where detailed manuals are expected to standardize the procedures in order to increase comparability of collection and processing of disease data. One possible way to handle these context-related differences related to possible interventions (e.g. choice of treatment regimes) would be to conduct within-herd experiments, as argued by Enevoldsen (2006).

Q-FACTOR ANALYSIS

The concourse was a primary result. Essentially, both farmers and veterinarians accepted the concourse by face-validation, i.e. farmers before the interview sessions and veterinarians before and during the sorting process. Four families of farmers' perspectives (idealized Q-sorts) were identified with the Q-factor analysis. They explained a total of 65% of the variance between farmers. Table 4 in Kristensen and Enevoldsen (2008) illustrates the most distinguishing statements ($P < 0.05$) for each family of perspectives. Consensus statements (non-significant at $P > 0.05$) were: 1, 2, 4, 6, 8, 10, 15, 18, 21, 23, 31, 35, 37, 43, and 45. These statements were considered equally revelatory by virtue of their salience, i.e. none of the farmers placed much value on these statements be it positive or negative value.

Ranking of statements by idealized factor scores combined with the insight obtained from the most distinguishing statements and the consensus statements were submitted to a qualitative analysis with the insight obtained by the first author during the series of interviews into the farmers' lived experiences, perspectives and expectations. The purpose of this analysis was to construct informative names (labels) to each identified family of farmers' perspectives. The selected names to describe families of farmers' perspectives were (in decreasing order by explained variance, Kristensen and Enevoldsen (2008), table 1):

- Teamwork
- Animal welfare
- Knowledge dissemination
- Production

Equally, four families of veterinarians' beliefs on farmers' perspectives were identified explaining a total of 69% of variance. Informative names were identified by means of a qualitative analysis of the results, i.e. combining the idealized Q-sorts and the five most preferred statements from each family of veterinarians' perception of farmers' perspectives (not shown). It was realized that the family names from the farmers' families of perspectives could be re-used as 'PQMethod' identified a number of veterinarians' families of perspectives equal to the families of farmers' perspectives. The families of veterinarians' perception of farmers' perspectives explained 48%, 9%, 6% and 6% of variance for families Production, Animal welfare, Knowledge dissemination and Teamwork, respectively.

THE SEMI-STRUCTURED INTERVIEWS

The raised question regarding animal welfare and herd health (AWHH) divided farmers into two points of view. Farmers associated with the first viewpoint explained their interest in AWHH primarily as a consequence of society's scepticism towards the production system of dairy industry as experienced by the farmers, i.e. *'people are watching us'* and *'society thinks, that farmers are the kind of people that beat up animals'*. Farmers sharing the second viewpoint believed that HHM was an important tool to increase AWHH. These farmers explained that an increase of AWHH was an inevitable consequence of the HHM program. However, the follow-up question: 'Why do you value AWHH?' revealed that farmers associated with the second viewpoint had to be divided into two sub-views to be meaningfully described. The farmers belonging to the first sub-viewpoint placed value on AWHH because of the farmers' firm belief that AWHH is a precondition to increase the overall farm production, i.e. *'I tell you, animal welfare and economy is really closely connected. The reason that I care about animal welfare is because it is a financially reasonable way to do things'* and *'it's obvious that we are quite interested in increasing animal welfare because it will improve the financial bottom-line in the long run'*. Farmers sharing the second sub-viewpoint experienced AWHH to hold a unique value associated with their subjective well-being. These farmers emphasized a feeling of personal satisfaction related to being around healthy animals, providing the farmers with a feeling of 'a job well done', i.e. *'animal welfare reflects other values in our lives'* and *'I have a philosophy on animal welfare; the day I can't tend to each cow as well as the time I had twenty, then I have too many cows'*. Farmers from both sub-viewpoints stated (even though it was not a specific question) that AWHH and the cost of the HHM program had to compete for limited resources (primarily time and money) with other investment opportunities (e.g. the dairy business, the farmer's subjective well-being related to values provided by the HHM program, family) both on and off the farm in terms of expected return on investment.

The second thematic question related to farmers' time-budget. We suggested that each farmer was given an extra hour every day, i.e. the 25th hour. Farmers were divided into four points of view based on their different viewpoint on how to spend this extra time: 1) Farmers associated with the first viewpoint wanted to increase leisure time. The explanations were primarily found within two subjects: Family; *'it is really important to me that I am a visible dad'*; daily stress: *'I constantly feel that my presence is needed; therefore I have an unsatisfied need to experience freedom'*; 2) The second viewpoint included farmers that clearly stated they would choose to increase management within the present framework of the dairy farm, i.e. *'I would try to correct the errors that I do not have the time to at the moment'* and *'one extra hour is not* *enough at all. There are so many things in my daily work that I could improve – but I do not have the time'*. Some of the farmers related to the second viewpoint elaborated on the question and explained that they would have liked to answer 'family', however, realities were likely to be different, i.e. *'looking at myself, I sometimes feel that I should have spent more time with my family, you know, gone with the kids to soccer, but I also know that if this 25th hour was really true, I would probably not follow the kids, but go into stable and try to improve something – even though it really wasn't, what I wanted to do'*; 3) Farmers from the third viewpoint asked if it was an acceptable answer to increase management with the intent to provide a basis for a near-future expansion of the herd size; 4) Last, farmers sharing the fourth viewpoint stated that given extra time they would buy more cows *'because an increasing number of cows leads to an increasing number of employees, making it possible to run the farm without my daily presence'*. From all of the abovementioned viewpoints a common viewpoint could be summarized: It is necessary that veterinarians include opportunity time in addition to a strict focus on profitability (and welfare?) when proposing recommendations.

It was the farmers' experience that veterinarians knew almost nothing about herd health economics, finances in general or strategy related to running a business. However, the farmers expressed a willingness to buy such a service if provided by a veterinarian able of combining the classical veterinary disciplines with management, strategy and finances.

Chapter 5

DISCUSSION OF SUBPROJECTS

Faced with the choice between changing one's mind and proving that there is no need to do so, almost everybody gets busy on the proof, Galbraith’s law on human nature

SUBPROJECT 1: TECHNICAL INDICATORS OF FINANCIAL PERFORMANCE…

The condensed metamodel from this study fits very well to the aggregated data from the simulation experiment conducted with the SimHerd model (R^2 = 0.96). The gross margin output from SimHerd and consequently from the metamodel responded to changes in KPI levels in the direction that agreed with prior qualitative knowledge about the simulated problem entity. In most cases plausible explanations were provided to the rather complex interactions between KPI. These interactions offered increased insight into the complex behavior of the herd as a system. Further, the metamodel circumvented the problems related to obtaining the large number of input variables needed for complex simulation models for decision support in dairy herds. The face-validation of the pathways from assumed management adjustments, to KPI, to simulation input, to simulation output and finally to the output from the metamodel suggests that the metamodel is a valid tool in applied settings. The knowledge provided by this study has been added to the previous knowledge about the SimHerd model and now serves as part of the background knowledge in an innovation project supported by the Danish Ministry of Food, Agriculture and Fisheries and as such this research is expected to reach application soon.

SUBPROJECT 2: RANDOM WITHIN-HERD VARIATION IN FINANCIAL PERFORMANCE…

It is impossible to obtain a valid estimate from the field of the true empirical within-herd random variance (because ‘real life’ farms cannot relive their ‘lives’ and management cannot be kept constant). The stochastic elements specified in the individual input factors in the SimHerd model are derived from empirical studies, literature and experience from the field. However, in many cases only point estimates are represented in SimHerd, e.g. parameters in the functions for the reproductive events. Consequently, it is likely that the resulting variance of the output from SimHerd underestimates the random variance in real farming. Phimister et al. (2004) reported results for within-herd variance between years from a longitudinal field study. In that study more than 40 percent of the herds experienced movements in relative income group (quintiles) in subsequent years and 20 percent moved more than 2 income groups in a year. The empirical within-herd standard deviation of € 248 per cow year between subsequent years found in subproject 2 implies that much caution must be recommended when trying to explain any shifts in income group as a consequence of any direct management change. The estimate of within-herd variation between subsequent years from the field include unknown systematic effects like changes in prices, quality of silage production, management strategies, errors in data management etc. Consequently, it overestimates the random within-herd variance.

The link between management changes (cause) and effect (measured as improvement of gross margin per cow year) is simply too blurred by the large within-herd variation in available real life accounting data to make valid inferences about effects of interventions. The 'financial randomness' identified in this study may explain the apparently unmotivated shifts in income group reported by Phimister et al. (2004). Consequently, it becomes very important that farmers, financial advisors and veterinarians acknowledge that the changes in financial and technical indicators from year to year to a large extent is 'random' and thus avoid making too simple conclusions regarding cause and effect. My experiences from meetings, interviews and years in veterinary practice indicate that consultants in Denmark unfortunately seem to systematically ignore this element of 'financial randomness'. That is, a benchmarking-culture seems to be growing among financial agro-consultants who present league-tables of dairy farmers according to 'best gross margin per cow year' or the farmer with the 'highest increase in gross margin from subsequent years' in the agricultural press. The identified problems with data quality (subproject 3), especially between dairy herds, and the identified element of random within-herd variation in financial and technical performance between subsequent years raise a fundamental question: Have the winning farmers accomplished anything in terms of improved management or were they simply lucky?

SUBPROJECT 3: A MIXED METHODS INQUIRY INTO THE VALIDITY OF DATA

To evaluate validity of the input to the simulation model (e.g. relations between disease and milk yield), data quality from dairy farms was explored to provide insight into possible biases. We used a series of semi-structured qualitative interviews. The results from this study showed that most veterinarians included local conditions connected to cow, herd and farmer in their decision making and subsequent processing of data. Therefore, major input-parameters can be seriously biased. We showed that the veterinarians changed the predefined scales in a system to score the severity of metritis according to the veterinarian's perception of the farmer's needs or the expected effects of risk factors at cow level. Important issues were (ab)use of the scoring system, time of clinical examination, exploration method, inclusion of parameters that were not included in the scoring system for decision support (body temperature), threshold for treatment and data processing.

The relations between risk factors and metritis in the quantitative research project find support in several other epidemiological studies based on similar data and study design. However, the design of these observational studies seems to be inherently flawed by purposive sampling and misclassification. Bartlett and co-authors (2001) also suggest that there is much variability between veterinarians' diagnostic abilities and procedures but they did not study these issues explicitly. Our qualitative research approach strongly supports this suggestion by providing concrete evidence.

These types of biases and uncertainty probably cannot be revealed and corrected in (large) multi-herd databases like the Danish Cattle Database without a major herd-specific effort with qualitative techniques. A first step would be to distinguish between data collected in a cross-sectional design (at routine visits) and incidence data. This distinction should be straight forward to make. It is much more difficult, if not impossible, to distinguish between cases where specific clinical manifestations at cow level lead to medical treatment and cases where the farmers and veterinarians focus on a disease and the related risk factors (e.g. prior long dry period or retained placenta). This problem is also relevant in breeding programs and has been labeled 'preferential treatment' (Kuhn and Freeman, 1995). Preferential treatment describes any management practice that is applied to one or several cows but not to their contemporaries (Kuhn et al., 1999). Examples could be separate housing, better food, and differences in the farmer's threshold for initiating a medical treatment. Kuhn and Freeman (1995) simulated how preferential treatment of cows would inflate the sire's predicted transmitting ability. These authors concluded that biases increased linearly as the percentage of cows receiving preferential treatment increased. The later study investigated several potential approaches to correct for preferential treatment in the genetic evaluation of US dairy cattle. No obvious solution was presented.

Will inclusion of a random herd effect in the statistical model correct the problems we have identified? Probably not. Kuhn et al. (1999) have described the practical difficulties of identifying cows affected by preferential treatment in contrast to their contemporaries by means of cow records. Further, these authors had serious problems deciding what variance they should attribute to the random effect of preferential treatment. Modeling genetics for breeding programs are beyond the scope of this thesis; however, the problem of preferential treatment is more important in HHM because we need estimates to be used in the individual herd. In breeding the estimates (e.g. heritabilities) are used across herds. Essentially, the heterogeneity of recording, treatment criteria etc. that we have revealed indicate the presence of interaction between the risk factors and the herd. That is, the risk factors may have different effects in different herds. If that is the case, there is a need to do analyses by herd to provide ‘the local truth’. Another approach is to standardize the recordings. The detailed manuals for recording metritis manifestations at routine visits were in fact developed and distributed in an attempt to solve these problems by standardizing the procedures in order to increase uniformity of collection and processing of disease data within and between both veterinarians and herds. More effort obviously is needed to make this approach successful. Other disease complexes like mastitis seem to be even more complicated to handle as indicated by Vaarst et al. (2002).

An unbiased estimate of an input-parameter for the simulation models can be achieved by eliminating the diversity of farmers, herds and veterinarians. This is possible if researchers and local veterinarians conduct randomized within-herd experiments thereby avoiding biased estimates of effects of cow-level interventions in other herds.

Our study supports the claim that no single research methodology can produce results that are universally transferable and directly applicable without adjustments, when applied in a completely different context (Malterud, 2001). This study demonstrates the validity of Malterud’s claim with regard to the discipline of HHM by example.

SUBPROJECT 4: HOW DAIRY FARMERS PERCEIVE THE VALUE(S) OF…

VALIDITY OF RESULTS

The objective of this study was not to generalize possible findings to the whole population of farmers or veterinarians but to obtain insight into a phenomenon as experienced by a range of individuals selected for this study because of their ‘information richness’ (Patton, 1990). Consequently, results are only directly applicable to the particular participants, settings and contexts (Onwuegbuzie and Leech, 2007). However, the active participation of the end-users, i.e. farmers and veterinarians, in the modeling-validating process is emphasized as an important part of the usefulness dimension of validity in operations research (Landry et al., 1983). Further, we have taken into consideration the length of the interviews and the number of respondents to increase the likelihood of data saturation as discussed by Onwuegbuzie and Leech (2007). These authors studied literature and have presented a sample size guideline to qualitative research. In phenomenological research 6-10 respondents are recommended when homogeneous samples are selected for interviews. We regard our sample as homogenous because all the participating farmers are associated with the same veterinary practice and have chosen to be involved in the same intensive HHM program. Additionally, Onwuegbuzie and Leech (2007) present their reflections regarding the importance of the length of each contact to reach informational redundancy. The length of our interviews followed the description by both Vaarst et al. (2002) and Onwuegbuzie and Leech (2007). Morse (1995) defines the concept of 'saturation' in qualitative data as 'data adequacy' and adds that it is 'operationalized as collecting data until no new information is obtained'. Consequently, the face-validation of the concourse by farmers and veterinarians may be seen as an acceptance of a 'saturation' of perceptions of the Q-set providing the data with 'interpretive sufficiency' to take into account the multiple interpretations of life (Christians, 2005).

Q-Methodology is about respondents ranking matters of opinion within a concourse to identify the existence of families of perspectives. Consequently, the results of a Q-factor analysis is useful to identify and describe a population of viewpoints and not, as in R, a population of people (Risdon et al., 2003). The difference between Q and R being that the issue of large numbers, so fundamental to R, becomes rather unimportant in Q. The most important type of reliability for Q is replicability: Will the same 'condition of instruction' lead to factors that are schematically reliable, that is, represent similar families of perspectives on the topic? (van Exel and de Graaf, 2005). In contrast to most studies Q-studies cannot obtain 'true replication' because: 1) an identical set of participants, contexts and experiences is impossible to find and; 2) the concourse as it expresses itself in a Q-study becomes context-bound to the particular participants, settings and contexts. It follows that the present Q-study could not be replicated with the same farmers as participants because these farmers were likely to have reflected on the Q-sorting and the interviews making them 'different persons' than in the beginning of the study. Thomas and Baas (1992) concluded that scepticism related to the issue of reliability is unwarranted as the objective in Q-studies is to reach an in-depth understanding of the context in question and thus requires an equally in-depth understanding of a different context to draw possible inferences between the two different contexts. The results of a Q-study are the distinct families of perspectives on a topic (as described by the concourse) that are operant, not the percentage of the sample (or the general population) that adheres to any of them. This would require a (questionnaire) study of a representative sample of people and such a study could be relevant as a follow-up of to this study. It follows that quality is operationally distinct from quantity. Consequently, the required number of respondents to establish the existence of a factor is substantially reduced for the purpose of comparing one factor with another compared to traditional R statistics (van Exel and de Graaf, 2005).

DISCUSSION

In this study farmers' statements could meaningfully be placed into four groups with distinctly identified differences related to the individual farmers' perception of value added by a HHM program. Maybery and co-authors (2005) applied a different technique but reported largely analogous findings in a study on economic instruments and common good interventions in Australia. Kiernan and Heinrichs (1994) discussed how information on similarities between groups of farmers may be utilized by veterinarians to increase the effectiveness of management programs.

The Q-factor analysis divided farmers' perspectives on HHM programs into groups labeled: Teamwork, Animal welfare, Knowledge dissemination and Production, respectively. Veterinarians believed the correct order to be: Production; Animal welfare; Knowledge dissemination and Teamwork, respectively. It follows that the veterinarians' perception of farmers' perspectives as compared to the farmers' expectations were quite different. From the explained variances it follows that most farmers are correlated with Teamwork and most veterinarians are correlated with Production. Potentially, this difference may lead to differences of opinion when the farmer and veterinarian, respectively, evaluate the impact or success of a HHM program. Generally, the veterinarian believes that the success criterion is increased production and subsequent profit whereas the farmer expects to be part of a team working with shared ambitions and common goals.

Farmers focusing on AWHH were divided between those focusing on an expected correlation between increases in AWHH and financial performance and those focusing on a feeling of increased subjective well-being from being around healthy cows. This is an important finding which is also discussed in details by Kristensen et al. (2007) illustrating how 'qualitative studies can be added to quantitative ones to gain better understanding of the meaning and implications of the findings' (Malterud, 2001).

This study has provided evidence that it is unlikely that (all) the time saved due to systematic work procedures implemented by a HHM program is re-invested in production to increase financial performance. Obviously, the potential increase in financial performance is not realized if time is allocated towards leisure and away from production. Trying to understand and predict human behavior primarily on monetary incentives is problematic (Tversky and Fox, 1995; Pingle and Mitchell, 2002) as income only explains about 2-5% of the variance related to measures of subjective well-being (Ahuvia, 2008). Further, farmers' decision making obviously is not confined to herd health (Stott and Gunn, 2008). In practice, the level of investment in management systems will never be the 'optimal' solution from a herd health perspective, because 1) investment prospects are better elsewhere (van Schaik et al., 2001); 2) value added to overall financial performance is measured by a different currency than money (Valeeva et al., 2007); 3) short-term gains are valued more than a possible larger future gain predicted by a model or a HHM program (Ahuvia, 2008).

A marked discrepancy was identified between the family of veterinarians that focused on production and how farmers view the veterinarians' competences in areas like business, farm management etc. Most veterinarians correlated with Production; however, none of the farmers would ask their veterinarian to sit in a farm board because of what the farmers perceived as a general lack of knowledge on farm management and a more specific lack of knowledge on strategy and finances. De Kruif and Opsomer (2004) report similar findings. The farmers, however, expressed an interest in buying such a service if provided by an experienced veterinarian able of combining the classical veterinary disciplines with the disciplines of business and management. The overall impression from the interviews was that farmers view their affiliated veterinarian as a 'master' of the classical veterinary virtues (diagnostics and treatment at cow-level and to some extent herd-level) but much less qualified to handle the management aspects of HHM consultancy. This finding may be important to veterinary schools as changes in the educational structure towards 'whole farm' management seem warranted.

