ECONOMIC VALUE OF MANAGEMENT INFORMATION SYSTEMS IN PIG FARMING

J.A.A.M. Verstegen

Stellingen

1. De technisch-economische effecten van management-informatiesystemen kunnen beter worden afgeleid van daadwerkelijke beslissingen van agrarische ondernemers in positief onderzoek dan van vooronderstelde beslissingscriteria in normatief onderzoek.
Dit proefschrift

2. Het gecombineerd inzetten van panelgegevens en een statistisch model met een "dummy" variabele voor ieder afzonderlijk bedrijf is essentieel bij de technisch-economische evaluatie van management-informatiesystemen omdat daarmee tegelijkertijd effecten binnen en tussen bedrijven kunnen worden geschat.
Dit proefschrift

3. Experimentele economie is een veelbelovende methodiek om complexe besluitvormingsprocessen van agrarische ondernemers verder te ontrafelen.
Dit proefschrift

4. Management-informatiesystemen verbeteren de besluitvorming en (daarmee) de productieresultaten van varkenshouders.
Dit proefschrift

5. Alhoewel varkenshouders met een hoog managementniveau ook los van het gebruik van een management-informatiesysteem meestal over meer informatie beschikken dan hun collega's met een lager managementniveau hebben ze toch meer profijt van een management-informatiesysteem.
Dit proefschrift

6. De beste houding van een onderzoeker om economische fenomenen beter te leren begrijpen is skeptisch te zijn over zowel de theorie als het bewijs.
Smith, Vernon L. (1989). "Theory, Experiment and Economics." Journal of Economic Perspectives, 3(1). p. 168.

7. Noch de hand, noch de geest, zijn tot veel in staat wanneer ze zelfstandig moeten opereren; instrumenten en hulpmiddelen vormen de wegen naar perfectie.
Citaat van Francis Bacon, in: Hogarth, Robin M. (1987). Judgment and Choice: The Psychology of Decision. New York: Wiley. p. 200.

8. De mate waarin begeleiders concept-artikelen veranderen en terug veranderen is een goede indicator voor het stadium waarin het concept zich bevindt.

9. Dat de mens nog steeds dicht bij de natuur staat blijkt o.a. uit het sterk territoriale gedrag van sommige wetenschappers.

10. Het zou de toegankelijkheid van wetenschappelijke kennis ten goede komen wanneer bij de wetenschappelijke beoordeling vaker onderscheid gemaakt zou worden tussen “ingewikkeld onderzoek” en “moeilijk leesbare onderzoeksrapportages”.

11. De gemeentelijke herindelingen, waarbij vaak kleine kernen worden samengevoegd tot één grote gemeente, worden vooral gerechtvaardigd doordat de voordelen hiervan op voorhand beter kwantificeerbaar zijn dan de nadelen.

12. Gelet op het structurele tekort aan zitplaatsen in de trein verdient het aanbeveling om attaché-koffers van een zachte bovenkant te voorzien.

13. Onderzoek naar marktmechanismen is een kwestie van vraag en aanbod.

14. Het toppunt van risico-mijdend gedrag is een uitvaartverzekering.

Proefschrift van Jos A.A.M. Verstegen
Economic Value of Management Information Systems in Pig Farming
Wageningen, 18 februari 1998

ECONOMIC VALUE OF
MANAGEMENT INFORMATION SYSTEMS IN PIG FARMING

Promotoren: dr ir J.A. Renkema
hoogleraar Agrarische Bedrijfseconomie

dr ir A.A. Dijkhuizen
bijzonder hoogleraar Economie van Dierziekten en Dierziektenbestrijding

Co-promotor: dr ir R.B.M. Huirne
universitair hoofddocent departement Economie en Management

J.A.A.M. Verstegen

Economic Value of Management Information Systems in Pig Farming

Proefschrift
ter verkrijging van de graad van doctor
op gezag van de rector magnificus
van de Landbouwuniversiteit Wageningen,
dr C.M. Karssen,
in het openbaar te verdedigen
op woensdag 18 februari 1998
des namiddags te half twee in de Aula

CIP-DATA KONINKLIJKE BIBLIOTHEEK, DEN HAAG

Verstegen, J.A.A.M.

Economic value of management information systems in pig farming /
J.A.A.M. Verstegen - [S.1. : s.n.]
Thesis Wageningen. - With ref. - With summary in Dutch
ISBN 90-5485-811-7
Subject headings: economic value of management information systems ; pig farming ; farm management ; survey study ; experimental economics.

Omslag: Siva-software b.v.
Druk: Grafisch Bedrijf Ponsen & Looijen B.V., Wageningen

The research described in this thesis was funded by the Dutch Ministry of Agriculture, Nature Management and Fisheries, the Dutch Product Boards for Livestock, Meat and Eggs, and the Dutch Research Institute for Pig Husbandry. The completion of the thesis was financially supported by the Agricultural Economics Research Institute (LEI-DLO).

ABSTRACT

Economic value of management information systems in pig farming
Economische waarde van management-informatiesystemen in de varkenshouderij
Verstegen, J.A.A.M., 1998.

The research described in this thesis focused on developing and testing methods to determine the profitability of management information systems (MIS) in livestock farming. Methods were first applied to evaluating MIS in pig farming. Economic value of MIS arises from the fact that farmers have limited time, motivation or skills to decide consistently. Therefore, positive research approaches that derive MIS benefits from actual decision making of farmers, such as survey studies and economics experiments, have more potential for MIS evaluation than normative research approaches that assess MIS benefits with predetermined decision criteria, such as decision tree analysis and simulation studies. Firstly, a survey study was conducted to evaluate MIS in pig farming. To sort out the effect of "better management" from the actual benefits of MIS, a panel data set was created by combining data of the survey study with data collected on the same farms in 1983. Adjusted for farm, trend, and learning effects, production on farms adopting MIS increased by 0.56 piglets per sow per year (p=0.09). Tests for autocorrelation, influential observations, and nonequivalent control time-series indicated that this outcome is robust. Secondly, the impact of farm characteristics on MIS profitability was investigated, comparing two conceptually different farm classification methods within the same research population: the sociological "style of farming" approach and the farm-economic "management level" approach. Farmers with high management levels got more added value from MIS. Finally, an individual decision-making experiment was conducted to yield insight into whether laboratory economics experiments can be used as an alternative to surveys for determining the profitability of MIS in sow farming. Instead of linking MIS use to farm results directly, the effect of different information levels on decision making was investigated under controlled laboratory conditions. Many of the farmers in the experiment also participated in the above-mentioned survey study. Although an overall effect of MIS was found in both the experiment and the survey study, experimental and survey MIS estimates were not significantly correlated. Possible explanations for these uncorrelated estimates are discussed in the thesis.

PhD-thesis, Department of Economics and Management, Wageningen Agricultural University, Hollandseweg 1, 6706 KN Wageningen, The Netherlands.

VOORWOORD

De beslissing om een promotie-onderzoek te starten is er één met vele onzekerheden. Kan ik het wel? Hoe is de begeleiding? Is het wel een leuk onderwerp? Vind ik dat over een aantal jaren nog steeds? Word ik nu automatisch een duffe onderzoeker? Kom ik er wel verder mee op de maatschappelijke ladder?

De besluitvormingstheorie leert ons dat de meeste beslissingen genomen worden onder onzekerheid. Niks nieuws onder de zon dus. Verder weten we dat inzicht in een beslissingsprobleem verkregen kan worden door onzekerheden te kwantificeren. De statistieken geven aan dat ongeveer 1 op de 7 promovendi er uiteindelijk niet in zal slagen om een doctor's-graad te behalen. Alhoewel dit een niet te onderschatten schrikbeeld is, betekent het ook dat 6 van de 7 wel de eindstreep halen. Waarmee maar weer eens wordt onderstreept hoe belangrijk de presentatie ("framing") van een beslissingsprobleem is. Helaas bestaat er geen management-informatiesysteem om de beslissing "wel/geen promotie-onderzoek" te ondersteunen en is de beschikbare informatie vaak erg "fuzzy". Een promotie-onderzoek blijft derhalve een risicovolle onderneming.

Dat ik nu met veel voldoening en plezier kan terugkijken op de achterliggende periode mag niet (alleen) worden toegeschreven aan mijn selectief geheugen maar heeft vooral te maken met de vele mensen die in de afgelopen jaren hebben meegeholpen bij de totstandkoming van het proefschrift. Een aantal van hen wil ik er hier even uitlichten.

Allereerst zijn dit mijn begeleiders dr ir Ruud B.M. Huirne en prof. dr ir Aalt A. Dijkhuizen. Jullie enthousiasme en positief-kritische begeleiding bij een eerder afstudeervak deden mij besluiten om aan dit avontuur te beginnen. Dat de "historische" informatie van het afstudeervak een goede voorspellende waarde had voor het promotie-onderzoek is gebleken uit vele jaren voortreffelijke samenwerking. Alhoewel elke verandering moeilijk is ben ik ervan overtuigd dat ook hier de geschiedenis zich zal herhalen.

Op de tweede plaats wil ik de overige leden van de begeleidingscommissie, te weten prof. dr ir Jan A. Renkema, prof. dr Jack P.C. Kleijnen, prof. dr Albert L. Mok en dr ir Ge B.C. Backus, bedanken voor het stevig "op de rails zetten" van mijn promotie-onderzoek. Ook in latere fases van het onderzoek waren er waardevolle bilaterale contacten die in een aantal gevallen zijn onderstreept met een gezamenlijk wetenschappelijk artikel.

Een speciaal woord van dank is ook verschuldigd aan prof. dr Frans A.A.M. van Winden en dr Joep Sonnemans. In eerste instantie was niet voorzien dat experimentele economie een belangrijk onderdeel zou gaan vormen van mijn promotie-onderzoek. Één brainstorm-sessie bij de Universiteit van Amsterdam bracht daar snel verandering in. Jullie creativiteit en ogenschijnlijk simpele vragen over het gebruik van management-informatie-systemen door varkenshouders hebben sterk bijgedragen aan de uiteindelijke invulling van het experiment. Bedankt dat jullie deze jongen uit de provincie de "basics" hebben willen bijbrengen. Otto Perdeck, bedankt voor het ontwikkelen van de software die alle experimenten met glans heeft doorstaan. Also, I would like to thank prof. dr James C. Cox and prof. dr Vernon L. Smith for the valuable discussions we had on the experimental design and for giving me the opportunity to visit the University of Arizona and participate in the graduate course on experimental economics.

Empirisch economisch onderzoek doen is leuk maar betekent wel dat je voor het welslagen ervan sterk afhankelijk bent van de medewerking van anderen. In totaliteit hebben ruim 120 varkenshouders (m/v) aan één of meerdere onderdelen van dit proefschrift bijgedragen. Zij werden het hemd van het lijf gevraagd tijdens urenlange interviews, enquêtes en/of besluitvormingsexperimenten. Dat dit een behoorlijke inspanning vergde, was vaak van de gezichten af te lezen. Des te prijzenswaardiger is het dat geen enkele varkenshouder tussentijds is afgehaakt (uitgezonderd die ene varkenshouder waarbij ik per ongeluk de stekker van de computer uit het stopcontact trok). Aansluitend hierbij wil ik Johan Aalenhuis en John van Gorp bedanken voor het afnemen van de enquêtes bij varkenshouders en Linda van Laar en Bert-Jan Braakman voor het onderzoek dat ze in het kader van een afstudeervak voor mij verricht hebben.

Dank is ook verschuldigd aan de talloze mensen die zorg hebben gedragen voor de financiering van het onderzoek, die geholpen hebben bij het opstellen van de interviewschema's en de enquêtes, bij het aanpassen van het HMP-programma en bij de statistische analyses, die ideeën en literatuurreferenties hebben aangedragen, die deelgenomen hebben aan pilot-experimenten, die (concept-)teksten hebben gecorrigeerd en de lay-out van het proefschrift hebben verfraaid, die samen met mij hebben hardgelopen om het luie zweet kwijt te raken of die gewoon gezorgd hebben voor een gezellige, maar daarom niet minder productieve, werksfeer. Ook diegenen die de laatste jaren, subtiel doch beslist, bleven vragen naar de vorderingen bij mijn proefschrift mogen hier niet worden vergeten.

Als een na laatste wil ik mijn ouders bedanken voor de vele inspanningen die zij zich hebben getroost om van mij toch nog iets te maken. Dit varieert van het "overhoren" van de lessen na schooltijd tot het uitdragen van een visie over hoe de wereld in mekaar zit en hoe je daar mee om moet gaan.

Tot slot, Anja. Dat het voor de beste beslissing soms nodig is om er snel bij te zijn, heb ik ervaren vlak nadat ik in Wageningen ging studeren en jou leerde kennen. Sinds we vorig jaar april ook nog verblijd zijn met de geboorte van ons Henriette, moet ik moeite doen om andere belangrijke dingen in het leven (zoals een promotie) niet teveel te relativeren. En dat voelt goed!

Jos Verstegen
Berghem, januari 1998

CONTENTS

CHAPTER 1

GENERAL INTRODUCTION

1.1 INTRODUCTION

Developments in commercial pig farming are generally characterized by extended herd sizes and narrowed income margins. Minor differences in productive performance have an increasing impact on economic results (Huirne et al., 1992). Therefore, good management becomes more and more important for farmers to stay in business.

In the past decades, many efforts have been made to develop electronic tools to support management on pig farms. Before 1970, recording of yearly farm data, if any, was done manually. In the seventies, the Dutch state advisory service (in Dutch, "Consulentschap voor de Varkens- en de Pluimveehouderij") started automated data processing at herd level. Quarterly herd data were processed on a central mainframe computer. From the eighties onward, sow-herd management information systems (MIS) have been developed that can provide daily or weekly production information at the level of the individual sow. Farmers can operate these MIS on their farms or use the mail-in services of the MIS providers. In the nineties, computerized pig management support continues with the development of simulation models, optimization models and expert systems (Huirne et al., 1992; Jalvingh et al., 1992; Jørgensen and Kristensen, 1995; Den Ouden, 1996).

Although much effort is put in the development of advanced computer systems, a thorough evaluation of the added value of using MIS in pig farming is lacking. Insight into this value is useful to farmers making investment decisions and to companies that design and market MIS (King et al., 1990). Therefore, the Dutch Ministry of Agriculture, Nature Management and Fisheries, and the Dutch Product Boards for Livestock, Meat and Eggs decided to fund a research project on this topic. The research project was carried out at the Department of Farm Management of Wageningen Agricultural University, in cooperation with the Research Institute for Pig Husbandry, and has resulted in this thesis.

The overall objective of the reseach project was to develop and test methods to determine the profitability of MIS in livestock farming. The methods should first be applied to evaluating MIS in pig farming. In the first stage of the project, several research approaches were compared; practical use and internal and external validity of the approaches were illustrated using the evaluation of sow-herd MIS as a test case. In the next stage, two promising research approaches namely a survey study and an economics experiment were applied to find out if current use of MIS by farmers was justified through better decision making and better farm performance. In the third and final stage, an in-depth analysis was conducted to find indicators that can explain or predict whether specific farmers will or will not derive benefits from MIS.

1.2 RESEARCH PROBLEM

Management information systems (MIS) in livestock farming are defined as tools designed to provide daily production information at the individual animal level that is of potential value in making management decisions (Boehlje and Eidman, 1984). Determining the profitability of MIS is difficult because of the specific product of MIS, i.e., processing of animal data into useful management information. Costs of MIS are relatively easy to determine. They include costs for interest and depreciation related to the investments in hardware and software (updates), and operating costs, such as labor costs, MIS training costs, and help desk costs.

Benefits of MIS, however, are more difficult to evaluate, because of the wide range of decisions and activities that can be affected by MIS (King et al., 1990) and the crucial role of the MIS user in creating MIS benefits (Hamilton and Chervany, 1981). Sow-herd MIS, for instance, designed to support production management, check for incorrect data entries, calculate key ratios, provide sorted sow overviews, and offer opportunities for (simple) farm analyses. Added value of these MIS thus depends on the number of data recording errors and the number of calculations that were made before MIS adoption, and the actual use of MIS figures and MIS analysis opportunities in livestock management. The added value originates from the fact that farmers have limited time, motivation, or skills to decide in a way that is consistent with their farm goals (Simon, 1979). Economic value of MIS arises from *improvements* in livestock management decisions, which includes (1) higher benefits because MIS cause farmers to choose other decision alternatives, (2) higher benefits because MIS cause farmers to make decisions more timely, and (3) loss-avoidance because MIS allow farmers to control larger herds with the same decision quality as before farm expansion (Kleijnen, 1980; Boehlje, 1997).

Personal characteristics of farmers determine whether MIS will be purchased (Putler and Zilberman, 1988). Farmers who adopt MIS may be different from non-adopters with respect to many more farm-related aspects than MIS adoption alone. This so-called “self-selection problem” is an important issue to deal with when comparing performances of MIS users and nonusers in an MIS evaluation study.

1.3 OUTLINE OF THE THESIS

After the introduction, Chapter 2 describes various methods that could be used to determine the economic value of MIS in agriculture. Two main types of research approaches are identified: normative and positive approaches. Two positive approaches are being applied in this thesis.

Chapter 3 describes a study, set up to quantify the economic effects of MIS using panel analysis. A panel data set was created by combining data of a survey study conducted in 1983 (Mok and Van den Tillaart, 1990) and a survey study conducted on the same farms in 1992. The relationship between MIS use and economic results of sow farms was investigated in a quasi-experimental nonequivalent time-series design (Weiss, 1972). Analysis of the panel data in a mixed-effects model using ordinary least-squares procedures allowed for a separation in farm-specific and (common) trend effects.

An in-depth analysis of the impact of farm characteristics on MIS profitability is executed in Chapter 4. Two conceptually different farm classification methods are compared within the same research population: the sociological "style of farming" approach (Van der Ploeg, 1990) and the farm-economic "management level" approach (Alleblas, 1988).

In Chapter 5, an experimental economics approach (Smith, 1982) is introduced as an alternative to determining MIS profitability in field studies. Instead of linking MIS use to farm results directly, the effect of different information levels on decision making is investigated under controlled laboratory conditions. An investment project selection problem was constructed to be an abstract experimental economics analogue of the sow replacement problem, and 86 pig farmers were used as subjects in the experiment. Many of the farmers also participated in the above-mentioned survey study.

Chapter 6 discusses a general framework of MIS profitability in livestock management. The research approaches applied are evaluated and an outlook for future MIS developments and MIS evaluation research is presented. The chapter ends with the main conclusions of this thesis.

REFERENCES

Alleblas, Joop T.W. (1988). "Management in de Glastuinbouw" [Management in Glasshouse Horticulture]. LEI Onderzoekverslag 34 [LEI Research report 34], Agricultural Economics Research Institute. The Hague, The Netherlands. 217 pp. (in Dutch: English summary).

Boehlje, Michael D., and Vernon R. Eidman (1984). *Farm Management*. New York: Wiley. 806 pp.

Boehlje, Michael D. (1997). Personal communication.

Den Ouden, Marjan (1996). Economic Modelling of Pork Production-Marketing Chains. *Mansholt Studies*, 4. Oegstgeest, The Netherlands: Backhuys. 166 pp.

Hamilton, Scott, and Norman L. Chervany (1981). "Evaluating Information System Effectiveness -- Part I: Comparing Evaluation Approaches." *MIS Quarterly*, 5: 55-69.

Huirne, Ruud B.M., Aalt A. Dijkhuizen, Jan A. Renkema, and Paul van Beek (1992). "Computerized Analysis of Individual Sow-Herd Performance." *American Journal of Agricultural Economics*, 74(2): 388-399.

Jalvingh, Alien W., Aalt A. Dijkhuizen, Johan A.M. van Arendonk, and E.W. Brascamp (1992). "An Economic Comparison of Management Strategies on Reproduction and Replacement in Sow Herds using a Dynamic Probabilistic Model." *Livestock Production Science*, 32: 331-350.

Jørgensen, Erik, and Anders R. Kristensen (1995). "An Object Oriented Simulation Model of a Pig Herd with Emphasis on Information Flow." Dina Notat 32. 11 pp.

King, Robert P., Stephen B. Harsh, and Craig L. Dobbins (1990). "Farm Information Systems: Farmer Needs and System Design Strategies." *Tijdschrift voor Sociaalwetenschappelijk Onderzoek van de Landbouw*, 5(1): 34-59.

Kleijnen, Jack P.C. (1980). *Computers and Profits: Quantifying Financial Benefits of Information*. Reading MA: Addison Wesley. 262 pp.

Mok, Albert L., and Harrie J.M. van den Tillaart (1990). "Farmers and Small Businessmen: A Comparative Analysis of their Careers and Occupational Orientation." In: *New Findings and Perspectives in Entrepreneurship*. R. Donckels and A. Miettinen, eds. Aldershot UK: Avebury. p. 203-230.

Putler, Daniel S., and David Zilberman (1988). "Computer Use in Agriculture: Evidence from Tulare County, California." *American Journal of Agricultural Economics*, 70(4): 790-802.

Simon, Herbert A. (1979). "Rational Decision Making in Business Organizations." *American Economic Review*, 69(4): 493-513.

Smith, Vernon L. (1982). "Microeconomic Systems as an Experimental Science." *American Economic Review*, 72(5): 923-955.

Van der Ploeg, Jan-Douwe (1990). "The Challenge of Heterogeneity; Notes on Science, Capital and Agriculture." Paper presented at the 14th European Congress of Rural Sociology, Giessen BRD.

Weiss, Carol H. (1972). *Evaluation Research: Methods of Assessing Program Effectiveness*. Englewood Cliffs, NJ: Prentice-Hall. 160 pp.

CHAPTER 2

ECONOMIC VALUE OF MANAGEMENT INFORMATION SYSTEMS IN AGRICULTURE: A REVIEW OF EVALUATION APPROACHES[1]

ABSTRACT

An important criterion for farmers to select an investment is its profitability. Difficulties arise when this criterion is applied to investments in management information systems (MIS), because the impact of MIS on farm performance is unclear. To cope with this problem, specific MIS evaluation approaches have to be applied. Two main types of research approaches are identified: normative and positive approaches. Normative approaches are considered to have limited potential in practice. The value of positive approaches, on the other hand, depends very much on the availability and quality of (longitudinal) field data and the type of research design. Experimental economics is identified as a means to obtain data on decision making in a highly controllable environment and is, therefore, considered to be an interesting alternative for MIS evaluation in agriculture.

2.1 INTRODUCTION

Farmers are constantly faced with decisions regarding various investment opportunities to improve their farm results. An important criterion for farmers to select an investment is its profitability. Difficulties arise when this criterion is used to consider investments in management information systems (MIS), because their profitability is generally unknown. MIS are electronic tools for data collection, processing, and management and are designed to provide information that is of potential value in making management decisions (Boehlje and Eidman, 1984). The costs of MIS (i.e., hardware, software, and, to some extent, personnel costs) are represented by market prices, but not their benefits (i.e., the effects of MIS on farm performance).

Since the introduction of MIS in the early eighties, about 40 percent of the sow farmers in the Netherlands have decided to invest in this type of systems. This adoption rate may suggest that sow farmers do benefit from MIS use, but it certainly does not prove such benefits (Sharda et al., 1988). More objective measures for MIS profitability are

---

1 paper by Jos A.A.M. Verstegen, Ruud B.M. Huirne, Aalt A. Dijkhuizen, and Jack P.C. Kleijnen, published in *Computers and Electronics in Agriculture*, 13(4), December 1995: 275-290.

desirable as MIS development proceeds. This information can be of use, not only to farmers who consider (new) MIS investments, but also to firms that design and market MIS.

The purpose of this paper was to review the various evaluation approaches to the determination of the economic value of MIS in agriculture. Two types of approaches were found in the literature on information technology (IT): normative and positive approaches. Relatively few studies have mentioned both approaches, but King et al. (1990), and Streeter and Hornbaker (1994) did. This paper reviews and compares both types, referring to evaluation studies in the IT literature (including MIS literature). The strengths and weaknesses of both types are illustrated, using the evaluation of sow-herd MIS as a test case.

2.2 INVESTMENT EVALUATION

2.2.1 Benefit-cost analysis

The standard procedure for investment evaluation is benefit-cost analysis. For example, a labor-saving investment is evaluated by comparing the output of employees with the (expected) output of machinery, and by comparing salary costs with (expected) depreciation, interest, and maintenance costs. However, this traditional benefit-cost approach is difficult to apply to MIS evaluation, because of the wide range of decisions and activities that can be affected by MIS information (King et al., 1990) and the crucial role of the MIS user in creating MIS benefits (Hamilton and Chervany, 1981).

Lincoln and Shorrock (1990) also recognized the peculiar aspects of information, as a product of a technology investment; they state that “traditional benefit-cost analysis techniques lag behind the capabilities of IT applications. They are unable to predict the full impact systems have on corporate performance”. Kleijnen (1980) reports that “traditional cost-benefit analysis alone does not seem to contribute much to the analysis of the value of computerized MIS”. He suggests an alternative two-stage approach, extending the traditional cost-benefit analysis with a second stage that includes the intangible benefits (and thus capturing a wider range of activities and decisions affected by MIS). Parker et al. (1988) distinguish three levels: tangible, quasi-tangible, and intangible benefits. To include effects of IT on effectiveness and efficiency of organizations, they expand the benefit-side in traditional benefit-cost analysis with four elements: value linking, value acceleration, value restructuring, and innovation valuation. This classification of potential benefits makes quasi-tangible and intangible effects more visible, and thus allows for a better evaluation of alternative IT investments. Banker and Kauffman (1989) adopted this approach in an IT evaluation study on the value of automated teller machines for bank branches and found that IT benefits consisting of operating cost savings, such as labor savings, were most tangible. Quantifying IT benefits of production improvements tended to be more difficult, and IT benefits resulting from product differentiation and market share improvements were even less tangible. However, their study also demonstrated that the largest IT benefits resulted from the less tangible benefits, namely an increase in market share.

Our study addresses the problem of MIS evaluation. MIS form a special category of IT applications, since they primarily focus on the decision support function, whereas other IT applications typically have additional functionalities, such as data-processing and operational functions. For instance, automated milking systems (an IT example in dairy farming) collect pedometer and daily milk yield data, control feed rations in the milking parlor, and provide farmers with monitoring information on individual cow performance, in order to support the farmers' decisions on insemination and replacement of cows. The costs savings of the operational functions of these applications are clear and may be sufficient justification for their investment costs. MIS operating costs savings, however, are modest, meaning that most of the MIS benefits must originate from the less tangible benefits. Therefore, investment evaluation of MIS has to go beyond traditional benefit-cost analysis, including less tangible benefits, as we shall see next (Section 2.2.2).

2.2.2 Extensions of traditional benefit-cost analysis

The problem of MIS evaluation is addressed in many publications outside agriculture (Kleijnen, 1980; Kleijnen, 1984; Banker and Kauffman, 1989; Kauffman and Weill, 1989; Hamilton and Chervany, 1981) and inside agriculture (King et al., 1990; Streeter and Hornbaker, 1994). Two main types of research approaches can be identified: normative and positive approaches (Figure 2.1).