Chapter 6

THE COMPETENT HERD HEALTH MANAGEMENT CONSULTANT

The best consultants are those who are able to analyze a situation and add just that ingredient which is missing, modified from Haagerup (2006)

VETERINARIANS' COMPETENCES AS EXPERIENCED BY FARMERS

Herd health management studies primarily have tried to estimate the value of HHM programs by means of a monetary scale (Valeeva et al., 2007). Classical economic theory on the bargaining situation between two persons (e.g. farmer and veterinarian) assumes that decision utility will reach equilibrium for mutual benefit provided both persons have made a choice based on accurate information (Ahuvia, 2008). However, Nash (1950) elaborated on the term 'accurate information' and stated that full knowledge of the tastes and preferences of the other person and the concept of anticipation is equally important to reach an 'optimal' solution between two persons in a bargaining situation. Further, studies of decision making under risk or uncertainty have shown that people often violate both the expected utility model and the principle of risk aversion underlying most economic models (Tversky and Fox, 1995; Pindyck and Rubinfeld, 2005). Subproject 4 revealed significant differences between families of farmers' perspectives with regard to HHM programs and between farmers (as a group) and veterinarians. Following Faro and Rottenstreich (2006), I made an effort to understand the risks associated with giving and receiving advice.

'Know thy customer' is a mantra in marketing. In Kristensen et al. (2008c) and Kristensen and Enevoldsen (2008) we argue that HHM researchers and veterinarians may benefit from taking a more keen interest in the management literature and start viewing dairy farmers as individuals with individual values, attitudes, perspectives and scale(s) for measuring the success of a HHM program and how this perception of success eventually becomes incorporated into the farmer's subjective well-being. During the interviews in subproject 4, I asked the 11 farmers to list the competences they would attribute to 'an excellent herd health consultant'. The farmers were free to state as many competences, as they liked. Next, the farmers were asked to prioritize between the competences mentioned. Subsequently, the listed competences were submitted to a qualitative analysis and allocated into groups identical themes. An equidistant range between veterinary competences as valued and ranked by the farmers was assumed and numbers were attributed to each identified group in decreasing order, i.e. if 'high level of professional skills' was valued most highly by farmer A, then 'high level of veterinary skills' would receive 6 points (because the largest number of competences mentioned by any farmer was 6). Assuming farmer A mentioned ‘empathy’ as the second most important competence then ‘empathy’ would receive 5 point. Finally, I named the groups according to their thematic heading to provide a classification of professional skills: ‘Softcore’; ‘in between’ and ‘hardcore’, respectively, as decided by their weight in percentages (figure 2).

Competences that farmers attribute to ‘an excellent consultant’.

Softcore skills:	Personal integrity (12); Empathy (7); Enthusiasm (7); Coaching abilities (6); Not afraid to take difficult decisions (5); Innovative and focusing on the future (5); Thoroughness (4); Ambitious on behalf of the farmer (2); Open for second opinion (1)
Skills in between:	Able to communicate in lay language (12); Practical approach (7); Experience (3)
Hardcore skills:	Able to provide a general view of the entire herd (15); High level of veterinary skills (11); Knowledge about feeding-plans (3)

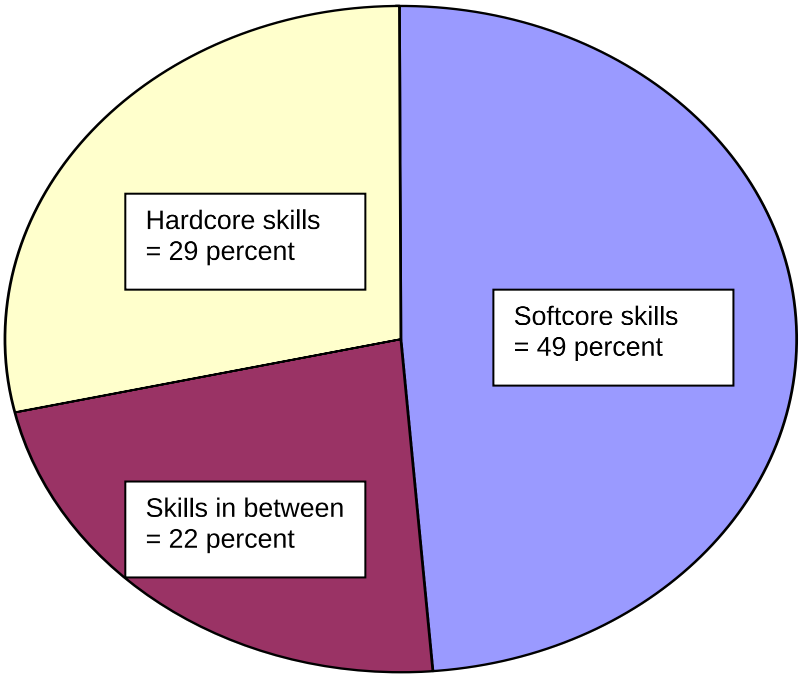

Figure 2. Competences attributable to an excellent consultant as valued by dairy farmers

Figure 2 may provide consultants with important knowledge as it opposes the view of HHM to be a process independent of ‘owner-perceived problems’ (Schwabe, 1991). This aspect is discussed in details in Kristensen and Enevoldsen (2008) and in the discussion of the thesis.

GIVING ADVICE UNDER UNCERTAINTY

Making effective decisions under risk or uncertainty often requires making accurate predictions of other people’s decisions under risk or uncertainty, Faro and Rottenstreich (2006)

Another interesting HHM subject is the matter of risk preferences or more precisely risk aversion. The question ‘what do consultants rely on in case of uncertainty?’ is interesting to the farmer only to the extent that the veterinarian’s personal values, beliefs and (risk) preferences differ from his own beliefs and preferences. Kristensen and Enevoldsen (2008) provide an example of such discrepancies between farmers and veterinarians. Veterinarians tended to believe that farmers’ objective for participating in a HHM program was to increase productivity and subsequent profit whereas the farmers placed more value on subjects like teamwork, animal welfare and learning. Hadar and Fischer (2008) have recently published an insightful paper building on Faro and Rottenstreich (2006) describing how a consultant’s own risk preferences unconsciously blends into the advice given. These authors concluded that advice giving is heavily influenced by the consultant’s personal risk preferences and less by the consultant’s estimate of the client’s risk preferences. I have repeated some of the experiments described by Hadar and Fischer (2008) with largely identical results.

FARMER-CONSULTANT DISCREPANCIES IN RISK PREFERENCES

The purpose of the experiment was to characterize one’s predictions of other’s beliefs and risk preferences under uncertainty. The hypothesis was that when the target event is positive one’s personal likelihood judgment will be higher than one’s assessment of other’s likelihood judgment and visa versa.

Method. Ten veterinarians attending a continued education course in HHM participated in this small study. The veterinarians were asked to write down their answers to the following questions. Each question was asked separately.

1. *You decide to try the lottery. There is only one price that amounts to DKK 40,000 and there are 1,000 lottery-notes*

- What will you pay for one lottery-note? – this is a choice
- What do you think your colleagues as an average would be willing to pay? – this is a prediction

2. *I have 100 envelopes on my desk. 99 of these hold DKK 4,000. The last one is empty*

- What will you pay for one lottery-note? - choice
- What do you think your colleagues as an average would be willing to pay? - prediction

In the prediction condition, participants indicated the cash amount they believed a randomly selected colleague would choose measured as the group average. These conditions were repeated in the loss domain, i.e. loosing DKK 4,000. Cash equivalents in the choice conditions followed a four-fold pattern of risk attitudes, expressing risk seeking for low probability gains and high probability loses, and risk-aversion for low probability losses and high probability gains. Cash equivalents in the prediction conditions also followed the identified four-fold pattern, but the risk attitudes were not as pronounced as they were in personal choices. To illustrate, the median cash equivalent for 0.001 probability of DKK 40,000 was DKK 120 in the choice condition and DKK 60 in the prediction condition. Both amounts are greater than the expected value of the imaginary lottery (DKK 40). This indicates risk-seeking, but the amount in the choice condition was higher, suggesting that risk-seeking was more pronounced in choices than in predictions. Prospect theory explains that people generally tend to consider themselves luckier than others. Similarly, the median cash equivalent for 0.99 probability of DKK 4,000 was DKK 2,800 in choice condition and DKK 3,500 in prediction. Both amount are lower than the expected value of that lottery (DKK 3,960), an indication of risk-aversion, but the amount in the choice condition was lower, suggesting that risk-aversion is more pronounced in choices than predictions (personal risk-aversion).

This small experiment illustrates that veterinarians, despite some knowledge on statistics, are no better than most people to handle risk(s). This allows the inferences made by Hadar and Fischer (2008) on approximately 230 MBA students from University of Chicago to be equally valid for veterinarians. These authors suggest that it is the human nature to over-weigh small probabilities (i.e. 'the law of small numbers', Pindyck and Rubinfeld, 2005) and under-weigh moderate to high probabilities (Tversky and Fox, 1995). Hsee and Weber (1997) reported that when people make a risky choice themselves, the decision is influenced by their subjective feeling toward risk. In contrast, people are likely to have trouble understanding other peoples risk preferences or aversions and thus predictions of other people’s behavior tend to regress towards risk neutrality. Faro and Rottenstreich (2006) found that a self-reported measure of empathy towards a specific other person moderated the magnitude of these mispredictions. The greater the self-reported ability to empathize with the other person, the less regressive was the prediction of this other person’s risky preferences.

In the experiment the veterinarians had to make a risky decision with consequences for themselves, and consequently their decision was influenced by their subjective feelings toward risk. If these results are equally valid in HHM programs veterinarians may experience difficulties when trying to understand farmers’ decision making. This farmer-veterinarian discrepancy can be reduced if the farmer and veterinarian share a mutual understanding of the purpose of the HHM program and how to manage a dairy enterprise.

Chapter 7

CONCLUSIONS

QUIZ: Try to connect all the nine dots with four straight lines – without lifting the pen from the paper - The answer can be found on the last page…

*	*	*
*	*	*
*	*	*

The overall research question was addressed from a veterinary point of view focusing on the health promotion aspects in dairy herds. Initially, available knowledge on herd dynamics, as synthesized in the SimHerd model, was used for deduction of the most important financial effects related to practically relevant management changes in dairy herds. This deduction was followed by the development of a metamodel, i.e. a condensation of a series of herd simulations with the SimHerd model that provided a more user-friendly and nevertheless valid tool for predicting the financial effect of the management adjustments in question. This approach contributed to circumvent some of the problems related to obtaining a large number of input variables needed for the complex SimHerd model. The SimHerd model was also used to estimate the random within-herd variation in financial performance between subsequent years following changes in selected technical key performance indicators assumed to mimic changes in herd management thereby illustrating the problems related to the commonly applied league-tables for motivating farmers.

If the input to the model (biological and technical associations at cow and herd level) is biased or imprecise the predictions of financial performance will also be biased or imprecise. Such input-parameters are usually estimated from observational field data. Consequently, we explored the validity of field data reported by veterinarians and utilized by modelers in dairy herd management research. Unfortunately, 'real life' is almost impossible to capture in multi-herd databases due to the different circumstances from which the data is collected and processed. Last, I inquired into dairy farmers' perceptions of herd health management.

Clearly, financial performance and optimization of production was only a part of the whole picture. Apparently, farmers' expectations when participating in a herd health management program are more directed towards teamwork and animal welfare than towards increased production and profit.

The following is a list of the specific conclusions from the thesis:

POTENTIAL FINANCIAL EFFECTS OF HEALTH RELATED MANAGEMENT CHANGES

- Eight key performance indicators were identified and implemented in a mechanistic, dynamic and stochastic simulation model of a dairy herd (the SimHerd model)
- The statistically significant key performance indicators were defined in the areas of shape of lactation curves, reproduction efficiency, heifer management, dynamics of body condition, mortality in cows and calves, and somatic cell counts
- In a 10-year horizon the relative effects (percent of the long term effect on gross margin per cow) were: Shape of lactation curve 53 (€ 227), reproduction efficiency 21 (€ 89), heifer management 8 (€ 34), dynamics of body condition score 6 (€ 25), mortality in cows 5 (€ 23), mortality in calves 4 (€ 18) and somatic cell counts 3 (€ 15)
- The results showed numerous significant interactions between the different combinations of key performance indicators. This implies that financial performance related to certain management strategies will depend significantly on the management level in other areas of herd management
- The standard deviation of the annual gross margin per cow year between subsequent years in the default herd with a constant production strategy and constant prices given the study context was € 26
- The standard deviation of the annual gross margin per cow year between subsequent years in real life was € 248
- The main effects of the key performance indictors were divided in two groups: The default herd, high reproduction efficiency, heifer management, mortality in cows and calves, dynamics of body condition score and somatic cell counts reached steady state in less than 5 years whereas low reproduction efficiency and changes in shape of lactation curve needed more than 5 years to reach steady state
- Approaches to implement the metamodel in veterinary cattle practice is outlined

PROBLEMS RELATED TO COLLECTION AND ANALYSIS OF HEALTH RELATED DATA

- This thesis supports previous findings that variability is high between veterinarians' diagnostic abilities, procedures and criteria for decision making

- Semi-structured interviews of 20 veterinarians showed that even if a very detailed protocol was distributed to the veterinarians, validity of field data was problematic
- Veterinarians may cause serious bias because they allow their own beliefs and the local context to be expressed implicitly in the construction of the field data
- Identified associations may therefore not reflect biological relations but may be heavily influenced by implicit decisions taken by the farmer or the veterinarian
- Estimates obtained from across-herd quantitative statistical analyses of large data files recorded in numerous herds may be misleading and very problematic as information for decision support systems to be used in individual herds
- Researchers are urged to increase their knowledge on the local context, i.e. the circumstances in which the data was constructed before inferring generalizations between cause and effect to the entire dairy population and the individual herd
- This thesis suggests that much research in herd health management will benefit substantially from a mixed methods research approach

FARMERS' PERCEPTION OF HERD HEALTH MANAGEMENT

- Farmers' perception of herd health management programs could meaningfully be divided into four families of perspectives
- The families of farmers' perspectives explained 37, 12, 9 and 7 percent of variance for families labeled: Teamwork, Animal welfare, Knowledge dissemination and Production
- Identical families of perspectives were identified among the affiliated veterinarians; however, veterinarians believed that farmers primarily were motivated by production
- Families of veterinarians' beliefs on farmers' perspectives were Production, Animal welfare, Knowledge dissemination and Teamwork explaining 48, 9, 6 and 6 percent of variance, respectively
- Farmers valued animal welfare for different reasons: 1) to please society; 2) because the farmers believed that increased animal welfare was a necessary prerequisite to increase production; 3) to increase the farmer's subjective well-being
- It is necessary that veterinarians include opportunity time when proposing recommendations
- Farmers apparently view veterinarians as largely incompetent when it comes to herd health economics, finances in general and strategy related to running a business

IMPLICATIONS AND PERSPECTIVES FOR RESEARCH, CONSULTANCY AND EDUCATION

- From the knowledge about random variation in financial performance between subsequent years it is concluded that a league-table approach to present empirical financial results (to motivate farmers) is very problematic and probably invalid
- From the study on data validity it is concluded that field data may benefit substantially from supplementary validation to reduce bias
- Within-herd experiments with a randomized design are suggested to researchers and local veterinarians as a tool to avoid biased estimates of effects of cow-level interventions in the herds
- I suggest that scientists with a need to understand a certain field of human action and the consequences of these actions can come far by combining the strengths of quantitative and qualitative methods into mixed methods research
- Farmers apparently request competences from veterinarians that are not taught at veterinary schools
- Apparently, veterinarians are no better than most people to handle risk(s) in decision making. This thesis suggests that decision making related to herd health may be influenced by the veterinarians' subjective feeling toward risk. More research on this topic is needed.
- I suggest that veterinary schools employ researchers from other scientific disciplines to fully cover the discipline of dairy herd health management. Disciplines like psychology, sociology, economics and marketing may offer new methodological approaches to the scientific field of herd health management
- To acknowledge the uniqueness of every farm and farmer is central to understanding the stimulus for change, i.e. 'know thy customer'

Epilogue

Our veterinarian parked his two-wheel drive in the dark shadows of the university's ivory towers. He was going to discuss the presentation of his thesis at the PhD-defence with his Principal Supervisor. Suddenly, he became acutely aware of the darkness and how it obscured his vision. He realized that he might have lost sight of the mission; might have forgotten why he started the PhD-project. What if he couldn't provide the answer to the research question that his colleagues in the field were waiting for?

The vet got worried that he had become too focused on satisfying the norms and requirements of the scientific community and perhaps had forgotten the initial intentions of the project. His Process Supervisor, Esben, a practicing cattle veterinarian, for sure would ask the nasty 'so what' questions, when he read the thesis. The choice between being mocked by Esben and cancelling the appointment with his Principal Supervisor was easy. The vet quickly left the shadows. While driving home, the vet decided to write a letter to Esben, describing how Esben could valuate dairy herd health management in his herds and veterinary practice. This is what he wrote:

Dear Esben,
You have been waiting impatiently for an answer to the question:

How to valuate dairy herd health management?

After reading hundreds of publications, fighting with the academic community, having written and rewritten a number of papers and learned about different methods to describe and analyze dairy farms and farmers I am now able to bridge the gap between science and practice and present to you my research-based recommendations. This is what you should do:

I. Learn what herd dynamics means

Learning about herd dynamics is for the herd consultant what anatomy and physiology is to the cow vet. Knowledge about this issue is vital if you want to be accepted as a trustworthy and competent consultant by the farmer and other stakeholders at the farm. I have provided some examples with estimates of biological, technical and financial effects of management changes using the SimHerd model. These estimates are directly applicable to you as a platform for prioritization of your efforts as a herd health management consultant. In addition, the changes we have implemented in the SimHerd model and the user-friendly metamodel provide a framework for this learning process. You will probably need some help for this, but competent training support is readily available. Initially, you will have to invest a lot of time to master these tools. The good news is that having made the investment you will experience almost no market competition because other consultants in the field aren't demonstrating convincing insight into herd dynamics or interpretation of performance indicators and seem to totally ignore random variation. Try to take a look at the league-tables ranking farmers by gross margin per cow year or the financial calculations presented by many production consultants and you will agree with me. Another example is the current email-discussion between our colleagues in cattle practice about why and how to select fresh cows for collection of clinical data.

II. Provide the necessary and sufficient information needed for valuation

You need to provide two types of information:

1. Find out how the suggested management changes affect key performance indicators

When you have identified the management changes that are relevant to the herd in question, you need to provide numerical estimates of the effects associated with these changes, e.g. how the changes affects the shape of the lactation curve, fertility etc. Suitable tools for such analyses have been available for years and they are continuously being developed. The premise is valid data. Therefore, you need to be very systematic (disciplined) when you collect data. My study has shown that the data collection process in cattle practice is very problematic. An important reason for this is that veterinarians apparently include own values and beliefs in the data collection process. Many recommendations from research to practice are based on estimates from studies of multi-herd data files where data quality is unknown. Again, I refer to the present email-discussion as an illustration of an apparent lack of epidemiological knowledge in veterinary practice. Therefore, you should provide your own herd-specific estimates to answer possible questions from individual farmers. The positive thing is that such studies will allow you to learn more about the local context, i.e. learn more about the cows, the herd and the management. This creates a win-win situation where you and the farmer both will benefit from sharing knowledge about the herd in question thereby increasing the value of the herd health management program.

2. Reveal the true goals of the farmer

I have demonstrated that the value of herd health management cannot be measured on a monetary scale alone. You need to establish a true communication with the farmer to understand his true expectations and goals related to the herd health management program – 'know your costumer'! The data collection process addressed above may be seen as an important part of the foundation for this kind of communication.

Knowing the farmer's true goals bring you into a position where you can learn how the farmer valuates herd health management. Because you are present at the farm 1 or 2 times per week, you have a unique opportunity to learn about the farmer's needs and priorities. Having demonstrated enthusiasm, involvement and knowledge about the cows, the herd and the proper use of performance indicators, the farmer is likely to be willing to discuss more profound values in life.

The interview techniques described in my thesis may guide you to this. Also, I suggest you get training in communication; such skills were not part of the veterinary curriculum, as you know. Please remember that communication means 'make common', do not perceive communication as 'injection' of your knowledge and your values into the mind of the farmer.

As you see, I haven't provided a concrete estimate of the value of herd health management. Instead, I provide a framework that will allow you to support the farmer's own valuation. This is the only way that we can respect the local context and thus provide valid and valued consultancy. Essentially, this is in line with the mantra of Oded Nir-Markusfeld that we have heard so often: **'There is no universal truth'**.

It is no secret that I have found it difficult to communicate my research. Science ultimately seeks to describe and understand the World through generalizations. However, the discipline of herd health management is about providing concrete recommendations in a local and applied context that also qualifies to meet the traditional research-based standards.

You may find my recommendations quite different from what you learnt at vet school but don't despair; the World simply has changed and we need to adjust to those changes. It follows that implementation of my recommendations requires a very intense personal learning process. I truly hope that you can establish a transdisciplinary network to provide you with all the necessary knowledge.

I asked my Principal Supervisor how he viewed my thesis and conclusions and he answered me by quoting Churchill (1942):

‘Now, this is not the end.
It is not even the beginning of the end.
But it is, perhaps, the end of the beginning’

Quite profound, don’t you think?

Regards,
Erling

Authors' contributions

I would like to use this opportunity to thank my co-authors for participating in the different subprojects.

Subproject 1 and 2. EK and SØ developed the simulation experiment. SØ did the parameterization with help from MAK and CE regarding shape of lactation curve. EK did the literature review, drafted the manuscript and coordinated among authors. All authors participated in the statistical analysis and made substantial contributions to conception and revision of the manuscript for important intellectual content in detail. All authors read and approved the final manuscript.

Subproject 3. LNJ collected and analysed the data. EK did the literature review, drafted the manuscript and coordinated among authors. EK, DBN, MV and CE made substantial contributions to conception and revision of the manuscript for important intellectual content in detail. All authors read and approved the final manuscript.

Subproject 4. EK collected and analyzed the data, did the literature review and drafted the manuscript. CE made substantial contributions to conception and revision of the manuscript for important intellectual content in detail. Both authors read and approved the final manuscript.

Paper # I

Technical Indicators of Financial Performance in the Dairy Herd

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Technical Indicators of Financial Performance in the Dairy Herd

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ABSTRACT

Monte Carlo simulation was used to predict the long-term financial performance related to the technical performance of dairy herds. The indicators addressed were derived from data collected routinely in the herd. They indicated technical performance that can be affected by the farmer or the consultant, and they were derived from expected cause-effect relations between technical performance and financial performance at the herd level. The study included the indicators shape of lactation curve, reproduction efficiency, heifer management, variation between cows in lactation curve persistency, mortality in cows and calves, dynamics of body condition, and somatic cell counts. Each indicator was defined by 2 or 3 levels, and 2- and 3-factor interactions were included in the simulation experiment, which included 72 scenarios. Each scenario was replicated 200 times, and the resulting gross margin per cow was analyzed as the measure of financial performance. The potential effects of the selected indicators on the gross margin were estimated by means of an ANOVA. The final model allowed estimation of the financial value of specific changes within the key performance indicators. This study indicated that improving the shape of the herd-level lactation curve by 1 quartile was associated with an increase in gross margin of €227 per cow year. This represents 53% of the additional available gross margin associated with all the management changes included in the study. The improved herd-level lactation curve increased the gross margin 2.6 times more than improved reproduction efficiency, which again increased the gross margin 2.6 to 5.9 times more than improved management related to heifers, body condition score, mortality, and somatic cell counts. These results were implemented in a simple "metamodel" that used data extracted from ordinary management software to predict herd-specific financial performance related to major management changes. The metamodel was derived from systematic experiments with a complex simulation model that was used directly for advanced herd-specific decision support. We demonstrated the use of these key performance indicators to forecast the financial consequences of different "what-if" herd management options, with emphasis on herd health economics.
Key words: key performance indicator, benchmarking, financial performance, herd health economics

INTRODUCTION

The financial impact related to changing the levels of input factors (e.g., management changes or changes in housing) in the dairy herd must be documented (Ko-Net-Praksis, 2006). Usually, it is straightforward to estimate the direct costs associated with a change in one input factor, but for the following reasons, it is a very complex task for assessing the financial value of the technical effects of one or more changes in input factors that occur at the same time (Dijkhuizen et al., 1995; Tauer and Mishra, 2006). First, the dairy herd is a very complex system with numerous feedback mechanisms (Enevoldsen et al., 1995; Østergaard et al., 2000). Consequently, simple partial budgeting techniques are invalid in most situations (Dijkhuizen et al., 1995; Ferguson et al., 2000). Next, because of the long generation interval in cattle breeding, several years may pass before changes in individual animal performance (e.g., effects of the rearing period of dairy heifers) affect the financial performance of the herd as a whole (Mourits et al., 1997). During such a long time span, numerous other determinants of financial performance probably change as well (e.g., prices of inputs and outputs from the herd, and herd-level production constraints). Consequently, it is likely to be practically impossible to collect empirical data at the herd level from a sufficient number of herds and years that will allow a valid comparison of financial performance in herds with different levels of input factors of interest.

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Still, extensive use of empirical evidence from studies on various relationships and combining the evidence into a modeling framework is a way of estimating the technical and economic consequences of health-control strategies in a dairy herd (Seegers et al., 2003).

Several decision support models for use at the herd level have been developed to solve the problems described above (Ferguson et al., 2000; Shalloo et al., 2004). It can be argued that simulation models lack the credibility of field experiments, but using a simulation model provides an opportunity to explore complex relationships between input factors that cannot be studied in any other way. By using a simulation model, it is possible to keep all input factors and herd-level constraints constant except for the input factor(s) of interest. The Monte Carlo-type models provide estimates of random variation associated with technical and financial output variables. Such estimates are essential for planning interventions (Shalloo et al., 2004). Nevertheless, it has been difficult to develop an analytical model that provides estimates that are perceived as trustworthy by farmers and consultants, including practicing veterinarians. One explanation may be related to the difficulty associated with providing relevant and valid herd-specific input parameters for the models when using a decision support model for herd-specific interventions (Østergaard et al., 2000).

Provided that the relations between measures of financial performance and some (key) indicators of technical performance are consistent and precise, such key performance indicators (**KPI**) may be used as indicators of financial performance (Kaplan and Norton, 1998). Nonetheless, Enevoldsen et al. (1996) found KPI to be correlated. Even if correlations among KPI are accounted for by means of suitable techniques, such as factor analysis or principal component analysis (Enevoldsen et al., 1996), they may not be independently related to financial performance, or the effect may be too small to be distinguished accurately from the very large variance in income caused by other factors (Dijkhuizen et al., 1984). This may lead to double counting of some financial effects of interventions (Østergaard et al., 2000). If the KPI are varied systematically in a simulation experiment (i.e., a sensitivity analysis), where it is possible to identify the existence of interactions (Shalloo et al., 2004) between KPI, then it would be reasonable to interpret the KPI as indicators of financial performance of the herd. The objective of this study was to define and rank technical KPI that were tightly related to long-term effects on the financial performance in dairy herds predicted by means of Monte Carlo simulation.

MATERIALS AND METHODS

Selection of KPI and Study Design

On the basis of experience with herd management and modeling (Enevoldsen et al., 1996; Østergaard et al., 2000, 2005) and theoretical considerations (Kleijnen and Sargent, 2000; Shalloo et al., 2004), 8 herd-level potential KPI were selected, which are described below. The following general criteria were used to select the potential KPI:

1. The level of the variable describing the potential KPI must be likely to be obtained from data collected within a typical herd management program.
2. The level of the variable must vary between herds.
3. The potential KPI must describe a technical variable that can be affected by the farmer or the advisor.
4. A cause-effect relation between the potential KPI and financial performance is plausible.

The potential KPI addressed were 1) shape of the lactation curves (**LC**), 2) reproduction efficiency (**RE**), 3) heifer management (**HM**), 4) variation between cows in lactation curve persistency (**LC-V**), 5) mortality in cows (**MCow**), 6) mortality in calves (**Mcalf**), 7) dynamics of body condition (BCS), and 8) SCC.

The potential KPI were defined in the context of the SimHerd model described by Sørensen et al. (1992) and implemented in the modeling framework presented by Østergaard et al. (2005), with some model modifications to address the current research questions. For each potential KPI, the 75th percentile and the 25th percentile were calculated as found in various Danish standard protocols. The term "high" ($_{H}$) was defined as applicable to "good farm management" and the term "low" ($_{L}$) to "pitiable farm management," and these corresponded with the 75th percentile and the 25th percentile. Because of the model design, the term "middle" ($_{M}$) was calculated as the average of $_{H}$ and $_{L}$ so that the numerical distance between $_{L}$ and $_{M}$ was equal to the numerical distance between $_{M}$ and $_{H}$. When the percentiles were not directly available, $_{M}$ was defined as the mean of the potential KPI and $_{L}$ and $_{H}$ were based on our expectations. The models ensured that the numerical distance between $_{L}$ and $_{M}$ was still equal to the distance between $_{M}$ and $_{H}$.

For ease of interpretation, $_{H}$, $_{L}$, and $_{M}$ were regarded as quartiles. The selected scenarios represented practically relevant levels of management and associated performance. In the context of the simulation model, gross margin was defined as sales income less variable costs (feed, AI, and other costs) for cows and heifers. "Other costs" included veterinary assistance, medicine, bedding, and milk control. Labor and management costs were not included as variable expenses (Østergaard et al., 2005).

The selected levels of each potential KPI were varied systematically at levels $_{H}$, $_{L}$, and $_{M}$ for LC, RE, and HM and at levels $_{H}$ and $_{M}$ for the remaining potential KPI. The potential KPI were combined according to the following initial model specification:

$$\text{Gross margin} = LC_{(H,\,M,\,L)} + RE_{(H,\,M,\,L)} + HM_{(H,\,M,\,L)} + LC\text{-}V_{(H,\,M)} + MCow_{(H,\,M)} + Mcalf_{(H,\,M)} + BCS_{(H,\,M)} + SCC_{(H,\,M)} + \text{all possible 2-factor interactions} + \text{the 3-factor interaction among LC, RE, and HM.}$$

This initial model represented 72 scenarios of all possible scenarios. Each scenario was simulated 200 times (replicates) with the modified SimHerd model described below.

General Framework of the SimHerd Model

The applied simulation model (SimHerd) was a dynamic, mechanistic, and stochastic model predicting the production and states of a herd over time. Each cow and heifer was described by a state. The states were characterized by identification number, age, reproductive status, parity, DIM, genetic milk yield level, lactation curve parameters for the current lactation, BW, BCS, culling decision, health status on each simulated disease, milk withdrawal, and SCC. The prediction was made weekly for each animal in the herd. The state of the individual animal was updated, and the production and input consumption of the herd were calculated. Input and output of animals from the herd were also simulated. The drawing of random numbers by using relevant probability distributions triggered variation between animals and discrete events such as pregnancy and culling. The production and development within the herd were determined indirectly by simulation of the production and change in state of the individual animal.

Details About the Modified SimHerd Model and Parameterization

LC. The Wilmink function (Wilmink, 1987) was used to describe the fixed part of the lactation curves. The model of daily milk yield of a cow in SimHerd was modified for this study to represent empirically estimated lactation curve parameters more directly in the simulations. This implied that the feed intake was a consequence of energy needed to match the production level. The new lactation curve model was based on the Wilmink function:

$$Y_{ijk} = W0_{ij} + W1_{ij} \times DIM_{ijk} + W2_j \times \exp(W3_j \times DIM_{ijk}),$$

where Y_{ijk} is the daily milk yield in kilograms of ECM, $W0_{ij}$ is the yield level (intercept), $W1_{ij}$ is the lactation curve slope after peak yield of cow_i in $lactation_j$, DIM_{ijk} is the DIM of cow_i in $parity_j$ at time $step_k$, $W2_j$ and $W3_j$ are parameters for the lactation curve shape until the peak in $parity_j$, and exp is the exponential function. $W0_{ij}$ and $W1_{ij}$ were drawn randomly at each calving from the 2-dimensional normal distribution:

$$N[(W0g\_3_i + W0_j - W0\_3),\ (SdW0g\_3^2 + SdW0e_j^2),\ W1_j,\ SdW1_j^2,\ \rho_j],$$

where ρ_j is the phenotypic correlation coefficient between yield level and lactation curve slope after peak yield. $W0g\_3_i$ is the permanent part of the yield level of the individual cow_i. $W0g\_3_i$ was drawn randomly for individual $animal_i$ at birth from the normal distribution $N(W0\_3,\ SdW0g\_3^2)$, where $W0\_3$ and $SdW0g\_3^2$ are the mean and variance for the yield level (intercept) in parity 3; $W0_j - W0\_3$ is the fixed effect of $parity_j$ on the yield level; $SdW0e_j^2$ is the environmental variance of the yield level in $parity_j$; and $W1_j$ and $SdW1_j^2$ are the mean and variance of the lactation curve slope after peak yield in $parity_j$.

The data used for parameterization of the model originated from 39 Danish dairy herds, which are described by Thomsen et al. (2007). To parameterize $SdW0g\_3$ and $SdW0e_j$, a certain level of heritability and permanent environment was assumed. In Denmark, heritabilities of 0.43, 0.29, and 0.27 for kilograms of milk were found for parities 1, 2, and 3+, respectively, in Danish Holsteins (Danish Agricultural Advisory Service, 2005–2006). Those for protein and fat were slightly smaller. Jakobsen et al. (2002) reported similar estimates. These heritabilities originated from 305-d lactations. Jakobsen et al. (2002) showed that the heritability was lower in early lactation. For permanent environment, a heritability of 0.35 was used and the permanent environment accounted for 0.15, so that the repeatability accounted for approximately 0.50 of the total variance. The value of $SdW0g\_3$ was fitted to 3.0 kg of ECM and subsequently fitted to the estimated variance components $SdW0e_j$, $SdW1_j$, and ρ_{W0W1j} (Table 1). From the variance components, the resulting repeatabilities of W0 were calculated (heritability and permanent environment) at 0.58, 0.33, and 0.25 for parities 1, 2, and 3+, respectively.

Table 1. Variance components $SdW0e_j$, $SdW1_j$, and ρ_{W0W1j} used to calculate repeatabilities (heritability and permanent environment) of W0 in the Wilmink function[1]

Variance component	$SdW0e_j = \sqrt{(SdW0g\_3^2 - SdW0_j^2)}$	$\rho_{W0W1j} = Cov_{W0W1j}/(SdW0_j \times SdW1_j)$	$SdW1_j = \sqrt{(SdW1_j^2)}$
Parity 1	2.57	−0.62	0.0147
Parity 2	4.31	−0.61	0.0216
Parity 3+	5.15	−0.65	0.0251

[1]The Wilmink function is $Y_{ijk} = W0g\_3_i + W0e_{ij} + W1_{ij} \times DIM_{ijk} + W2_j \times \exp(W3_j \times DIM_{ijk})$, where $W0g\_3_i$ is the permanent part of the yield level of the individual cow_i. $W0g\_3_i$ was drawn randomly for the individual animal at birth from the normal distribution $N(W0\_3, SdW0g\_3^2)$, where W0_3 and $SdW0g\_3^2$ are the mean and variance for the intercept (W0).

The levels for LC were derived from Enevoldsen and Krogh (2006), where $_H$ and $_L$ were the averages of the upper and lower quartiles, respectively, from their study of herd-level lactation curves. The lactation curves for parity 3+ in the simulation experiment are illustrated in Figure 1.

RE. The levels of RE were derived from Freudendal and Strudsholm (2003). The end of the voluntary waiting period was set at 42 DIM. In this context, heat detection was defined as the probability of correctly identifying a cow in heat and that the farmer wanted this cow inseminated, and conception rate was the probability of conception following AI as measured by a pregnancy test at 42 d after AI. The levels were defined as products of heat detection and conception rate (Table 2).

HM. Intensified HM usually focused on feeding intensity, increased heat detection, and time to start of AI based on the size of the individual heifer. Heifers would calve at a younger age without a negative effect on milk

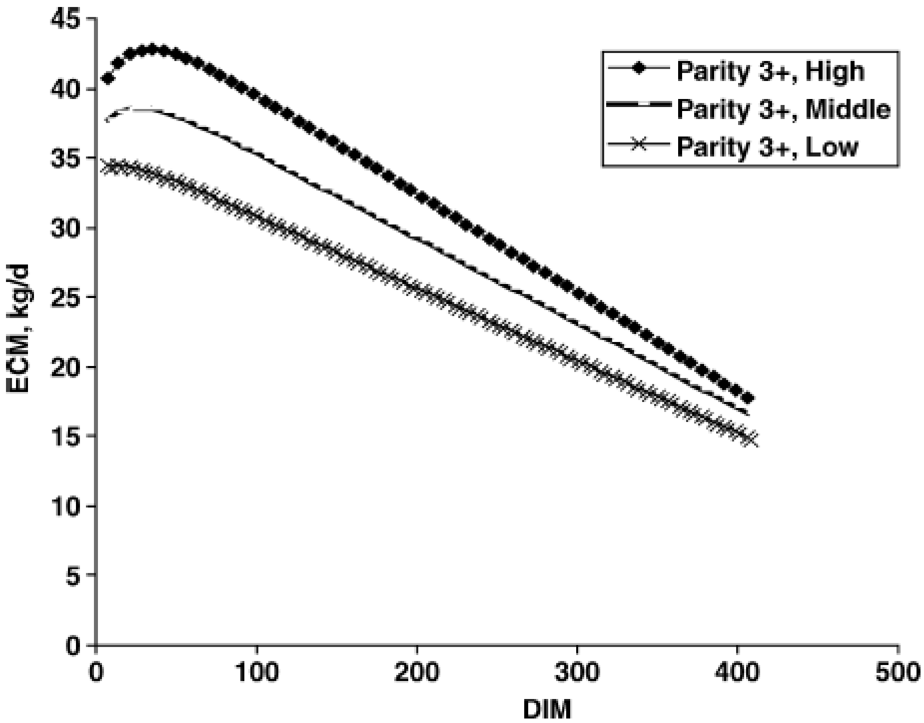

Figure 1. Visualization of the lactation curves at different levels of management for parity 3+ based on the Wilmink function applied in the simulation experiment. High is applicable to "good farm management"; low is applicable to "pitiable farm management"; and middle is the average of H and L.