Normative approaches provide a theoretical pre-audit measure of what the profitability of MIS could be or should be, based on the net returns of their functions (e.g. improved decision making, labor savings), and according to some predefined decision making criteria (Kleijnen, 1980). In Figure 2.1, normative approaches are further distinguished into decision theoretical approaches (decision tree analysis, Bayesian Information Economics, Control Theory) and decision analytical approaches (simulation approaches, linear programming, dynamic programming).

Positive approaches determine what the profitability appears to be through empirical studies (post-audit). Examples include experimental, quasi-experimental, and nonexperimental designs. Within the group of experimental designs, a further distinction can be made between field experiments and experimental economics.

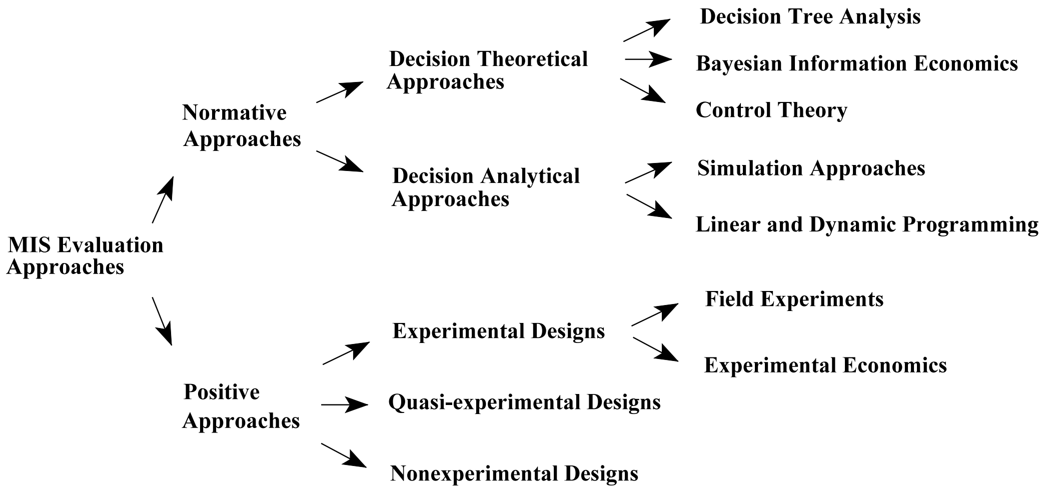


Figure 2.1. A classification of evaluation approaches to the determination of the economic value of MIS

2.3 NORMATIVE MIS EVALUATION APPROACHES

2.3.1 Decision theoretical approaches

Decision theoretical approaches refer to a strong axiomatically oriented and formal treatment of decision making that can be considered as "normative, theoretical" (Smidts, 1990). Three examples are considered here: decision tree analysis, Bayesian Information Economics, and Control Theory (Figure 2.1).

Decision tree analysis makes use of a decision tree, which is a visual representation of potential steps taken in a decision process. In the standard formulation, decision alternatives branch from square nodes, whereas the probabilities of uncertain events branch from round nodes. By multiplying the probabilities and the payoff of each branch diverging from a square node, a measure for the expected payoff of this decision alternative is derived (Makeham et al., 1968; Anderson et al., 1977; Baker, 1981). Figure 2.2 shows the use of a decision tree in analyzing the sow culling problem (being one of the decision problems supported by sow-herd MIS). Two decision alternatives are available; to keep a sow (for the next production cycle), or to replace it by a gilt. The probabilities attached to the litter sizes are based on the production history of the sow, the litter sizes of other sows on the farm, and the farmer's expectations of the sow.

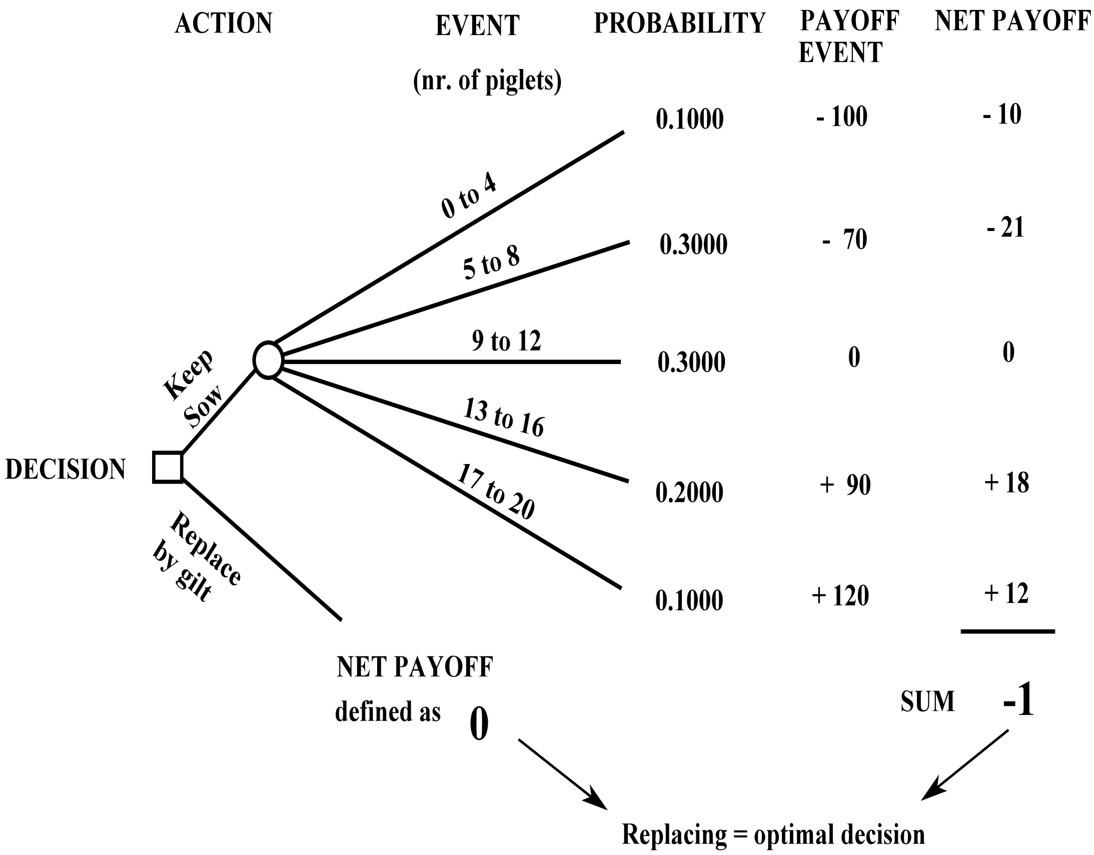


Figure 2.2 An example of the use of decision tree analysis in analyzing the sow culling problem

The optimal decision, according to these data, is to cull the sow, because the expected relative value of the replacement gilt (which equals that of the average sow in the herd, i.e. 0) exceeds the relative value of the sow under consideration (0.1 * -100 + ... + 0.1 * 120 = -1.0). Decision tree analysis finds the best decision alternative in a structured way; moreover it finds the effect of additional information on the best decision alternative. The difference between (i) the benefits of the best decision alternative after receiving the information and (ii) the benefits of the previously determined best decision is the value of the information, and thus, the value of the MIS that provided this information.

However, using decision tree analysis for MIS evaluation has some limitations. First, it requires a detailed description of the decisions supported by MIS, consisting of the possible choice alternatives, the mutually exclusive uncertain events with their probabilities, and the payoffs for each combination of choice alternative and uncertain event. Second, in their purest form, decision trees can value perfect information only, by replacing a round node (with uncertain events) by a certain outcome. Unfortunately, sow management typically involves biological processes with high uncertainty on future outcomes, meaning that perfect information is rarely available. For instance, in the earlier sow culling example, it is impossible to obtain perfect information on the litter size of the sow in the next production cycle. However, with MIS use, probabilistic data become available and decision trees can handle these data in combination with the key element of the second decision theoretical approach, Bayes Theorem.

Bayesian Information Economics is based on Bayes Theorem, a noncontroversial elementary theorem of probability derived originally by the eighteenth-century English clergyman Thomas Bayes (Anderson et al., 1977, p.50):

$$P(\Theta_i|z_k) = \frac{P(\Theta_i) * P(z_k|\Theta_i)}{P(z_k)}$$

where

Θ_i	= uncertain event i
z_k	= additional information k (e.g. MIS output)
$P(\Theta_i\|z_k)$	= posterior probability of uncertain event i, given z_k
$P(\Theta_i)$	= prior probability of uncertain event i
$P(z_k\|\Theta_i)$	= likelihood of prediction z_k, given Θ_i
$P(z_k)$	= likelihood of prediction z_k

Farmers who use sow-herd MIS receive additional information on the performances of their sows. This enables them, for example, to decide more accurately on keeping or replacing sows. The Bayes Formula can be used to calculate the best decision alternative upon receiving new information, taking into account the sow information that farmers already have prior to MIS use.

Table 2.1 Revision of probabilities using Bayes Theorem

Θ_i[1]	$P(\Theta_i)$[2]	$P(z\|\Theta_i)$[3]	$P(z \cap \Theta_i)$[4]	$P(\Theta_i\|z)$[5]	$[6]	$P(\Theta_i\|z)$*$
Θ_1 = 0 to 4	0.1000	0.46	0.046	0.046/0.498 = 0.0924	- 100	- 9.24
Θ_2 = 5 to 8	0.3000	0.48	0.144	0.144/0.498 = 0.2892	- 70	- 20.24
Θ_3 = 9 to 12	0.3000	0.50	0.150	0.150/0.498 = 0.3012	0	0
Θ_4 = 13 to 16	0.2000	0.52	0.104	0.104/0.498 = 0.2088	+ 90	+ 18.79
Θ_5 = 17 to 20	0.1000	0.54	0.054	0.054/0.498 = 0.1084	+ 120	+ 13.01
	1.000		P(z)=0.498	Check: 1.000		+ 2.32[7]

1 Uncertain event = number of piglets in next litter of third-parity sow
2 Prior probability of uncertain event i
3 Likelihood of prediction z, given uncertain event i; z = one piglet extra in next litter
4 Joint probability
5 Posterior probability of uncertain event i, given z
6 Payoff with uncertain event i
7 Expected payoff of sow in next cycle

Based on the information and expectations the farmer had in the decision tree example (Figure 2.2), the sow should be culled and replaced by a gilt. When using MIS, additional information revealing the performances of sows within the same parity, can be used to revise the five prior probabilities with Bayes Theorem. Suppose the sow of Figure 2.2 is a third-parity sow and MIS indicate that those sows farrow on average one piglet more (in the next production cycle) than other sows do. Further assume that the likelihood of revealing such information (instead of "no difference with the herd average") is 0.46 if a third-parity sow actually farrows 0 to 4 piglets (in her next cycle) and 0.48, 0.50, 0.52, and 0.54 if this sow farrows 5 to 8, 9 to 12, 13 to 16, and 17 to 20 piglets, respectively. Table 2.1 reveals the expected payoff of keeping the sow, after updating the prior probabilities. In this case, the sow should be kept, because her expected value in the next production cycle exceeds the one of the replacement gilt (2.32 - 0). The value of MIS information, defined as the difference in expected payoff of (i) the best decision with MIS information (keep: 2.32) and (ii) the best decision without MIS information (replace: 0), is now 2.32.

Bayes Theorem is a widespread formal procedure to revise probabilistic data (Lindley, 1971). It has great appeal as a general approach to measure and valuate information, with great potential for applications (Chavas and Pope, 1984). Bayesian

Information Economics is the only theory explicitly aimed at evaluating the value of information in decision making (Kleijnen, 1984). The literature gives many practical applications of Bayes Theorem (Baquet et al., 1976; Byerlee and Anderson, 1982; Bosch and Eidman, 1987; Kennedy and Stott, 1990; Jørgensen, 1992, Swinton and King, 1994).

Bayesian Information Economics also has some limitations (Kleijnen, 1980). First, Bayes Theorem requires even more detailed descriptions of the decision problems than decision tree analysis does: besides the decision alternatives, the uncertain events, and prior probabilities, now Bayes Theorem requires the specification of likelihoods, i.e., the probabilities of obtaining certain information, conditional on a specific event. Second, using Bayes Theorem may raise some problems with the independence of information types. Data is information (and can have value) only if it has some surprising content to the receiver. However, much of the output of MIS may have already been incorporated in the farmer's assessment of the prior probabilities, meaning that the true amount of information provided by MIS is overestimated. Also, farmers who conduct two MIS analyses (on the same set of farm data) may receive less information than it seems. The implicit assumption that the likelihood P(second MIS analysis|Θ_i, farmer's assessment, first MIS analysis) equals P(second MIS analysis|Θ_i) holds only when the three information sources (second MIS analysis, farmer's assessment, and first MIS analysis) are conditionally independent (Anderson et al., 1977).

Control theory focuses on the dynamic aspects of production systems, and studies such phenomena as oscillations. It highlights the role of feedback and feedforward information. The application of control theory requires drastic simplifications in order to keep the mathematical problems within limits. One application of control theory to the evaluation of MIS has been found (Politzer and Wilmès, 1977, in: Kleijnen, 1980). The researchers investigated the effect of a planning model on production and inventories costs. A similar approach could be used for sow farming, using control theory to study the (timeliness) effect of MIS on the delays between the occurrence of management problems and the farmers' corrective action. However, because of the complexity of farm management problems, and the need for drastic simplifications in control theory, it is not likely that this approach will provide reliable MIS profitability estimates.

2.3.2 Decision analytical approaches

Decision analytical approaches consist of a set of techniques and procedures designed to help individuals and organizations make inferences and decisions. Decision analysis structures complex decisions and performs sensitivity analyses to gain insight into decision problems. Decision analytical approaches can be considered as "normative, empirical" (Smidts, 1990).

Simulation approaches are one type of decision analytical approaches (see also Figure 2.1). A simulation model is a symbolic model (Dent and Blackie, 1979) formed by input parameters and a number of mathematical equations that are solved by "experimentation" (Kleijnen, 1980). This model type has particular strengths in mimicking complex situations, characterized by uncertainty and change over time (Dent and Blackie, 1979). Information provided by MIS may affect simulated results in two distinct ways. First, it may change the model input, e.g. weekly instead of monthly production records. This change may be valuable if, for example, sow culling decisions can be made more accurately. Second, information may consist of new decision rules to be used in the system. For example, new index figures that appropriately weigh the litter size history of a sow, may be applied to support sow culling decisions. Simulating the farm results, with and without this new index figure respectively, provides a measure for the value of the index figure information (Jalvingh et al., 1992). This approach was applied in combination with Bayes Theorem by Baquet et al. (1976), Bosch and Eidman (1987), and Swinton and King (1994).

An advantage of simulation models is that they can reproduce parts of the complex reality of farm management. In swine farming, for instance, they can simulate the (secondary) effects of the decision to "keep the sow" on aspects such as labor use, feed supply, and medicine use. The models applied in decision tree analysis and Bayesian Information Economics do not usually include such details. Conceptually, simulation models are not restricted by any limitation. However, the potential of a simulation model to evaluate MIS relies very much on the skills of the researchers, when they try to include natural farm management aspects. They have to deal with complex issues, such as (dynamic) interrelationships among various decisions and irrational behavior of farmers. Studies on natural farm management aspects conducted while developing a simulation model, can be considered as positive research approaches. The outcomes of simulation runs, however, are normative, since they represent what could or should occur in practice, not what has actually occurred.

2.3.3 General critique of normative approaches

Theoretically, normative approaches can evaluate MIS by aggregating the benefits of decision improvements resulting from various types of MIS information. However, determining these benefits is difficult because of the wide range of (interrelated) decisions and activities affected by an information system (King et al., 1990). Before researchers can apply normative approaches to evaluate sow-herd MIS, they have to specify the farm management decisions that are supported by MIS information. A problem, however, is that each ranking or grouping of variables (e.g. litter sizes per pig breed, parity, or breed*parity-interaction) can provide new insights, i.e., information to the farmer. Moreover, many kinds of information can be used to support several decision problems; for instance, information used for culling decisions can also be used for other decisions, such as the pig breed selection or insemination strategy.

Use of Bayes Theorem and decision tree analysis is limited to simple decision problems. In practice, decision problems are usually complex; they do not occur only at prescheduled points of time, but are triggered, for instance, when certain problems in farm management occur. Moreover, Bayes Theorem and decision tree analysis disregard the dynamic aspect of farm management: MIS value not only results from changes in decision alternatives, but also from improvements in timeliness of decision making; with MIS information, a farm management problem may be identified and solved a few weeks earlier than before. Also, decisions taken at a certain point in time, can affect future decisions. Finally, decision tree analysis and Bayesian information economics assume consistent decision making, according to a predefined decision making criterion (Kleijnen, 1980). In practice, farmers will decide inconsistently due to failures of knowing all decision alternatives and uncertainty about relevant exogenous events, and inability to calculate decision consequences (bounded rationality: Simon, 1979). Actually, MIS value originates from the fact that most farmers have limited time, motivation, or skills to decide consistently. The consequence of the incorrectness of the consistency assumption is a low external validity; the estimates on the value of MIS obtained with normative approaches will differ from its real value in practice.

Conceptually, simulation can deal with inconsistent behavior. For instance, a simulation model can be built that randomly picks from a set of decision criteria. However, little is known about the criteria and the magnitudes and directions of inconsistencies in farmers' decision making. Therefore, it is unlikely that in practice such a simulation approach will provide a value corresponding to the real MIS value when used in practice.

For farmers to make the right investment decisions, the real MIS value has to be known; hence normative approaches are not very useful. The normative approaches reported in the literature typically deal with single, well-defined decision problems (e.g. the timing of crop harvesting) and specific types of information (e.g. weather forecasts). These studies, which also provide a theoretical rather than a practical value of information, are worthwhile; they provide insight into the consequences of various decision actions, which may be useful to both farmers and farm advisors. The use of normative approaches becomes more difficult when the focus of attention shifts from particular kinds of information to an entire information system affecting a wide range of decisions and activities (Kleijnen, 1980).

2.4 POSITIVE MIS EVALUATION APPROACHES

Positive approaches evaluate MIS through observations on decisions and farm results in practice. General program evaluation theory (Weiss, 1972; Fitz-Gibbon and Morris, 1987) offers many research designs that can be applied. They can be classified into experimental, quasi-experimental, and nonexperimental designs, based on their internal validity (Figure 2.1). Internal validity refers to the degree of control over disturbing effects outside the program. Experimental designs protect against nearly all possible threats to internal validity; quasi-experimental designs generally leave one or several of them uncontrolled; nonexperimental designs face many threats to internal validity (Weiss, 1972). Internal validity depends on a combination of (i) type of control group, and (ii) way of measuring before and after MIS introduction. This is shown in Table 2.2, where internal validity diminishes from the upper left corner towards the lower right corner.

Table 2.2 Classification of research designs[1] according to the type of control group and the way of measuring before and after MIS introduction

	Time-series (TS)	Pretest-posttest (PP)	Posttest only (PO)
True Control (T)	TTS	TPP	TPO
Nonequivalent Control (N)	NTS	NPP	NPO
No Control	TS	PP	PO

[1] TTS, TPP, and TPO are experimental designs;
NTS, NPP, and TS are quasi-experimental designs;
NPO, PP, and PO are nonexperimental designs.

"True Control" means that the control group and the program group are equivalent, except for the use of MIS; "Nonequivalent Control" means that there may exist some differences between the control group and the program group, and "No Control" indicates the absence of a control group. "Time-series" calls for measurements at several points in time, before and after MIS introduction; "pretest-posttest" refers to two measurements only, namely one before and one after MIS introduction; finally "posttest only" indicates that variables are measured at only one time after MIS introduction.

2.4.1 True control group

A typical feature of experimental designs is that assignment of subjects to either the MIS group or the control group is the result of a randomization procedure, before the start of the experiment. This procedure prohibits self-selection bias; it is also an effective way of preventing other types of bias. All possible distorting factors (e.g. firm size) are randomly divided over the MIS and control groups, and will therefore not bias the comparison. Therefore, control groups in experimental designs are also indicated as true control groups.

To evaluate MIS in agriculture, farmers are randomly assigned to either an MIS group or a true control group. Farmers in the MIS group then receive the program, whereas farmers in the true control group receive nothing (or a placebo). Depending on the type of experimental design, posttest, time-series or pretest data are collected, on which inferences about the MIS effect will be based. There are several requirements: none of the farmers already uses the MIS, every farmer voluntarily participates, and no contamination (information exchange) between the true control group and the MIS group takes place. However, in practice, researchers often plan an evaluation after the MIS has been introduced. It is then too late for an ex-ante random assignment of subjects to the MIS and control groups. Furthermore, it is not easy to get subjects to participate voluntarily, especially when they are assigned to the control group. Finally, running such experiments in the field is time-consuming and expensive. These practical limitations explain the moderate use of experimental designs in IT evaluation studies. Examples that are found in the IT literature, include those by Schoonaert (1973) and Banker et al. (1990).

2.4.2. Nonequivalent control group

An alternative for the true control group is the nonequivalent control group. The basic selection criterion for this control group is its similarity with the MIS group. In agriculture, criteria for farms to be selected in the nonequivalent control group, could be that they have no MIS but a similar farm structure, farm size and type of management as the farms in the MIS group have. However, since MIS in agriculture are available to every farmer, the nonequivalent control group will always differ from the MIS group, simply because the "control" farmers chose not to invest (yet) in MIS, whereas the other farmers did. Nevertheless, when a high similarity exists between the nonequivalent control group and the MIS group, reliable inferences can be made that the MIS effect is measured and not some other (exogenous) effect. Otherwise, statistical models may be useful to adjust for the dissimilarity between treatment and control groups.

2.4.3 No control group

Research designs without a control group face many threats to internal validity. Claims that high farm performances result from MIS use, are difficult to prove if no comparison can be made with the production results of farmers who do not use MIS. This is particularly true for the pretest-posttest (PP) designs and the posttest-only (PO) designs (Table 2.2). The PO design can hardly be labeled a research design. Only one-shot performance data of MIS users are available. There is no opportunity to compare these data with data on other farms or on the same farms before MIS use. The PP design does include a comparison with data before MIS use. However, many fluctuations in production results happen over time; these fluctuations may explain the observed differences between pretest and posttest measurements. Therefore, no reliable conclusions can be drawn from this “no control” design. The no-control-time-series design (Table 2.2: TS) is the only “no control” design that may give reliable conclusions.

2.4.4 Time-series

When herd performances at several points in time after MIS introduction are significantly better than those before (within-farm comparisons), great opportunities to draw conclusions on the MIS effect are available. The advantage of time-series (apart from the type of control group applied and in contrast to pretest-posttest designs) is that they enable the researcher to separate differences between posttest and pretest values which result from MIS use, from those differences that are caused by usual trends and biases. Another advantage of applying time-series in MIS evaluation research is that the processes through which MIS affect performance, take time; for many MIS the time needed for an effect to occur is unknown (Kauffman and Weill, 1989). In the IT evaluation literature, three studies using a time-series design with a nonequivalent control group (Table 2.2: NTS) were found (Alpar and Kim, 1990; Lazarus et al., 1990; Carmi, 1992).

2.4.5 Pretest-posttest

Pretest-posttest designs call for collection of data at “only” two points in time: before and after MIS introduction. The researcher can still make within-farm comparisons, thus reducing self-selection bias. However, with pretest-posttest designs, it is more difficult to separate MIS effects from normal trends, especially when a control group is missing.

In longitudinal (pretest-posttest or time-series) studies, researchers compare the difference between the posttest and the pretest value in the MIS group, with the difference in the control group. This is more precise than comparing absolute posttest values in a posttest-only design, because, when a reasonable correlation exists between pretest and posttest values, variation in difference values will be less than variation in absolute posttest values[2]. In sow farming, for instance, the difference, between the number of piglets produced before and after MIS use, will likely have less variation than the absolute number of piglets produced on farms.

2.4.6 Posttest-only

Posttest-only designs call for only one measurement after MIS introduction. Cross-sectional data (as opposed to longitudinal data) form the basis for inferences on the MIS effect, leaving no opportunities to adjust for differences between the control group and the MIS group before MIS introduction. Therefore, the suitability of posttest-only designs depends on the comparability of the MIS and control groups before MIS introduction. In general, these designs are not recommended for MIS evaluation, unless there is some evidence that pretesting itself will bias the evaluation; this bias is called the Hawthorne effect (Fitz-Gibbon and Morris, 1987). In agriculture, pretesting may induce "control" farmers to pay more attention to their production data than before, thereby reducing the "real" effect of MIS. In case pretest-values are recorded for a different purpose or when objective historical pretest data can be retrieved from databases, the Hawthorne effect is negligible. In that case pretest-posttest designs, as well as time-series designs, are preferred to posttest-only designs. For simplicity reasons, however, researchers frequently apply posttest-only designs, and in particular, nonequivalent posttest-only designs (Table 2.2: NPO) for MIS evaluation. A statistical model is sometimes used to adjust for self-selection bias (Overbeek, 1992); yet the bias being connected with MIS use hinders proper adjustment. Therefore, conclusions based on posttest-only designs should be interpreted with care. Examples of IT evaluation studies that applied (nonequivalent) posttest-only designs include Kauffman and Weill (1989), King and Shuker (1991), and Overbeek (1992).

2.4.7 Experimental Economics

Experimental designs protect against nearly all possible threats to internal validity. However, as was mentioned in §4.1, field experiments are not frequently applied because of practical limitations. Experimental economics is a means to benefit from the strengths of

---

[2] $Var(Y_1\text{-}Y_2) = \sigma_1^2 + \sigma_2^2 - 2\rho\sigma_1\sigma_2$ where $\rho\sigma_1\sigma_2 = Cov(Y_1\text{-}Y_2)$;
if $\sigma_1 = \sigma_2 = \sigma$ then $Var(Y_1\text{-}Y_2) = 2\sigma^2(1\text{-}\rho) < \sigma^2$ if $\rho > ½$.

experimental designs and to overcome some of their weaknesses (Davis and Holt, 1993). In a laboratory environment, subjects solve decision problems that are abstract representations of the natural decision problems under study. Abstract decision problems are an essential feature of experimental economics. They allow control of the amount of information available to the subjects and result in highly repeatable outcomes. In contrast, when natural decision problems are used, subjects can have certain beliefs and experiences with them that are unknown to the experimenter, but affect the way they decide. Subjects may also become discouraged by natural decision problems when they feel that the experimental parameters do not adequately reflect the problems they are facing. For MIS evaluation in agriculture, two important effects of MIS on farmers' decision making have to be included in the abstract decision problems. First, the effect of MIS on the quality of the decisions itself must be included: MIS give the farmers insight into the bulk of farm data, by offering them data ranking and analysis options, and by calculating various index figures and key ratios. Second, the effect of MIS on the timeliness of decision making must be included: MIS provide the farmers with information more frequently than before, allowing farmers to decide more timely (in case some problems or opportunities arise).