Table 2. Values of variables that defined levels of reproduction efficiency in the simulation experiment

Reproduction efficiency level	Low	Middle	High
Heat detection rate	0.44	0.50	0.58
Conception rate at 42 d after AI	0.42	0.52	0.62

yield. The effect of calving age on milk yield among individuals was reduced because of the focus on time to start of AI based on the size of the individual heifer. The HM at level $_M$ was simulated by a heat-detection rate of 0.50, and at the resulting average calving age, a marginal effect was assumed of 1 extra day of calving age of 0.0066 kg of ECM/d in first lactation. At levels $_H$ and $_L$, heat-detection rates of 0.60 and 0.40, respectively, were assumed, and at the resulting average calving ages, marginal effects of 1 extra day of calving age of 0.0033 and 0.0099 kg of ECM/d, respectively, were assumed in first lactation (C. Enevoldsen, unpublished data; J. Ettema, Department of Animal Health, Welfare and Nutrition, Faculty of Agricultural Sciences, University of Aarhus, Research Center Foulum, Tjele, Denmark, 2006). In all scenarios, the marginal effect of an extra day of calving age was simulated to decline linearly to zero at a calving age of 30 mo.

LC-V. The between-cow variation within herds is highly variable between herds. One reason could be that social stress, meager housing design, or diseases such as lameness limit the feed intake of some cows. Consequently, LC-V could be a potential KPI. From an unpublished analysis (M. A. Krogh, unpublished data), the 10th percentile herd had a variance 50% the size of the variance in the 50th percentile herd, so the $SdW1_j$ was reduced accordingly for level $_H$:

Parity 1: $SdW1_j = \sqrt{(0.0147^2 \times 0.50)} = 0.0104$,

Parity 2: $SdW1_j = 0.0153$, and

Parity 3+: $SdW1_j = 0.0177$.

MCow. The estimates used were from an unpublished analysis by P. T. Thomsen (Department of Animal Health, Welfare and Nutrition, Faculty of Agricultural Sciences, University of Aarhus, Research Center Foulum, Tjele, Denmark, 2006) regarding mortality in Danish dairy cows for weekly estimates of incidence rate of cow death: $_L$ = 0.001233, $_M$ = 0.000678, and $_H$ = 0.00024.

Mcalf. From Danish standard protocols, the probability of a calf surviving birth and the first 180 d postpartum for first parity was $_L$ = 0.77, $_M$ = 0.84, and $_H$ = 0.90, and the probability of a calf surviving birth and the first 180 d postpartum for second parity and 3+ parity was $_L$ = 0.81, $_M$ = 0.87, and $_H$ = 0.93.

BCS. The model for BW and BCS of a cow in SimHerd was modified for this study to empirically represent estimated parameters more directly in the simulations. This implied that the feed intake was a consequence of energy needed to match the production level. A Gompertz curve was used to describe the BW of the animal corrected to a BCS of 3.0 and excluded any weight of a fetus:

$$BW_{BCS=3.0} = MatureBW \times \exp[-m \times \exp(-n \times Age_{ik})],$$

where Age_{ik} is the age in days of $animal_i$ in the kth time step, and m and n are model parameters describing the shape of the curve. Based on the results from Nielsen et al. (2003), estimates were MatureBW = 680, m = 2.5483, and n = 0.00314.

Figure 2 shows the applied Gompertz curve describing the BCS-corrected BW. The BCS change of the cow was based on the model of Friggens et al. (2004). First, the cows were assumed to be driven to a certain BCS at the nadir after the first part of the lactation (phase 1). Second, the BCS would not change until pregnancy (phase 2). Finally, during pregnancy the cows were assumed to be driven to a certain BCS at calving (phase 3). Body condition was specified at the 2 different time points in the lactational cycle: at calving (a fixed BCS of 3.50) and at nadir, which was 70 d after calving. There was a relationship between BCS and fertility in the simulation model for the individual cow. If BCS dropped below 2.75, there was a reduced likelihood of the onset of the first ovulation. This relationship was based on the model described by Friggens and Chagunda (2005).

In the context of the simulation experiment, defined variables were high mobilization ($_H$), an expected mobilization ($_M$), and a low mobilization ($_L$). Input variables at the parity level are shown in Table 3.

SCC. The SCC input parameters were fitted from Østergaard et al. (2005) and represented estimates of SCC at the herd level, given different levels of management (Table 4). Because of the selection criteria, clinical mastitis was excluded. The reason for this decision was the large variation in practical management (i.e., medical treatment(s) or selective drying off of infected quarters) of clinical mastitis at the herd and cow levels (Vaarst et al., 2002), which makes comparison of the occurrence of clinical mastitis in different herds complicated. The impact of SCC on milk yield was mediated through LC. Consequently, SCC affected only gross margin through the milk price. The corrections for bulk tank SCC per milliliter on the milk price per kilogram of ECM (€0.291; Table 5) were +1.8, +0.9, −3.6, and −9.0% for bulk tank SCC of ≤200,000; 200,000 to

Figure 2. Visualization of the Gompertz curve describing the dynamics of BCS-corrected BW within the SimHerd model (see Table 3).

Table 3. Parity-specific values of BCS used to define management levels in the simulation experiment

BCS at parity level	Low	Middle	High
Parity 1, at calving	3.50	3.50	3.50
Parity 1, at nadir	3.25	3.00	2.75
Parity 2, at calving	3.50	3.50	3.50
Parity 2, at nadir	3.00	2.75	2.50
Parity 3+, at calving	3.50	3.50	3.50
Parity 3+, at nadir	3.00	2.75	2.50

Table 4. Parity-specific values of SCC used to define management levels in the simulation experiment

Level of SCC management	Low	Middle	High
Parity 1, × 1,000/mL	191	152	112
Parity 2+, × 1,000/mL	451	360	268

Table 5. Examples of prices or costs (€) applied in the simulation experiment

Variable	€
ECM per kg	0.291
AI per insemination	13.33
Heifer <1 yr per head (buy or sell)	453
Pregnant heifer per head (buy or sell)	1,067
Slaughter price per kg	0.893
Cost of dead cow, obliteration	49
Bull calf, price for sale at 14 d	173
Scandinavian Feeding Unit (SFU)	0.17

300,000; 400,000 to 500,000; and >500,000, respectively (Østergaard et al., 2005).

Simulation Experiment and Statistical Analysis

The simulation experiment was conducted as follows:

1. The choice of the potential KPI (e.g., lactation curves with different levels of peak yield and persistency) was assumed to mimic effects of a systematic change in input factors in the herd management programs.
2. Simulated management changes (expressed as changes in KPI levels) were translated into changes in gross margins through the SimHerd model.
3. The set of assumptions made SimHerd aim at keeping the herd size as close as possible to the maximum of 250 cows.
4. The simulation took place in a situation without any quota constraints; that is, the production was constrained by a maximum number of cows in the herd.
5. Cows and heifers were fed TMR with a standard feed price.
6. Prices were set (in €) according to typical prices in Denmark in 2006 (Table 5).
7. The output from the 10th simulation year was used for analysis, because initial exploration of the simulated data showed that in some scenarios, it took up to 9 yr to obtain steady state (i.e., the "burn-in"

Table 6. Key characteristics of the default herd (no changes in management) in the 10th simulation year after 200 independent replications

Selected variable	Mean	SD	Minimum	Maximum
Parity 1, n	93	6.6	73	109
Parity 2, n	59	6.1	42	79
Parity 3+, n	95	7.2	75	113
Heifers >1 yr, n	155	10.0	124	178
Heifers <1 yr, n	116	8.2	98	139
Cows per year,[1] n	248	0.2	247	248
Bulk tank SCC, × 1,000/mL	261	6	240	280
ECM per cow/yr, kg	9,735	77.7	9,530	9,972
Culling rate[2]	40	3.0	31	50
Calves born per cow/yr	1.08	0.03	0.96	1.15
AI per cow/yr	2.26	0.10	1.99	2.59
Age at first calving, mo	28.40	0.2	27.8	29.0
Total revenue, €	791,820	8,055	764,734	814,562
Total expenses, €	400,637	3,813	391,302	411,612
GM[3] per cow, €	1,578	25	1,508	1,642

[1]Cows per year = total number of cow days in a year/365.

[2]Calculated according to the Danish definition: (number of cows going into the herd + number of cows leaving the herd)/2/number of cows per year.

[3]GM = gross margin from the herd as a whole divided by the number of cows per year.

period reflecting the initial bias; Abate and Whitt, 1987; Chen and Kelton, 2003).

The simulation took place in a no-quota situation. The reason was that the quota system had become more liberal in Denmark and was expected to be lifted within the European Community in the near future.

Key characteristics of the default herd in the 10th simulation year after 200 independent replications are described in Table 6. This herd was defined by having all the KPI placed at level $_M$.

Statistical Analysis. The simulated results from the 10th simulation year were analyzed by means of an ANOVA using SAS PROC MIXED (Littell et al., 2006). The full model described above was reduced by backward elimination of the KPI and their interactions until the *P*-values of all factors were highly significant ($P < 0.0001$). The residuals from the resulting model were not normally distributed (Kolmogorov-Smirnov <0.01). A qualitative analysis was performed on each of the 72 scenarios, and 6 scenarios were identified in which the residuals were not normally distributed (Shapiro-Wilk <0.05). These 6 scenarios were excluded from the data set and were referred to a qualitative analysis of relevant herd-level variables (calving interval, cows per year, calf mortality, total milk yield, culling decision, heifers per year, age at first calving, total gross margin, gross margin per cow, total income, total expenses). The qualitative analysis revealed that the input variables for RE_L may have been too low compared with RE_H, making the data skewed within 4 scenarios of the initial model. Other systematic relationships between the "not acceptable" scenarios were not identified, indicating that the stochastic elements of the SimHerd model probably were responsible for the remaining 2 scenarios. Subsequently, the 6 "not acceptable" scenarios were removed from the data set.

The potential effect of the selected variables was estimated on the gross margin with the ANOVA model by using Satterthwaite's approximation. The level of financial significance was set at €1.33/cow per year. The potential KPI and their interactions had to comply with both statistical and financial significance to be retained in the final model. Eight scenarios were removed because of financial nonsignificance.

Range of Effects. By using linear contrasts, the 2- and 3-factor interactions were dissolved to study the differences between KPI and their relation to the gross margin when changing the KPI levels. To compare the KPI, the differences from $_L$ to $_M$ and from $_M$ to $_H$ were used, making it possible to compare the 2-level KPI with the 3-level KPI. That is, the unit of KPI change was largely 1 quartile within the interquartile range. The design provided a direct link to data from benchmarking facilities in herd management programs, yet the study design did not allow us to draw conclusions on the contrasts between $_M$ and $_L$ for the 2-level KPI.

RESULTS

The Model

The initial ANOVA model was reduced (statistical significance: $P < 0.0001$) to the following final model (the metamodel):

Table 7. Estimates of statistically and financially significant effects on gross margin of a series of key indicators of technical performance (KPI)[1]

Main effect of KPI	Estimate, €	2-factor interaction	Estimate, €	3-factor interaction	Estimate, €
Intercept	1,578	$LC_H \times RE_L$	1.7	$LC_H \times RE_H \times HM_H$	−4.6
Shape of lactation curve (LC_H)	206.7	$LC_L \times RE_L$	7.4	$LC_H \times RE_H \times HM_L$	−3.5
Shape of lactation curve (LC_L)	−222.9	$LC_H \times HM_H$	−1.5	$LC_H \times RE_L \times HM_L$	−16.6
Reproduction efficiency (RE_H)	9.1	$LC_L \times HM_L$	3.7	$LC_L \times RE_H \times HM_H$	−3.9
Reproduction efficiency (RE_L)	−67.0	$RE_L \times HM_H$	25.4	$LC_L \times RE_H \times HM_L$	3.1
Heifer management (HM_H)	16.9	$RE_L \times HM_L$	−21.0	$LC_L \times RE_L \times HM_L$	21.0
Cow mortality ($MCow_H$)	19.8	$RE_H \times MCow_H$	3.5		
Calf mortality ($Mcalf_H$)	16.7	$RE_H \times Mcalf_H$	1.6		
SCC (SCC_H)	15.4	$RE_H \times BCS_H$	7.9		
		$RE_L \times BCS_H$	9.6		

[1]The intercept represents the gross margin in the default herd (see Table 6). $_H$ = good farm management; $_L$ = pitiable farm management. Mean SE, € = 28.6; assuming variance homogeneity, a confidence interval of the predictions can be estimated from 2 × mean SE ∼ €57.

$$\text{Gross margin} = LC(_{H,\ M,\ L}) + RE(_{H,\ M,\ L}) + HM(_{H,\ M,\ L}) + MCow(_{H,\ M}) + Mcalf(_{H,\ M}) + BCS(_{H,\ M}) + SCC(_{H,\ M}) + LC \times RE + LC \times HM + RE \times HM + LC \times RE \times HM + RE \times MCow + RE \times Mcalf + RE \times BCS.$$

KPI

Table 7 presents the KPI and interactions that complied with both statistical and financial significance (LC, RE, HM, MCow, Mcalf, BCS, SCC). The final model explained 96% of the variation in the simulated data. The within-scenario variation was negligible (0.5% of total variance; $P < 0.0001$) for practical purposes.

Example. An example use of KPI was derived from Table 7. A farmer owns a herd identical to the default herd (herd characteristics in Table 6) and asks about the expected financial performance if all the KPI change from $_M$ to $_H$. The answer is: We simply add or subtract the values (€) of the KPI and the interactions in question from each other: 206.7 + 9.1 + 16.9 + 19.8 + 16.7 + 15.4 − 1.5 + 3.5 + 1.6 + 7.9 − 4.6 ∼ €291. The 95% confidence interval for financial performance, given the specified changes in KPI, was €235 to €349 (based on the root mean standard error; Table 7).

In our setup, the default herd consisted of 248 cows, with a mean gross margin per cow per year equal to €1,578 (Table 6). Thus, the gross margin for the default herd equaled €391,344. The best-case scenario equaled an improvement of the gross margin by almost 20%. This value took into account important interactions among the KPI and prevented double counting because of the simulation design. Nonetheless, costs of increasing the quality of management, such as additional labor, management support, and quality of feed, necessary to obtain the changes were not included.

Interactions and Range of Effects

Tables 7 and 8 show that the relation between LC and gross margin was modified by RE and HM. The lowest difference between LC_H and LC_L was €332, which occurred when both RE and HM were $_L$. The remaining differences between LC_H (€206.7) and LC_L (€−222.9) were very similar (∼€430). When RE and HM were $_L$, the difference was smaller because of the impact of the 3-factor interaction when all 3 KPI (LC, RE, and HM) were $_L$ (€21.0 in Table 7).

The relation between RE and gross margin was modified by LC and HM. The lowest difference between RE_H and RE_L was €52, which occurred when both LC and HM were $_L$. The remaining differences between RE_H and RE_L were €71 to €89. The contrasts revealed that the impact of RE on the gross margin was skewed, making losses associated with moving from $_M$ to $_L$ (€67) much larger than the gain associated with moving from $_M$ to $_H$ (€9), regardless of the levels of LC and HM. If RE was $_L$ and LC was kept constant, it was only possible to increase the gross margin slightly (€16 to €34) by improving HM.

Reproduction efficiency was involved in 2-factor interactions with MCow, Mcalf, and BCS. The smallest effect including MCow was €20, and for Mcalf it was €17. Both occurred when RE was different from $_H$. In contrast, the smallest effect of BCS (€15) was found at RE_M.

Somatic cell count was not significant in any interactions. The effect of SCC was €15 (the difference between SCC_H and SCC_M).

Table 8 ranks the KPI by the largest effects on gross margin, measured as quartiles within the interquartile ranges, and provides estimates of the relative financial performance of the KPI and the interactions.

Table 8. The numerical and relative importance of key indicators of technical performance (KPI) with respect to their long-term impact on the financial performance in dairy herds, measured as gross margin per cow

KPI	Interquartile range,[1] €	Percentage of total	Short description of the most important findings between levels of KPI
Shape of lactation curve (LC)	227	53	The range is independent of the levels of RE and HM.
Reproduction efficiency (RE)	89	21	Most affected by LC. At LC_L the effect decreases to €52.
Heifer management (HM)	34	8	The effect is €34 at levels LC_H and RE_L. Otherwise HM is €17.
BCS dynamics (BCS)	25	6	At BCS_M and RE_L, the gross margin is €10 if BCS_M improves to BCS_H.
Cow mortality (MCow)	23	5	The effect is €23 regardless of RE level.
Calf mortality (Mcalf)	18	4	The effect is €18 regardless of RE level.
SCC	15	3	SCC is not affected by interactions; thus, the effect is equal to the main effect.

[1]To compare the potential financial performance of the KPI, we used the differences from levels $_L$ to $_M$ and from $_H$ to $_M$, making it possible to compare the 2-level KPI with the 3-level KPI. These differences correspond largely to 1 quartile within the interquartile ranges. $_H$ = good farm management; $_L$ = pitiable farm management; $_M$ = middle (average of $_H$ and $_L$).

Examples. To illustrate the interpretation of the results, 2 small examples are presented and show a particularly interesting finding:

1. Figure 3 illustrates the 3-factor interaction between levels of RE, HM, and LC_H. The maximum value (€17) from moving HM 1 quartile was found at RE_L and LC_H when the movement was from $_L$ to $_M$. The maximum value (€89) of RE was found at HM_L and LC_H when the movement was from $_L$ to $_M$. Notice that at RE_M, there was no additional gross margin associated with moving HM from $_L$ to $_M$.
2. The differences in expected number of median days open between RE_L and RE_M and between RE_M and RE_H were calculated from the parameters in Table 1. The corresponding differences in the gross margin were divided by these numbers of days open. With this approach, it was possible to estimate the cost per day open within different levels of RE. At $MCow_H$, the average cost of moving RE_L to RE_M and RE_M to RE_H was €5 and €1 per day open, respectively. At HM_L, the average cost of moving RE_L to RE_M was €7.

The change in gross margin was calculated between scenarios that were only different regarding levels of MCow and Mcalf, respectively (data not shown). This provided the financial loss associated with 1 dead animal within different levels of LC. At $Mcalf_H$ and LC_H, the average cost of moving $MCow_M$ to $MCow_H$ was €1,013 for a dead cow. At LC_L, the cost was €863. With the same approach, the cost of a dead calf was estimated at €291 and €264, respectively, in herds with LC_H and LC_L.

Table 8 describes the most important findings based on quartiles within the interquartile ranges. All differences were significant ($P < 0.0001$) and were numerically larger than the level of financial significance (€1.33/cow per year).

DISCUSSION

Validation of the Metamodel with Respect to the Simulation Model (SimHerd)

The metamodel fit very well with the aggregated data from the simulation experiment conducted with SimHerd (R^2 = 0.96). The gross margin output from Sim-

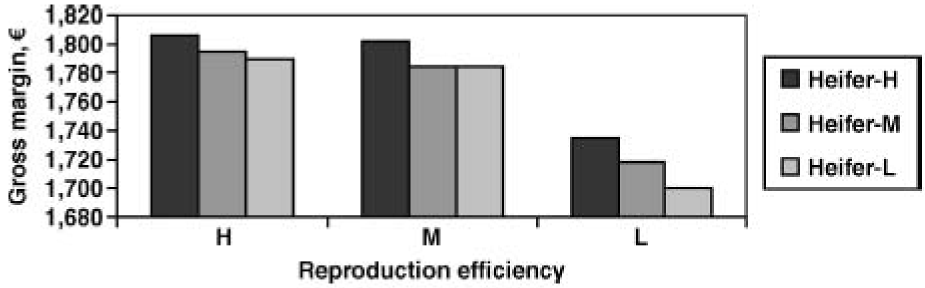

Figure 3. Visualization of the financial performance related to reproduction efficiency and heifer management, given the shape of lactation curves corresponding to a high management level. H is applicable to "good farm management"; L is applicable to "pitiable farm management"; and M is the average of H and L.

Herd, and consequently from the metamodel, responded to changes in KPI levels in the direction that agreed with prior qualitative knowledge about the simulated problem entity. In most cases, plausible explanations were provided for the rather complex interactions between KPI. These interactions provided more insight into the complex behavior of the herd as a system. The face validation of the pathways from assumed management adjustments, to KPI, to simulation input, to simulation output, and finally to metamodel output suggests that the metamodel provides a valid tool for herd advisors (Sørensen, 1990).

A word of caution when using the metamodel: the low reproduction efficiency within the 4 "not acceptable" scenarios made it impossible for SimHerd to maintain a steady number of cows in the simulated herd without frequent purchase of pregnant heifers. The same situation with unfortunate reproduction management could easily occur in real life, but SimHerd was probably too simple to simulate such extreme examples. SimHerd simply assumed that the farmer would wait until the herd size had dropped to a certain number of cows and then pregnant heifers were purchased, 1 heifer at a time, to ensure that the herd size did not drop further. Consequently, at present there are extreme scenarios that cannot be modeled in a satisfactory way with SimHerd. This may be due to the simple nature of the feedback mechanism for purchase in the SimHerd model. This is an important finding that has added further information to the validity of the SimHerd model.

General Discussion

Our study basically was a condensation of a series of herd simulations with the SimHerd model that provided a much more user-friendly, and nevertheless valid, tool for predicting the financial effect of the most relevant management adjustments in herd management. The chosen metamodel circumvented the problems related to obtaining the large number of input variables needed for complex simulation models for decision supports (Enevoldsen et al., 1995).

The financial performance associated with changes in herd management did not include labor and management costs or costs associated with needs for improved feed quality, which may be important costs in a real herd decision problem. In that case, these costs must be estimated and subtracted from the gross margin estimated with the metamodel. In the interpretation of the results, it should be mentioned that the difficulty or ease of achieving a certain management change is herd specific. For instance, it is likely that for some farmers, it is easier or less costly to obtain the gross margin indicated by our study than for others. It would be easier to move most of the KPI from $_L$ to $_M$ than from $_M$ to $_H$.

In situations in which the milk quota is the major production constraint in the herd, rather than the number of cows (as we have assumed), the gross margin per kilogram of milk produced is a relevant measure of financial performance because of the extra costs of producing more or less than the milk quota. The general mechanism of a milk quota was that strategies that affected the milk yield were generally reduced; that is, the loss per dead animal dropped to about half compared with a no-quota situation (Sørensen and Enevoldsen, 1991). The reason for this is that by implementing preventive measures, a herd under an unadjustable quota can prepare for this situation (the dead animal) by increasing production; however, if the situation does not occur, the herd will need to be fit into the allowable production by reducing the cow numbers. The possibility of buying and selling quotas offers the farmer another option, which makes gross margin per kilogram of milk produced an incomplete financial measure. The European milk quota system is accelerating, and in Denmark it is now possible to buy and sell milk quotas 4 times a year. This provides the individual farmer with great flexibly to adjust to the quota situation. It would be very difficult, perhaps impossible, to implement this flexibility in the simulation. Because simulation under a quota restriction will not reflect reality and because of the long time intervals of some of the simulated management changes, we deliberately chose to simulate without adjusting for the financial effect of a milk quota.

The ranking of the KPI was based on the gross margin obtained after 10 yr of simulation, where the simulation experiment reached steady state. On the other hand, the financial value of a given management change obviously depends on the time span until full manifestation of the effects. That is, the gross margin obtained in all the simulation years ideally should be discounted and transformed into a net present value.

The planning horizon differs among farmers and within farmer, depending on the characteristics of the management change. Therefore, both short-term and long-term predictions will be relevant for the decision-making process, but the short-term behavior of the SimHerd model has not been studied in sufficient detail to allow this type of analysis. Consequently, the short-term consequences on gross margin until the time of steady state need to be explored further.

Implications from the Results

The results of this study are intended to support the prediction of the financial performance associated with practically feasible changes in specified KPI. The constructed KPI levels cover the interquartile ranges of KPI obtained in Danish dairy herds reasonably well. Consequently, benchmarking facilities in efficient herd management software probably could produce the information needed to use the general results described in Table 8. The detailed descriptions of the modeling assumptions allow potential users to judge whether the metamodel is valid for contexts of interest to them.

The financial performance associated with RE is mediated through 2-factor interactions between RE and each of MCow, Mcalf, and BCS. This was an important finding, because this made RE at the herd level even more important than what was calculated if a simpler model was used (partial budget or similar).

The interaction between BCS and RE was explained by the effect of the period of negative energy balance on BCS postpartum and the likelihood of onset of estrus (Friggens and Chagunda, 2005), because a low BCS indicates postponed onset of estrous cycling. Body condition score thereby affects RE. If BCS drops below 2.75, then SimHerd links the negative energy balance with an increase in time to onset of estrous cycling of 1 wk. Increasing BCS from level $_M$ to $_H$ reduced the impact of negative energy balance postpartum on RE in the SimHerd model. Then again, in our scenarios only a few cows experienced a detrimental effect on RE. The interaction between BCS and RE was expected to be more pronounced if the BCS levels became lower than what we had simulated.

Variation between cows in lactation curve persistency was not significant in the metamodel. The changes related to LC-V may be too subtle to be identified by using only 1 quartile, or the modeling may have been too crude; that is, we assumed that the reduction in variance affected all cows.

It may seem rather surprising that SCC did not interact with culling or production level as would be expected in real life. On the other hand, the study design prevented us from drawing any conclusions regarding such interactions; that is, we included data that were possible to obtain from a normal herd health program, with focus on potential production improvements. They may be caused partly by (absence of) disease, yet the decreased milk production caused by SSC in real life may not be fully reflected when estimating the impact of SCC on financial performance. In other words, the model underestimated the financial impact caused by SCC.

The metamodel showed that more than 50% of the changes in additional gross margin could be obtained by means of improving the LC by 1 quartile. Next, RE represented 20%. The other KPI included represented approximately the same value (€15 to 20).

CONCLUSIONS

The result from a complex long-term simulation experiment was used to estimate the financial performance of specified key technical performance indicators, measured as gross margin per cow per year. The results from the simulation experiment were condensed into a metamodel to improve user-friendliness compared with the rather complex SimHerd model. The metamodel used data extracted from routinely collected management data to forecast the financial performance related to specified management changes in specific dairy herds characterized by very different sets of key technical performance indicators.

This study indicated that improving the shape of the herd-level lactation curve by 1 quartile was associated with a gross margin increase of up to €227/cow year in a no-quota situation. This was 2.6 times more than improved RE, which increased the gross margin 2.6 to 5.9 times more than improved HM, BCS, mortality, and SCC.

The results showed numerous significant interactions between the different combinations of technical performance indicators. This implies that financial performance related to certain management strategies will depend significantly on the management level in other areas of herd management. This is perhaps the most important finding of this study.

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Paper # II

Random Within-Herd Variation in Financial Performance and Time to Financial Steady-State following Management Changes in the Dairy Herd

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SHORT COMMUNICATION

Random within-herd variation in financial performance and time to financial steady-state following management changes in dairy herd

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Abstract

The manager of a diary herd and the affiliated consultants constantly need to judge whether financial performance of the production system is satisfactory and whether financial performance relates to real (systematic) effects of changes in management. This is no easy task because the dairy herd is a very complex system. Thus, it is difficult to obtain empirical data that allows a valid estimation of the random (within-herd) variation in financial performance corrected for management changes. Thus, simulation seems to be the only option. This study suggests that much caution must be recommended when claming effect of changes in herd management because the link between management changes (cause) and effect (measured as improvement of gross margin per cow year) is extensively blurred by a large within-herd variation in available real life accounting data and differences between herds in time to steady state following management changes.

Keywords: *Financial performance, herd health economics, herd health management, time to steady state.*

Introduction

The manager of a dairy herd and the affiliated consultants constantly need to judge whether financial performance of the production system is satisfactory and whether financial performance relates to real (systematic) effects of changes in management (Kristensen et al., 2008). Such assessments (monitoring) require information about the magnitude of the random (within-herd) variation in financial performance relative to the effect of the key performance indicators (KPI) such as shape of lactation curve, reproduction efficiency heifer management etc. For the reasons that follow it is a complex task to estimate the financial performance associated with changes in management on dairy farms. First, the dairy herd is a very complex system with numerous feed-back mechanisms (e.g. Sørensen, 1990; Enevoldsen et al., 1995). Second, due to the long generation interval in cattle breeding several years may pass before changes in the individual animal's performance affects the financial performance of the herd as a whole (Mourits et al., 1997). Next, during a longer time span numerous other determinants of financial performance change as well (e.g. price level). Consequently, it is likely to be practically impossible to collect empirical data at herd level from a sufficient number of herds and years that will allow a valid comparison of financial performance in herds with different levels of input factors of interest (Dijkhuizen et al., 1995; Seegers et al., 2003). Furthermore, management typically involves biological processes with high uncertainty meaning that perfect information is rarely available (Verstegen et al., 1995). For the same reasons it is also very difficult to obtain empirical data that allows valid estimation of the random (within-herd) variation in financial performance that is corrected for management changes.

Several decision support models for use at the herd level have been developed to solve such problems (Ferguson et al., 2000; Shalloo et al., 2004). Simulation experiments have been widely used to study the effects of various management changes. However, to our knowledge they all provide information about effects when the simulation

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system was assumed to be in steady state. The Monte Carlo type studies provide information about the random (within-herd) variation. In Kristensen et al. (2008) the initial explorative studies on calving interval, cows per year, calf mortality, total milk yield, culling decision, heifers per year, age at first calving, total gross margin, gross margin per cow, total income and total expenses revealed a great time difference between scenarios from onset of simulation until time of steady state following changes in management mimicked by changing the level of KPI. It is obviously of major importance to both farmers and consultants to increase available financial information, e.g. the length of predicted payback time (a consequence of time to financial steady state) and an estimation of the random within-herd variation in financial performance before deciding between costly management changes. The objectives of this study were: 1) to provide an estimate of the random (within-herd) variation in the financial performance in the dairy herd; 2) assess time to financial steady state associated with changes in selected technical KPI in a dairy herd.

Materials and methods

The dataset and the simulation context of this study are identical to the raw data from Kristensen et al. (2008) using SimHerd (Sørensen et al., 1992; Østergaard et al., 2005); a dynamic, mechanistic, and stochastic model predicting the production and states of a herd over time. The stochastic element of the model relates to technical and biological dynamics. The stochastic element of the model relates to the use of random drawings from relevant distributions for simulating individual milk yield capacity and events for the individual animal. The mechanistic part relates to the fact that the model simulates two organizational levels: the animal level and the herd level. Prices were assumed fixed throughout the simulation period. Shape of lactation curve, reproduction efficiency, heifer management, variation between cows in lactation curve persistency, mortality in cows, mortality in calves, dynamics of body condition and Somatic Cell Count (SCC) were varied systematically at level High, Low and Medium representing the 75, 25 and 50 percentile as found in various Danish standard protocols. Because of the model design, Medium was the average of High and Low, i.e. the numerical distance between Low and Medium was equal to the numerical distance between Medium and High. For ease of interpretation High, Low and Medium can be regarded as quartiles within KPI for practically relevant levels of management. According to the model specification KPI were included as fixed effects to estimate the gross margin per year cow:

> Gross margin = Shape of lactation curve$_{\text{(High, Medium, Low)}}$ + Reproduction efficiency$_{\text{(High, Medium, Low)}}$ + Heifer management$_{\text{(High, Medium, Low)}}$ + Variation between cows in lactation curve persistency$_{\text{(High, Medium)}}$ + Mortality in cows$_{\text{(High, Medium)}}$ + Mortality in calves$_{\text{(High, Medium)}}$ + Dynamics of body condition$_{\text{(High, Medium)}}$ + SCC$_{\text{(High, Medium)}}$ + all possible 2-factor interactions plus the 3-factor interaction among: Shape of lactation curve, reproduction efficiency and heifer management.

Accumulation of net present value (NPV) from years 1 to 10 from the default herd (characterized by having all KPI at level Medium as a whole divided by number of cows per year (total number of cow days in a year/365)) was selected as the measure of financial performance, where $NPV = |K_n| \times (1+r)^{-n}$ and $|K_n|$ is the numerical difference between the selected scenario and the default herd measured at the gross margin intercept for year 10; r = interest rate (5%) and n = time to steady state. To measure the magnitude of the random (within-herd) variation in gross margin (GM) the variance components related to the default herd were estimated in a multilevel mixed model with repeated measurements using SAS PROC MIXED (Littell et al., 2006). Thus, the study design was equivalent to an experimental longitudinal study. Each scenario was replicated 200 times to allow estimation of the variance within herds across time. Replications were specified as a random effect and year of simulation as a fixed effect. The intercept of the model was selected as the 10th year of simulation. It was expected that errors could be correlated because the gross margin per cow year was considered to be repeated measurements within each replication. However, several different correlation structures were examined and the correlations were all very low (<0.02 between years) and non-significant ($P>0.5$) using the -2 log likelihood ratio test. Subsequently, gross margin per cow year was regarded to be independent within replication in the analysis. KPI interactions had to comply with both statistical ($P<0.05$) and financial significance (set at €1.33) to be retained in the final model.

Results and discussion

The random (within-replication) variance in gross margin per cow year was 663. That is, the standard deviation of a random annual gross margin per cow year in the default herd with a constant production strategy and constant prices given the study context was €26.

Time to financial steady state following changes in KPI levels are illustrated in Table I.

Steady state was defined as the first year no longer statistically significantly different from year 10 measured by GM. The main effects of KPI were divided in two groups: The default herd; reproduction efficiency High; heifer management; variation between cows in lactation curve persistency; mortality in cows; mortality in calves; body condition score (BCS) and SCC reached steady state in less than five years whereas reproduction efficiency Low and shape of lactation curve needed more than five years to reach steady state. Scenarios, which included changing the level of lactation curve, did not reach financial steady state within the simulated timeframe and reducing the level of variation on slope between cows only shortened time to steady state with one year. If steady state instead was declared by means of a qualitative approach (set at €5) then scenarios heifer management High and mortality in cows High would reach steady state one year earlier.

NPV was included to evaluate the financial effects related to changes in KPI levels. The importance of NPV is illustrated with two examples: The variation between replicates within scenario accounted for 2% of the total variation in the default herd. The final model estimated the gross margin intercept from the default herd in year 10 to DKK11,839 (€1,579). The default herd reached steady state in year 4. The 95% confidence interval for gross margin was calculated from the estimate of the residual variance $11{,}839 \pm 2 \times \sqrt{35{,}116} = €1{,}579 \pm 50$. The confidence interval for gross margin in NPV was: €168 – €179 per year cow. The gross margin intercept in year 10 for the best case scenario (shape of lactation $\text{curve}_{\text{High}} \times$ reproduction $\text{efficiency}_{\text{High}} \times$ heifer $\text{management}_{\text{High}}$) was estimated to €1,806. Steady state was reached after nine years. The covariance parameter estimates accounted for 2.1% of the total variance. The 95% confidence interval for gross margin was €1,806 ± 50. The confidence interval for gross margin in NPV was €151 – €160 per year cow. A qualitative approach was applied to identify the least possible statistical significant

Table I. Time to steady state, intercept at 10th simulation year, residual estimate, variation between replicates within scenario and net present value (NPV) of these management changes.

Scenario specification[1]	Steady state, (year)	Intercept, 10th simulation year, (DKK)	Residual variance	Variation between replicates within scenario (%)	NPV[3] per year cow, DKK
Default herd	4	11,839	35,166	0.019	Default
Shape of lactation $\text{curve}_{\text{High}}$	NS[2]	13,383	33,295	0.014	948
Shape of lactation $\text{curve}_{\text{Low}}$	NS[2]	10,156	31,828	0.026	−1,033
Reproduction $\text{efficiency}_{\text{High}}$	2	11,923	34,540	0.018	76
Reproduction $\text{efficiency}_{\text{Low}}$	8	11,319	59,341	0.180	−352
Heifer $\text{management}_{\text{High}}$	4	11,968	33,627	0.031	106
Heifer $\text{management}_{\text{Low}}$	4	11,835	34,792	0.024	−3
Variation between cows in lactation curve $\text{persistency}_{\text{High}}$	3	11,821	33,636	0.035	−16
Mortality in $\text{cows}_{\text{High}}$	4	11,995	31,043	0.042	128
Mortality in $\text{calves}_{\text{High}}$	4	11,958	35,486	0	98
BCS_{High}	4	11,848	35,077	0.028	7
SCC_{High}	3	11,935	33,263	0.025	83
Reproduction $\text{efficiency}_{\text{High}} \times \text{BCS}_{\text{High}}$	2	11,961	39,550	0.022	111
Shape of lactation $\text{curve}_{\text{High}} \times$ reproduction $\text{efficiency}_{\text{High}} \times$ heifer $\text{management}_{\text{High}}$	9	13,543	35,317	0.021	1,098
Shape of lactation $\text{curve}_{\text{Low}} \times$ reproduction $\text{efficiency}_{\text{Low}} \times$ heifer $\text{management}_{\text{Low}}$	8	9,750	66,728	0	−1,414
Shape of lactation $\text{curve}_{\text{High}} \times$ variation between cows in lactation curve $\text{persistency}_{\text{High}}$	9	13,372	33,853	0.020	988
Shape of lactation $\text{curve}_{\text{Low}} \times$ Variation between cows in lactation curve $\text{persistency}_{\text{High}}$	9	10,166	34,450	0.018	−1,078

[1]Only KPI levels different from $_{\text{Medium}}$ are noted

[2]NS = Gross margin estimate is no longer statistically different ($P < 0.05$) from the gross margin estimate of year 10.

[3]Net present value: $\text{NPV} = |K_n| \times (1+r)^{-n}$, where $|K_n|$ is the numerical difference between the selected scenario and the default herd measured at the gross margin intercept for year 10; r = interest rate (5%) and n = time to steady state.

difference between two scenarios provided the chosen criteria. This revealed that a difference of less than €4 was needed to obtain statistical significance ($P<0.05$) regardless of KPI combination.