The basic assumption of experimental economics is that the results, obtained in a laboratory environment, carry over to the more complex natural environment (Davis and Holt, 1993). Experimental economic institutions have some typical characteristics to make this assumption hold (Smith, 1982). First, subjects receive (monetary) incentives to decide optimally; they get paid according to the effectiveness of their decisions. Second, the key elements of the natural decision-making environment under study (e.g. type of decision problems, information supply, communication among subjects) are incorporated into the laboratory institution.

Some threats to external validity exist. The subjects' risk attitudes in a laboratory environment may differ from the ones they normally have. Furthermore, subjects may not be able to picture the abstract problem situation and, therefore, decide unnaturally. Using more natural decision problems, e.g. management games (Dickson et al., 1977; Kleijnen, 1980, Van Schaik, 1988) may (partly) overcome this problem. Sow farmers, for instance, will decide more naturally if they are confronted with a management game of a sow farm with in one treatment general herd information and in another treatment MIS information on individual sows. However, in this case, it is likely that the farmers also use their own experiences (with MIS) to make the decisions, meaning that there is no control of the amount of information available (ánd provided) to the farmers. The "art" of experimental economics is to design an experimental institution that contains the key elements of its natural counterpart, maintains a high level of control, and motivates subjects to decide naturally.

2.5 CONCLUSION

MIS benefits mainly result from improved decision making and are not easy to quantify. Traditional benefit-cost analysis cannot cope with this problem, meaning that more advanced evaluation approaches have to be applied when calculating MIS profitability.

Normative approaches have practical limitations when defining and describing the decisions that may be supported by MIS. Furthermore, they implicitly assume that farmers decide according to some predetermined decision criteria. This is not likely, because decision making is known to be inconsistent; and no good theory on the magnitudes and directions of these inconsistencies is available yet. Therefore, it is hard to translate outcomes of normative approaches to real-life situations.

Positive approaches evaluate MIS indirectly, analyzing (changes in) production results under the influence of MIS use. This overcomes some of the practical limitations that normative approaches have, because it does not require the specification of each decision that may have been improved by MIS information. However, such indirect measurements bear some risks, because other factors (besides MIS use) may also have affected the production results at the same time. To properly adjust for this, positive approaches put high demands on the availability and quality of field data and the type of research design.

The strength of experimental economics lies in the control over intervening variables. The “art” of experimental economics is to design an experimental institution that contains the key elements of its natural counterpart, controls intervening variables, and motivates subjects to decide naturally. However, the abstract problem formulation and the laboratory setting that are required to obtain this level of control, may cause problems when extrapolating results to real-life situations. Nevertheless, the external validity of experimental economics methods will probably outperform the validity of normative approaches, because experimental economics uses real-life decision makers instead of decision criteria. Therefore, experimental economics is considered to be an interesting alternative for MIS evaluation in agriculture.

REFERENCES

Alpar, Paul, and Kim, Moshe (1990). “A Microeconomic Approach to the Measurement of Information Technology Value.” *Journal of Management Information Systems*, 7(2): 55-69.

Anderson, Jock R., John L. Dillon, and J. Brian Hardaker (1977). *Agricultural Decision Analysis*. Iowa: Iowa State University. 344 pp.

Baker, Alan J. (1981). *Business Decision Making*. London: Croom Helm. 266 pp.

Banker, Rajiv D., and Robert J. Kauffman (1989). "Quantifying the Business Value of Information Technology: A Conceptual Framework and Application to Electronic Banking." Working Paper # 219. New York: Center for Research on Information Systems, New York University. 27 pp.

Banker, Rajiv D., Robert J. Kauffman, and Richard C. Morey (1990). "Measuring Gains in Operational Efficiency from Information Technology: A Study of the Positran Deployment at Hardee's Inc." *Journal of Management Information Systems*, 7(2): 29-54.

Baquet, Alan E., Albert N. Halter, and Frank S. Conklin (1976). "The Value of Frost Forecasting: A Bayesian Appraisal." *American Journal of Agricultural Economics*, 58(3): 511-520.

Boehlje, Michael D., and Vernon R. Eidman (1984). *Farm Management*. New York: Wiley. 806 pp.

Bosch, Darrell J., and Vernon R. Eidman (1987). "Valuing Information when Risk Preferences are Nonneutral." *American Journal of Agricultural Economics*, 69(3): 658-668.

Byerlee, Derek, and Jock R. Anderson (1982). "Risk, Utility and the Value of Information in Farmer Decision Making." *Review of Marketing and Agricultural Economics*, 50(3): 231-246.

Carmi, S. (1992). "The Performance of an Automated Dairy Management Data-Gathering System" In: *EAAP Publication no. 65, Proceedings of the International Symposium on Prospects for Automated Milking*. A.H. Ipema, A.C. Lippus, J.H.M. Metz, and W. Rossing, eds. Wageningen, The Netherlands: Pudoc. p. 346-352.

Chavas, Jean-Paul, and Rulon D. Pope (1984). "Information: Its Measurement and Valuation." *American Journal of Agricultural Economics*, 66(II): 705-710.

Davis, Douglas D., and Charles A. Holt (1993). *Experimental Economics*. Princeton NJ: Princeton University. 572 pp.

Dent, John B., and M.J. Blackie (1979). "Systems Simulation in Agriculture." London: Applied Science Publishers Ltd. 180 pp.

Dickson, Gary W., James A. Senn, and Norman L. Chervany (1977). "Research in Management Information Systems: the Minnesota Experiments." *Management Science*, 23(9): 913-923.

Fitz-Gibbon, Carol T. and Lynn L. Morris (1987). *How to Design a Program Evaluation.* Newbury Park, CA: Sage. 168 pp.

Hamilton, Scott, and Norman L. Chervany (1981). "Evaluating Information System Effectiveness -- Part I: Comparing Evaluation Approaches." *MIS Quarterly*, 5: 55-69.

Jalvingh, Alien W., Aalt A. Dijkhuizen, Johan A.M. van Arendonk, and E.W. (Pim) Brascamp (1992). "An Economic Comparison of Management Strategies on Reproduction and Replacement in Sow Herds Using a Dynamic Probabilistic Model." *Livestock Production Science*, 32: 331-350.

Jørgensen, Erik (1992). "The Utility Value of Information in Pig Production." In: *Proceedings of the Satellite Symposium "Pig Management Information Systems" at the 43th EAAP Meeting*. S. Martin Rillo, A. Aumaitre, L. den Hartog, G. Backus, P. Glodek, F. Saiz, and A. Salehar, eds. Madrid: Ministerio de Agricultura, Pesca y Alimentacion. p. 183-194.

Kauffman, Robert J., and Peter Weill (1989). "An Evaluative Framework for Research on the Performance Effects of Information Technology Investment." Working Paper # 214. New York: Center for Research on Information Systems, New York University. 19 pp.

Kennedy, John O.S., and Alistair W. Stott (1990). "An Adaptive Decision-Making Aid for Dairy Cow Replacement." Proceedings of the VIth European Congress of Agricultural Economists. EAAE. The Hague, The Netherlands. 3-9 September. p. 62-73.

King, Robert P., and Ian G. Shuker (1991). "Information Systems Adoption and Use in Local Cooperatives." *Journal of Agricultural Cooperation*, 6: 54-65.

King, Robert P., Stephen B. Harsh, and Craig L. Dobbins (1990). "Farm Information Systems: Farmer Needs and System Design Strategies." *Tijdschrift voor Sociaalwetenschappelijk Onderzoek van de Landbouw*, 5(1): 34-59.

Kleijnen, Jack P.C. (1980). *Computers and Profits: Quantifying Financial Benefits of Information*. Reading MA: Addison Wesley. 262 pp.

Kleijnen, Jack P.C. (1984). "Quantifying the Benefits of Information Systems." *European Journal of Operational Research*, 15: 38-45.

Lazarus, William F., Deborah Streeter, and Eduardo Jofre-Giraudo (1990). "Management Information Systems: Impact on Dairy Farm Profitability." *North Central Journal of Agricultural Economics*, 12: 267-277.

Lincoln, Tim J., and David Shorrock (1990). "Cost-Justifying Current Use of Information Technology." In: *Managing Information Systems for Profit*. T.J. Lincoln, ed. New York: Wiley. p. 309-330.

Lindley, Dennis V. (1971). *Making Decisions*. London: Wiley. 195 pp.

Makeham, J.P., Albert N. Halter, and John L. Dillon (1968). *Best-Bet Farm Decisions. Professional Farm Management Guidebook no. 6*. Armidale, Australia: Department of Farm Management, University of New England. 69 pp.

Overbeek, M. (Greet) M.M. (1992). “Informatietechnologie in de Melkveehouderij.” [Information Technology in Dairy Farming] LEI Onderzoekverslag 99 [LEI Research Report 99]. The Hague, The Netherlands: Agricultural Economics Research Institute. 92 pp. (in Dutch, with English Summary).

Parker, Marilyn M., Robert J. Benson, and H. Edward Trainor (1988). *Information Economics: Linking Business Performance to Information Technology*. Englewood Cliffs NJ: Prentice-Hall. 287 pp.

Schoonaert, James H. (1973). “Adoption of a Computerized Least-Cost Dairy Ration Program by Inham County, Michigan Dairymen.” MSc thesis. East Lansing, Michigan: Michigan State University. 37 pp.

Sharda, Ramseh, Steve H. Barr, and James C. McDonnell (1988). “Decision Support System Effectiveness: A Review and an Empirical Test.” *Management Science*, 34(2): 139-159.

Simon, Herbert A. (1979). “Rational Decision Making in Business Organizations.” *American Economic Review*, 69(4): 493-513.

Smidts, Ale (1990). “Decision Making Under Risk: A Study of Models and Measurement Procedures with Special Reference to the Farmer’s Marketing Behaviour.” *Wageningen Economic Studies No. 18.* Wageningen, The Netherlands: Pudoc. 329 pp.

Smith, Vernon L. (1982). “Microeconomic Systems as an Experimental Science.” *American Economic Review*, 72(5): 923-955.

Streeter, Deborah H., and Robert H. Hornbaker (1994). “Value of Information Systems: Alternative Viewpoints and Illustrations.” In: *Proceedings of the 1993 Meeting of the USA North Central Regional Research Project NC-191, Farm Level Information Systems.* R.B.M. Huirne, S.B. Harsh, A.A. Dijkhuizen, eds. 10-14 May, Zeist, The Netherlands. p. 283-293.

Swinton, Scott M., and Robert P. King (1994). “The Value of Pest Information in a Dynamic Setting: The Case of Weed Control.” *American Journal of Agricultural Economics*, 76(1): 36-46.

Van Schaik, François D.J. (1988). “Effectiveness of Decision Support Systems.” *PhD Thesis* Delft, The Netherlands: Delft University. 157 pp.

Weiss, Carol H. (1972). *Evaluation Research: Methods of Assessing Program Effectiveness.* Englewoord Cliffs, NJ: Prentice-Hall.160 pp.

CHAPTER 3

QUANTIFYING ECONOMIC BENEFITS OF SOW-HERD MANAGEMENT INFORMATION SYSTEMS USING PANEL DATA[1]

ABSTRACT

Economic benefits of management information systems (MIS) in sow farming were quantified by combining data from two survey studies. Panel analysis was conducted through estimation of a mixed-effects model by ordinary least-squares. Effects were analyzed both within farms and over farms at the same time, controlling for self-selection bias and changes over time. Adjusted for other effects in the model, production on farms adopting MIS increased by 0.56 piglets per sow per year, indicating a return on investment of between 220% and 348%. Additional tests and checks indicate that this outcome is robust.

3.1 INTRODUCTION

In the Netherlands, electronic data recording and processing facilities have developed rapidly in sow farming. The state advisory service calculated all annual herd data manually just thirteen years ago. Since 1982, manual calculations have been replaced almost completely by quarterly central computer processing of herd data. At about the same time as these changes were occuring, personal computer based systems became available to sow farmers. These systems, designed to provide daily production information on individual animal levels that is of potential value in making management decisions (Boehlje and Eidman, 1984), are indicated here as Management Information Systems (MIS).

In 1992, ten years after the introduction of MIS in sow farming, nearly 40 percent of Dutch sow farmers used MIS, including approximately 75 percent of all Dutch sows (SIVA, 1992). Various brands of MIS are used that are all very similar. The farmers run these MIS on their own personal computer, or hire central processing services. Sow

---

[1] paper by Jos A.A.M. Verstegen, Ruud B.M. Huirne, Aalt, A. Dijkhuizen, and Robert P. King, published in *American Journal of Agricultural Economics*, 77, May 1995: 387-396. The authors thank Jack P.C. Kleijnen, Erik Jørgensen, and two anonymous reviewers for their valuable comments on earlier versions of this paper.

farming has the highest MIS adoption rate among Dutch Agriculture (DCRA, 1991). The NC-191 survey on adoption and use of information systems (Batte, 1997), conducted in 1991 in thirteen midwestern states, showed that U.S. sow farmers had a computer adoption rate similar to their Dutch counterparts (33% in the US versus 37% in the Netherlands).

MIS adoption may be an indication that farmers benefit from MIS, but it is certainly not solid evidence. More objective measures for MIS benefits are desirable as development of MIS proceeds. This information can be of use to not only farmers, considering (new) MIS investments, but also to firms that design and market MIS.

The purpose of this study is to quantify the benefits of MIS adoption and use in Dutch sow farming. We first explain our research approach involving a quasi-experimental, nonequivalent time-series research design. This research design was used for investigating the relationship between MIS use and economic results. Two survey studies, conducted on the same farms in 1983 and 1992, provided panel data on animal recording practice, year of MIS adoption, and annual herd performances from 1982 to 1991. These data were analyzed in a mixed-effects model using ordinary least-squares procedures. For the average sow farm in our study, MIS use turns out to be highly profitable. Tests for autocorrelation, influential observations, and nonequivalent control time-series indicate that this outcome is robust.

3.2 RESEARCH APPROACH AND RESEARCH DESIGN

Researchers outside agriculture (Kleijnen, 1980; Kleijnen, 1984; Banker and Kauffman, 1989; Kauffman and Weill, 1989; Hamilton and Chervany, 1981) and researchers inside agriculture (King et al., 1990; Streeter and Hornbaker, 1993) address the problem of MIS evaluation. Two main research approaches can be identified. The first one is the normative approach which tries to provide a theoretical (pre-audit) measure of what MIS profitability *could be* or *should be*, based on the beneficial effects of MIS processes (e.g., better information supply, labor savings) and some predefined decision making criteria (Kleijnen, 1980). Examples of this approach are decision-tree-analysis, Bayesian Information Economics, and computer simulation. The other research approach, the positive approach, determines what the profitability of MIS *appears to be* through empirical studies (post-audit). This approach includes experimental and survey studies.

In this study, the positive approach was used because the purpose was to evaluate MIS currently used by sow farmers rather than to measure the theoretical economic value of MIS information. MIS use is a crucial aspect in MIS evaluation. MIS affect performance through the use process only (Hamilton and Chervany, 1981), either directly through the output or indirectly through advice from consultants (Jørgensen et al., 1992). MIS prove beneficial when this information leads to improved managerial decision making and, consequently, to more effective and more efficient production. Improved decision making can result from changes in decisions as well as from improved timeliness in decision making and implementation (Kleijnen, 1980). Obviously, opportunities to improve decision making through MIS use will depend on the farmers' prior record keeping and analysis practices.

Several methods are available to analyze the impact of MIS using a positive approach (Weiss, 1972; Fitz-Gibbon and Morris, 1987). They are as follows: (1) experimental designs (Schoonaert, 1973; Banker et al., 1990), (2) quasi-experimental designs (Lazarus et al., 1990), and (3) non-experimental designs (Kauffman and Weill, 1989; King and Shuker, 1991; Overbeek, 1992). Experimental designs protect against nearly all possible threats to internal validity, i.e., the degree of control for disturbing variables intervening between MIS use and the economic results of farms. Experimental designs require that farmers be randomly assigned to an MIS or control group (pre-audit). Quasi-experimental designs generally leave one or several threats to internal validity uncontrolled; nonexperimental designs face many of these threats (Weiss, 1972).

In this study, the quasi-experimental, nonequivalent time-series design was used. The term "nonequivalent" denotes that no random procedure was used to assign farmers to the MIS or control time-series. The more controlled, experimental designs could not be used because the MIS under study were already in use, prohibiting pre-audit random assignment of farmers.

One issue that arises in a study of benefits from MIS use is whether good managers are more likely to use MIS; therefore, a concern is how to sort out the effect of "better management" from the actual benefits of MIS (Lazarus et al., 1990). Computer users tend to be better educated, operate large farms, are younger (Putler and Zilberman, 1988; Batte et al., 1990), and typically have more contacts with colleagues using computers, or have children interested in computers (Jarvis, 1990). Panel data - time-series from several farmers - can overcome this self-selection problem by within-farms investigation (before and after MIS adoption).

In one of the first articles exploring relationships between farm computer systems and economic results, Lazarus et al. (1990) applied a quasi-experimental, nonequivalent time-series design. However, despite the use of time-series, problems were encountered in separating farmer characteristics (management) from computer system effects on those farms that used computers over the entire time period. In this study, we follow Mundlak (1961) by constructing dummy variables for each individual farm in the statistical model.

3.3 DATA

Various sociological, technical and economic data on 143 Dutch sow farms were recorded in a socio-economic survey conducted in 1983. These data investigated relationships between farmer characteristics and production performance on sow farms (Mok and Van den Tillaart, 1990). The farmers belonged to a group of 205 sow farmers who had received questionnaires from their extension officers. The 205 farmers in this group were selected according to three criteria: a) ownership of a farrow-to-finish unit for pigs; b) 1982-membership of the state advisory service and its central Herd Record System, which means that all farmers received basic information about their herd performance; and c) living in the operational area of one specific state advisory service (including two provinces in the southern part of the Netherlands).

An important aspect of this survey (henceforth referred to as 1983-survey) is that very few Dutch sow farmers made use of MIS at that time. This means that the data recorded in this survey are adequate to use as "results before MIS use". Between 1983 and 1992, about 40 percent of the Dutch sow farmers started to use MIS (SIVA, 1992). Therefore, a second survey on the same farms, the 1992-survey, was organized to obtain "results after MIS use" as well. Of the initial 143 1983-survey farmers, ninety-three could be approached. Seventy-one of these farmers still owned a farm and were willing to participate in the 1992-survey. These farmers were interviewed on the basis of a questionnaire similar to that used in the 1983-survey. In addition, data on animal recording practice, year of MIS adoption, and annual herd performances from 1983 to 1991, were collected.

The "number of piglets raised (to about 25 kg live weight) per sow per year" was used to analyze the MIS effect. This highly aggregated figure contains all the effects that MIS may have on major herd performances, including an increased number of farrowings per sow per year and reduced piglet mortality.

The data collected in the 1983-survey and 1992-survey contain 442 annual observations from 71 farms on the "number of piglets raised per sow per year". This indicates that, from the average farm, more than 6 annual observations ($442/71 \approx 6.2$) were derived. All farms could provide the "number of piglets raised per sow per year" in 1982. Also, the corresponding values for 1990 and 1991 are available from the 71 farms. Over twenty farmers could provide a complete time-series, consisting of the "number of piglets raised per sow per year" for each year between 1983 and 1992.

The representativeness of the survey farms was assessed by comparing the average number of sows and the average number of piglets raised per sow per year on the sow farms that participated in both surveys to other sow farms in the same region, and to Dutch sow farms in general (DMANMF, 1993). In 1983, survey farms had, on average, 126 sows whereas the average values for the same region and the Netherlands were 110 sows. However, the expansion from 1983 till 1992 was about the same in the three groups (between 35 and 43 sows). This means, that in 1992, survey farm sizes were still larger than the others. The number of piglets raised per sow in 1982 (as recorded in 1983) was a little above the regional average, but below the national average (17.2 versus 17.0 and 17.4). In 1991, survey farms had better results than those in their region and in the Netherlands (19.2 versus 18.6 and 18.8). From these figures, no conclusion can be drawn about the MIS effect, since all three groups contain farmers who do and do not use MIS. The differences in average number of piglets between 1991 and 1982 underestimate the actual technological trend in the production results by at least 1.5 piglets raised per sow per year because of an outbreak of blue ear disease in Dutch pig farming in 1991 (Dijkhuizen et al., 1991). In 1990, the averages on the number of piglets raised per sow per year were 20.7, 20.4, and 20.4, respectively, for the survey study, survey region, and the Netherlands (DMANMF, 1993).

Table 3.1 Percentage of sow farmers using MIS, percentage of MIS users processing data at central services and percentage of MIS users working with personal computers (survey vs national average, 1992)

	% of Sow Farmers Using MIS	% of Users Processing Centrally	% of Users Processing on Own P.C.
Survey	76%	20%	80%
National Average[1]	41%	55%	45%

[1] source: SIVA, 1992

Differences between the survey farms and other Dutch farms are more marked when looking at MIS use. Table 3.1 shows that the percentage of survey farmers using MIS in 1992 was considerably higher than the national average. Of the 71 farms in the survey, 54 used MIS. Apparently, the initial selection criterion in 1983, requiring that sow farmers should be a member of the advisory service, resulted in an implicit selection of a more information-seeking type of farmer. Furthermore, 43 (80%) of the 54 survey farmers using MIS made use of their own personal computer, compared to 45% of the nation as a whole. This also indicates that the more information-seeking type of farmers was selected. Many farmers who have used MIS at a central processing organization for a number of years decide to buy a personal computer to process data themselves. Apparently, the survey farmers lead the way in the automation of their information supply. The consequences of this selection are discussed in the final section of this paper.

The advantage of the high MIS adoption in our study is that more before-and-after-MIS comparisons could be made than in the Lazarus et al. (1990) study. At the end of their study in 1987, only 23 of the 196 dairy farms had adopted on-farm computers for accounting. Moreover, seven of them already adopted MIS before the start of their study in 1984, implying that only 16 before-and-after-MIS comparisons could be made.

3.4 STATISTICAL MODEL

By merging data collected in the 1983-survey and the 1992-survey, we obtained a panel data set with 442 observations from 71 farms over the period 1982-1991, on the dependent variable, i.e., number of piglets raised per sow per year. Earlier studies evaluating MIS with panel data showed that least-squares techniques can account for trend effects and variation in periods of MIS use (Lazarus et al., 1990; Carmi, 1992). Therefore, these panel data were statistically analyzed through ordinary least-squares (OLS) procedures (SAS). A mixed-effects model was constructed to estimate the effect of MIS on the dependent variable. After elimination of non-significant FARM*FYA dummies, the following regression model was estimated:

$$(1)\quad PSY_{ij} = \alpha_{83}\,YR82_{ij} + ... + \alpha_{91}\,YR90_{ij} + \beta_1\,FARM1_{ij} + ... + \beta_{70}\,FARM70_{ij} + \gamma FYA_{ij} + \delta MIS_{ij} + \varepsilon_1(FARM1{*}MIS)_{ij} + ... + \varepsilon_{70}\,(FARM70{*}MIS)_{ij} + error_{ij}$$

where PSY_{ij} is the number of piglets raised per sow per year on farm i in year j (i= farm 1 to farm 71; j= 1982 to 1991); $YR82_{ij}$ ...$YR90_{ij}$ are YEAR dummies (e.g., $YR82_{ij}$ =1, if PSY_i is derived in year j=1982; otherwise $YR82_{ij}$ =0); $FARM1_{ij}$ ...$FARM70_{ij}$ are FARM dummies (e.g., $FARM1_{ij}$ =1, if PSY_j is derived from farm i=1; otherwise $FARM1_{ij}$ =0); FYA_{ij} is the first-year adjustment (FYA_{ij}=1, if year j is the first year of MIS use on farm i; otherwise FYA_{ij} =0); MIS_{ij} is the MIS effect (MIS_{ij} =1, if farm i uses MIS in year j; otherwise MIS_{ij} =0); and $error_{ij}$ are normally and independently distributed error terms: $N(0,\sigma^2)$. Finally, the α's, β's, γ, δ, and ε's are 125 model parameters to be estimated.

A great advantage of having panel data is that effects can be estimated both within and between farms, allowing for a separation of farm-specific and common (trend) effects. The YEAR dummies in model (1) control for variation in the number of piglets per sow per year (PSY) resulting from trends in management, technological progress, disease outbreaks, and other aspects that are common to all farms.

An important distinction between model (1) and the model used by Lazarus et al. (1990), is the inclusion of a FARM dummy for each individual farm in model (1). After adjustments (with YEAR dummies) for trends in production results that are common to all farms, the FARM dummies adjust for variation between farms in the level of production, as a result of differences in farm lay-out, intellectual and motivational aspects of the farmers (Mundlak, 1961).

An additional advantage of using FARM dummies is that, in this way, only farms with observations before ánd after MIS use can contribute to the MIS estimate, thus avoiding problems of distinguishing between production level and MIS effects on farms that had MIS during the entire period of data collection.

The process of MIS installation, data entry, learning and finally using MIS information in farm management takes time, and MIS benefits will be delayed. Ignoring this starting period in the estimation of MIS effects could lead to an underestimation of the effect. Therefore, the dummy variable “First-Year Adjustment” (FYA) was defined. The variable adjusts the MIS effect for starting-up problems and for not having MIS during the entire year. For example, when a farmer starts using a management information system in November 1984, this will not likely affect the 1984-observation of “number of piglets raised per sow per year”.

To estimate the MIS effect, the variable MIS was added to the model and so were the FARM*MIS dummies. These interactions account for differences in MIS effect between farms.

Because the regression model has a special form (only dummy variables), an analysis of variance procedure was used in estimation (PROC GLM, type III SS; SAS). The 70 FARM dummies in the regression model are represented by the class variable FARM with 71 levels (and 70 degrees of freedom), and the 9 YEAR dummies by the class variable YEAR with 10 levels (and 9 degrees of freedom).

The present study was designed to quantify MIS benefits for sow farming in general, rather than quantifying MIS benefits for selected survey farms. Consequently, the FARM effect and FARM*MIS effect had to be considered as random effects. A mixed-effects model was applied defining YEAR, FYA, and MIS as fixed effects and FARM, and FARM*MIS as random effects. Because of confounding (“only” 45 of the 71 farms contribute to the MIS estimate), the expected mean squares of both the FARM and MIS effect contain variation due to FARM*MIS. This results in an overstating of the numerators in normal F-tests and, therefore, will give rise to too many significant outcomes for the FARM and MIS effect. To adjust for overstatement, an approximation was employed to adjust the denominators of the F-tests for the FARM*MIS variation in the numerator (Satterthwaite, 1946).

3.5 RESULTS

In this section, the econometric estimation is provided, followed by tests for autocorrelation, and checks on influential observations and nonequivalent time-series.

3.5.1 Econometric estimation

The results of the analysis of variance are presented in tables 2 and 3.
The statistical model explains 80% of the total variation of the number of piglets raised per sow per year, as indicated in Table 3.2.