If the standard deviation of a random annual gross margin in an average herd with no missing information (a simulation study) in Denmark with a constant production strategy and constant prices is €26 as indicated by the simulation model it follows that a systematic financial effect associated with a change in management at the individual herd level must exceed $2\times$€26 to be statistically significant at the 5% level. This degree of financial uncertainty may seem high. However, from an unpublished observational longitudinal study (S. Østergaard and M. A. Krogh, 2007, private communication) including 77 typical Danish herds (each with two or three years of well-verified production and accounting data) the within-herd standard deviation of gross margin was €248. This estimate of within-herd variation from the field includes unknown systematic effects like changes in prices, quality of silage production, management strategies, errors in data management, etc. We find it impossible to obtain a valid estimate from the field of the true empirical within-herd random variance. Simulation is the only option. The stochastic elements specified in the individual parameters in the SimHerd model are derived from empirical studies, literature and experience from the field. However, in many cases only point estimates are represented in SimHerd, such as parameters in the functions for the reproductive events, and the uncertainty (e.g. related to price level) was not fully represented by hyper-parameters. Consequently, it was likely that the resulting variance of the output from SimHerd underestimated the variance in real farming. Phimister et al. (2004) reported results for within-herd variance from a longitudinal field study. In that study more than 40% of the herds experienced movements in relative income group (quintiles) in consecutive years and 20% moved more than 2 income groups in a year. The empirical within-herd standard deviation of €248 found in the present study implies that much caution must be recommended when claming effect of changes in herd management because the link between management changes (cause) and effect (measured as improvement of gross margin per cow year) is extensively blurred by a large within-herd variation in available real life accounting data. This may explain the apparently unmotivated shifts in income group reported by Phimister et al. (2004). It is necessary for both farmers and consultants to take this element of randomness into account when evaluating the financial performance related changes in management.

Conclusions

The main result of this study was the substantial difference between estimates of time to financial steady state following management changes mimicked by changing the levels of KPI. To qualify the farmer's decision making such information is useful a priori before deciding between management changes that may be mutually exclusive. The dynamic properties of SimHerd allowed illustration and assessment of the dynamics of financial performance in real life explaining why simulation models may be an important tool to support decision making on typical management changes in dairy herds. Additional research is needed to describe other aspects of short-term simulation models to satisfy the farmer's obvious interest in predicted payback time following herd health management investments.

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Paper # III

A Mixed Methods Inquiry into the Validity of Data

E Kristensen, DB Nielsen, LN Jensen, M Vaarst, C Enevoldsen

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Case study

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A mixed methods inquiry into the validity of data

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Abstract

Background: Research in herd health management solely using a quantitative approach may present major challenges to the interpretation of the results, because the humans involved may have responded to their observations based on previous experiences and own beliefs. This challenge can be met through increased awareness and dialogue between researchers and farmers or other stakeholders about the background for data collection related to management and changes in management. By integrating quantitative and qualitative research methods in a mixed methods research approach, the researchers will improve their understanding of this potential bias of the observed data and farms, which will enable them to obtain more useful results of quantitative analyses.

Case description: An example is used to illustrate the potentials of combining quantitative and qualitative approaches to herd health related data analyses. The example is based on two studies on bovine metritis. The first study was a quantitative observational study of risk factors for metritis in Danish dairy cows based on data from the Danish Cattle Database. The other study was a semi-structured interview study involving 20 practicing veterinarians with the aim to gain insight into veterinarians' decision making when collecting and processing data related to metritis.

Discussion and Evaluation: The relations between risk factors and metritis in the first project supported the findings in several other quantitative observational studies; however, the herd incidence risk was highly skewed. There may be simple practical reasons for this, e.g. underreporting and differences in the veterinarians' decision making. Additionally, the interviews in the second project identified several problems with correctness and validity of data regarding the occurrence of metritis because of differences regarding case definitions and thresholds for treatments between veterinarians.

Conclusion: Studies where associations between specific herd health management routines and disease outcome variables are drawn based purely on quantitative observational studies may benefit greatly by adding a qualitative perspective to the quantitative approach as illustrated and discussed in this article. The combined approach requires, besides skills and interdisciplinary collaboration, also openness, reflection and scepticism from the involved scientists, but the benefits may be extended to various contexts both in advisory service and science.

Background

Herd Health Management (HHM) has emerged from veterinary sciences and related fields primarily as a response to the increasing herd sizes [1]. HHM is characterized by the use of knowledge encompassing numerous disciplines, especially epidemiology and veterinary clinical sciences, but also business and herd health economics, law, sociology, psychology and ethics as embedded in philosophy of life and involvement of the farmer [2]. Consequently, professionals working with HHM need to combine knowledge and skills related to cows, housing system, management strategies, human behaviour and all relevant interactions to understand the different stakeholders involved in a dairy setting. This is consistent with the view of Schwabe *et al*. [3]: "In a herd health type situation, field research should be virtually indistinguishable from practice", indicating that the HHM approach in practice is an analytical approach, which involves many different disciplines. Consequently, HHM research must combine diverse types and fields of knowledge and research.

HHM professionals aim at making a difference in the dairy setting in terms of a) improvement of production and b) improvement of life quality for cows, herds, and farmers. As such, a principal interest in HHM is to support decisions on how resources best can be transformed into products which the farmer value. In real life situations the HHM professional therefore continuously has to reassess the criteria, which have been used to decide what is 'optimal'. This is possible, if HHM studies are conducted as field studies involving relevant stakeholders since studies 'in the stable(s)' are unarguably complex, dynamic and contextually diverse [4].

Classical experimental research for the evaluation of HHM programs involving herds with or without intervention of some kind may be problematic in applied and highly diverse settings [5]. The reason for this being that both individual farmers and veterinarians will respond to their observations based on previous experiences and own beliefs and in a way that they perceive as optimal [6]. The consequences of such continuous alterations of stakeholders' responses may be reduced data validity associated with the non-exposed herds in the experimental field studies, as these herds cannot be regarded as static controls throughout the study period.

Quantitative field research can be conducted at the individual herd level, which offers some advantages, as modified from Enevoldsen [7]: 1) it becomes possible to conduct within-herd field studies including classical epidemiological techniques; 2) the researcher is close to the collection and processing of data, which makes it possible to relate data and/or results to changes in management; 3) it allows benchmarking or comparison of production results over time to previous measures from the same herd; and 4) is it possible to combine the herd specific context (interviews and dialogue) expressing the farmer's implicit values and goals with 1–3? This complex situation calls for a continuous innovative development of the solely quantitative approach as suggested by Houe *et al.* [8]. This group of authors suggested a more integrated research approach based on the view that epidemiology often integrates different research disciplines. Integrated research may improve the potential for evolving new research fields and increasing validity, precision and transparency of data and results from HHM programs [7]. Others have reported similar considerations [2,4,9]. Integrated research is also a current trend in the (business) management literature [10] and other parts of agricultural economics [11]. Houe and co-authors [8] call for a 'broader approach'. The objectives of this paper are to demonstrate and discuss the need for integrated research within HHM and to introduce the concept of mixed methods research. A practical example of combining different scientific methods will illustrate how uncertainties and biases in databases can be revealed by integrating explicit knowledge giving the background for the included variables.

Presentation of the quantitative metritis study

In Denmark, there is a legal requirement for all practicing veterinarians to record veterinary treatments (cow identification and diagnosis) whenever drugs regulated by law, e.g. antibiotics or prostaglandins, are administered. All treatments of metritis were therefore assumed to be recorded, and this study aimed at identifying risk factors for cases of metritis treated by a veterinarian. Based on various sources in literature, potential risk factors for metritis were identified, i.e. milk yield, herd size, parity, calving season, breed, other reproductive diseases, digestive disorders, metabolic diseases, nutrition, and age. The objective was to estimate effects of important diseases and other risk factors on the risk of being treated for metritis before 21 days *post partum* utilizing data from the Danish Cattle Database, which stores the treatment records from around 4,600 dairy herds.

The selection criteria for the model were: a) only herds with regular milk control were included; b) only the first registration of a disease diagnosis to be considered a potential risk factor for metritis was included and that registration had to proceed the registration of metritis at cow level or occur the same day; c) the minimum registered incidence rate of disease at herd level was 0.05 treatments per 100 cow years (to reduce the risk of underreporting). Disease registrations from 30 days *ante partum* until 90 days *post partum* from 428,411 calvings occurring from 2003–2005 in 4,647 herds were included in the dataset.

Metritis was defined by a single diagnosis (leading to treatment conducted by the veterinarian) recorded between calving and 21 days *post partum*. It was not possible to distinguish between cases having generalized symptoms (i.e. fever) and cases having only local symptoms (i.e. only vaginal discharge) or whether records came from routine fertility programs or the treatment was due to farmers applying for veterinary assistance.

Presentation of the qualitative interview study on metritis

From a database containing records from routine clinical examinations of fresh cows [7], 71 veterinarians with experience in collecting and processing data according to the 'Danish concept' [12] were identified. In this concept fresh cows are systematically screened, uterine discharge is scored (0–9) and cows are treated for metritis, if they meet the criteria decided in the individual herds. The veterinarians represented 53 different veterinary practices. Twenty veterinarians were randomly selected to participate in a semi-structured interview with the restriction that only one veterinarian per practice could participate in the study. All invited veterinarians accepted the invitation. Interviews were performed by phone and lasted from 10 to 30 minutes and were based on the interview guide in table 1. The interviews focused on the application of criteria for metritis treatment and the metritis scoring system as defined by the 'Danish concept'.

Results from the quantitative metritis study

Approximately 10 percent of the herds had an incidence risk above 18 percent, with a maximum at 39 percent. This indicated that the distribution of the herd incidence risks was highly skewed. The following risk factors were identified in the final model as significantly associated with metritis: Energy corrected milk, herd size, parity, breed, assisted calving, stillbirth, twins, retained placenta, vagin-

Table 1: Interview guide and summaries of the answers of a series of semi-structured interviews.

Questions	Answers from 20 practising veterinarians
1. What percentage of your work is spend working with cattle?	Range from 30–100%
2. How many days *post partum* do you examine the fresh cow?	Fifteen veterinarians performed the clinical examination between 5–12 days *post partum*. Two veterinarians used 4–12 days and three veterinarians used 5–19 days *post partum*.
3. How do you examine the uterus of the fresh cow?	Sixteen veterinarians used vaginal exploration by hand. Two veterinarians only used rectal exploration. Two veterinarians used both vaginal and rectal exploration.
4. Which criteria do you include to diagnose metritis?	Nineteen veterinarians used a standardized metritis scoring system. The last veterinarian used his own scoring system. The nineteen veterinarians used metritis score 5 as a threshold for medical treatment. Three veterinarians consequently used temperature as a diagnostic indicator. Ten veterinarians included temperature on indication (depression, anorexia). Seven veterinarians never used the thermometer. One of these veterinarians explained that he could feel the temperature of the cow during the examination procedure. Another veterinarian told that elevated temperature was indicative to medical treatment.
5. Do you treat all cows according to the same criteria or could there be some considerations that would call for initiation of treatment nonetheless?	Nineteen veterinarians claimed to initiate treatment on identical and repeatable criteria with metritis score 5 as the threshold for medical treatment. However, during the interviews ten veterinarians in retrospect realized that various cow and herd factors (e.g. ketosis, mastitis, reduced milk production, change in behaviour as reported by the farmer, knowledge on metritis problems in the herd or knowledge on a difficult calving) changed their treatment threshold with a range of metritis scores from 4 (three veterinarians); 6 (six veterinarians) and 7 (one veterinarian) for treatment to be initiated.
6. Do you use the score system differently with increasing days in milk?	Four veterinarians said they would treat more aggressively by lowering the threshold for treatment as a consequence of increasing DIM.
7. Do you evaluate the results of the treatments, i.e. control the effect of the treatments?	Nine veterinarians reported that a systematic control effort was unnecessary because of the high success rate in metritis treatment. Nine veterinarians consequently controlled all cows treated at the last visit. Two veterinarians performed controls if the farmer requested it.
8. If you are called to a cow having a badly smelling placenta retained for 4–5 days, how do you then register the case in the Danish Cattle Database?	Twelve veterinarians would register a retained placenta into the database. Two veterinarians motivated this by the price difference between metritis and retained placenta (+ 25%) and that the registrations are combined with the billing system. One veterinarian explained that it was time-consuming to register two diagnoses, so he would only register the retained placenta. Six veterinarians would register a metritis.

itis, prolapsed uterus, milk fever, ketosis, displaced abomasum, indigestion, traumatic reticuloperitonitis, foot disorder and diarrhoea. Details regarding the results are provided in [13], and will not be further discussed in this paper.

Results from the qualitative interview study on metritis

The results of the semi-structured qualitative research interviews are summarized in table 1. Important issues were:

• Scoring system. Nineteen veterinarians used the metritis scoring system described above. One veterinarian used his own scoring system despite the presence of very explicit guidelines.

• Time of clinical examination (defined in the manual in the interval 5–12 days *post partum*): Fifteen veterinarians performed the clinical examination between 5–12 days *post partum*. Two veterinarians examined 4–12 days *post partum* and three veterinarians 5–19 days *post partum*.

• Exploration method (not defined in the manual). Sixteen veterinarians used vaginal exploration by hand; two used rectal exploration and two veterinarians used both vaginal and rectal exploration.

• Body temperature (not a parameter included in the manual). Three veterinarians consistently included temperature as a diagnostic tool. Ten veterinarians included temperature on indication (e.g. depression or anorexia). Seven veterinarians never used the thermometer; however; one of these veterinarians explained that he believed he could feel the temperature of the cow during the examination procedures.

• Threshold for treatment. One veterinarian stated that elevated temperature would always lead to a medical treatment. Nineteen veterinarians used metritis score 5 as an indicator of clinical metritis and thus indicative of medical treatment. During the interviews ten veterinarians retrospectively realized that various cow and herd factors (e.g. ketosis, mastitis, reduced milk production, changes in cow behaviour as reported by the farmer, knowledge on metritis problems in the herd or knowledge on a difficult calving) changed their treatment threshold from 5 to one of the following: 4 (three veterinarians); 6 (six veterinarians) and 7 (one veterinarian) for treatment to be initiated.

• Data processing. Twelve veterinarians would record a smelly placenta not expelled 4–5 days *post partum* as 'retained placenta' in the Danish Cattle Database. Two veterinarians were motivated by the price difference (treatment costs) between a case of metritis and a case of retained placenta (+ 25%) to record it as the latter, and charge for this. One veterinarian explained that it was time-consuming to enter two diagnoses into the database, so he would only record the retained placenta. The remaining six veterinarians normally recorded these findings as a metritis.

Discussion and Evaluation

The relations between risk factors (i.e. retained placenta, parity, milk yield etc.) and metritis in the quantitative research project supported the findings in several other observational quantitative studies [14-16]. However, the results of the semi-structured qualitative interviews already point to potential biases regarding data collection and analyzing data both in purposive sampling and sampling related to routine screenings.

• The veterinarian may examine the cow more carefully if called to attend a "sick" cow.

• The risk of many diseases is higher in early lactation. Consequently, it is likely that more than one disease can be diagnosed. Potential statistical associations may not reflect a biological association between diseases but rather between e.g. lactation stage and disease detection, and therefore reflect bias due to human decision making.

• A veterinarian may initiate medical treatment on basis of an observed predisposing factor such as retained placenta, without actually observing the disease in focus, as indicated in the semi-structured qualitative interview study.

These types of cases cannot be identified in analyses of large databases like the Danish Cattle Database, where medical treatments are recorded irrespective of the farmers' and veterinarians' motivation for treatment and recording. The associations may reflect not only biological relations but also be heavily influenced by decisions taken by the farmer or the veterinarian. The interview results furthermore indicated the presence of herd specific decision making, because most veterinarians included local conditions connected to cow, herd and farmer factors in their decision process. This raises the important issue about what data included in an observational quantitative study actually represents, and it might point to the suggestion that 'the general population of dairy herds' may consist of widely different herds, all subject to individual decision making in their own context. It also points to the important difference between data collected in situations where the farmers and veterinarians focus on a disease outcome and the related risk factors and data collected more 'passively' in relation to disease treatments in different contexts where there is no specific focus on the particular disease. The interview study shows that none of the situations will create uniform data, because perceptions and disease treatment decisions are related to the involved persons. Bartlett and co-authors [17] address this by stating that there is a high variability between veterinarians' diagnostic ability and there is often lack of standardized case definitions. The qualitative research project strongly supports this, and vividly illustrates existing discrepancies in data related to screening of risk animals, also in cases where detailed manuals are expected to standardize the procedures in order to increase comparability of collection and processing of disease data. However, the implicit and individual differences between veterinarians when collecting and processing data may potentially create difficulties when interpreting and inferring across herds. One possible way to handle these contexts related differences would be to perform within-herd experiments, as argued by Enevoldsen [7].

Skewed Herd Incidence Risk

The highly skewed herd incidence risk of metritis based on treatment data is an important finding. Similar skewed distributions were found in studies of clinical mastitis [17,18]. This 'problem' was handled statistically by selecting a distribution that fitted the data [18] or by cutting off the extreme values due to suspected non-compliance "based on the subjective opinion of the investigators' during the data collection phase" [17]. In the quantitative study described here, herds with very low incidence risks were also excluded. However, there may be simple practical reasons for the skewed distribution like underreporting in many herds [17,19] or significant differences in veterinarians' beliefs in the use of diagnostic tools and in thresholds for treatment, i.e. misclassification errors, as shown in the qualitative research project presented above.

The interview study indicated that an unknown proportion of herds in the database were subject to the veterinarians' more or less systematic clinical examinations, because some herds participated in the described extended herd health program and other herds did not. Thus, cows may have been selected for metritis treatment because of the presence of one or more fixed criteria (e.g. smelling discharge) or known occurrence of expected predisposing risk factors. Consequently, at least 2 types of metritis might be represented in the data utilized in the quantitative study; cases that are truly new incidents and cases that are more or less chronic (or subclinical) because they basically are sampled in a cross-sectional protocol. It may be complicated to distinguish between the 2 types of data based on the available information from the Danish Cattle Database.

The Methodological Framework of Mixed Methods Research

Qualitative research methodologies and natural scientific research methods do not have any obvious common philosophical or methodological platform. Generally, qualitative approaches are received with scepticism by the natural scientific community because of an accused subjective nature and the absence of 'facts' [11]. However, in many cases the two approaches are mixed. For example, qualitative research results often include some kind of quasi-statistics to report conclusions [10]. Similarly, much quantitative research includes some kind of literature review that is subsequently modified by (qualitative) expert opinion and value(s) [17]. In other words: any researcher will use his or her background and position to judge and select focus areas for an angle of investigations, appropriate methodologies to answer the research question, and interpreting the results and the framing and communication of scientific claims [20,21]. Consequently, contemporary theory of knowledge acknowledges the effect of a researcher's position and perspectives, and disputes the belief of an unprejudiced observer [22].

Mixed Methods Research (MMR) is defined as an intellectual and practical synthesis based on the combination of qualitative and quantitative research methodologies and results [23]. It recognizes the importance of both quantitative and qualitative research methods but also offers a powerful third mixed research methodology that potentially will provide the most informative, complete, balanced, and useful research results. MMR aims at linking theory and practice [19,24] as illustrated in Figure 1. We believe that an appropriate and well-reflected integration of different scientific methods may contribute significantly to the understanding of any data potentially influenced by human action. In the following, it is suggested that scientists with a need to understand a certain field of human action and the consequences and background of these actions can reach far by implementing different methods in their research, and we point to three different methodologies [10,25]: a) supplementary validation; b) triangulation and c) knowledge generation.