Table 3.2 Results of the analysis of variance with a mixed-effects model

Source	Effects	DF	Type III Sum of Squares	F Value	Pr > F
Model		125	1,776.51	9.90	≤ 0.0001
FARM	Random	70	962.78	3.73[1]	≤ 0.0001[1]
YEAR	Fixed	9	242.22	18.74	≤ 0.0001
FYA[2]	Fixed	1	4.04	2.82	0.0943
MIS	Fixed	1	6.58	3.19[1]	**0.0763[1]**
FARM*MIS	Random	44	147.51	2.33	≤ 0.0001
Error		316	453.76		
Adjusted Total		441	2,230.27		

Note: Dependent variable: number of piglets raised per sow per year (PSY); Mean dependent variable = 19.30; R-square = 0.80; Adjusted R-square = 0.72; Coefficient of variation = 6.21; Root mean square error = 1.20;

1 F-test with Satterthwaite approximation;

2 Adjustment for the first year of MIS use.

Adjusting for the number of independent variables gives an adjusted R-square of 0.72. Forty-five farms were able to provide data on years before and after MIS adoption, shown by the 44 degrees of freedom for FARM*MIS in Table 3.2. The remaining 9 farms using

MIS were kept in the analysis but did not affect the MIS estimate because they provide only observations before, or only observations after, MIS use. The results indicate some support for an MIS effect (p=0.08). (The MIS coefficient estimate is constructed by adding the average FARM*MIS effect to the "pure" MIS effect, resulting in the estimate of 0.56 - Table 3.3.) This indicates that from the second year of MIS use onward average production of the 45 MIS farms (adjusted for other effects in the model) increased by 0.56 piglets raised per sow per year. The estimated coefficient for FYA is - 0.45 piglets raised per sow per year, indicating a small MIS benefit in the first year of MIS use (i.e., 0.56 - 0.45 = 0.11).

Table 3.3 Coefficient estimates of two major variables of interest: MIS and FYA

Parameter	Coefficient	Std. error	t-statistic	Pr > |T|
MIS[1]	**0.56**	0.26	2.14	0.0331[2]
FYA[3]	-0.45	0.27	-1.68	0.0943

1 MIS effect = sum of "pure" MIS effect and average FARM*MIS effect
2 F-test with Satterthwaite approximation reveals p = 0.08;
3 Adjustment for the first year of MIS use.

3.5.2 Tests for autocorrelation

A disadvantage of using panel data (or single time-series) is that the model error terms may be correlated over time (autocorrelation). A basic assumption of ordinary least-squares (OLS) procedures (in contrast with methods such as generalized least-squares) is that the error terms are mutually independent. Autocorrelation is a symptom of systematic lack of fit. Moreover, autocorrelation adversely affects the efficiency of OLS parameter estimates and biases standard errors estimates (Maddala, 1992).

Because the Durbin-Watson statistic is biased towards 2 when using panel data, an alternative procedure to detect autocorrelation was employed using the linear correlation coefficient r (Press et al., 1988). The linear correlation coefficient was estimated after adding a blank error term between different farms in the data set. The estimated (auto)correlation coefficient was very low (0.01) and the null hypothesis of zero-correlation was not rejected. This provides evidence of no first-order autocorrelation in the model. Other correlations between the error terms (e.g., between farms) are not likely to exist. Consequently, there was no need for use of other statistical methods like generalized least-squares.

3.5.3 Check on influential observations

Influential observations are those that, according to various criteria, appear to have a great influence on the parameter estimates. A small number of influential observations is an indication for good model stability; elimination of one of the observations has little or no effect on the parameter estimates. A check on influential observations was carried out using the RSTUDENT diagnostic statistic of the SAS procedure GLM (SAS, 1988; Belsley et al., 1980).

According to this statistic, 22 of the 442 observations in the data set were found to be influential ($\alpha = 0.05$). However, with multiple pairwise comparisons representing one of many "draws" from the distribution one may find (442 * 0.05 =) 22 observations just by chance. Therefore, an alternative, more appropriate, test statistic was applied for multiple comparisons: the Bonferroni t-value. The Bonferroni t-value is used to test the hypothesis that a studentized residual occurs with α/n probability, where α is the probability of mistakenly rejecting the hypothesis that e_i is an outlier when n is the number of observations in the sample (Kleijnen, 1992). In order to protect its power, the Bonferroni inequality test is usually based on a somewhat higher error rate, i.e., an error rate of 0.20 instead of the usual error rate of 0.05 (Kleijnen, 1987). In this study, the Bonferroni multiple comparisons error rate was {0.20 / (2*442) =} 0.000226. The corresponding Bonferroni critical t-value with (442 - 125 =) 317 degrees of freedom is approximated by the area below the standard normal distribution function and equals 3.51. According to this critical value, only two of the initial 22 observations are influential. Recalculation of the model after elimination of these influential observations resulted in an MIS coefficient estimate of 0.80 (p=0.001). Re-examination of the questionnaires revealed that a serious disease outbreak and poor recording of one farmer may explain why these observations are outliers. However, these problems may (to a lesser extent) also be present on the other farms in the survey. Therefore, the more conservative 0.56 estimate is preferred to the 0.80 estimate.

3.5.4 Check on nonequivalent control time-series

Estimation of the MIS effect with panel data makes it possible to determine effects within farms over time. However, we need to check whether the YEAR dummies are negatively influenced by the farms that have never used MIS. If technological progress (besides MIS use) is lower over time for the nonequivalent control farms, the MIS effect on the other ("treated") farms may be overestimated. Therefore, the same statistical model was estimated with a sample of the data set containing only farms that made use of MIS during at least one of ten years (Table 3.4).

Table 3.4 Coefficients of two major variables of interest, MIS and FYA estimated without nonuser farms in the data set

Parameter	Coefficient	Std. error	t-statistic	Pr > |T|
MIS[1]	**0.55**	0.31	1.79	0.0745[2]
FYA[3]	-0.52	0.28	-1.89	0.0600

1 MIS effect = sum of "pure" MIS effect and average FARM*MIS effect;
2 F-test with Satterthwaite approximation reveals p = 0.1222;
3 Adjustment for the first year of MIS use.

Due to the reduction of observations, and hence a reduction in the degrees of freedom in the denominator of the F test, the p-value of the MIS effect increased from 0.08 to 0.12 and the p-value of the FYA effect decreased from 0.09 to 0.06. It is important to note, however, that the estimate of the MIS effect changed only slightly (from 0.56 to 0.55). The change in the estimate of the FYA effect was also small (-0.45 to -0.52). This suggests that control farms realized a technological progress similar to that of the MIS farms, and therefore their inclusion did not bias the MIS estimate.

3.6 DISCUSSION

In the first part of the discussion, we illustrate the meaning of the MIS effect in economic terms. The second part discusses the robustness of the MIS effect.

3.6.1 Economic contribution of MIS

In this study we quantified the benefits of MIS as they are currently used in sow farming by combining data from two survey studies in a quasi-experimental, nonequivalent time-series research design. Panel analysis was conducted through estimation of a mixed-effects model by ordinary least-squares. The model contained one dummy variable per individual farm (Mundlak, 1961) and effects were analyzed both within farms and over farms at the same time, controlling for self-selection bias and changes over time. The result is an adjusted R-square of 0.72 (Table 3.2) which is high compared with an adjusted R-square of 0.18 in a similar study without FARM dummies (Lazarus et al., 1990). Therefore, it is possible to show a fairly strong positive relationship between MIS use and technical production results of sow farms (Table 3.2). Adjusted for other factors in the model, production on farms adopting MIS increased by 0.56 piglets per sow per year, from the second year of MIS use onward (Table 3.3). This indicates a positive economic contribution of MIS to sow farm results. Under normal Dutch price conditions, the marginal economic value per sow per year of one piglet equals U.S. $40. Therefore, the yearly benefits of an increase of 0.56 piglets per sow on a 165-sow farm (about the average farm size in the survey) equal $3,696. The costs of MIS use consist of hardware and software costs. The retail prices of hardware are about $1,500 for a personal computer and $250 for a matrix printer. The retail price of the MIS software is about $2,750 with an additional $225 for yearly updates (from the second year onward). Depreciating both hardware and software over five years brings the total yearly MIS costs to $1,080. Therefore, the yearly profit of MIS use on a 165-sow farm equals (3,696-1,080=) $2,616.

The MIS costs of farmers who use central processing services, instead of on-farm computers, range from $5 to $7 per sow per year, i.e., $825 to $1,155 for a 165-sow farm. This results in an MIS profit ranging from $2,541 to $2,871 per year, with returns on investments ranging from 220% {100% * (3696-1155)/1155} to 348% {100% * (3696-825)/825}. Net returns to labor and management on a 165-sow farm are typically about $33,000 ($ 200 per sow), implying that MIS increase profits between 7.7% and 8.7%.

An interesting question is whether farms outside the research population can be expected to earn this return. The survey farmers, MIS users as well as nonusers, are not a random sample of Dutch sow farmers, but are above average in farm size and production results. The survey farmers also seem to be above average in information-seeking, expressed by a higher MIS adoption rate (Table 3.1). Moreover, participation in the second survey means that all these farms survived competition in sow farming during the last ten years and thus might be better than the average farm. The survey farmers may be better in processing and incorporating MIS information in their farm management, suggesting higher MIS benefits than with other sow farmers. On the other hand, all the farmers in the survey already received basic herd information from the state advisory service. They also had regular contact with advisors, implying that they are likely to receive less value added from MIS information than farmers who lack these information sources. A prerequisite is that these latter farmers are interested in management information. Only when their decisions are influenced by MIS will they receive benefits. Otherwise, MIS purchase will only raise production costs.

3.6.2 Intervening variables

A general disadvantage of quasi-experimental or nonexperimental studies is that causality of the relationships cannot be proved. The improvement in number of piglets raised per sow per year after MIS use may also (partly) be the result of exogenous changes other than MIS use. If these changes coincide with the start of MIS use and do not occur in the group of nonusers, then they will be regarded as MIS effects. This is no problem if these changes are caused by MIS use (e.g., change of feed ration after detecting a specific piglet mortality). However, changes that are the result of differences in the characteristics or goals of MIS adopters, in farm lay-out or in intergenerational transfer situation, may also be incorrectly included in the measurement of MIS benefits. The applied research design reduced self-selection bias drastically, but not completely. Tests based on field studies bring credibility to the results compared to alternative explanations. One alternative explanation may be that the estimate of 0.56 piglets raised per sow per year results from inconsistency in the way in which this figure is defined and calculated over time. This is particularly important when differences exist between definitions of the MIS types that are included in this study, and previously used record systems. However, additional calculations showed that the bias in the MIS estimate is likely to be small and will not affect the significance of the MIS effect. Possible changes in definitions over time cause a reduction in the number of piglets raised per sow per year, indicating that the actual effect of MIS exceeds 0.56.[2]

As mentioned above, another factor that may interfere with the MIS effect is intergenerational transfer. In thirteen cases, the 1992-questionnaire was completed by a person different from the one who completed the 1983-questionnaire. Four of them were relatives of about the same age, and nine of them were heirs. This indicates that a shift in responsibilities between 1983 and 1992 had taken place because the actual farm manager was asked to complete the questionnaire. Although intergenerational transfer usually takes place without turbulent changes, MIS introduction may coincide with the time heirs take over responsibilities for farm management decisions. All nine farms with an heir started to use MIS between 1983 and 1992. Additional analyses showed that MIS effects on these nine farms were above average because eliminating them from the data set would decrease the MIS coefficient estimate to 0.4. A reason the MIS effects were above average for these farms may be that farmers with heirs, and the heirs themselves, are more focused on MIS use and thereby experience higher MIS benefits. Another explanation may be that the heirs are better managers than their predecessors. Trends in management and technological progress on succeeding farms may deviate from those of the average survey farm (adjusted

2 Before MIS use, all survey farmers used the “number of piglets *raised* per sow per year”. MIS provide this figure as well, but also the “number of piglets weaned per sow per year”. Figures are approximately 0.3 higher with the latter definition, thus underestimating the actual MIS effect. Possible changes over time in the definitions of the average number of sows on a farm would also result in higher figures.

for in the YEAR effect) and may, therefore, be incorrectly included in the MIS effect. In-depth analyses of the MIS benefits per individual farm (FARM*MIS effects) would allow for a better separation of MIS effects from deviant trends in management, not covered by the YEAR effect. However, due to large variation and a small number of observations per farm in this study, individual FARM*MIS coefficients are non-interpretable and this inhibits in-depth analyses. It is difficult to overcome this problem because aggregated figures, such as the number of piglets raised per sow per year, will always fluctuate widely within farms over time; it would require a comprehensive list of variables to adjust for this variation in a statistical model. Collecting data over a longer period of time, thus providing more observations per farm, is not likely to solve the problem because more things may have changed. For instance, intergenerational transfer or important investments may have taken place.

3.7 CONCLUSION

The significance of the present study is that it demonstrates a powerful combination of research design and statistical analysis to quantify overall MIS effects. An MIS estimate was revealed of 0.56 piglets per sow per year for an average farm, indicating a return on investment of between 220 and 348 percent. Some factors such as changes in performance definitions or intergenerational transfer may bias this estimate but are not likely to affect the significance of the MIS effect. Quantification of MIS benefits on individual farms, and quantification of relationships between MIS benefits and individual farm characteristics are the new challenges to MIS evaluation research. Quantification of these effects is needed to evaluate the role of extension services in supporting MIS investment decisions of individual farmers. Controlled positive research approaches through experimental designs seem to be most adequate for this purpose.

REFERENCES

Banker, Rajiv D., and Robert J. Kauffman (1989). "Quantifying the Business Value of Information Technology: A Conceptual Framework and Application to Electronic Banking." Working Paper # 219. New York: Center for Research on Information Systems, New York University. 27 pp.

Banker, Rajiv D., Robert J. Kauffman, and R.C. Morey (1990). "Measuring Gains in Operational Efficiency from Information Technology: A Study of the Positran Deployment at Hardee's Inc." *Journal of Management Information Systems*, 7(2): 29-54.

Batte, Marvin T. (1997). "Report of the NC-191 Survey on Adoption and Use of Information Systems." Ohio State University, forthcoming.

Batte, Marvin T., Eugene Jones, and Gary D. Schnitkey (1990). "Computer Use by Ohio Commercial Farmers." *American Journal of Agricultural Economics*, 72: 935-945.

Belsley, David A., Edwin Kuh, and Roy E. Welsch (1980). *Regression Diagnostics: Identifying Influential Data and Sources of Collinearity*. New York: Wiley. 292 pp.

Boehlje, Michael D., and Vernon R. Eidman (1984). *Farm Management*. New York: Wiley. 806 pp.

Carmi, S. (1992). "The Performance of an Automated Dairy Management Data-Gathering System" In: *EAAP Publication no. 65, Proceedings of the International Symposium on Prospects for Automated Milking*. A.H. Ipema, A.C. Lippus, J.H.M. Metz, and W. Rossing, eds. Wageningen, The Netherlands: Pudoc. p. 346-352.

Dutch Council for Research in Agriculture (1991). "Information Technology in Agriculture." NRLO Report 91/3. The Hague, The Netherlands: Nationale Raad voor Landbouwkundig Onderzoek (in Dutch; English translation available).

Dutch Ministry of Agriculture, Nature Management, and Fisheries (1993). Unpublished Data on Technical and Economic Results of Swine Breeding Herds in the Netherlands. Rosmalen: Information and Knowledge Center for Livestock Farming.

Dijkhuizen, Aalt A., Alien W. Jalvingh, Freddy W.M.M. Bolder, Jentje Stelwagen, and Ynte-Hein Schukken (1991). "Determining the Economic Impact of the 'New' Pig Disease." Proceedings EC-seminar, Brussels, 4-5 November 1991, p. 53-60.

Fitz-Gibbon, Carol T., and Lynn L. Morris (1987). *How to Design a Program Evaluation.* Newbury Park, CA: Sage. 168 pp.

Hamilton, Scott, and Norman L. Chervany (1981). "Evaluating Information System Effectiveness -- Part I: Comparing Evaluation Approaches." *MIS Quarterly*, 5: 55-69.

Jarvis, Anne Marie (1990). "Computer Adoption Decisions - Implications for Research and Extension: The Case of Texas Rice Producers." *American Journal of Agricultural Economics*, 72: 1388-1394.

Jørgensen, Erik, V. Ruby, and L. Herløv (1992). "Review of Danish Experiences with Decision Support Systems in Pig Production." Proceedings of the 4th International Congress for Computer Technology in Agriculture, Société des Agriculteurs de France, France, 1-3 June 1992, p. 201-204.

Kauffman, Robert J., and Peter Weill (1989). "An Evaluative Framework for Research on the Performance Effects of Information Technology Investment." Working Paper # 214, New York: Center for Research on Information Systems, New York University. 19 pp.

King, Robert P., and Ian G. Shuker (1991). "Information Systems Adoption and Use in Local Cooperatives." *Journal of Agricultural Cooperation*, 6: 54-65.

King, Robert P., Stephen B. Harsh, and Craig L. Dobbins (1990). "Farm Information Systems: Farmer Needs and System Design Strategies." *Tijdschrift voor Sociaalwetenschappelijk Onderzoek van de Landbouw*, 5(1): 34-59.

Kleijnen, Jack P.C. (1980). *Computers and Profits: Quantifying Financial Benefits of Information*. Reading MA: Addison Wesley. 262 pp.

Kleijnen, Jack P.C. (1984). "Quantifying the Benefits of Information Systems." *European Journal of Operational Research*, 15: 38-45.

Kleijnen, Jack P.C. (1987). *Statistical Tools for Simulation Practitioners*. New York: Marcel Dekker. 429 pp.

Kleijnen, Jack P.C., and Willem J.H. van Groenendaal (1992). *Simulation: a Statistical Perspective*. Chichester UK: Wiley. 241 pp.

Lazarus, William F., Deborah Streeter, and Eduardo Jofre-Giraudo (1990). "Management Information Systems: Impact on Dairy Farm Profitability." *North Central Journal of Agricultural Economics*, 12: 267-277.

Maddala, Gangadharrao S. (1992). *Introduction to Econometrics*. New York: Macmillan. 631 pp.

Mok, Albert L., and Harrie J.M. van den Tillaart (1990). "Farmers and Small Businessmen: A Comparative Analysis of their Careers and Occupational Orientation." In: *New Findings and Perspectives in Entrepreneurship*. R. Donckels and A. Miettinen, eds. Aldershot UK: Avebury. p. 203-230.

Mundlak, Yair (1961). "Empirical Production Function Free of Management Bias." *Joural of Farm Economics*, 43: 44-56.

Overbeek, M. (Greet) M.M. (1992). "Informatietechnologie in de Melkveehouderij." [Information Technology in Dairy Farming] LEI Onderzoekverslag 99 [LEI Research Report 99]. The Hague, The Netherlands: Agricultural Economics Research Institute. 92 pp. (in Dutch, with English Summary).

Press, William H., Brian P. Flannery, Saul A. Teukolsky, and William T. Vetterling (1988). *Numerical Recipes*. Cambridge: Cambridge University Press. 818 pp.

Putler, Daniel S., and David Zilberman (1988). "Computer Use in Agriculture: Evidence from Tulare County, California." *American Journal of Agricultural Economics*, 70(4): 790-802.

SAS (1988). *SAS/STAT® User's Guide*. Release 6.03 Edition. Cary, NC: SAS Institute. 1028 pp.

Satterthwaite, Franklin E. (1946). "An Approximate Distribution of Estimates of Variance Components." *Biometrics Bulletin*, 2:110-114.

Schoonaert, James H. (1973). "Adoption of a Computerized Least-Cost Dairy Ration Program by Inham County, Michigan Dairymen." MSc thesis. East Lansing, Michigan: Michigan State University. 37 pp.

SIVA. (1992). "Aantal Gebruikers blijft groeien". [The Number of MIS Users is Still Increasing]." *Siva Visie*, 3(2): 1 (in Dutch).

Streeter, Deborah H., and Robert H. Hornbaker (1994). "Value of Information Systems: Alternative Viewpoints and Illustrations." In: *Proceedings of the 1993 Meeting of the USA North Central Regional Research Project NC-191, Farm Level Information Systems.* R.B.M. Huirne, S.B. Harsh, A.A. Dijkhuizen, eds. 10-14 May, Zeist, The Netherlands. p.283-293.

Weiss, Carol H. (1972). *Evaluation Research: Methods of Assessing Program Effectiveness*. Englewood Cliffs, NJ: Prentice-Hall. 160 pp.

CHAPTER 4

IMPACT OF STYLES OF FARMING AND MANAGEMENT LEVELS ON THE PROFITABILITY OF SOW-HERD MANAGEMENT INFORMATION SYSTEMS[1]

ABSTRACT

Profitability of sow-herd management information systems (MIS) arises from improved managerial decision making and, therefore, will vary from farm to farm. Insight into this variation will be of use not only to sow farmers who consider (new) MIS investments, but also to companies that design and market MIS. In this study, the impact of farm characteristics on MIS profitability is investigated, comparing two conceptually different farm classification approaches within the same research population: the sociological "style of farming" approach and the farm-economic "management level" approach. Management levels of sow farmers were positively correlated with MIS profitability (r=0.35, p=0.02). Although farmers with high management levels tend to be better-informed than farmers with low management levels, they still get more added value from MIS.

4.1 INTRODUCTION

Sow-herd management information systems (MIS) are systems designed to provide daily production information at individual sow levels that is of potential value in making management decisions (Boehlje and Eidman, 1984). The profitability of MIS arises from improved managerial decision making (Hamilton and Chervany, 1981) and, therefore, will vary from farm to farm, affected by farm characteristics such as the competence and goals of the farmer and the farm size. Insight into the variation of MIS profitability among farms will be of use not only to sow farmers who consider (new) MIS investments, but also to companies that design and market MIS (King et al., 1990). Moreover, farm advisors can use the insight to more specifically support farmers in improving farm results with MIS.

Farm characteristics have been studied extensively in relationship with farm performance (e.g., Alleblas, 1988; Mok and Van den Tillaart, 1990), and in relationship with MIS use (Putler and Zilberman, 1988; Batte et al., 1990, Jarvis, 1990).

---

[1] paper by Jos A.A.M. Verstegen, Ruud B.M. Huirne, Aalt A. Dijkhuizen, and Jan A Renkema, submitted to Agricultural Economics. The authors thank E.(Bert-Jan) H.J. Braakman for his valuable contribution to this study.

The purpose of the present study is to determine the impact of farm characteristics on MIS profitability. Two farm classification approaches that are commonly used in the Netherlands are compared within the same research population: the sociological "style of farming" approach (Van der Ploeg, 1990) and the farm-economic "management level" approach (Alleblas, 1988). Panel data of 71 pig farms in the southern part of the Netherlands are obtained from a survey study of Verstegen et al. (1995). Unlike many cross-sectional MIS-evaluation studies, their study could investigate farm performances over time by merging survey data collected in 1983 and 1992. Farm developments before and after MIS use were compared and the result was that, from the second year of MIS use onward, average production of the MIS farms (adjusted for farm, trend, and learning effects) increased by 0.56 piglets raised per sow per year. Converted into economic terms, MIS use resulted in a profit of US$ 15 to US$ 17 per sow per year, meaning a return on investment of 220 to 348% and 7.7 to 8.7% of the typical Dutch income per sow per year. The study also revealed that MIS effects differed significantly between farms.

This paper reports on an in-depth analysis of the differences in MIS effects. It starts with a short description of the survey study of Verstegen et al. (1995), followed by a characterization of the two farm classification approaches. Subsequently, the results of each classification approach are presented and a comparison is made between both approaches. Finally, the results are discussed and conclusions are drawn.

4.2 SURVEY STUDY

Various sociological, technical and economic data were recorded on 143 Dutch pig farms in a survey study conducted in 1983 (Mok and Van den Tillaart, 1990). These data investigated relationships between farmer characteristics and production performance on pig farms. The farmers belonged to a group of 205 pig farmers who had received questionnaires from their extension officers. The 205 farmers were selected according to three criteria: a) ownership of a farrow-to-finish unit for pigs; b) 1982-membership of the state advisory service and its central Herd Record System, which means that all farmers received basic information about their overall herd performance; and c) living in the operational area of one specific district of the state advisory service (including two provinces in the southern part of the Netherlands). An important aspect of this survey (henceforth referred to as 1983-survey) is that very few Dutch pig farmers made use of MIS at that time. This means that the data recorded in this survey are adequate to use as "results before MIS use". Between 1983 and 1992, 41 percent of the Dutch sow farmers started to use MIS (SIVA, 1992). Therefore, a second survey on the same farms, the 1992-survey, was organized to obtain "results after MIS use" as well. Of the initial 143 1983-survey farmers, ninety-three could be approached. Seventy-one of these farmers still owned a farm and were willing to participate in the 1992-survey. These farmers were interviewed on the basis of a questionnaire similar to that used in the 1983-survey. In addition, data on animal recording practice, year of MIS adoption, and annual herd performances over the period 1983-91, were collected. By merging data collected in the 1983-survey and the 1992-survey, a panel data set was obtained with 442 observations from 71 farms over the period 1982-91, on the "number of piglets raised per sow per year" (to about 25 kg live weight). This highly aggregate figure was used to analyse the MIS effect because it contains all the effects that sow-herd MIS may have on major herd performances, including an increased number of farrowings per sow per year and reduced piglet mortality.

In 1992, 54 of the 71 survey farms (76%) had started using MIS, of which 43 (80%) used MIS on their own personal computer, and eleven (20%) hired a central processing service. The MIS adoption rate of 76 percent was considerably higher than the national average of 41 percent. Further comparisons of the survey farms with other pig farms in the same region and in the nation as a whole showed that survey farms were somewhat larger than other pig farms in both 1983 and 1992. The number of piglets raised per sow in 1982 (as recorded in 1983) was similar in the survey, the region and the nation (17.2 versus 17.0 and 17.4). In 1991, survey farms raised slightly more piglets than farms in the region and the Netherlands as a whole (19.2 versus 18.6 and 18.8: Verstegen et al. 1995).

The panel data were statistically analyzed in a mixed-effects model using ordinary least-squares (OLS) procedures. Forty-five survey farms could provide data on before and after MIS use and, thus, could be used for estimation of the effect of MIS on the number of piglets raised per sow per year (PSY). A great advantage of having panel data was that effects could be estimated both within and between farms, allowing for a separation of farm-specific and common (trend) effects. The statistical model explained (R^2=) 80% of the total variation of the number of piglets raised per sow per year and the results suggested an effect of MIS on PSY ($p=0.08$). From the second year of MIS use onward, average production of the MIS farms (adjusted for farm, trend, and learning effects) increased by 0.56 piglets raised per sow per year (Verstegen et al., 1995). The interaction between farm characteristics and MIS effect in the statistical model demonstrated that differences in MIS profitability between farms were highly significant ($p \leq 0.0001$). The next section describes the two farm classifications that we will use in this study to gain more insight into these differences.

4.3 FARM CLASSIFICATIONS

Classification entails the use of a class variable to form groups in such a way that there is little variation *within*, and much variation *between* groups. Class variables can be derived from simple variables, such as farm size or age of the farmer, or multi-faceted variables, such as management skills or modernity of a farm. Group comparisons and statistical tests can demonstrate the variation explained by the class variable and, thus, provide insight into the relationships between the variable and other variables in the data set. If ordinary least-squares (OLS) procedures are applied, also continuous variables (covariates) can be used to explain variation and provide insight.

If one class variable explains only little of the variation in the data set, a second class variable may be used to form subgroups within groups. However, each further subdivision of the data set results in a lower number of observations per subgroup and, consequently, less discriminatory power in statistical tests.

Studies relating farm characteristics to farm performance have shown that farm performance results from a complex combination of several variables that cannot be captured by one or a few variables (Ziggers, 1992). This means that the number of observations, i.e., the number of farms in the study, is usually limiting the number of (sub)groups that can be formed. Moreover, many explanatory variables, e.g., age of the farmer and farming experience, tend to be correlated, which complicates interpretation of group comparisons and proper use of OLS procedures.

The solution to these problems is usually sought in combining farm variables into factors, (management) indices, or farming styles. In this study, two conceptually different approaches that are commonly used for combining farm variables in the Netherlands, are compared within the same research population: the sociological "style of farming" approach (Van der Ploeg, 1990) and the farm-economic "management level" approach (Alleblas, 1988).

4.3.1 Sociological "style of farming" approach

The sociological style of farming concept (Hofstee, 1985) is defined as the specific structuring of farm aspects, based on a complex of opinions of what farming should be like, shared by a group of farmers (Van der Ploeg, 1990). It emphasizes the strategic component of farming and assumes that farmers have freedom to structure their farms according to their goals, instead of being the result of past experiences (Nooij, 1993). A typical characteristic of the style of farming concept is that it entails self-classification of farmers. For instance, if a farmer beliefs to manage his or her farm economically, he or she will be classified as an "economical farmer". Therefore, styles of farming can be studied in close cooperation with the farmers only.

The "styles of farming" approach was extensively applied to dairy farmers at the end of the 1980s (Van der Ploeg, 1990). At the start of the semi-structured interviews with dairy farmers, the researchers used a scheme to get the dialogue started. The scheme consisted of a simple cross with a farm scale axis and a production intensity axis. Farmers were asked to express the types of farmers that could be found at the four quadrants of scale and intensity. This procedure revealed opinions on specific structurings of farm aspects, which the researchers described in so-called style of farming portraits.

An advantage of this qualitative approach is that farmers are not "ex-ante" captured into farm aspects that researchers think are important. A disadvantage, however, is that, although portraits are derived from exact wordings of farmers, interpretation and selective recall of the researchers are inevitable. Also, style of farming portraits may be influenced by the use of the scheme; farmers may be focused on classifications in scale and intensity, whereas normally they would classify farmers into other dimensions, i.e., have other mental maps (Nooij, 1993).

In our study, the 1992-survey was preceded by 12 semi-structured interviews with pig farmers, similar to the approach used by Van der Ploeg (1990). However, the scheme was used only after about an hour of conversation, when farmers already had indicated the (classification) dimensions that were important to them. Four styles of farming were portrayed (Appendix 4.1) and were included in the questionnaire of the 1992-survey. The 71 survey farmers were asked if they could identify themselves entirely, partly, or not at all with each of the four portraits. Also, they were asked to indicate the portrait that fitted best their opinion of what "pig farming" should be like. Following Leeuwis (1993) and Braakman (1994), a discriminant analysis was used to classify the farmers into styles of farming; the answers on the first four "identification" questions were used as the independent variables, and the answers on the "best fit" question were used as the class variable.[2] The same data set was used for both the estimation of the discriminant functions and the classification of farmers into styles of farming. Using this approach, the classification is based on more information than when using the single "best fit" question only (Leeuwis, 1993). A canonical analysis was used to reveal the underlying structure of the applied classification.

---

[2] Although the "identification" variables are not normally distributed, discriminant analysis can be used when its primary goal is classification rather than inference (Leeuwis, 1993).

4.3.2 Farm-economic "management level" approach

The management level classification is based on an index method for scoring management that originally has been developed for glasshouse horticulture in the Netherlands (Alleblas, 1988). Alleblas started his study with the development of a conceptual management model. Horticultural management was divided into three subsystems, i.e., economic, technical, and social subsystems. The economic subsystem included decisions, actions, and circumstances that related to the firm's (strategic) policy, tactical management, and operational activities. Benefits and costs aspects played an important role and key words were prognosis, financing, and accounting. The technical subsystem included decisions, actions, and circumstances that related to the technical level of the firm and were deduced from the degree of modernity, mechanization, and automation of a firm. The social subsystem emphasized the quality of human activities and inter-human relationships in the firm's policy, tactical management, and operational activities. Within the three subsystems, horticultural management was further divided into six management factors, i.e., education and training, modernity of facilities, firm policy, tactical planning, operational planning, and social aspects.

The management model was used as a framework in the development of a questionnaire for horticultural growers. In a Delphi-like approach, horticultural experts divided 1000 points over the eighteen combinations of subsystems and management factors. The economic subsystem was rated highest with 375 points, versus 320 and 305 points for the technical subsystem and social subsystem, respectively. Of the management factors, the modernity of facilities, firm policy, and tactical planning ranked highest with respectively 200, 250, and 240 points. The other management factors, i.e., training and education, operational planning, and social aspects got 100, 130, and 80 points.

A questionnaire was developed including multiple questions per subsystem and per management factor. For each question, scores were assigned to the different answer categories. This was done in such a way that the maximum score that horticultural growers could obtain for a certain management factor or subsystem, corresponded with the maximum number of points that was specified by the experts.[3] The management level of a horticultural grower in the survey was determined by summing the scores of the actually marked answer categories.

Where the "style of farming" approach relies on opinions of "what farming should be like" recorded in semi-structured interviews, the "management level" approach

---

[3] For instance, the maximum scores on "modernity" questions added up to 200 points, those on "firm policy" to 250 points, etc.

emphasizes the recording of quite objective entities in a highly-standardized questionnaire. An advantage of this approach is that the interpretation required by the researchers is kept to a minimum. Further, the answers given by the growers on questions about aspects of their firm are likely to be more stable than the opinions given by the dairy farmers in the "style of farming" approach. A disadvantage of the "management level" approach follows from the correlation between various management aspects. If, for instance, a strong correlation exists between the education of a farmer and his or her level of information search, a farmer will score either high or low on both items in the questionnaire, meaning that the discriminatory power of the management level score decreases.

For the 1992-survey, the management model for horticulture was converted for application in pig farming, and a questionnaire was developed around the six management factors. For the management factor "education and training", farmers were asked about their level of education, participation in courses and off-farm-activities (subdivided into peer meetings, farmers' organizations and sports clubs), level of communication with other farmers, and intensity of reading farm magazines. For the management factor "modernity", farmers were asked to indicate the machineries, installations and types of building constructions that were available on their farm. Also, farmers were asked about major renovations of their pig houses and the number of separate facilities they have. The management factor "farm policy" included additional questions on changes in facilities, machineries, production routines and pig breeds. For each change, farmers had to indicate what the planning horizon was, which people or instruments supported their decision making, and whether they had calculated additional figures. The management factor "tactical planning" consisted of questions similar to those with "farm policy". However now, attention was directed towards possible changes in the routine of purchasing and selling of pigs, financial planning, sow reproduction planning, and feeding schedules. The management factor "operational planning" relied on questions about working schedules, frequency of scheduling, and whether schedules are evaluated. Finally, the management factor "social aspects" included questions on sanitary facilities for farm personnel and farm visitors, equipment for improving labor conditions, and the frequency of visitors on the farm.

Six pig farm management experts were recruited from the Wageningen Agricultural University, the Dutch Research Institute for Pig Husbandry, the nationwide extension service, a pig farmers organization, and two governmental organizations concerned with pig farming. First, each expert divided 1000 points over the six management factors to indicate the importance of each management factor. Subsequently, the experts divided the points per management factor among the survey questions that characterized that management factor. Finally, all possible answer categories for each survey question were valued by the experts. This valuation was done before the 1992-survey was conducted.

After the execution of the 1992-survey, farmers' management scores were calculated by combining their answers in the questionnaire with the values of the answer categories given by the experts.

4.4 RESULTS

The results section consists of three parts. First, the results of the style of farming classification will be presented. In the second part, the same is done for the management level classification, and in the third part, the management level classification is compared to the style of farming classification. For each type of classification, important farm characteristics, recorded in the 1983-survey and 1992-survey, are described. These characteristics include the age of the farmer in 1992, the (difference in) number of fattening pigs in 1983 and 1992, the (difference in) number of sows in 1983 and 1992, the solvency of the farms in 1992, the start year of MIS use, the MIS effect, and the number of piglets raised per sow in the (calendar) years preceding the surveys, i.e., 1982 and 1991. Because the 1991-production data are somewhat biased by a nationwide outbreak of PRRS, i.e., a highly contagious pig disease that variably affected the performances of the Dutch sow herds, the 1990-production data are included as well.

4.4.1 Style of farming

Table 4.1 Distributions of styles of farming before and after discriminant analysis

	"Best-fit question"[1]				
Discriminant analysis classification	"Entrepreneur"	"Manager"	"Pig farmer"	"Withdrawer"	Row totals
"Entrepreneur"	8	1	1	–	10
"Manager"	3	34	2	–	39
"Pig farmer"	1	2	13	–	16
"Withdrawer"	–	–	–	6	6
Column Totals	12	37	16	6	71
% classif. differently	33	8	19	0	14

[1] Farmers indicated the portrait that fitted best their opinion of what "pig farming" should be like

Using discriminant analysis, 39 of the 71 farmers were classified as “manager”, 10 farmers as “entrepreneur”, 16 farmers as “pig farmer”, and 6 farmers as “withdrawer”. Table 4.1 compares the distribution of styles of farming with the answers of the farmers on the “best-fit question”. Thirty-seven of the 71 farmers indicated that the “manager” portrait fitted best their opinion of what “farming” should be like. The “entrepreneur” portrait was selected by 12 farmers. The numbers for the “pig farmer” and “withdrawer” portraits were 16 and 6, respectively. On average, discriminant analysis classified 14% of the farmers differently from the “best-fit question”, ranging from 0% of the “withdrawers” to 33% of the “entrepreneurs”.

Table 4.2 Farm characteristics in relation with styles of farming[1]

Style	Entrepreneur (10)		Manager (39)		Pig farmer (16)		Withdrawer (6)	
Farm characteristic	Mean	N	Mean	N	Mean	N	Mean	N
Age of the farmer	44[ab]	10	41[a]	39	44[ab]	16	54[b]	6
No. of fattening pigs in 1992	1717[a]	10	708[b]	37	514[b]	15	645[b]	6
No. of fattening pigs in 1983	174[a]	10	114[ab]	39	80[b]	16	102[ab]	6
Δ fattening pigs (92 - 83)[2]	1543[a]	10	595[b]	37	430[b]	15	543[b]	6
No. of sows in 1992	251[a]	10	168[b]	38	108[b]	16	140[ab]	4
No. of sows in 1983	166[a]	10	131[ab]	39	94[b]	16	113[ab]	6
Δ sows (1992 - 1983)	85[a]	10	36[b]	38	14[b]	16	5[b]	4
No. of piglets per sow in 1991	20.23[a]	8	19.16[a]	34	18.54[a]	13	19.11[a]	2
No. of piglets per sow in 1990	21.81[a]	7	20.98[a]	33	19.88[a]	14	17.70[a]	1
No. of piglets per sow in 1982	18.05[a]	10	17.61[a]	38	16.09[a]	16	16.30[a]	6
Δ piglets per sow (90 - 82)	3.73[a]	7	3.29[a]	32	3.72[a]	14	1.61[a]	1
Solvency	0.63[a]	10	0.64[a]	38	0.64[a]	14	0.68[a]	5
Start year of using MIS	4/86[a]	9	10/86[a]	32	2/88[a]	11	6/88[a]	2
The effect of MIS use[3]	1.41[a]	7	0.42[a]	27	0.49[a]	10	-0.69[a]	1

1 Classification based on discriminant analysis, different letters in the same row indicate significant differences: Bonferroni t-test ($p \leq 0.05$); unless mentioned otherwise data refer to the situation in 1992

2 Δ = change in the number of ...

3 The effect of MIS use is the change in the average number of piglets (raised to about 25 kgs) per sow per year, as was determined with the statistical model of Verstegen et al., 1995.

Table 4.2 describes some farm characteristics for each style of farming. The (conservative) Bonferroni t-test reveals significant differences in “age of the farmer” between two styles of farming, indicating a family-firm life cycle effect (Boehlje and Eidman, 1984) on the classification of style of farming. Furthermore, farm size appears to differ significantly between styles of farming. The “entrepreneurial” farmers have expanded their farm more than the farmers with other styles and, consequently, have larger farms in 1992. MIS effects are (non-significantly) higher for these farmers, suggesting a (weak) relationship between farm size and MIS effect. A linear regression between the MIS effect and the number of sows per farm in 1992 gives some support for this suggestion (p=0.07). MIS apparently improve the possibilities of managing large amounts of individual sow production data, thus, allowing farms to increase in scale without a decrease in the individual sow results (Boehlje, 1997). This could not explicitly be tested because of confounding between growth rate of farms and MIS use: twenty out of twenty-one farms with an above average increase in the number of sows started using MIS between 1983 and 1992.

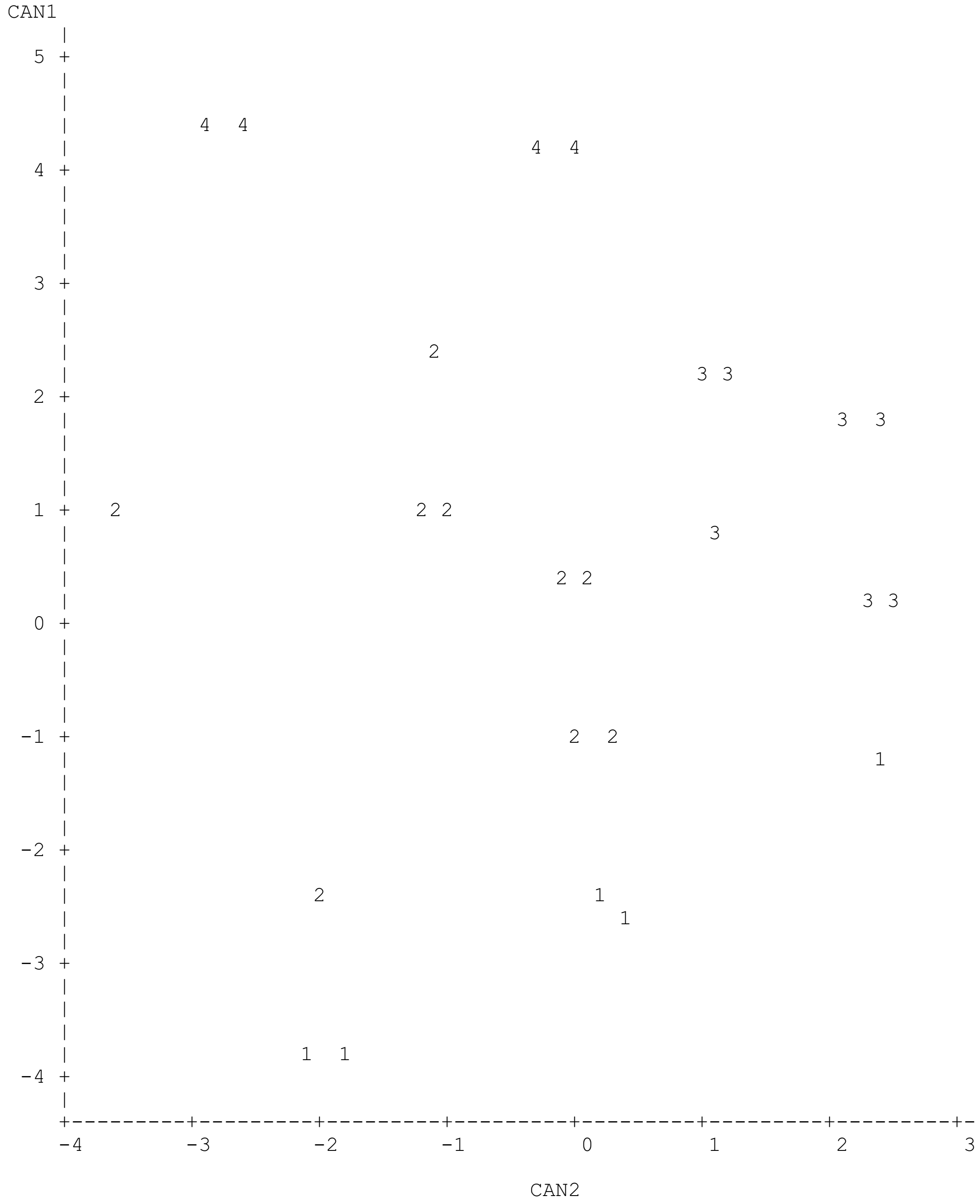
Table 4.3 Canonical coefficients of the discriminating variables in the canonical functions[1]

Identification with:	Variable name	Canonical function 1	Canonical function 2	Canonical function 3
“Entrepreneur”	x_1	-1.4554	0.1414	1.8414
“Manager”	x_2	-0.0147	0.2332	-0.7081
“Pig farmer”	x_3	1.3216	2.2438	0.3323
“Withdrawer”	x_4	1.9905	-1.2619	1.0339
Fraction explained by		0.6015 [2]	0.2508	0.1477

1 The alternative classification in styles of farming is used as class variable

2 To be interpreted as: 60% of the differences between classes is explained by the canonical function: class = $-1.45x_1 - 0.01x_2 + 1.32x_3 + 1.99x_4$

Additional insight into the underlying structure of the “style of farming” classification was obtained through a canonical discriminant analysis. Canonical discriminant analysis reduces the number of variables, that explain a certain classification, by deriving independent canonical functions from linear combinations of the original (explanatory) variables. In this study, three independent canonical functions, being linear combinations of



NOTE: 46 obs hidden. Hidden observations are from the same style of farming as the one that hides them

Symbols indicate styles of farming according to the new classification
1 = entrepreneur; 2 = manager; 3 = pig farmer; 4 = withdrawer

Figure 4.1 Scores on canonical function 1 and canonical function 2 the four "identification" variables (henceforth x_1 to x_4), were formed in a way that function 1 explained most of the classification in styles of farming (60%), followed by function 2 (25%) and function 3 (15%). The likelihood ratios in the output of the canonical discriminant analysis (SAS, 1988) indicated that the contributions of the three canonical functions to the classification were highly significant ($p<0.0001$). Table 4.3 presents the (raw) coefficients of x_1 to x_4 for each canonical function. The contrasting values for x_1 and x_4 in function 1 reveal that farmers who identify themselves with the "entrepreneur" style, rarely will identify themselves with the "withdrawer" style. These two styles of farming are clearly polar-opposites. The coefficients of x_3 and x_4 for canonical function 2 are highly contrasting as well, but function 2 explains only 25 percent of the differences between classes. The relatively high impact of function 1 and the relatively low impact of function 2 on the classification in styles of farming are visualized in Figure 4.1, where the scores on both functions are plotted. Clearly, the "entrepreneur" and the "withdrawer" are further apart than any other combination of styles of farming.

4.4.2 Management level

Large differences were found in the valuation of management factors by the experts. Table 4.4 presents the values that each of the six management experts had assigned to the management questions in the survey. Two general expert viewpoints could be characterized, of which one emphasizes a good background in education as a basis for curiosity, i.e., active information search, and the other emphasizes the actual on-farm activities. On average, the factors farm policy and tactical planning were valued highest. Because of the extent of disagreement, we decided not to use a Delphi approach that could result in a compromise rather than an agreement on the importance of the management factors. Instead, we scored each farm on each expert. Table 4.5 shows the average management scores of the 71 pig farmers, based on both individual and average valuations of the six management experts. A non-parametric Friedman two-way analysis of variance revealed that management levels of the 71 farms were significantly different between experts ($\chi^2=67.4$, n=71, df=5, p=3.6E $^{-13}$). However, the same test also showed that there is no significant difference in ranking of farms ($\chi^2=1.8$, n=71, df=5, p=0.8). Experts appear to agree on the relative position of farms, although they value management factors differently. Therefore, further calculations with management levels were based on the average valuation of the six experts. A Kolmogorov-Smirnov test demonstrates that the management levels can be described by a normal distribution (n=71, mean=466, $\sigma=106$, 2-tailed P=0.73).

Table 4.4 The maximum values assigned to the management questions of the 1992-survey

Expert number	1	2	3	4	5	6	Avg[1]
Maximum management level	**1000**	**1000**	**1000**	**1000**	**1000**	**1000**	**1000**
Education and training	**250**	**200**	**100**	**150**	**100**	**200**	**167**
Education	20	60	17	15	20	30	27
Courses	40	50	25	35	20	80	42
Off-farm activities	85	10	25	50	30	40	38
Peer discussions	85	30	25	20	15	20	33
Information gathering	20	50	8	30	15	30	26
Modernity	**65**	**100**	**150**	**100**	**200**	**100**	**119**
Machineries and installations	25	20	50	80	65	50	48
Renovation	40	40	100	20	65	50	53
Number of separate facilities	0	40	0	0	70	0	18
Farm policy	**250**	**220**	**150**	**250**	**250**	**250**	**228**
Planning horizon	50	60	100	120	100	50	80
People and instruments used	100	100	40	80	75	100	83
Calculation of figures	100	60	10	50	75	100	66
Tactical planning	**250**	**200**	**200**	**250**	**200**	**200**	**217**
Planning horizon	34	80	120	100	100	50	75
People and instruments used	108	60	50	75	50	100	77
Evaluation	108	60	30	75	50	50	65
Operational planning	**60**	**180**	**250**	**150**	**175**	**120**	**156**
Frequency and type of planning	30	80	150	100	87	50	83
Control	30	100	100	50	88	70	73
Social aspects	**125**	**100**	**150**	**100**	**75**	**130**	**113**
Sanitary issues	15	20	30	20	40	25	25
Labor conditions	90	40	40	30	15	55	45
Frequency of contacts	20	40	80	50	20	50	43

1 Average valuation of the six management experts

Table 4.5 The average management scores of the 71 pig farmers, based on both individual and average valuations of the six management experts

Expert number	1	2	3	4	5	6	Avg[1]
Management level	**445**	**435**	**448**	**480**	**500**	**491**	**467**
Education and training	**125**	**113**	**58**	**90**	**64**	**99**	**92**
Education	9	43	13	7	15	14	17
Courses	11	18	12	21	12	35	18
Off-farm activities	36	4	11	31	18	18	20
Peer discussions	57	25	17	14	10	14	23
Information gathering	11	22	6	18	9	18	14
Modernity	**44**	**33**	**61**	**39**	**103**	**65**	**58**
Machineries and installations	9	2	40	30	24	18	21
Renovation	35	3	22	9	16	46	22
Number of separate facilities	0	28	0	0	63	0	15
Farm policy	**49**	**93**	**66**	**91**	**103**	**128**	**88**
Planning horizon	-27	36	51	35	42	37	29
People and instruments used	34	32	11	35	29	37	30
Calculation of figures	42	25	4	21	31	54	30
Tactical planning	**127**	**110**	**106**	**128**	**107**	**77**	**109**
Planning horizon	21	51	74	60	61	20	48
People and instruments used	29	16	11	14	9	20	17
Evaluation	78	43	22	54	36	37	45
Operational planning	**28**	**34**	**86**	**57**	**67**	**36**	**51**
Frequency and type of planning	16	20	71	41	29	15	32
Control	12	13	15	16	38	21	19
Social aspects	**72**	**53**	**71**	**75**	**56**	**87**	**69**
Sanitary issues	14	19	28	19	38	23	24
Labor conditions	55	21	19	20	9	30	26
Frequency of contacts	3	14	24	36	9	34	20

[1] Management scores based on the average valuation of the six management experts

Table 4.6 Mean value and standard deviation of farm characteristics and the correlations between farm characteristics and management level

			correlation with management level [1]		
Farm characteristic [2]	Mean	σ	r	N	p
Management level	466.39	106.13	1.00	71	–
Age of the farmer	42.79	9.48	-0.20	71	0.10
No. of fattening pigs in 1992	808.19	621.47	0.27	68	0.03
No. of fattening pigs in 1983	113.82	71.23	0.26	71	0.03
Δ fattening pigs (1992 - 1983) [3]	693.62	575.69	0.25	68	0.04
No. of sows in 1992	164.16	94.54	0.32	68	0.01
No. of sows in 1983	125.90	60.96	0.27	71	0.02
Δ sows (1992 - 1983)	36.09	52.58	0.30	68	0.01
No. of piglets raised per sow in 1991	19.17	1.87	0.14	57	0.31
No. of piglets raised per sow in 1990	20.75	1.87	0.16	55	0.24
No. of piglets raised per sow in 1982	17.22	2.43	0.03	70	0.82
Δ piglets per sow (1990 - 1982)	3.43	2.42	0.27	54	0.04
Solvency	64.52	23.05	-0.82	67	0.51
Start year of using MIS	87	3	-0.80	54	0.56
The effect of MIS use [4]	0.56	1.72	0.35	45	0.02

1 Pearson correlation test: r=correlation coefficient, N= no. of observations, p=2-tailed significance
2 unless mentioned otherwise data refer to the situation in 1992
3 Δ = change in the number of ...
4 The effect of MIS use is the change in the average number of piglets raised per sow per year, as was determined with the statistical model of Verstegen et al., 1995

Table 4.6 presents mean values and standard deviations of farm characteristics, and the (Pearson) correlation of these characteristics with management level. A weak negative correlation exists between the age of the farmer and management level (p=0.10). Farms with higher management levels appear to have not only larger farm sizes measured by the number of fattening pigs in 1983 and 1992 and the number of sows in these years, but also have expanded more than farms with lower management levels. No significant correlations with management level were found for technical production figures, i.e., the number of piglets raised per sow in 1991, 1990, and 1982. However, farms with higher management levels appear to have improved their technical production figures (between 1982 and 1990) more than farms with lower management levels (p=0.04). MIS use has (partly) contributed to this; farms with lower management levels appear to have less MIS effect than farms with higher management levels. A linear regression of MIS effect against management level suggests that a 100-points increase in management level corresponds to a 0.6-increase in MIS effect, i.e., a 0.6-increase in the number of piglets raised per sow per year (Table 4.7).

Table 4.7 A linear regression of the relationship between MIS effect and management level of farms [1]

Source	DF	Sum of Squares	F Value	Pr > F
Regression	1	16.12	6.08	0.0177
Residual	43	113.94		

Variable	B	SE B	T	Pr > |T|
Management level	0.0062	0.0025	2.466	**0.0177**
intercept	-2.4880	1.2608	-1.973	0.0549

[1] Dependent variable: MIS effect; mean dependent variable = 0.56; R-square = 0.12; adjusted R-square = 0.10.

The same type of regression, but with management level substituted by each of the six underlying management factors, showed that a significant relationship exists between the score on management factor "farm policy" and the MIS effect (p=0.002) only. "Farm policy" includes the planning horizon and information sources used by farmers when changing facilities, machineries, production routines and pig breeds. The farmers who benefit more from MIS use, actively involve the right people in important farm decisions and calculate figures to support their (strategic) decision making.