Supplementary Validation

An important use of MMR is to expand primarily qualitative (in particular) or quantitative studies by including other types of scientific methods and data in order to improve and justify a broader understanding of the nature of the results of the studies. Understanding the occurrence of metritis may benefit greatly by supplementary validation, as clearly illustrated by the examples given above. This approach seems to be neglected in most HHM-related publications. This might be understandable, because quantitative observational studies often do not include primary data collection of both qualitative and quantitative nature. Consequently, supplementary validation may often be regarded as 'extra work', i.e. visiting farms again. This paper is an example of supplementary validation.

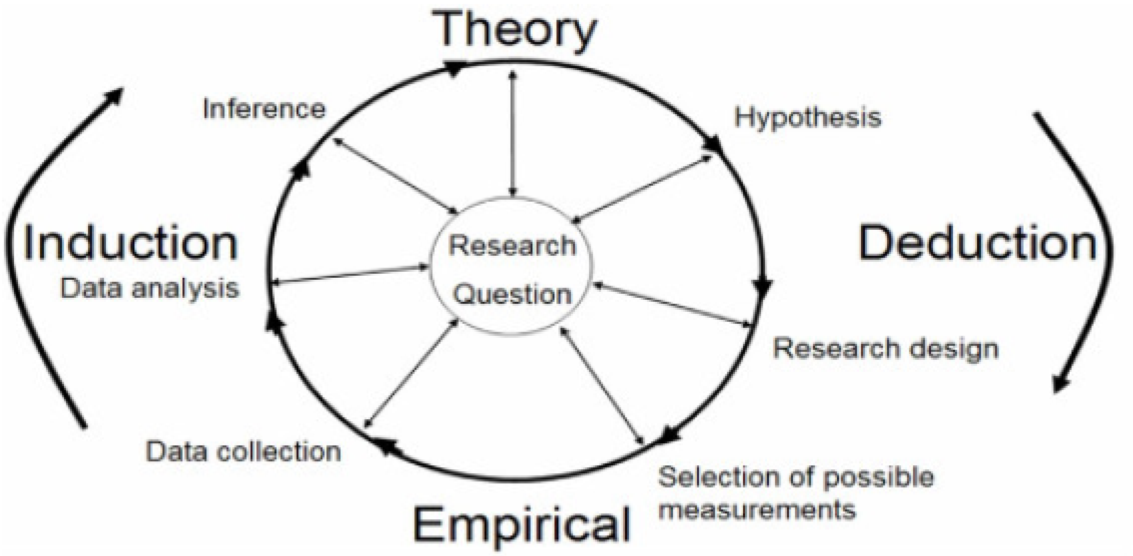

Figure 1
Conceptual model of the iterative process of induction and deduction in Herd Health Management. Modified from [19] with inspiration from [2,31].

Triangulation
The classical definition of triangulation requires that identical findings are reported from separate studies, preferably through different scientific methods [26,27]. Research projects using multiple methods for the purpose of triangulation are characterised by the following two factors: a) the emphasis on testing the same hypothesis multiple times, using different methods in each iteration and b) the focus on aggregating knowledge, rather than on discovering new relationships. That is, each component of a triangulation research project independently illustrates the central argument of the research [25]. The relationship between the component studies is one of joint reinforcement; each component can stand alone, but make a stronger argument in combination. Essentially, this is what happens in the 'Discussion' section of most manuscripts when the (experimental) results are (qualitatively) compared by the authors to previous results reported in literature.

Knowledge Generation
Herd health management is characterized by an iterative process of refinement of concepts and propositions [2,19]. The initial inductive approach to formulate questions is typical for the iterative process of HHM. Next, the inductive and deductive analyses are mixed [25]. When an epidemiological pattern or a theory has been inductively identified from experimental observations, a hypothesis can be deduced and submitted to testing. The aim of this test would be to reject or accept the generated knowledge in this hypothesis. Consequently, the iterative processes provide new research questions and strengthen conclusions related to the involvement of stakeholders. The multiple stages of inquiry aiming at reframing questions, reconstructing instruments, reanalyzing data and refining interpretations and conclusions all form part of this iterative process. With a mixed design, the different methods are combined into a coherent whole making the evaluation of results a synthesis of all the study data and less a report of findings from each method separately. Mixed designs are generative, yield new insight, or redirect research questions [28].

The Contribution of Mixed Methods Research in Herd Health Management Studies
Mixed Methods Research is called for in HHM studies to incorporate both perceptions of life and values embedded in the individual dairy setting [7]. As such, MMR requires openness to different views, approaches and perspectives in order to avoid creating barriers to new knowledge [11], including profound modes of thinking and valuing [29]. Disciplines like psychology, sociology, economics and marketing may offer new methodological approaches to the scientific field of HHM. These disciplines have long understood that accounting for individual differences is central to understand the stimulus for change, i.e. 'know thy customer' [30]. This does not imply that HMM professionals should be transformed into social scientists or visa

versa, but rather that HHM research may be likely to benefit from a broader approach.

Acknowledgement is needed to the fact that no single research methodology can produce results that are universally transferable and directly applicable without adjustments, when applied in a completely different context [17,22]. This study demonstrates the validity of this statement with regard to the discipline of HHM by example. To understand the actions or preferences of stakeholders [9,21] and approach the diversity of farmers, herds and veterinarians in a scientific manner, the option of conducting farm studies, where more aspects of the herd as well as the human decision making, seems obviously relevant. The results from the two studies on metritis jointly points to the fact that data validity remains a constant challenge.

Conclusion

Studies where associations between specific herd health management routines and disease outcome variables are based purely on quantitative observational studies multi-herd databases may benefit greatly by adding a qualitative perspective to the quantitative approach as illustrated and discussed in this paper. The combined approach requires besides skills and interdisciplinary collaboration also openness, reflection and scepticism from the involved scientists, but the benefits may be extended to various contexts both in advisory service and science. The need to understand the preferences of stakeholders and the diversity between farmers, herds and veterinarians by combining the strengths of quantitative and qualitative methods and to identify promising solutions to ensure data validity in applied settings remains a constant but rewarding challenge.

Abbreviations

HHM: Herd health management; MMR: Mixed methods research.

Competing interests

The authors declare that they have no competing interests.

Authors' contributions

LNJ collected and analysed the data. EK did the literature review, drafted the manuscript and coordinated among authors. DBN, MV and CE made substantial contributions to the conceptual ideas and revision of the manuscript for important intellectual content in detail. All authors read and approved the final manuscript.

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Paper # IV

A Mixed Methods Inquiry:
How Dairy Farmers perceive the Value(s) of their Involvement in
An Intensive Dairy Herd Health Management Program

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A mixed methods inquiry: How dairy farmers perceive the value(s) of their involvement in an intensive dairy herd health management program

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Abstract

Background

Research has been scarce when it comes to the motivational and behavioral sides of farmers' expectations related to dairy herd health management programs. The objectives of this study were to explore farmers' expectations related to participation in a health management program by: 1) identifying important ambitions, goals and subjective well-being among farmers, 2) submitting those data to a quantitative analysis thereby characterizing perspective(s) of value added by health management programs among farmers; and 3) to characterize perceptions of farmers' goals among veterinarians.

Methods

The subject was initially explored by means of literature, interviews and discussions with farmers, herd health management consultants and researchers to provide an understanding (a concourse) of the research entity. The concourse was then broken down into 46 statements. Sixteen Danish dairy farmers and 18 veterinarians associated with one large nationwide veterinary practice were asked to rank the 46 statements that defined the concourse. Next, a principal component analysis was applied to identify correlated statements and thus families of perspectives between respondents. Q-methodology was utilized to represent each of the statements by one row and each respondent by one column in the matrix. A subset of the farmers participated in a series of semi-structured interviews to face-validate the concourse and to discuss subjects like animal welfare, veterinarians' competences as experienced by the farmers and time constraints in the farmers' everyday life.

Results

Farmers' views could be described by four families of perspectives: Teamwork, Animal welfare, Knowledge dissemination, and Production. Veterinarians believed that farmers' primary focus was on production and profit, however, farmers' valued teamwork and animal welfare more.

Conclusion

The veterinarians in this study appear to focus too much on financial performance and increased production when compared to most of the participating farmers' expectations. On the other hand veterinarians did not focus enough on the major products, which farmers really wanted to buy, i.e. teamwork and animal welfare. Consequently, disciplines like sociology, economics and marketing may offer new methodological

approaches to veterinarians as these disciplines have understood that accounting for individual differences is central to motivate change, i.e. ‘know thy customer’.

Background

More than two decades have passed since Bigras-Poulin and co-authors [1] in a classical paper demonstrated that the farmer’s socio-psychological characteristics are more important to farm performance than the herd level variables describing production, health and fertility. The perspective brought forth by Bigras-Poulin *et al*. finds support in other scientific fields like management, rural sociology and economic psychology. These disciplines acknowledge that people take actions for a variety of reasons like relative income standing [2], risk aversion [3], a feeling of uncertainty [4], employee satisfaction [5] and subjective well-being [6]. Nonetheless, research has remained scarce in veterinary science when it comes to the motivational and behavioral side of farmers’ perspectives and overall decision utility in relation to disease and health [7], perhaps because it is complex, context-related, and contains elements that cannot be addressed with the research methodologies usually applied in veterinary science?

Studying farmers’ expectations and subsequent valuation when participating in a herd health management (HHM) programs requires an interdisciplinary approach [8,9,10,11]. This is needed to understand the variables, relationships, dynamics and objectives forming the dairy farm context, e.g. time-dependent variables related to cows and herd(s) as well as variables dealing with the farmer’s goals and attitudes.

The distribution of limited resources between herd health and production and between overall farm performance and personal leisure and preferences sums up to a very complex and farm specific equation or context. Choices in this equation reveal preferences and define decision utility. Thus, studying farmers’ choices may reveal farmers’ expectations from participating in a HHM program. However, farmers’ decision making is obviously not confined to herd health, explaining why the level of investment in management systems may not always be the ‘optimal’ level [12].

The objectives of this study were to study farmers’ expectations related to participation in a HHM program by: 1) identifying important ambitions, goals and subjective well-being among farmers, 2) submitting those data to a quantitative analysis thereby characterizing perspective(s) of value added by health management programs among farmers; and 3) to characterize perceptions of farmers’ goals among veterinarians.

Methods

Q-factor analysis

In this study we needed to address the dairy farmers' subjective points of view and the veterinarians' perception of dairy farmers' points of view. The question was: How do dairy farmers perceive the value(s) of their involvement in an intensive dairy herd health management program?

The core research tool of this study was Q-methodology, which was first described by Stephenson [13] and provides a foundation for the systematic study of subjectivity, that is, 'a person's viewpoint, opinion, beliefs, attitude, and the like' [14]. Consequently, Q-methodology does not aim at estimating proportions of different views held by the 'farmer population' (this would require a survey). Rather, Q identifies qualitative categories of thought shared by groups of respondents, i.e. farmers.

We followed the guidelines described by van Exel and Graaf [15], who divide the approach into the following steps:

1. Construction of the concourse
2. Development of the Q-set
3. Selection of the P-set
4. Q-sorting
5. Q-factor analysis

1. Construction of the concourse. In Q-methodology a 'concourse' refers to 'the flow of communicability surrounding any topic' [14]. The concourse is a technical concept for a contextual structure of all the possible statements that respondents might make about their personal views on the research question. In this study, the concourse was constructed by the authors' reflections on viewpoints in literature, our experience, and previous interviews and discussions with dairy farmers, veterinarians and researchers. This concourse supposedly contains the relevant aspects of all the discourses and thus forms the raw material for Q-methodology.

2. Development of the Q-set. The concourse is subsequently broken down into answers or statements that potentially could answer the research question (Table 1). Next, a subset of statements is drawn from the concourse (labeled the Q-set). The selection may be based on existing hypotheses or theory. The Q-set should include statements that are contextually different from one another in order to ensure a broad representation of points of view in the Q-set [16]. In this study all the 46 statements derived from the concourse were included in the Q-set to keep as broad a representation of points of view as possible.

3. Selection of the P-set. The P-set is a sample of respondents, which is theoretically relevant to the research question, i.e. it represents persons who probably will have clear and distinct viewpoints on the subject and, because of that quality, may define a factor [15]. Sixteen farmers were selected from a group of Danish dairy farmers managing conventional dairy enterprises and being clients in a single large nationwide cattle practice and participating in a recently developed intensive HHM program. Farmers were selected that we expected would provide breath and comprehensiveness to the P-set (Table 2) thereby acknowledging that the P-set is not supposed to be random [17]. The selected farmers (the P-set) were invited to participate in the study by a covering letter, an additional page describing the 'conditions of instruction' [14], an empty layout guide and a stamped envelope for the returning of the layout guide. Farmers did not receive any compensation for their participation.

4. Q-sorting. Respondents (P-set) were asked to rank (Q-sort) the statements (Q-set) according to their own point of view with minimum interference from our part. The fact, that the farmers ranked the statements from their own point of view and not according to 'facts', is what brings the subjectivity into the study. The statements were sorted on the layout guide along a quasi-normal distribution (mean 0, SD 2.67) ranging from 'agree mostly' (+5) to 'disagree mostly' (-5). Each of the statements was typed on a separate card and marked with a random number for identification.

During a continuing education course in November 2007, 18 experienced veterinarians associated with the abovementioned cattle practice sorted the same statements in a similar manner as the farmers. Here, the 'conditions of instructions' were delivered in a short oral presentation.

5. Q-factor analysis. The returned Q-sortings from the farmers and veterinarians were analyzed separately by means of the PC-program 'PQMethod' [18] that is tailored to the requirements of Q-methodology. Specifically, 'PQMethod' allows easy entering of data the way it was obtained, i.e. as 'piles' of statement numbers. 'PQMethod' computes correlations among the respondents (the variables or columns in the data matrix) that were characterized by the Q-sorting. That is, each of the 46 statements was represented by one row in the matrix. This is equivalent to reversing the correlation matrix used in traditional 'R-factor analysis', which is based on correlations between variables characterizing respondents. Respondents, who are highly correlated with respect to their ranking of statements, are considered to have a ‘familiar’ resemblance, i.e. those statements belonging to one family being less correlated with statements of other families. A principal component analysis was chosen in ‘PQMethod’ to estimate the total explained variance and the variance attributable to each identified factor (family of perspective). Following a commonly applied rule for including number of factors, factors with eigenvalues smaller than 1.00 were disregarded. A factor loading was determined for each respondent as an expression of which respondents were associated with each factor and to what degree. Loadings are correlation coefficients between respondents and factors. The remaining factors were subjected to a varimax (orthogonal) rotation to provide the rotated factor loadings (Table 3).

The final step before describing and interpreting the factors was the estimation of factor scores and difference scores. A statement’s factor score is the normalized weighted average statement score of respondents that define that factor. The weight (w) is based on the respondent’s factor loading (f) and is calculated as: $w = f / (1-f^2)$. The weighted average statement score is then normalized (with a mean of 0.00 and SD = 1.00) to remove the effect of differences in number of defining respondents per factor thereby making the statements’ factor scores comparable across factors. Thus, we take into account that some respondents are closer associated with the factor than others by constructing an idealized Q-sorting for each factor. The idealized Q-sorting of a factor may consequently be viewed as how a hypothetical respondent with a 100% loading on that factor would have ranked all the statements on the layout guide. The idealized layout guides for each family of farmers’ perspectives are provided in Table 1. The difference score is the magnitude of difference between a statement’s score on any two factors that is required for it to be statistically significant. ‘PQMethod’ offers the possibility to identify the most distinguishing statements for each family of perspectives, i.e. when a respondent’s factor loading exceeds a certain limit (often based on $P < 0.05$) and consensus statements between the families of perspectives, i.e. those that do not distinguish between any pair of families [15]. The limit for statistical significance of a factor loading is calculated as: Factor loading / (1 divided by the square root of the number of statements in the Q-set) [15]. If this ratio exceeds 1.96, the loading was regarded as statistically significant ($P < 0.05$). The idealized Q-sortings were assigned with informative names (labels) with input from both the most distinguishing statements for family of perspective and the consensus statements. The process of giving names to the idealized Q-sortings according to its characteristics may serve to facilitate the discussion and communication of the findings [19].

The semi-structured interviews

All farmers in the P-set were invited to participate in an interview to elaborate on their preferences as expressed by the placing of the statements on the layout guide and 12 farmers accepted the invitation. All farmers were men and managed conventional farms, all free-stalls. Additional herd characteristics are listed in Table 2. Veterinarians were not interviewed due to budget and time constraints. The first farmer accepting the invitation was defined to serve as a pre-test for the interview approach (leading to minor adjustments). This interview was eliminated from the data. The qualitative study therefore consisted of 11 interviews. Consequently, the entire data collection process was as follows: First, veterinarians face-validated the contextual structure of the concourse during the common Q-sorting session. Second, pre-testing was performed. Third, farmers sorted the Q-set and returned the layout guides. Fourth, the contextual structure of the concourse and the results from the individual Q-sortings were face-validated by the farmers during the interviews. Further, the interviews offered an opportunity to confirm farmers' understanding of the sorting technique and correct any misunderstandings. No misunderstandings were identified. Fifth, following the face-validation of the concourse each interview session with the 11 farmers included three thematic questions:

- What about animal welfare and herd health?
- Assume that you have an extra hour every day (i.e. the 25th hour) what would you do? – Increase the herd size, improve management or increase leisure time?
- Assuming you have a farm board: Would your practicing veterinarian be a member? – why/why not?

The interviews followed the approach described by Vaarst *et al.* [9] and lasted between 65 and 80 minutes. Interviews were digitally recorded and all interviews were administered (January to March, 2008) by the first author. The interviews were analyzed according to the inductive approach discussed by Kristensen *et al.* [8] for HHM research with inspiration from [20] on how to interpret a series of interviews with the intent to provide insight into a phenomenon of more general interest, e.g. to facilitate 'multivoices' [21].

Results

Q-factor analysis

The concourse was a primary result. Essentially, both farmers and veterinarians accepted the concourse by face-validation, i.e. farmers before the interview sessions and veterinarians before and during the sorting process. Four families of farmers' perspectives (idealized Q-sorts) were identified with the Q-factor analysis. They explained a total of 65% of the variance between farmers. Table 4 illustrates the most distinguishing statements ($P < 0.05$) for each family of perspectives. Consensus statements (non-significant at $P > 0.05$) were: 1, 2, 4, 6, 8, 10, 15, 18, 21, 23, 31, 35, 37, 43, and 45. These statements were considered equally revelatory by virtue of their salience, i.e. none of the farmers placed much value on these statements be it positive or negative value.

Ranking of statements by idealized factor scores combined with the insight obtained from both the most distinguishing statements and the consensus statements were submitted to a qualitative analysis with the insight obtained by the first author during the series of interviews into the farmers' lived experiences, perspectives and expectations. The purpose of this analysis was to construct informative names (labels) to each identified family of farmers' perspectives. The selected names to describe families of farmers' perspectives were (in decreasing order by explained variance, see Table 1):

- Teamwork
- Animal welfare
- Knowledge dissemination
- Production

Equally, four families of veterinarians' beliefs on farmers' perspectives were identified explaining a total of 69% of variance. Informative names were identified by means of a qualitative analysis of the results, i.e. combining the idealized Q-sorts and the five most preferred statements from each family of veterinarians' perception of farmers' perspectives (not shown). It was realized that the family names from the farmers' families of perspectives could be re-used as 'PQMethod' identified a number of veterinarians' families of perspectives equal to the families of farmers' perspectives. The families of veterinarians' perception of farmers' perspectives explained 48%, 9%, 6% and 6% of variance for families Production, Animal welfare, Knowledge dissemination and Teamwork, respectively.