4.4.3 Management level versus style of farming

Two conceptually different classification approaches were used in this study. The "style of farming" approach was based on self-classification of farmers. It represented a complex of shared opinions of what farming should be like and resulted in a classification of farmers into four non-ordinal "styles of farming". The "management level" approach, on the other hand, entailed scoring of management experts on quite objective entities. Completing highly-standardized questionnaires by farmers resulted in farm-specific, normally-distributed management levels. Table 4.8 shows that management levels vary considerably within and between styles of farming. For instance, a "withdrawer" not necessarily has another management level than an "entrepreneur". On average, entrepreneurs have the highest management levels, but Table 4.9 shows that these management levels do not differ significantly from those of the managers (p=0.314). Also, the difference between the "pig farmer" and "withdrawer", is not significant (p=0.450). The other contrasts in Table 4.9 are highly significant in a Student test with pooled variance estimates. Using the more conservative Bonferroni test reveals one significant difference (p<0.05) only, i.e., between the "entrepreneur" and the "withdrawer".

Table 4.8 Management level descriptives for the four styles of farming

Styles of farming	N	mean	min.	max.	standard deviation
"Entrepreneur"	10	522	396	643	74
"Manager"	39	487	242	694	103
"Pig farmer"	16	415	272	560	93
"Withdrawer"	6	379	220	537	117
Total	71	466	220	694	106

Table 4.9 Contrasts in management levels between the four styles of farming[1]

	"Entrepreneur"	"Manager"	"Pig farmer"	"Withdrawer"
"Entrepreneur"	-	35.52/35.00	107.21/39.81	143.09/50.99
"Manager"	0.314	-	71.69/29.32	107.57/43.30
"Pig farmer"	0.009	0.017	-	35.88/47.27
"Withdrawer"	0.007	0.015	0.450	-

1 Above the diagonal, means and standard errors of contrasts between styles are presented; p-values of contrasts between styles are below the diagonal (Student test with pooled variance estimates)

4.5 DISCUSSION

The results of this study show that management levels could explain part of the variation in MIS profitability between farms whereas styles of farming could not. A technical explanation may be that the normally-distributed management levels allowed the use of sensitive Pearson correlation tests, whereas differences between styles of farming had to be evaluated with rather conservative Bonferroni t-tests. The “style of farming” classification splits the number of observations into four styles, which means that one biased observation can affect the descriptives of one style of farming more seriously than those of the entire sample. Nevertheless, the “style of farming” approach did reveal significant differences on other variables, which means that the sensitivity of the test cannot be the only explanation. A more fundamental explanation may be that styles of farming in sow farming do not have a *direct* relationship with MIS profitability. According to Van der Ploeg (1990), each style of farming has its own rationality and goes its own way within a certain “room of manoeuvre”. This can be observed in dairy farming where farmers who specialize in grassland management gain an acceptable farm income because of relatively low feed costs, and farmers who specialize in cow breeding obtain a comparable farm income from selling breeding cows and bulls. In sow farming, however, the number of piglets raised per sow per year (PSY) is such a crucial key figure that an incentive to improve it will be included in the rationality of each style. Therefore, differences between styles in MIS profitability, i.e., improvements in PSY, will not likely result from different levels of specialization on PSY; the “room of manoeuvre” is less than in dairy farming. Nevertheless, differences in MIS profitability between styles of farming may exist because of intervening variables. The positive correlation between farm size and MIS profitability (Table 4.6) may partly explain the relatively high average MIS profitability for the “entrepreneurial” style.

Another topic for this discussion is the “style of farming” portraits. The four portraits were constructed in semi-structured interviews with twelve pig farmers and none of the 71 farmers in the survey study had difficulties choosing one of the four portraits. Nonetheless, there may exist other styles of farming as well. Although the “entrepreneur”, “manager”, and “pig farmer” styles were mentioned repeatedly, the “withdrawer” style was specifically portrayed by one of the twelve interviewed pig farmers only. Possibly, the relative large group of “managers” could have been subdivided into more styles of farming by interviewing more pig farmers. Yet, competitive forces are strong in pig farming and, consequently, the “room of manoeuvre” limited; subtle differences in opinions of what farming should be like exist, but there is a high degree of consensus concerning the importance of having a high added value per animal (as mentioned in the “manager” portrait).

Although for the purpose of this study, the “management level” approach is considered to be superior to the “style of farming” approach, some remarks can be made. The first remark concerns the large variation in expert valuations in this study. In contrast with the Delphi-approach used by Alleblas (1988), we have scored each farm for each expert. Although the experts varied heavily with respect to the maximum values assigned to questions (Table 4.4), the ranking of farms on total management level was similar. A plausible explanation may be that management aspects on a farm are highly correlated. It raises, however, the question whether management experts are needed for scoring.

Another remark on the “management level” approach, which to a lesser extent also holds for the “style of farming” approach, concerns the actual farm characteristics that we have measured in this study. The use of a highly-standardized questionnaire together with (intentionally) limited explanation by the interviewer, may have caused variation in responses among farmers that is the result of interpretation of the questions rather than actual differences between farmers. For instance, regardless of the actual situation, the question about the frequency of operational planning probably was answered differently by farmers who explicitly had reflected on their labor activities than by farmers who had not done so. Instead of measuring the frequency of operational planning, we implicitly may have measured the degree in which farmers look to their farm in terms of activities and processes (Taylor, 1911).

A third remark on the “management level” approach concerns the relationship between management level and the number of piglets raised per sow per year (PSY). Conceptually, farm management entails decision making to streamline and coordinate farm processes according to the farmer’s goals. Accordingly, farmers with a relatively high management level should be able to get a higher PSY than farmers with a low management level. Table 4.6 did show a positive correlation between management level and *improvement* in the number of piglets raised per sow per year between 1982 and 1990. However, no significant correlation was found between management levels and the absolute number of piglets raised per sow per year in respectively 1982, 1990, and 1991. The significant correlation of farm size with management level (farm size was not included in the management level), suggests that farmers with high management levels see more opportunities for achieving their long-term goals in expanding their farms than in raising more piglets per sow per year.

4.6 CONCLUSION

The survey study of Verstegen et al. (1995) showed that MIS profitability differs significantly between farms. In this paper, the sociological “style of farming” approach and the farm-economic “management level” approach were applied to gain insight into these differences. For this purpose, the “management level” approach proved to explain better than the “style of farming” approach. Management levels of sow farmers were positively correlated with MIS profitability ($r=0.35$, $p=0.02$). This means that, although farmers with high management levels tend to be better-informed anyway than farmers with low management levels, they get more added value from MIS. Also, positive relationships exist between management level and farm size, and between farm size and MIS profitability (although MIS profitability is defined as improvement in piglets per year at a sow level). Apparently, common-cause effects of management level occur, enhancing farm size and piglets per sow per year at the same time. Further research is needed to investigate the value of MIS in avoiding lower sow performances with increasing farm scales, and the opportunities to improve farmers' management levels and, consequently, MIS benefits.

REFERENCES

Alleblas, Joop T.W. (1988). "Management in de Glastuinbouw" [Management in Glasshouse Horticulture]. LEI Onderzoekverslag 34 [LEI Research report 34], Agricultural Economics Research Institute. The Hague, The Netherlands. 217 pp. (in Dutch: English summary).

Batte, Marvin T., Eugene Jones, and Gary D. Schnitkey (1990). "Computer Use by Ohio Commercial Farmers." *American Journal of Agricultural Economics*, 72: 935-945.

Boehlje, Michael D. (1997). Personal Communication.

Boehlje, Michael D., and Vernon R. Eidman (1984). *Farm Management*. New York: Wiley. 806 pp.

Braakman, E.(Bert-Jan) H.J. (1994). "Managementstijl en het Rendement van een MIS" [Management Style and the Profitability of MIS]. MSc Thesis. Wageningen, The Netherlands: Department of Farm Management, Wageningen Agricultural University. 71 pp. (in Dutch).

Hamilton, Scott, and Norman L. Chervany (1981). "Evaluating Information System Effectiveness -- Part I: Comparing Evaluation Approaches." *MIS Quarterly*, 5: 55-69.

Hofstee, E.W. (1985). *Groningen van Grasland naar Bouwland, 1750 - 1930 : Een Agrarisch-Economische Ontwikkeling als Probleem van Sociale Verandering*. [From Pasture to Arable Land, 1750-1930: An Agricultural-Economic Development as Problem of Social Change]. Wageningen: Pudoc. 422 pp. (in Dutch).

Jarvis, Anne Marie (1990). "Computer Adoption Decisions - Implications for Research and Extension: The Case of Texas Rice Producers." *American Journal of Agricultural Economics*, 72: 1388-1394.

King, Robert P., Stephen B. Harsh, and Craig L. Dobbins (1990). "Farm Information Systems: Farmer Needs and System Design Strategies." *Tijdschrift voor Sociaalwetenschappelijk Onderzoek van de Landbouw*, 5(1): 34-59.

Leeuwis, Cees (1993). "Of Computers, Myths and Modelling: the Social Construction of Diversity, Knowledge, Information and Communication Technologies in Dutch Horticulture and Agricultural Extension." Dissertation. Wageningen, The Netherlands: Department of Communication and Innovation Studies, Wageningen Agricultural University. 469 pp.

Mok, Albert L., and Harrie J.M. van den Tillaart (1990). "Farmers and Small Businessmen: A Comparative Analysis of their Careers and Occupational Orientation." In: *New Findings and Perspectives in Entrepreneurship*. R. Donckels and A. Miettinen, eds. Aldershot UK: Avebury. p. 203-230.

Nooij, Ad T.J. (1993). "Classificaties in het Sociologisch Onderzoek." [Classifications in Sociological Research] *Tijdschrift voor Sociaalwetenschappelijk Onderzoek van de Landbouw*, 8(1): 5-19.

Putler, Daniel S., and David Zilberman (1988). "Computer Use in Agriculture: Evidence from Tulare County, California." *American Journal of Agricultural Economics*, 70(4): 790-802.

SAS (1988). *SAS/STAT® User's Guide*. Release 6.03 Edition. Cary, NC: SAS Institute. 1028 pp.

Taylor, Frederick W. (1911). *The Principles of Scientific Management*. New York: Harper and Brothers.

SIVA (1992). "Aantal Gebruikers blijft groeien". [The Number of MIS Users is Still Increasing]." *Siva Visie*, 3(2): 1 (in Dutch).

Van der Ploeg, Jan-Douwe (1990) "The Challenge of Heterogeneity; Notes on Science, Capital and Agriculture." Paper Presented at the 14th European Congress of Rural Sociology, Giessen BRD.

Verstegen, Jos A.A.M., Aalt A. Dijkhuizen, Ruud B.M. Huirne, and Robert P. King (1995). "Quantifying Economic Benefits of Sow-Herd Management Information Systems Using Panel Data." *American Journal of Agricultural Economics*, 77: 387-396.

Ziggers, Gerrit Willem (1992). "Agrarisch Ondernemerschap in een Bedrijfskundig Perspectief." [Agricultural Entrepreneurship in a Management Science Perspective]. Dissertation. Wageningen, The Netherlands: Department of Management Studies, Wageningen Agricultural University. 155 pp.

Appendix 4.1 Portraits of styles of farming[4]

Portrait 1 "entrepreneur"
I feel like I'm an entrepreneur. My aim is to follow new developments as well as possible. I make sure that I'm ready for the future. My farm is well-structured. I have a good overview of my farm because I have a strong work plan and many production figures that show me where I stand. I consider it a kind of game to have the best production results. I find anecdotes of other pig farmers (in farm magazines, or at peer meetings) usually not very interesting. Farm magazines and farm advisors have an important task in keeping me informed. However, I draw my own conclusions.

Portrait 2 "manager"
The economy keeps growing and, therefore, a pig farm has to expand to keep in pace. However, it's not my aim to grow but to reach a high added value per animal. I don't envy farmers having those gigantic facilities; they have to work hard to keep their bank satisfied. I prefer having some leisure time to do something else besides pig farming. To get a high added value per animal, contacts with other pig farmers (e.g. peer meetings) are very useful. Farm advisors must be able to think along on the many aspects of pig farming. Specialized advisors are not very suitable for regular farm advisement.

Portrait 3 "pig farmer"
I love to work with animals on the farm. I enjoy it when my pigs do perform well. Health care of the animals is one of my major topics in farm management and keeps the involuntary replacement costs low. I avoid risks as much as possible. Advice from the farm advisor or veterinarian is a crucial element. Technical and financial record keeping has to be done, but it is something I don't like and costs too much time. If the government doesn't put too many restrictions on pig farming, we can keep our business going for many more years, because we keep a good eye on our costs and avoid risks.

Portrait 4 "withdrawer"
I'm a bit older and probably don't have an heir. I regularly do some new investments on my farm, but I won't expand my farm anymore (even if I were allowed to do so). My investments are intended to make farming easier. I don't invest in entirely new developments such as a management information system. The farm advisors and the veterinarian give good advice, which I usually implement. Governmental regulations give me an awful lot of paper work. It's a tough job to keep up with all of these things.

---

4 The quoted portrait labels are used to improve readability of this paper only; to avoid researcher effects, they were not presented to the survey farmers.

CHAPTER 5

QUANTIFYING THE EFFECTS OF SOW-HERD MANAGEMENT INFORMATION SYSTEMS ON FARMERS' DECISION MAKING USING EXPERIMENTAL ECONOMICS[1]

ABSTRACT

In 1992, a survey study revealed that, after adjustments for farm, learning, and trend effects, sow farmers using management information systems (MIS) produced 0.56 piglets per sow per year more than they did before MIS use (Verstegen et al., 1995a). The purpose of the present study was to learn if experimental methods support these findings and hence can be used as an alternative approach to determine the profitability of MIS in sow farming. In total, 86 sow farmers, including 51 from survey farms, participated in an individual decision-making experiment, which was executed in a quasi-experimental, nonequivalent control, pretest-posttest design. In an MIS group, MIS estimates were derived by within-subjects comparisons of decision quality with and without MIS features. A baseline group was included to control for learning or exhaustion effects during an experimental session. Decision quality of subjects in the MIS group significantly improved when offered MIS features (p=0.02). Correlation between MIS estimates of the survey study and MIS estimates of the experiment was not significant.

5.1 INTRODUCTION

During the last decade, developments in electronic data recording and processing systems have provided strong support for farmers' efforts to improve farm performance. A category of more advanced systems is management information systems (MIS), which are "designed to provide daily production information on the individual animal level that is of potential value in making management decisions" (Boehlje and Eidman, 1984). MIS record and structure the bulk of individual animal data on a farm, calculate certain key figures and produce farm overviews and working and attention lists. These MIS attributes give farmers the opportunity to identify deviations in performance sooner and to identify other, less

---

[1] paper by Jos A.A.M. Verstegen, Joep Sonnemans, Ruud B.M. Huirne, Aalt A. Dijkhuizen, and James C. Cox, accepted for publication in *American Journal of Agricultural Economics*. The authors thank Frans A.A.M. van Winden, Eric H.P. Houben en Anders R. Kristensen for their valuable contribution to this study.

obvious deviations as well. Moreover, calculation of key figures and specific analyses of farm data provide new types of information that can improve decision making.

Verstegen et al. (1995a) conducted a survey study on the profitability of MIS in sow farming. Using a quasi-experimental nonequivalent time-series design, they showed that after MIS adoption farmers raised 0.56 piglets per sow per year more than before (adjusted for farm variation, learning and trend effects). The estimated MIS profit of U.S. $15 to $17 per sow per year meant a return on investment of 220% to 348% and an improvement in net returns to labor and management of 7.7% to 8.7%.[2] However, the small number of observations per farm obstructed in-depth analysis of the relationship between MIS use and *individual* farm performance. A controlled field experiment would have provided more opportunities for in-depth analyses but could not be done because the MIS under study were already in use, thus making impossible a random assignment of farmers to MIS treatment and control groups (Verstegen et al. 1995a).

This paper reports a pilot experiment intended to yield insight into whether laboratory experiments can be used as an alternative to surveys for determining the profitability of MIS in sow farming. Compared to survey studies, experiments have better control of intervening variables and require less historical data. If the experimental economics approach proves to be a good alternative to a survey study, it may be used for (ex-ante) evaluation of new MIS systems and, possibly, other information services.

In this study, a comparison is made between experimental and survey MIS estimates, both derived from the same pig farmers. An overall effect of MIS is found in both the experiment and the survey study. However, the two MIS estimates are not significantly correlated. The most likely explanations for the uncorrelated estimates are problems with the experimental design, biases in survey MIS estimates due to exogenous changes on farms other than MIS use, and differences between the laboratory and the natural environment in levels of communication and decision making routine.

5.2 EXPERIMENTAL ECONOMICS

Experimental economics is a means to benefit from the strength of field experiments (such as control of determining variables) and to overcome some of their practical limitations (such as pre-audit assignment of subjects and high labor and money requirements).

---

[2] Return on investment of MIS = MIS profit divided by MIS investment costs; net return to labor and management = net farm profit plus compensation for labor and management.

Economics experiments typically are conducted in a laboratory environment, and a basic precept is that their results carry over to the more complex natural environment (Davis and Holt, 1993). Economics experiments need to have some typical properties to achieve this (Smith, 1982, 1994). Firstly, abstract decision problems are used to control for the amount of information available to the subjects. If natural decision problems are used, subjects can have beliefs, derived from experience, that affect their decisions but are unknown to the experimenter. Subjects may also become discouraged by natural decision problems when they feel that the experimental parameters do not adequately reflect the problems they are accustomed to facing. Secondly, the key elements of the natural decision making environment have to be incorporated into the economics experiment. For example, if in real life people have to make several decisions in an information overload situation and under time pressure, this should also be the case in an experiment. Finally, real economic incentives are used in the laboratory to induce economically-motivated decision making; subjects get paid according to the effectiveness of their decisions.

5.3 OUTLINE OF THE MIS EVALUATION EXPERIMENT

In sow farming, MIS support sow replacement decisions and thus contribute to a reduction in the average number of unproductive days per sow.[3] The risk and payoff per individual sow replacement decision are low but the quality of the decision making process significantly affects farm results because of the large number of replacement decisions that must be made. In the experiment, these characteristics are included in the abstract experimental economics analogue of the sow replacement problem presented as an investment project selection problem.[4]

5.3.1 Investment project selection problem

Instead of making sow replacement decisions, subjects in the experiment decide on keeping or replacing investment projects. Appendix 5.1 shows the parallels between the abstract and the natural decision problem. An experimental year is defined in which subjects decide

[3] Pig farmers in the survey study of Verstegen et al. 1995a stated that most MIS benefits originate from this reduction.

[4] The personal computer software was developed for this experiment by Otto Perdeck at the Center for Research in Experimental Economics and Political Decision Making (CREED), University of Amsterdam.

on one group of fifteen projects first, and then on a second group of fifteen projects.[5] In the next experimental year, they again decide on the first fifteen projects, and so on. This procedure is repeated for nine experimental years per treatment. Time available for decision making is limited (to resemble its opportunity cost in sow farming). Terminated projects are replaced by new projects to keep the total number of projects per group at fifteen. Each experimental year the number of production years of a project increases by one; e.g., a project with four production years in experimental year 1 has five production years in experimental year 2.

Yearly production results are sampled from a normal distribution around a project's production potential. The more years a project has produced, the more (still imperfect) information subjects have about its production potential. The production potential of an investment project in the experiment consists of two properties: the number of production weeks in a production year (PW) and the yield, i.e., the number of points that can be scored per production week (Y/PW).[6] The property PW is constant over time and has two levels only, which are "many" and "few". The difference between the values of these levels equals one standard deviation of the normal distribution around PW (Figures 5.1a and 5.1b).

Analogous to the (age-related) trend in litter sizes of sows, Y/PW expectations of projects change over time, with a maximum value in the fourth and fifth production year. As shown in Figures 5.1c and 5.1d, two levels ("high" and "low") are used; these levels also differ by one standard deviation. With equal probabilities, a project has the property, "many" or "few" production weeks in a production year throughout its lifetime. Similarly, a project has 0.5 probabilities of generating "high" or "low" yields per production week. Consequently, projects' production potentials define four different project types with a 0.25 probability of occurrence: HM (high Y/PW; many PW), LM (low Y/PW; many PW), HF (high Y/PW; few PW), and LF (low Y/PW; few PW). The project types and their probabilities, as well as Figures 5.1a to 5.1d, were explained to the subjects in the experiment.[7]

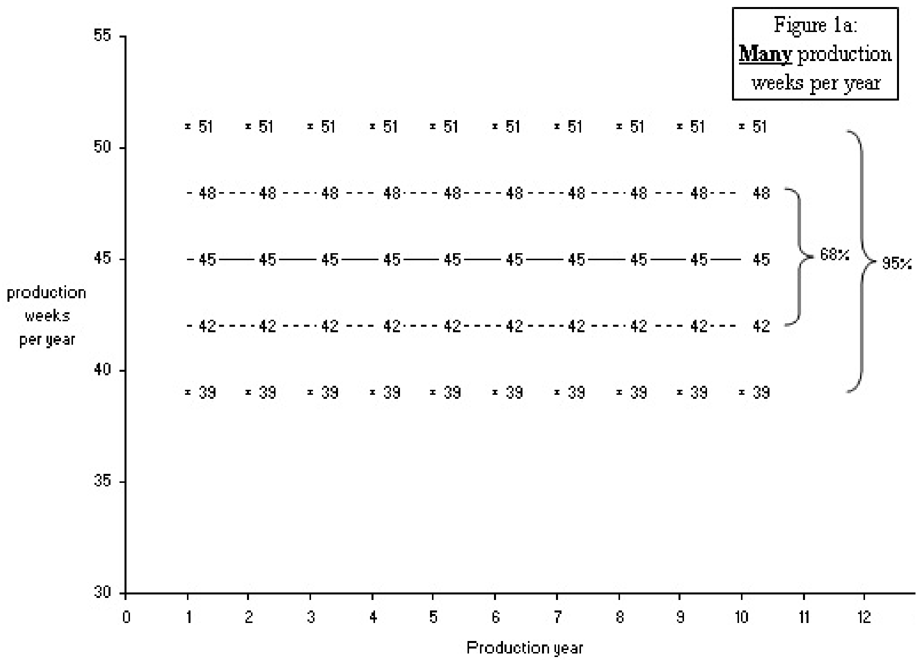
---

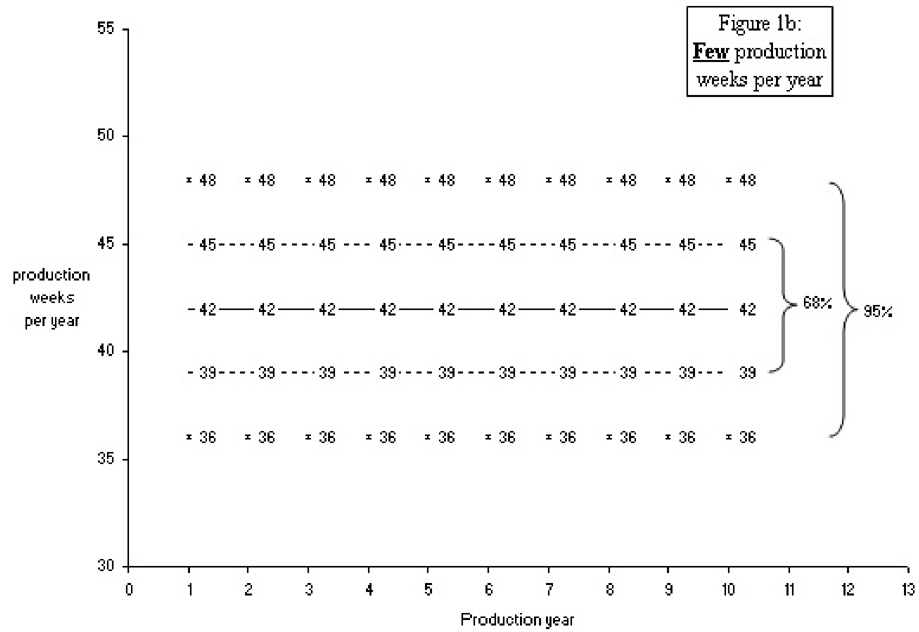
5 Parameters, such as time for decision making and group sizes were determined in pilot tests, executed with staff members and (under)graduate economics students of both the University of Amsterdam and the Wageningen Agricultural University.

6 The coefficients of variation of those properties match their natural counterparts.

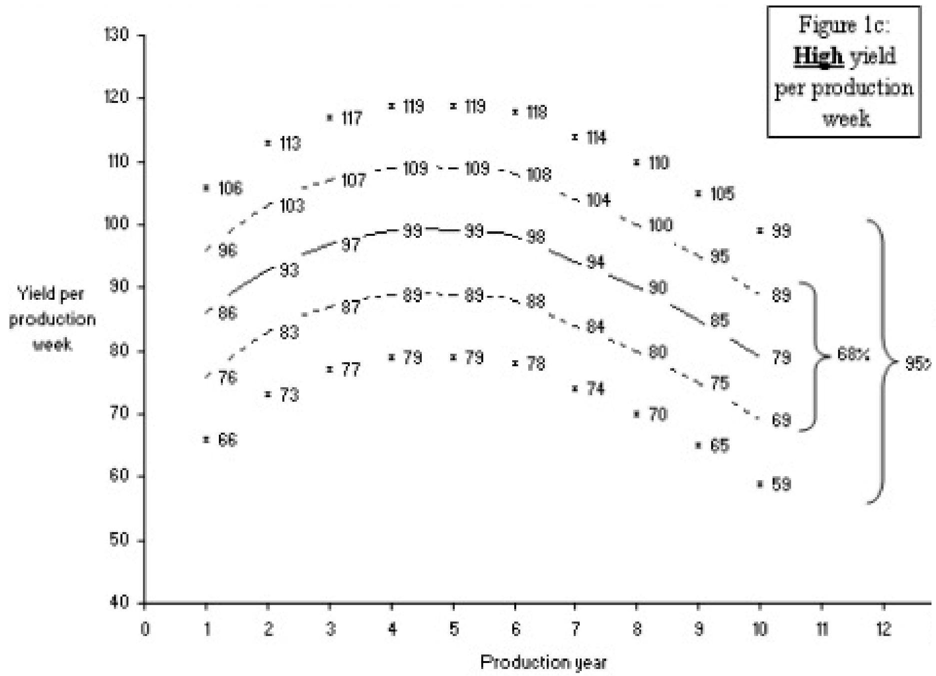
7 An English translation of the instructions is available on request.