The semi-structured interviews

The raised question regarding animal welfare and herd health (AWHH) divided farmers into two points of view. Farmers associated with the first viewpoint explained their interest in AWHH primarily as a consequence of society's scepticism towards the production system of dairy industry as experienced by the farmers, i.e. *'people are watching us'* and *'society thinks, that farmers are the kind of people that beat up animals'*. Farmers sharing the second viewpoint believed that HHM was an important tool to increase

AWHH. These farmers explained that an increase of AWHH was an inevitable consequence of the HHM program. However, the follow-up question: *‘Why do you value AWHH’* revealed that farmers associated with the second viewpoint had to be divided into two sub-views to be meaningfully described. The farmers belonging to the first sub-viewpoint placed value on AWHH because of the farmers’ firm belief that AWHH is a precondition to increase the overall farm production, i.e. *‘I tell you, animal welfare and economy is really closely connected. The reason that I care about animal welfare is because it is a financially reasonable way to do things’* and *‘it’s obvious that we are quite interested in increasing animal welfare because it will improve the financial bottom-line in the long run’*. Farmers sharing the second sub-viewpoint experienced AWHH to hold a unique value associated with their subjective well-being. These farmers emphasized a feeling of personal satisfaction related to being around healthy animals, providing the farmers with a feeling of ‘a job well done’, i.e. *‘animal welfare reflects other values in our lives’* and *‘I have a philosophy on animal welfare; the day I can’t tend to each cow as well as the time I had twenty, then I have too many cows’*. Farmers from both sub-viewpoints stated (even though it was not a specific question) that AWHH and the cost of the HHM program had to compete for limited resources (primarily time and money) with other investment opportunities (e.g. the dairy business, the farmer’s subjective well-being related to values provided by the HHM program, family) both on and off the farm in terms of expected return on investment.

The second thematic question related to farmers’ time-budget. We suggested that each farmer was given an extra hour every day, i.e. the 25th hour. Farmers were divided into four points of view based on their different viewpoint on how to spend this extra time: 1) Farmers associated with the first viewpoint wanted to increase leisure time. The explanations were primarily found within two subjects: Family; *‘it is really important to me that I am a visible dad‘*; Daily stress: *‘I constantly feel that my presence is needed; therefore I have an unsatisfied need to experience freedom’*; 2) The second viewpoint included farmers that clearly stated they would choose to increase management within the present framework of the dairy farm, i.e. *‘I would try to correct the errors that I do not have the time to at the moment’* and *‘one extra hour is not enough at all. There are so many things in my daily work that I could improve – but I do not have the time’*. Some of the farmers related to the second viewpoint elaborated on the question and explained that they would have liked to answer ‘family’, however, realities were likely to be different, i.e. *‘looking at myself, I sometimes feel that I should have spent more time with my family, you know, gone with the kids to soccer, but I also know that if this 25th hour was really true, I would probably not follow the kids, but go into stable and try to improve something – even though it really wasn’t, what I wanted to do’*; 3) Farmers from the third viewpoint asked if it was an acceptable answer to increase management with the intent to provide a basis for a near-future expansion of the herd size; 4) Last, farmers sharing the fourth viewpoint stated that given extra time they would buy more cows *'because an increasing number of cows leads to an increasing number of employees, making it possible to run the farm without my daily presence'*. From all of the abovementioned viewpoints a common viewpoint could be summarized: It is necessary that veterinarians include opportunity time in addition to a strict focus on profitability (and welfare?) when proposing recommendations.

It was the farmers' experience that veterinarians knew almost nothing about herd health economics, finances in general or strategy related to running a business. However, the farmers expressed a willingness to buy such a service if provided by a veterinarian able to combining the classical veterinary disciplines with management, strategy and finances.

Discussion

Validity of results

The objective of this study was not to generalize possible findings to the whole population of farmers or veterinarians but to obtain insight into a phenomenon as experienced by a range of individuals selected for this study because of their 'information richness' [22]. Consequently, results are only directly applicable to the particular participants, settings and contexts [23]. However, the active participation of the end-users, i.e. farmers and veterinarians, in the modeling-validating process is emphasized as an important part of the usefulness dimension of validity in operations research [24]. Further, we have taken into consideration the length of the interviews and the number of interviewees to increase the likelihood of data saturation as discussed by Onwuegbuzie and Leech [23]. These authors studied literature and have presented a sample size guideline to qualitative research. In phenomenological research 6-10 interviewees are recommended when homogeneous samples are selected for interviews. We regard our sample as homogenous because all the participating farmers are associated with the same veterinary practice and have chosen to be involved in the same intensive HHM program. Additionally, Onwuegbuzie and Leech [23] present their reflections regarding the importance of the length of each contact to reach informational redundancy. The length of our interviews followed the description by both Vaarst *et al*. [9] and Onwuegbuzie and Leech [23]. Morse [25] defines the concept of 'saturation' in qualitative data as 'data adequacy' and adds that it is 'operationalized as collecting data until no new information is obtained'. Consequently, the face-validation of the concourse by farmers and veterinarians may be seen as an acceptance of a 'saturation' of perceptions of the Q-set providing the data with ‘interpretive sufficiency’ to take into account the multiple interpretations of life [26].

Q-Methodology is about respondents ranking matters of opinion within a concourse to identify the existence of families of perspectives. Consequently, the results of a Q-factor analysis is useful to identify and describe a population of viewpoints and not, as in R, a population of people [27]. The difference between Q and R being that the issue of large numbers, so fundamental to R, becomes rather unimportant in Q [16]. The most important type of reliability for Q is replicability: Will the same ‘condition of instruction’ lead to factors that are schematically reliable, that is, represent similar families of perspectives on the topic? [15]. In contrast to most studies, Q-studies cannot obtain ‘true replication’ because: 1) an identical set of participants, contexts and experiences is impossible to find and; 2) the concourse as it expresses itself in a Q-study becomes context-bound to the particular participants, settings and contexts. It follows that the present Q-study could not be replicated with the same farmers as participants because these farmers were likely to have reflected on the Q-sorting and the interviews making them ‘different persons’ than in the beginning of the study. Thomas and Baas [28] concluded that scepticism related to the issue of reliability is unwarranted as the objective in Q-studies is to reach an in-depth understanding of the context in question and thus requires an equally in-depth understanding of a different context to draw possible inferences between the two different contexts. The results of a Q-study are the distinct families of perspectives on a topic (as described by the concourse) that are operant, not the percentage of the sample (or the general population) that adheres to any of them. This would require a (questionnaire) study of a representative sample of people and such a study could be relevant as a follow-up to this study. ‘Quality is operationally distinct from quantity’ [16]. Consequently, the required number of respondents to establish the existence of a factor is substantially reduced for the purpose of comparing one factor with another compared to traditional R statistics [15].

General Discussion

In this study farmers’ statements could meaningfully be placed into four groups with distinctly identified differences related to the individual farmers’ perception of value added by a HHM program. Maybery and co-authors [29] applied a different technique but reported analogous findings in a study on economic instruments and common good interventions in Australia. Kiernan and Heinrichs [19] discussed how information on similarities between groups of farmers may be utilized by veterinarians to increase the effectiveness of management programs.

The Q-factor analysis divided farmers' perspective on HHM programs labeled as: Teamwork, Animal welfare, Knowledge dissemination and Production, respectively. Veterinarians believed the correct order to be: Production; Animal welfare; Knowledge dissemination and Teamwork, respectively. It follows that the veterinarians' perception of farmers' perspective as compared to the farmers' expectations were quite different. From the explained variances it follows that most farmers are correlated with Teamwork and most veterinarians are correlated with Production. Potentially, this difference may lead to differences of opinion when the farmer and veterinarian, respectively, evaluate the impact or success of a HHM program. The veterinarian believes that the success criterion is increased production and subsequent profit whereas the farmer expects to be part of a team working with shared ambitions and common goals.

Farmers focusing on AWHH were divided between those focusing on an expected correlation between increases in AWHH and financial performance and those focusing on a feeling of increased subjective well-being from being around healthy cows. This is an important finding, which is also discussed in details by Kristensen *et al*. [30] illustrating how 'qualitative studies can be added to quantitative ones to gain better understanding of the meaning and implications of the findings' [31].

This study has provided evidence that it is unlikely that (all) the time saved due to systematic work procedures implemented by a HHM program is re-invested in production to increase financial performance. Obviously, the potential increase in financial performance is not realized if time is allocated towards leisure and away from production. Trying to understand and predict human behavior primarily on monetary incentives is problematic [2,32] as income only explains about 2-5% of the variance related to measures of subjective well-being [6]. Further, farmers' decision making obviously is not confined to herd health [33]. In practice, the level of investment in management systems will never be the 'optimal' solution from a herd health perspective, because 1) investment prospects are better elsewhere [12]; 2) value added to overall financial performance is measured by a different currency than money [7]; and 3) short-term gains are valued more than a possible larger future gain predicted by a model or a HHM program [6].

A marked discrepancy was identified between the family of veterinarians that focused on production and how farmers view the veterinarians' competences in areas like business, farm management etc. Most veterinarians correlated with production; however, none of the farmers would ask their veterinarian to sit in a farm board because of what the farmers perceived as a general lack of knowledge on farm management and a more specific lack of knowledge on strategy and finances. De Kruif and Opsomer [34] report similar findings. The farmers, however, expressed an interest in buying such a service if provided by an experienced veterinarian able of combining the classic veterinary disciplines with the disciplines of business and management. The overall impression from the interviews was that farmers view their affiliated veterinarian as a ‘master’ of the classical veterinary virtues (diagnostics and treatment at cow-level and to some extent herd-level) but much less qualified to handle the management aspects of HHM consultancy. This finding may be important to veterinary schools, as changes in the educational structure towards ‘whole farm’ management seem warranted.

Implications of results to the herd health management community

To date, most research on subjective well-being has focused on the well-being of the individual, i.e. the farmer [35]. This study suggests that there may be good reasons to draw veterinarians’ attention to the overall well-being of the farmer’s household.

Where to go from here? If different farmers are motivated by very different factors then a stereotype ‘one-size-fits-all’ approach from veterinarians to stimulate improvements of management obviously is unlikely to succeed. The veterinarians in this study appear to focus too much on financial performance and increased production when compared to farmers’ expectations. On the other hand veterinarians apparently did not focus enough on a major product, which farmers really wanted to buy, i.e. teamwork and whole farm management. Consequently, disciplines like sociology, economics and marketing may offer new methodological approaches to scientists and veterinarians as these disciplines have long been based on the understanding that accounting for individual differences is central to understand the stimulus for change, i.e. ‘know thy customer’ [29].

Conclusions

Farmers’ expectations related to a HHM program could be divided into four families: Teamwork was most important followed by Animal welfare, Knowledge dissemination, and Production. Animal welfare was highly valued by farmers, but for varying reasons. In contrast, the dominant view of veterinarians was that farmers focused mainly on production and financial performance and least on the value of teamwork. Farmers, however, perceived veterinarians as largely incompetent in areas like finances and business management and would not invite their veterinarian to be a member of their farm board. These differences of perspectives and thus expectations to value added by a management program between farmers and veterinarians have implications for the future herd health management research and education. If dairy farmers value teamwork more than production and profit, as indicated by this study, veterinarians would be wise to change their focus or increase their abilities in combining veterinary science with knowledge on management and finances as this service was requested by, but apparently not available to, the dairy farmers. Equally, changes in pre-graduate veterinary education directed towards ‘whole farm’ management seem warranted.

Abbreviation

HHM = Herd health management

AWHH = Animal welfare and herd health

Competing interests

The authors declare that they have no competing interests.

Authors' contributions

EK collected and analysed the data, did the literature review and drafted the manuscript. CE made substantial contributions to the conceptual ideas and revision of the manuscript for important intellectual content in detail. Both authors read and approved the final manuscript.

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Tables

Table 1. The idealized (weighted and normalized) Q-sorting within each family of farmers' perspectives, i.e. how a hypothetical respondent with a 100% loading on that factor would rank all the statements according to the guide for ranking

	Statements derived from the concourse[1]	Family 1: Team work	Family 2: Animal welfare	Family 3: Knowledge	Family 4: Production
1	I make more money with the management program	2	0	2	0
2	Team spirit increases in the dairy setting	1	-1	-1	3
3	It makes antibiotics more available	-1	4	-1	0
4	It is an insurance of the production level	-1	-1	0	2
5	I like to be 'up front'	-3	-1	4	-1
6	I can outsource the responsibility of herd health	-3	-4	-4	-3
7	It gives the vet a chance to prove his worth	-2	-3	-2	3
8	Future insurance: The vet knows me and the herd	0	0	2	0
9	I want to make a contribution to develop the advisory service	-3	0	0	4
10	Reproduction increases	3	3	0	2
11	I get whole-farm consultancy	1	-2	2	1
12	A high management level in the stable vs. grazing	-1	0	-5	-5
13	It is preferable to the image of dairy industry – and me	-2	2	-3	2
14	Incidence of disease decreases	0	3	-3	-2
15	The vet and I share responsibility regarding herd health	-2	-1	-3	0
16	The vet updates me on the newest knowledge	-1	1	5	-2
17	More cows can be treated without paying the vet	-2	4	-2	-5
18	I like that only one vet works with me and my herd	1	3	1	4
19	Yield increases	4	1	-1	1
20	I work more systematically, when someone checks up on me	0	-2	0	-4
21	The vet has more experience than me	0	0	1	0
22	My understanding of herd dynamics as a whole increases	-1	-1	3	1
23	The vet and I work better together	4	2	1	3
24	My financial lenders requested it	-5	-5	-4	-1
25	The vet made me an offer I could not refuse	-5	-2	-5	-2
26	It is necessary for me to take in the herd size	2	-3	3	0
27	Incidence of mastitis decreases	0	3	-3	-1
28	Nothing is missed – and it increases joy in my work life	1	1	-2	-2
29	I need a loyal and independent advisor to spar with	1	-1	4	-4
30	It enhances the business aspect of my herd	-4	-3	3	-1
31	It was recommended to me (by farmers, consultant)	-4	-5	-4	-3
32	Incidence of dead animals decreases	2	-4	-2	-4
33	The vet said it was a good idea	-3	2	3	-1
34	It is a current trend – and I like new ideas	-4	-3	5	-1
35	The vet helps to educate my staff	-1	-2	-2	1
36	The vet bill decreases in the long run	0	1	2	-3
37	It gives me an opportunity to evaluate the effect of interventions	1	2	2	2
38	My knowledge on cows and herd increases	3	-2	-1	5
39	The vet is more enthusiastic regarding my problems	4	-4	0	-2
40	The vet helps to put up relevant performance indicators	3	0	4	1
41	I prefer prevention to treatment	5	5	0	4
42	The vet gets deep insight into the herd – better advices	5	1	1	2
43	I can exploit the vets knowledge more systematically	3	2	1	3

44	Time is saved due to systematic work procedures	2	1	-1	5
45	Animal welfare and herd health increases	2	4	1	1
46	Extended HHM programs reduce the use of antibiotics	-2	5	-1	-3
% variance attributable to each family of farmers' perspectives (unrotated factors(rotated factors))		37/22	12/18	9/13	7/12

[1] A concourse is a 'view of the world' constructed by the researcher from various sources of data. In Q-methodology the concourse is broken down by the researcher into a number of statements that respondents rank according to 'my point of view', i.e. how well the individual statement presents an answer to the research question

Table 2. Summary of characteristics of the herds of the farmers participating in the semi-structured interviews

Characteristics	1	2	3	4	5	6	7	8	9	10	11
Cows per year[1], n	105	140	115	123	161	141	106	137	92	141	182
ECM per cow per year, kg	8,908	9,932	8,276	7,943	9,847	9,420	8,898	10,050	10,712	10,023	9,722
Age at 1st calving, Months	25,3	25,4	28,7	26,0	27,9	25,9	25,7	25,7	25,5	26,3	24,9
Culling-rate[2]	30	48	37	73	34	30	38	40	36	59	52
Bulk tank somatic cell count, 1000 per ml	220	216	385	299	323	235	224	201	227	403	186
Milk delivered, percent of produced[3]	95	98	98	92	96	91	98	92	90	95	91
Automatic Milking System	No	No	No	Yes	No	No	No	No	No	Yes	No
Age of farmer, intervals	> 50	> 50	40-50	40-50	> 50	> 40	40-50	40-50	> 50	< 40	< 40

[1] Cows per year = total number of cow days in a year / 365

[2] Calculated according to the Danish definition: (number of cows going into the herd plus number of cows leaving the herd) / 2 / number of cows per year

[3] Percentage of milk shipped to the dairy of milk produced

Table 3. Rotated factor loadings of each of the participating farmers on the selected factors where 'X' indicates a defining sort ($P < 0.05$)

Farmer	Factor 1	Factor 2	Factor 3	Factor 4
1	0.12	-0.10	0.87X	0.00
2	0.70X	0.15	0.32	-0.24
3	0.72X	0.43	-0.07	0.02
4	0.12	0.86X	-0.02	0.22
5	0.66X	0.27	0.09	0.37
6	-0.02	0.40	0.60X	0.19
7	0.25	0.80X	0.06	-0.22
8	0.57	0.27	0.48	0.25
9	0.49	-0.29	0.14	0.56
10	0.36	0.30	0.41	0.44
11	0.08	0.49	0.22	0.46
12	0.65X	0.07	0.08	0.25
13	0.13	0.65X	0.40	0.19
14	0.18	0.14	0.05	0.79X
15	0.76X	-0.05	-0.02	0.23
16	0.55X	0.22	0.43	0.16

Table 4. The most distinguishing statements ($P < 0.05$) for each family of farmers' perspectives in decreasing order by idealized factor scores[1], respectively

Family most distinguishing statements	No. 1	No. 2	No. 3	No. 4	No. 5	No. 6	No. 7	No. 8
Family 1: Teamwork	39[2]	32[2]	14	9[2]	-	-	-	-
Family 2: Animal welfare	46[2]	17[2]	45	3[2]	14	27	38	26
Family 3: Knowledge dissemination	34[2]	16[2]	29[2]	5[2]	30	41	38	44
Family 4: Production	44	9[2]	7[2]	24	36	29[2]	17	-

[1] The idealized Q-sorting of a factor may be viewed as how a hypothetical respondent with a 100% loading on that factor would have ranked all the statements on the layout guide
[2] $P < 0.01$

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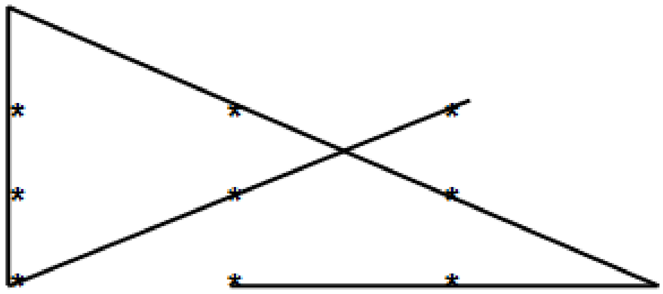
ANSWER TO QUIZ

Most people give up because they see a square and thus unconsciously try to solve the problem within the square. The creative solution is to think outside the box by expanding three of the four lines beyond the square.



Take home-message. It is often beyond what is perceived as 'conventional knowledge' that the best solutions and ideas can be found.

THANK YOU!