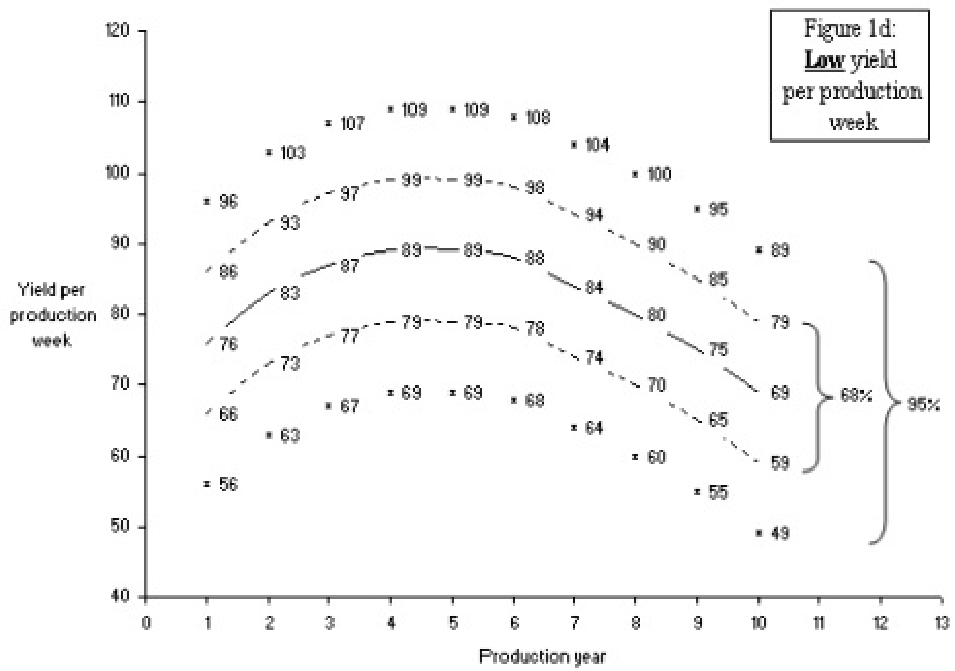
Figures 5.1a and 5.1b as handed out to the subjects in the experiment; the bold lines provide the expected values of the property "number of production weeks"; the dashed and dotted lines provide the +/- 1σ intervals and +/- 2σ intervals lines, respectively.





Figures 5.1c and 5.1d as handed out to the subjects in the experiment; the bold lines provide the expected values of the property "yield per production week"; the dashed and dotted lines provide the +/- 1σ intervals and +/- 2σ intervals lines, respectively.





With this information, subjects can form beliefs about the production potential of a project by relating its (sampled) production results to Figures 5.1a to 5.1d. If a project has a relatively high yield per production week during many production years, it will likely have the property “high Y/PW”. If this project repeatedly produces low yields per production week, it will likely have the property “low Y/PW”. The same logic applies to the property PW. If a subject believes that the production potential (formally, the expected future profitability) of a project exceeds that of an unknown new project, the best decision is to keep the project; otherwise replacing is the best option. If a subject is uncertain about a project’s potential, the decision to keep the project will reduce the uncertainty through observation of the project’s production results in the next year. This can improve the replacement decision in the next year but also includes the risk of having kept a bad project one year too long. The subjects’ task is to adequately form beliefs about a project’s production potential, and consequently keep the projects with a relatively high production potential and replace the projects with a relatively low production potential.

5.3.2 With and without MIS

In the natural situation, MIS support farmers in making sow replacement decisions by converting raw production data into more manageable performance indicators, and by structuring and sorting production data in herd overviews. Therefore, MIS effects on farmers’ decision making result from data processing, not from the provision of additional data. In the experiment, MIS are evaluated by looking at differences in subjects’ decision making between an experimental treatment “with” and a treatment “without” processing of investment project data. Appendix 5.2 describes the analogy between the economics experiment and the natural situation, “without” and “with” MIS.

In the “without MIS” treatment in the experiment, for each individual investment project subjects get a full-screen project card displaying the project’s production results in the past. Yearly production data include the average yield per production week (Y/PW) and the number of production weeks (PW). PW is indicated by production periods with starting and ending dates, e.g. the 2nd of February until the 6th of December. Only the last ten production years are displayed, although investment projects can be kept longer. Subjects can browse through fifteen projects and mark individual projects for replacement. A decision to replace is visualized by a red cross drawn through the project card. Subjects can undo this decision (remove the red cross) until a time limit of 120 seconds is exceeded (see Appendix 5.1).

In the “with MIS” treatment, subjects receive project cards that are similar to the ones in the “without MIS” treatment. However, average values are added and the starting and ending dates, which delineate the production period in a production year, are converted into the actual number of production weeks (PW) in a production year. Furthermore, the total yield per year (Y), which is the product of the number of production weeks (PW) and the yield per production week (Y/PW), is calculated for each project and each (displayed) production year. This figure is displayed on the individual project cards, together with averages per year of PW, Y/PW, and Y. Finally, subjects can request overviews of 15 projects that contain the averages per year of PW, Y/PW, and Y, and are sorted on Y or the number of production years (age of projects).

5.3.3 Experimental design and procedure

MIS effects are estimated in a quasi-experimental, nonequivalent control, pre-test/post-test design (Weiss, 1972; Verstegen et al., 1995b), involving an MIS and a Baseline group, as shown in Table 5.1. Subjects in the MIS group start with a “without MIS” treatment (M1) and continue with a “with MIS” treatment (M2); subjects in the Baseline group get two “without MIS” treatments (referred to as B1 and B2). Treatments M1 and B1 are identical and provide the pre-test values in the experiment. The “with MIS” treatment (M2) and the “without MIS” treatment (B2) provide the post-test values. MIS effects are estimated by subtracting the pre-test values from the post-test values within the MIS group, i.e., by M2-M1. The Baseline group is included for controlling autonomous or exogenous changes in decision making over time, e.g., learning or exhaustion effects. These effects are estimated by subtracting pre-test values from the post-test values within the Baseline group, i.e., by B2-B1.

The experiment is conducted with a stand-alone computer program. Before the experiment, the production potential and production results of each investment project are sampled randomly and stored in “project file 1" and “project file 2" as input for the computer program. The project files contain projects with different production data but, because of pairwise sampling, the projects’ production potentials and their order are the same in “project file 1" and “project file 2". All subjects in the experiment decide on the same projects; they start with “project file 1" in the first treatment and continue with “project file 2" in the second treatment (as shown in Table 5.1). Only the way production data are processed differs between the “without MIS” treatments (B1, B2, M1) and the “with MIS” treatment (M2).

Table 5.1 Outline of the experimental sessions for MIS evaluation

	instruc-tions[1]	training period	**first treatment**	coffee break	instruc-tions	training period	**second treatment**	subject payment
no. of exp. years		4	9			3	9	
MIS group	X	X	**M1** raw production data (project file 1)	X	X	X	**M2** converted data + overviews (project file 2)	X
Baseline group	X	X	**B1** raw production data (project file 1)	X	–	–	**B2** raw production data (project file 2)	X

[1] includes a comprehension test

X = applicable to this group

– = not applicable to this group

Each treatment is run for nine experimental years but, to avoid possible end-game behavior, time horizons are not announced to the subjects.

At the start of an experimental session, subjects receive a summary of the decision problem, a hard copy of Figures 5.1a to 5.1d, scrap paper, and a pencil. No communication is allowed between subjects. Instructions are given about important features of the decision problem, including the uncertainty in production potentials of investment projects. Part of the instruction is done by displaying some examples of investment projects using the same computer program that subjects will use later on. It is explained that, in each production year, the computer program automatically subtracts from the gross yield a fixed cost of 3450 points per project, and 500 points for each replacement in the previous production year. The remainder is added to the total score. After the experimental session, this score is divided by 1500 to give the payoff in Dutch guilders (or divided by 2475 to give the payoff in U.S. dollars). Subjects' understanding of the decision problem is checked with a test. The subjects' task is to find out the most likely production potential of two projects for which ten years of production data are presented on paper. After verification of the answers by the experimenter, a "without MIS" training period of four experimental years is executed (Table 5.1). This training period is identical to the first treatment (but without monetary payoffs), allowing subjects to learn (simple) keyboard handling and become familiar with the experimental decision task. After the first treatment, that is run for nine experimental years, and a coffee break (in which subjects are forbidden to talk about the experiment), subjects in the Baseline group continue with another "without MIS" treatment of nine experimental years (B2 in Table 5.1). The subjects in the MIS group get short instructions on the "with MIS" treatment, a three-year "with MIS" training period, and a nine-year "with MIS" treatment (M2 in Table 5.1). An experimental session ends after the second treatment, when each subject is paid in private an amount of cash equal to his or her earnings in the experimental session.

5.4 DECISION QUALITY

Quality of decision making is assessed by comparing subjects' decisions to those implied by the theoretically optimal decision making strategy (assuming risk-neutrality). This optimal strategy is calculated with a stochastic dynamic programming model (DP) using the hierarchic Markov technique (Kristensen, 1988; Houben et al., 1994) with Bayesian updating (Kristensen, 1993). Although payoff levels are good indicators of overall decision quality, they do not provide good insight into the decision making strategy that subjects (should) have applied, and into the type of decision making errors that are made. Some good decisions may result in bad outcomes, and vice versa, due to the uncertainty in the decision problem. For each project in the project files, the DP solution provides the optimal time of replacement and the losses from sub-optimal replacement (Bellman, 1957). Simulation of an experimental session using the optimal decision strategy results in a score of 1,042,287 points for the treatments M1 and B1, and 1,040,761 points for the treatments M2 and B2. Consequently, deciding according to the theoretically optimal strategy yields a total score in the experiment of 2,083,048 points, which equals a payoff of $88.91. In describing the results, we shall refer to opportunity costs from sub-optimal replacements as “losses”. If replacement is done too early, the loss is defined as the difference in expected future profitability between the replaced project (at the time of replacement) and a new project (Bellman, 1957). If replacement is done too late, the loss equals the summation of differences in expected future profitability over the years after the optimal time of replacement, updated with the new production data in each year.

5.5 RESULTS

The experiment consisted of eight separate experimental sessions involving a total of 86 Dutch pig farmers. The farmers were not randomly assigned to the treatment groups: 46 of the 48 farmers in the MIS group and 5 of the 38 farmers in the control group came from farms that participated in the survey study of Verstegen et al. (1995a). The only selection criterion for the other farmers in both treatment groups was a pragmatic one: they should live near the agricultural education center where the experiment was conducted. In 1992, the farmers in the survey study were only slightly above the national average with respect to farm size and production results. However, 76% of them used MIS whereas the national average was 41% (Verstegen et al., 1995a). Difference in MIS experiences are not a likely source for bias in the experiment because most Dutch pig farmers used MIS in 1996. The advantage of the assignment procedure was that survey MIS estimates previously derived for these farmers could be compared to MIS estimates derived from the experiment.

The farmers in the experiment learned to use the computer program rapidly and were very concentrated on their decision making until the end of the experimental session. Payoff levels ranged between $9.09 and $88.48. If more than one worker from a survey farm participated in the experiment, only the one with the best performance was actually paid. The average score of the subjects was 71% of the optimal-strategy score derived from the DP solution.

Table 5.2 Mean yield losses, i.e., optimal minus actual decision making, of the 48 subjects in the MIS group and 38 subjects in the Baseline group

		Loss (σ)	Loss (σ)	Wilcoxon test			
	n	1st treatment	2nd treatment	# -	# +	Z	P
MIS	48	55050 (53452)	47382 (53135)	20	28	-1.2923	.1962
Baseline	38	51784 (36342)	50930 (43923)	21	17	-1.0079	.3135

Table 5.2 shows the mean losses (i.e., mean opportunity costs from suboptimal replacement) and standard deviations for the 86 subjects in the experiment. Because the losses tend not to be normally distributed (Kolmogorov-Smirnov goodness of fit test), they were analyzed with non-parametric tests. In the MIS group, 20 subjects encountered higher losses (i.e., lower rankings) in the second treatment with processed data than in the first treatment with raw data, whereas the other 28 subjects in the MIS group reduced their losses. However, in the Baseline group 21 out of 38 subjects had higher losses in the second treatment. None of the differences in Table 5.2 was found significant due to large variation in losses across subjects (Wilcoxon test). Some of the subjects clearly misunderstood the essence of the decision problem and repeatedly kept investment projects past their productive lifetime of ten years. As was emphasized in the instructions and indicated on the project cards on the computer screen, projects have zero yield after ten production years (while the yearly fixed costs remain). It appeared that the losses of keeping projects after ten production years largely dominated the losses of sub-optimal replacement *within* the productive lifetime of ten years and were likely to disguise possible MIS effects. Therefore, subjects who clearly misunderstood the essence of the problem and did not correct themselves after they got feedback on the computer screen were excluded from the analysis. Further analysis was done with the 63 subjects who made fewer than five errors (1 project kept for 1 year after ten years = 1 error). The losses caused by these errors were replaced by the average loss of the subject (apart from these errors).

Table 5.3 Mean yield losses, i.e., optimal minus actual decision making, of the 35 selected subjects in the MIS group and 28 selected subjects in the Baseline group

		Loss (σ)	Loss (σ)	Wilcoxon test			
	n	1st treatment	2nd treatment	# -	# +	Z	P
MIS	35	27465 (11111)	24132 (12010)	10	25	-2.2767	.0228
Baseline	28	34493 (16459)	33537 (19778)	11	17	-0.9109	.3624

Table 5.3 shows that mean values and standard deviations of losses in the Baseline and MIS groups are drastically lowered by the exclusion of subjects who misunderstood the decision problem. In the first treatment, which was exactly the same for all subjects, eleven percent of the projects in both groups were replaced in the right production year. Losses from sub-optimal replacement tend to be higher for subjects in the Baseline group but the difference with the MIS group is not significant ($p = 0.13$ for the Mann-Whitney U test). The second treatment differed between the MIS and Baseline groups and resulted in significantly different mean losses ($p = 0.02$ with the Mann-Whitney U test). The subjects in the MIS group replaced fifteen percent of the projects correctly and reduced their losses by 3333 points ($p = 0.02$ with the Wilcoxon test). Projects appeared to be better evaluated. Those with a relatively low production potential were replaced earlier, and those with a relatively high production potential were replaced later. Reduction of losses was higher with the project types that had one good and one bad property (LM and HF) than with the simpler project types that had either two good (HM) or two bad properties (LF). In the second treatment, the subjects in the Baseline group replaced thirteen percent of the projects correctly, but this did not significantly reduce their losses ($p = 0.36$ with the Wilcoxon test). The reduction of losses in the MIS group relative to the Baseline group is 2377 (= 3333-956) points. However, this relative reduction is not significant ($p = 0.34$ for the Mann-Whitney U test) due to the large variation in losses across subjects.

The purpose of this study was to learn if experimental economics methods could confirm the outcome of the survey study and hence could be used as an alternative approach for determining the profitability of MIS in sow farming. Therefore, individual MIS estimates derived from the experiment were compared with individual MIS estimates from the survey study. Comparisons could be made only if MIS estimates were available from both the experimental and survey studies, and if the same farm member participated in both studies. Of the 35 subjects selected in the MIS group, 19 comparisons could be made. Unfortunately, no significant correlation was found between the two MIS estimates (Spearman correlation = -0.35; $p = 0.14$).

5.6 DISCUSSION

Although the experimental study revealed an overall effect of MIS, as did the survey study of Verstegen et al. (1995a), problems with the experimental procedures complicated translation of the results to the natural situation. Analysis of the errors in the experiment showed that, in both the first and second treatments, subjects replaced 60 percent of the projects too early and 27 percent too late, whereas in the natural situation, most farmers tend to replace sows too late (Dijkhuizen et al., 1989).

A refined experimental design, changing one parameter at a time, could have given more insight into the importance of differences between the laboratory and the natural environment. For this study, however, a specific group of farmers who already had participated in a survey study on the profitability of MIS was recruited, allowing a comparison between survey MIS estimates and experimental MIS estimates. Because of the small number of survey farmers, this procedure limited the number of parameters that could be varied in the experimental design. Experimental design features that should be varied in future research are: (a) the level of communication between subjects; (b) the length of the training period; (c) the amount of emphasis on marginal yields of projects; and (d) the specific way in which the decision problem is framed.

Communication between subjects was prohibited to ensure that the amount of information available to the subjects was identical in each of the eight experimental sessions. In the natural situation, however, decisions grow out of a synthesis of experiences, aspirations, and information from colleagues, and farm advisors (Nitsch, 1991).

Several training periods were included in the experiment to facilitate development of decision making rules, but in the natural situation "training periods" cover almost a lifetime (Nitsch, 1991) and are strongly affected by communication and farm comparisons (Leeuwis, 1993). In the experiment, only feedback on earlier decisions through the production results of the projects could be used for learning.

Some of the subjects repeatedly kept investment projects past the productive lifetime of ten production years. The projects then had zero marginal returns but still had fixed costs of 3450 points per period, meaning that the total scores of these subjects dropped drastically. In the natural situation, farmers will not likely make such a mistake because the marginal yield of a sow is prominently visualized through her last litter size. Redesigning the project cards, placing more emphasis on marginal returns, may avoid some of the problems encountered in the experiment.

Less training would be required and misunderstandings could be avoided if the natural decision problem (Dickson et al., 1977) were used instead of the more abstract investment project selection problem. The reason is that farmers could apply their usual decision making rules to the problem. However, framing the experimental task as sow replacement decisions would also mean that the amount of information available to the subjects was no longer controlled. In order to gain the advantages of a less abstract experimental task and also control the subjects' information about the decision problem, an interesting option for further research may be to frame the decision as a replacement problem of uncommon livestock with different parameters, such as crocodiles. With that approach, it would be easier for subjects to grasp the essence of the decision problem but their usual decision rules could not be thoughtlessly applied.

5.7 CONCLUSION

An investment project selection problem was constructed to be an abstract experimental economics analogue of the sow replacement problem, and 86 pig farmers were used as subjects in the experiment. Subjects receiving MIS features improved their decision making between the first and second treatments, whereas subjects without MIS features did not. In nineteen within-farmer comparisons, no significant correlation was found between the individual MIS estimates derived from the experiment and those from a survey study (Verstegen et al., 1995a). Biases in both the experimental MIS estimates and the survey MIS estimates (due to exogenous changes on farms other than MIS use) are the most likely explanation for this outcome.

A refined experimental design, including redesigned project cards placing emphasis on marginal yields of projects, varying abstractness of the decision problem, varying levels of communication between subjects, and varying lengths of the training period, is suggested for further research. The first two aspects entail a better explanation and framing of the investment selection problem. The other two aspects involve communication and learning. The inclusion of (controlled) interaction between subjects in the experimental procedures would stimulate learning and parallel the natural situation, where farmers exchange information with colleagues and farm advisors.

REFERENCES

Bellman, Richard E. (1957). *Dynamic Programming*. Princeton NJ: Princeton University Press. 340 pp.

Boehlje, Michael D., and Vernon R. Eidman (1984). *Farm Management*. New York: Wiley. 806 pp.

Camerer, Colin F. (1995). “Individual Decision Making”. In: *Handbook of Experimental Economics*. J.H. Kagel and A.E. Roth, eds., Princeton NJ: Princeton University Press. p. 587-683.

Davis, Douglas D., and Charles A. Holt (1993). *Experimental Economics*. Princeton NJ: Princeton University. 572 pp.

Dickson, Gary W., James A. Senn, and Norman L. Chervany (1977). “Research in Management Information Systems: the Minnesota Experiments.” *Management Science*, 23(9): 913-923.

Dijkhuizen, Aalt A., Rob M.M. Krabbenborg, and Ruud B.M. Huirne (1989). “Sow Replacement: A Comparison of Farmers’ Actual Decisions and Model Recommendations.” *Livestock Production Science*, 23: 207-218.

Houben, Eric H.P., Ruud B.M. Huirne, Aalt A. Dijkhuizen, and Anders R. Kristensen (1994). "Optimal Replacement of Mastitic Cows Determined by a Hierarchic Markov Process." *Journal of Dairy Science*, 77(10): 2975-2993.

Kristensen, Anders R. (1988). "Hierarchic Markov Processes and their Applications in Replacement Models." *European Journal of Operational Research*, 35: 207-215.

Kristensen, Anders R. (1993). "Bayesian Updating in Hierarchic Markov Processes Applied to the Animal Replacement Problem." *European Review of Agricultural Economics*, 20: 223-239.

Leeuwis, Cees (1993). "Of Computers, Myths and Modelling: the Social Construction of Diversity, Knowledge, Information and Communication Technologies in Dutch Horticulture and Agricultural Extension." Dissertation. Wageningen, The Netherlands: Department of Communication and Innovation Studies, Wageningen Agricultural University. 469 pp.

Nitsch, Ulrich (1991). "Computers and the Nature of Farm Management." *The Edited Proceedings of the European Seminar on Knowledge Management and Information Technology*. D. Kuiper and N.G. Röling, eds. Wageningen, The Netherlands, 23-24 November 1989: Wageningen Agricultural University. p. 99-106.

Smith, Vernon L. (1982). "Microeconomic Systems as an Experimental Science." *American Economic Review*, 72: 923-955.

Smith, Vernon L. (1994). "Economics in the Laboratory." *Journal of Economic Perspectives*, 8: 113-131.

Verstegen, Jos A.A.M., Ruud B.M. Huirne, Aalt A. Dijkhuizen, and Robert P. King (1995a). "Quantifying Economic Benefits of Sow-Herd Management Information Systems Using Panel Data." *American Journal of Agricultural Economics,* 77: 387-396.

Verstegen, Jos A.A.M., Ruud B.M. Huirne, Aalt A. Dijkhuizen, and Jack P.C. Kleijnen (1995b). "Economic Value of Management Information Systems in Agriculture: A Review of Evaluation Approaches." *Computers and Electronics in Agriculture*, 13: 275-290.

Weiss, Carol H. (1972). *Evaluation Research: Methods of Assessing Program Effectiveness.* Englewood Cliffs, NJ: Prentice-Hall.160 pp.

Appendix 5.1 Analogy between the investment project selection problem and the natural sow replacement problem

Investment project selection	Sow replacement
Two decision alternatives: to keep or to replace a project	Two decision alternatives: to keep or to replace a sow
First one group of fifteen projects is evaluated (during 120 seconds). Afterwards, the same is done with a second group of fifteen projects. This procedure is repeated each experimental year.	Each week ten to fifteen sows are evaluated. After one production cycle the sows that were kept before, are evaluated again
A project that has been replaced will never again return in the portfolio of projects	Once a sow has been replaced, the decision can never again be recalled
Replacement decisions become effective at the end of an experimental year. Marked projects are then immediately replaced by a new project	Sows that are removed from the herd are replaced by gilts to keep the herd size intact
A project's production history provides imperfect information about its potential to have a certain yield per experimental year	A sow's production history provides imperfect information about her potential to produce a certain amount of piglets per year
Each experimental year, new information on the production potential of a project becomes available	Each parity, new information on the production potential of a sow becomes available
The production potential of a project is fixed and consists of two properties, namely: 1) the yield per production week, and 2) the number of production weeks per experimental year	The production potential of a sow is fixed and consists of two properties, namely: 1) the number of piglets per litter, and 2) the number of litters per year
The yield per production week is at its maximum level in the fourth year of production	The litter size is at its maximum level in the fourth parity
The maximum productive lifetime of a project in the experiment is 10 experimental years	The maximum productive lifetime of a sow is 10 parities

Appendix 5.2 Analogy between the economics experiment and the natural situation, both 'without' and 'with' MIS

Economics experiment	Natural situation
without MIS (treatments M1, B1, B2)	
Individual project cards show per year:	Individual sow cards show per parity[1]:
1) starting and ending dates of the production period	1) insemination dates
	2) farrowing dates
3) yield per production week	3) litter sizes: no. of piglets born alive / dead
4) number of production years	4) number of parities
with MIS (treatment M2)	
Project cards with	Sow cards with
	1) insemination dates
	2) farrowing dates
3) number of production weeks per year	3) sow-specific farrowing index figures[2]
4) yield per production week	4) litter sizes: no. of piglets born alive / dead
5) total yield per year[3]	5) sow-specific number of piglets produced per year[3]
6) number of production years of the project	6) age of the sow
Options to obtain:	Options to obtain:
1) overviews of projects sorted on the number of production years or the average of total yields per year	1) standard overviews of sows
	2) user-defined overviews
	3) user-defined analyses
	4) working lists
	5) attention lists
Average values per project on project cards and overviews	Average values per sow on sow cards and overviews

1 sow production cycle

2 number of farrowings per year

3 '5)' is the product of '3)' and '4)'

CHAPTER 6

GENERAL DISCUSSION

6.1 INTRODUCTION

The study described in this thesis aimed at developing and testing methods to determine the profitability of management information systems (MIS) in pig farming. Chapter 2 provided an overview of the approaches that could be used for determining MIS profitability. Because positive approaches appeared to be most promising, two “positive” studies were elaborated and tested within the scope of this thesis. In the survey study (Chapters 3 and 4), MIS effects were estimated in a quasi-experimental, nonequivalent time-series research design; the experimental economics study (Chapter 5) was conducted in a quasi-experimental, nonequivalent control, pretest-posttest design.

Chapters 3, 4 and 5 already discussed opportunities and limitations of the research approaches applied in detail. Also implications of the results obtained were presented there. This chapter starts with outlining an integrating, general framework of MIS profitability in livestock management, followed by an evaluation of the research approaches applied in the survey study and the economics experiment. Further, an outlook for future farm and MIS developments and future MIS evaluation research is presented. The chapter ends with a summary of the main conclusions from this study.

6.2. GENERAL FRAMEWORK OF MIS PROFITABILITY IN LIVESTOCK MANAGEMENT

In this part of the discussion, a general framework of MIS profitability in livestock management is outlined by combining experiences reported in the MIS literature with experiences of the survey study and experimental economics study (Figure 6.1). The framework focuses on relationships between MIS use and economic farm results, and can be used to describe the role of MIS for various types of livestock management, such as pig management and dairy cow management. The squares and connecting arrows outline the links, from livestock production data, through MIS use, to livestock management, and technical and economic farm results. The dashed line marks the elements that were included in the survey study; the dotted line denotes the elements of the experimental economics study. Variables that (may) influence the level of MIS benefits are indicated as open arrows.

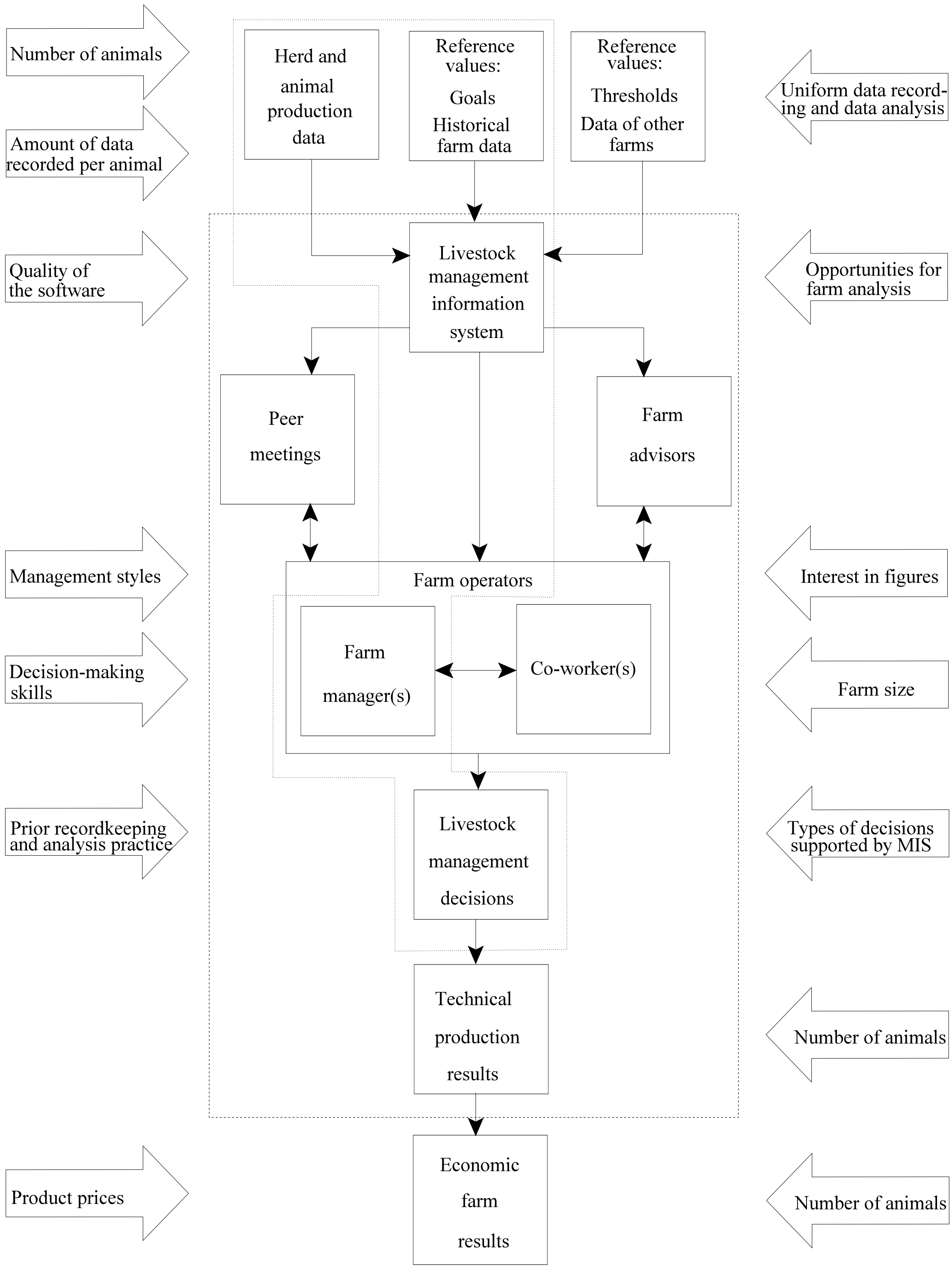


Figure 6.1 A general framework of MIS profitability in livestock management

The first two open arrows in the upper left corner of Figure 6.1 indicate effects of the number of animals and the amount of data recorded per animal on the MIS benefits. MIS benefits originate from the fact that most farmers have limited time, motivation, or skills to decide consistently ("bounded rationality"; Simon, 1979). Time and skills will become more restraining when the number of animals and the amount of data recorded per animal increase. The amount of data recorded per animal depends on the opportunities for farmers to manage animals individually. For instance, poultry farmers usually have large numbers of animals per farm but do not often use MIS. This is because production data are recorded at the flock level and the number of flocks is usually sufficiently small to manage them without MIS. MIS adoption in dairy farming has increased in the last decade, especially on farms with increasing numbers of cows and increasing amounts of data recorded per cow, e.g., in the milking parlor and at the concentrate-feed station (ATC, 1996).

Comparing farmers' own farm results with those of colleagues, e.g., in peer meetings, is important in the learning process of farmers (Leeuwis, 1993). Reliable comparisons can be made only if there is uniformity in data recording and data analysis. In Dutch agriculture, much effort was spent on uniforming data recording and data analysis through the development of so-called information models (Zachariasse, 1991). Uniformity in data recording and data analysis also facilitates the role of farm advisors in the interpretation of farm results and tracing of shortcomings on a farm. Part of the value of MIS results from the fact that farmers who use MIS can point at farm problems more precisely in discussions with farm advisors (Jørgensen et al., 1992).

Both opportunities for farm analysis and software quality affect the information that MIS can provide, the efforts needed to interpret the MIS output, the use of MIS and, consequently, the benefits of MIS (Kleijnen, 1980). Opportunities for farm analysis depend on the number and type of data recorded and the possibilities of the MIS software. Software quality depends on the number of syntax errors, the correctness of the calculations, the userfriendliness of the interface, and the presentation of the output. Some farmers in the survey study (Chapter 3) indicated that checks on data entries are the most valuable part of MIS. These checks do not only notify incorrect data entries but also missing data entries like "sow number X should have farrowed by now, please enter the farrowing data (or else the abortion date)". As such, the kinds of messages may point at potential problems in the herd that the farmer has to deal with.

"Farm operators" have intentionally been assigned a central position in Figure 6.1. Farm operators are the main users of MIS and thus play a crucial role in creating MIS benefits (Hamilton and Chervany, 1981). Their management styles, interests in figures and decision-making skills have a large impact on MIS use and consequently on MIS value. Moreover, personal characteristics determine whether MIS will be purchased (Putler and

Zilberman, 1990). Obviously, this so-called "self-selection problem" is an important issue to deal with when comparing MIS users and nonusers.

MIS appear to be used more often on larger farms (Putler and Zilberman, 1990). As explained before, one reason for this is that on larger farms it is more difficult to keep track of the performances of individual animals. However, another important reason is that MIS structure farm processes in a uniform way. This is convenient when more than one person works with the same animals and information exchange has to be formalized. Newly-hired co-workers with appropriate agricultural education or working experience will soon be familiar with the information system and can start working with it rightaway.

Eventually, economic value of MIS arises from *improvements* in livestock management decisions, which includes (1) higher benefits because MIS cause farmers to choose other decision alternatives, (2) higher benefits because MIS cause farmers to make decisions more timely, and (3) loss-avoidance because MIS allow farmers to control larger herds with the same decision quality as before farm expansion (Kleijnen, 1980; Boehlje, 1997). The magnitude of improvements depends on the quality of the decisions prior to MIS use. Furthermore, MIS value relies on the number of decision types that was improved. MIS can be used to support livestock culling decisions but also for various other types of decisions, such as improving feeding strategies or choice of animal breed.

6.3 RESEARCH APPROACHES

Although the survey study (Chapters 3 and 4) and the economics experiment (Chapter 5) are both positive research approaches, there are major conceptual differences. In this section, both approaches are evaluated and compared.

6.3.1 Survey study

The survey study (Chapter 3) investigated the links between "livestock management information system" and "technical production results" (Figure 6.1), assuming that all the intermediate factors are reflected in the technical production results. Initially, discussions on the effects of "farm size", "management styles", "decision-making skills", and "interest in figures" on farm results and MIS value were avoided by investigating MIS effects within farms over time. In Chapter 4, an in-depth analysis of the same survey data revealed the effects of some farm characteristics on MIS value.

Data quality

A general problem of MIS evaluation research is that data of farms that do not use MIS in a certain year tend to be of lower quality than data collected and processed by MIS farms. In our survey, this problem was highly reduced by selecting a group of farmers that had participated in a socio-economic survey in 1983. This had two major advantages. First, the participants in the 1983-survey were selected for their 1982-membership of the state advisory service and its central Herd Record System, which means that they all received basic information about their herd performance, including the dependent variable in the analyses, i.e., the average number of piglets raised per sow per year (PSY). Second, data of the 1983-survey were stored properly in a computer, which means that the PSY figure of 1982 was available for all survey farms. Originally, farm data of several years were stored at the central Herd Record System of the state advisory service but for fear of tax inspections, farms were renumbered and farm data were deleted. Therefore, most of the data that were used in the analysis of the MIS effect were provided by the farmers in the 1992-survey. Although most of the figures were derived from quite reliable sources, such as advisory services, MIS providers, and on-farm MIS, some farmers handed out vaguely-written summaries from unknown sources.

Recording and analyzing individual sow data were similar in the six commercial brands of sow-herd MIS that were used by the survey participants. Furthermore, two MIS brands covered nearly 80% of the MIS users in the survey. Therefore, we did not classify MIS brands in the analysis of the MIS effect.

Farm size

To analyze MIS effects, technical production results were characterized by the “number of piglets raised per sow per year” figure (PSY). This highly aggregated figure contains most of the effects that MIS may have on major herd performances, such as an increased number of farrowings per sow per year and a reduced piglet mortality rate. It was chosen because most farmers keep precise records of this figure and usually are not too reluctant to provide it for research purposes, as would have been the case when asking for a financial figure. Besides, a financial figure is affected by price changes over time that will mostly be unrelated to MIS use. MIS effects on farm size are not included in the PSY-figure. Boehlje (1997) argues that MIS allow farms to increase in scale without a decrease in the individual sow results. If, for instance, a farmer can maintain the same sow production performance on a ten-percent larger farm by using MIS, this loss-avoiding aspect will highly contribute to the economic value of MIS. The loss-avoiding aspect of MIS could not explicitly be tested in the survey study because of confounding between growth rate of farms and MIS use: twenty out of twenty-one farms with an above average increase in the number of sows started using MIS between 1983 and 1992 (Chapter 4). Of the 45 farms that provided sufficient data to calculate an individual MIS estimate, 19 had an above-average increase in farm scale and an average MIS estimate of 0.71 piglets per sow per year. The other 26 farms had a below-average increase in farm scale and an average MIS estimate of 0.45. This outcome suggests that farmers with increasing farm scales benefit more from MIS than farmers that do not increase their farm size. However, there may also be a so-called common-cause effect: the same characteristics and skills of farmers that make them expand their farms make MIS profitable. An interesting topic for further research is to disentangle the relationships between farmer characteristics, (increase in) farm size, and MIS profitability in a path analysis or a linear structural modelling approach (Bagozzi, 1980).

6.3.2 Experimental economics study

The advantage of an economics experiment is that it combines a high level of control with an assessment of actual decision making of subjects. The level of control guarantees repeatable outcomes whereas subjects' decision making avoids doubtful assumptions about how people decide. The experimental economics study (Chapter 5) investigated the links connecting "herd and animal production data", "reference values: goals and historical farm data", "livestock management information system", "farm manager", and "livestock management decisions" (Figure 6.1). Compared with the survey study, more specific elements were investigated in the economics experiment. Instead of looking at one "result variable", the economics experiment studied the process through which MIS benefits were realized.

Assignment procedure

In the economics experiment, MIS effects were estimated in a quasi-experimental, nonequivalent control, pretest-posttest design (Chapter 5; Weiss, 1972). All subjects started with a "without MIS" treatment. After this treatment, subjects in the Baseline group continued with another "without MIS" treatment, whereas subjects in the MIS group continued with a "with MIS" treatment (Table 5.1).

Although using a randomization procedure (Chapter 2) would have resulted in a more powerful experimental design, (most of the) survey participants were selected for the MIS group of the economics experiment. The aim of the experiment was to compare MIS estimates derived from the same farmers in the survey and in the experiment, which required survey participants to be included in the MIS group. However, it was not possible to obtain individual MIS estimates from 26 of the 71 participants in the survey, because these farmers were unable to provide data on years before and after MIS adoption. Some of those 26 farmers who participated in the experiment (and were selected for the MIS group) could have been exchanged with non-survey farmers in the Baseline group. This would have allowed for within-treatment groups comparisons of survey participants and non-survey participants and could have been a superior assignment procedure. However, the question then arises whether survey farmers who could provide data on years before and after MIS adoption, would decide in the experiment similar to those survey farmers who could not provide the data.

Experimental design

The quasi-experimental, nonequivalent control, pretest-posttest design of the economics experiment was appropriate for determining the effect of MIS. MIS estimates were derived from the subjects in the MIS group, and learning effects were controled in the Baseline group.[1] Treatments were run for nine experimental years to be able to check stability of subjects' decision making. The experiment was limited to two subsequent treatments to avoid exhaustion effects and to fit the instruction, training, and treatments within a three-hour evening session. A disadvantage of the design was that MIS estimates were derived from the subjects in the MIS group only.

Because decision making of the 63 subjects selected for the experiment appeared to stabilize very rapidly, an alternative design with three subsequent treatments would have been possible. An interesting option is the so-called switch-back or cross-over research design (Den Hartog and Verstegen, 1984) which renders MIS estimates of all subjects (Table 6.1).

Table 6.1 The switch-back research design for MIS evaluation

	first treatment	second treatment	third treatment
Group 1	"with MIS"	"without MIS"	"with MIS"
Group 2	"without MIS"	"with MIS"	"without MIS"

1 "Learning" in this context means "getting familiar with the software and with the abstract decision problem". This must be clearly distinguished from learning from MIS use.

Group 1 starts with a “without MIS” treatment, followed by a “with MIS” treatment and a second “without MIS” treatment. Group 2 starts with a “with MIS” treatment, followed by a “without MIS” treatment and a second “with MIS” treatment. In group 1, the difference between the first baseline treatment and the MIS treatment may overestimate the MIS effect. Although not significant in our experiment, learning effects incorrectly may have increased the MIS estimate, providing an upper bound to the true MIS effect. However, learning effects can be controlled by the third, “return to baseline” treatment. The difference between the MIS treatment and the second baseline treatment may underestimate the MIS effect due to the fact that subjects have learned in the MIS treatment to which attributes they should pay attention. Group 1 will thus provide a lower and upper bound to the true MIS effect. Group 2 allows for a separation of effects of treatment rounds (learning and exhaustion effects) and treatment ordering.

6.3.3 Comparison of the research approaches

The survey study and the economics experiment described in this thesis demonstrated that both approaches have advantages and disadvantages. The best approach for MIS evaluation depends on the purpose of the evaluation, the complexity of the decision problem, and the opportunities for obtaining high quality data with sufficient detail. If the interest is in a general effect of MIS in a complex decision environment, and there is a good data set available, survey studies should be preferred. If, on the other hand, the purpose of the evaluation study is to analyse in a well-defined decision environment to what extent, and how, MIS attributes affect decision making, economics experiments will give more insight into the underlying processes and should thus be chosen.

Figure 6.1 shows that the decision environment for MIS in livestock farming is multi-faceted. This complicates the use of economics experiments for MIS evaluation, because developing abstract analogues of the natural situation will be difficult, as will be the explanation to the subjects. More training and a better framing of the decision problem could have solved the problems that some of the farmers had to understand the abstract investment project selection problem in our experiment. However, Figure 6.1 shows that the natural situation in which MIS is used is more complex than the abstract situation in our experiment. Co-workers on a farm use MIS as a formal structure for information exchange, and part of the MIS benefits may come from improved discussions of farmers with colleagues (in peer meetings) and farm advisors. It will be difficult to include all these aspects in an abstract decision problem in such a way that it can easily be controlled, and explained to the farmers in the experiment.

Survey studies connect MIS use to farm results directly and, therefore, require little knowledge of the links in between. Conversely, economics experiments do give good insight into the MIS attributes and the decision processes that improve the farm results and cause the MIS effect, whereas survey studies usually do not.

Survey studies have high external validity, i.e., they reveal effects that actually have occurred in real life (Chapter 2), whereas results of economics experiments still need to be "translated" to the natural situation. Economics experiments have high internal validity, i.e., they have high control of variables intervening between MIS use and farm results. The amount of information available and provided to the subjects is controlled by the use of an abstract decision problem. Survey studies usually have low internal validity, meaning that they cannot guarantee that MIS use, and not some intervening variable, has affected the farm results (Chapter 2).

Data quality in economics experiments is high, because data are generated under the supervision of the experimenter. Data quality of survey studies varies widely but, in general, farm data before MIS use tend to be of poor quality. If, in a survey study, few data of poor detail and quality are available, possibilities to adjust for intervening variables are limited, which means that statistical analyses will not render good results. Because economics experiments generate their own data, they can also be used when no (historical) data are available. For instance, before market introduction of a new MIS attribute, economics experiments can evaluate calculation rules, presentation modes, and added value for different target groups, thus helping software companies to develop useful, tailor-made MIS products.

6.4 FUTURE OUTLOOK

6.4.1 Farm developments

Future farm developments will affect the profitability of MIS. Farm scales will further increase and income margins per animal will become narrower, meaning that farm management becomes increasingly important (Huirne et al., 1992). Farms will more often be managed by two or more operators who will specialize in different functions of livestock farming, such as mating management and farrowing management. This means that the MIS functionality of providing a formal structure for information exchange between co-workers will become increasingly important, and thus valuable. Also, cost-saving aspects of MIS become more meaningful with increasing scales of farming. Computerized management support can save expenditures on labor input through faster exchange of information and calculation of farm results.[2] Furthermore, MIS can be used to evaluate the performances of the farm operators or the feed quality of different feed companies. Finally, intangible MIS benefits, such as “having a good overview of the farm” and “feeling better because MIS confirm that you have made the right decisions” will become more significant in the future. Having control of the business means that labor stress is reduced (Mok, 1988). Although these intangible aspects are also considered valuable in current livestock farming, they increasingly will have economic consequences in terms of a lower number of inproductive hours of farm operators.

6.4.2 Developments in MIS and other information technology applications

Developments in MIS and other information technology (IT) applications will affect MIS use and, thus, MIS profitability. Technological innovations, societal trends, and changes on the farms and in the production-marketing chains are the driving forces behind IT and especially MIS developments.

Sensor techniques facilitate a detailed monitoring of individual animal performances (Carmi, 1992; Raemakers et al., 1995). Manual data entry will be made easier through the use of handheld computers (Vos and Koekkoek, 1997). New tools for farm analysis, calculating advanced performance figures (Huirne et al., 1992; Hennen, 1995) will enhance decision support. Computer networks, such as the Internet, will offer new opportunities for peer discussions, farm comparisons and interaction between farmers and farm advisors.

Because consumers demand guarantees concerning food safety, animal welfare, and environment, it will be necessary to record data on the health status of the animals, the type of production system on the farm (e.g., outdoor farming and organic farming), and the types of drugs and feed additives administered. Eventually, many of these data will be recorded through MIS and will become part of the integrated quality control system that will be used throughout the livestock production-marketing chain. Data exchange between the different stages of the production-marketing chain (e.g., feed company, farmer, slaughterhouse, retailer) will largely be done by MIS. In the Netherlands, electronic data interchange (EDI) is already available to farmers and horticultural growers in various branches, dairy product companies, breeding companies, slaughter plants, and flower auctions (ATC, 1996).

---

[2] Labor saving aspects will, to a lesser extent, take place on smaller farms as well, but farmers do not usually recognize these MIS benefits because of the usually low opportunity costs of labor.

6.4.3 Implications for further MIS evaluation research

To allow for an optimal comparison, the two research approaches reported on in this thesis were tested on one type of MIS only, i.e., sow-herd MIS. The concepts and procedures, however, can be generally applied in livestock farming. Recently, the same analysis procedure as described in Chapter 3 has been succesfully applied in an evaluation of dairy-cow MIS (Tomaszewski et al., 1997). Further research is under way, using the analysis procedure for evaluation of other information technology applications in dairy farming, e.g., sensors for measuring milk yield, activity levels of cows, and automated ration feeding (Van Asseldonk et al., 1997).

Future MIS evaluation research in livestock farming will become increasingly complex because of the farm and IT developments described above. In sow farming, MIS become important instruments for coordination between operators in the mating, gestating, and farrowing units and, as part of the integrated quality control system, for information exchange among the various stages in the production-marketing chain (Den Ouden, 1996). Gradually, more and more features affect the value of MIS. Using survey studies for future MIS evaluation becomes increasingly difficult, because it is complicated to determine the actual changes in decision making that are caused by MIS, and the period in which MIS have reached their full impact. Economics experiments could be applied to investigate the effect of individual MIS features. However, many features entail aspects of communication and coordination, that are difficult to control in experiments.

Experiences with MIS evaluation outside agriculture (e.g., Kleijnen, 1980; Parker et al., 1988; Amos, 1990; Lincoln and Shorrock, 1990; Smith, 1990) can be useful for MIS evaluation in agriculture, because of the growing number of parallels between the two settings. Corresponding to the MIS developments in agriculture, Lincoln and Shorrock (1990) report that industrial MIS will become part of a changing organization in which computer systems are increasingly closely inter-linked, and MIS benefits and organizational benefits are increasingly closely coupled. It will become more difficult to define the boundaries of MIS and, consequently, the results of MIS. Furthermore, defining credible, viable alternatives to MIS will become more difficult, which complicates comparisons of performances with and without MIS.

To include effects of IT on effectiveness and efficiency of organizations, Parker et al. (1988) suggest an extension of the traditional benefit-cost analysis with four elements: value linking, value acceleration, value restructuring, and innovation valuation. “Value linking” refers to improvements in the original process, e.g., the improved data recording with sow-herd MIS. “Value accelaration” refers to benefits due to faster data processing, e.g., earlier culling of less-productive sows. Benefits of upscaled functions, e.g. pig farmers who can concentrate on farm analyses instead of calculation of key figures, are included in “value restructuring”. Finally, “innovation valuation” includes benefits that arise from competitive advantage, e.g., sow farmers who get ahead of other farmers by participating in a quality control system and therefore receive higher piglet prices and/or realize lower costs.

The MIS benefits determined in this thesis can be classified as “value acceleration” and “value restructuring”: livestock management decisions are made more timely and better decision alternatives are chosen. Referring to Figure 6.1, the MIS benefits determined in this thesis include improved “livestock management decisions” through more timely decision making and through selection of better decision alternatives, i.e., “value acceleration” and “value restructuring”; operational cost reductions through the use of a “livestock management information system”, i.e., “value linking”, are not included. “Value restructuring” will become an increasingly important part of MIS benefits when MIS will be integrated into simulation models, optimization models, or expert systems. Besides a more or less routinely processing of animal data by MIS, farmers may then gain better insight into farm processes through advanced farm analyses, e.g., “what-if” scenarios. Furthermore, with increasing farm sizes and the shift from bulk production towards high-quality production for specific consumer segments, “value linking” and “innovation valuation” will become more important. Recognizing the different types of benefits described by Parker et al. (1988) will be helpful in designing questionnaires and experiments for MIS evaluation research in the future.

6.5 MAIN CONCLUSIONS

The main conclusions of this thesis are:

- Because MIS benefits arise from the fact that farmers have limited time, motivation or skills to decide consistently, positive research approaches that derive MIS benefits from actual decision making of farmers have more potential for MIS evaluation than normative approaches that assess MIS benefits with predetermined decision criteria
- The combination of panel data and a statistical model with a dummy variable per individual farm is very powerful in MIS evaluation because effects can be estimated both within and between farms at the same time, separating farm-specific and common (trend) effects
- In our study, average production of sow farms using MIS increased by 0.56 piglets raised per sow per year, from the second year of MIS use onward. Converted to economic terms, MIS use resulted in a profit of US$ 15 to US$ 17 per sow per year,

meaning a return on investment of 220 to 348% and 7.7 to 8.7% of the typical Dutch income per sow per year

- MIS value is positively correlated with the management level of the farmer; although farmers with high management levels tend to be better-informed anyway than farmers with low management levels, they derive more added value from MIS
- Providing subjects in an economics experiment with MIS features, such as processed data and sorted overviews, significantly improved their decision making, whereas subjects' decision making without MIS features did not
- Individual MIS estimates derived from the same farmers in the survey study and economics experiment did not correlate significantly. Further research using a refined experimental design is necessary to decide whether an economics experiment can be an alternative to a field study in determining the profitability of MIS in sow farming

REFERENCES

Amos, William J. (1990). "Demonstrating the IS Contribution." In: *Managing Information Systems for Profit*. T.J. Lincoln, ed. New York: Wiley. p. 331-350.

ATC (1996). Automatisering in de Agrarische Sector: Gebruik en Trends [Automation in Agriculture: Actual IT Use and Trends]. Agrarisch Telematica Centrum. Wageningen, The Netherlands. 61 pp.

Bagozzi, Richard P. (1980). *Causal models in marketing*. New York: Wiley. 303 pp.

Boehlje, Michael D. (1997). Personal Communication.

Carmi, S. (1992). "The Performance of an Automated Dairy Management Data-Gathering System" In: *EAAP Publication no. 65, Proceedings of the International Symposium on Prospects for Automated Milking*. A.H. Ipema, A.C. Lippus, J.H.M. Metz, and W. Rossing, eds. The Netherlands: Pudoc. p. 346-352.

Den Hartog, Leo A., and Martin W.A. Verstegen (1984). "The Effect of Energy Intake of Gilts on the Supply of Metabolizable Energy and Protein Deposition." *Netherlands Journal of Agricultural Science*, 32: 87-99.

Den Ouden, Marjan (1996). Economic Modelling of Pork Production-Marketing Chains. *Mansholt Studies 4*. Oegstgeest, The Netherlands: Backhuys. 166 pp.

Hamilton, Scott, and Norman L. Chervany (1981). "Evaluating Information System Effectiveness -- Part I: Comparing Evaluation Approaches." *MIS Quarterly*, 5: 55-69.

Hennen, Wil H.G.J. (1995). "Detector: Knowledge-Based Systems for Dairy Farm Management Support and Policy Analysis." LEI Onderzoekverslag 125 [LEI Research report 125], The Hague, The Netherlands: Agricultural Economics Research Institute. 205 pp.

Huirne, Ruud B.M., Aalt A. Dijkhuizen, Jan A. Renkema, and Paul van Beek (1992). "Computerized Analysis of Individual Sow-Herd Performance." *American Journal of Agricultural Economics*, 74(2): 388-399.

Jørgensen, Erik, V. Ruby, and L. Herløv (1992). "Review of Danish Experiences with Decision Support Systems in Pig Production." Proceedings of the 4th International Congress for Computer Technology in Agriculture, Société des Agriculteurs de France, France, 1-3 June 1992, p. 201-204.

Kleijnen, Jack P.C. (1980). *Computers and Profits: Quantifying Financial Benefits of Information*. Reading MA: Addison Wesley. 262 pp.

Leeuwis, Cees (1993). "Of Computers Myths and Modelling: The Social Construction of Diversity, Knowledge, Information and Communication Technologies in Dutch Horticulture and Agricultural Extension." Dissertation Wageningen Agricultural University. Wageningen, The Netherlands. 469 pp.

Lincoln, Tim J., and David Shorrock (1990). "Cost-Justifying Current Use of Information Technology." In: *Managing Information Systems for Profit*. T.J. Lincoln, ed. New York: Wiley. p. 309-330.

Mok, Albert L. (1988). "Over het Welzijn van de Ondernemer in de Veehouderij" [About the Welfare of the Entrepreneur in Livestock Farming]. In: *Kwaliteiten in de Dierlijke Produktie* [Qualities in Animal Production]. P.R. Wiepkema, P. Mekking, and W.B. van Muiswinkel, eds. Wageningen The Netherlands: Pudoc. p. 33-38 (in Dutch).

Parker, Marilyn M., Robert J. Benson, and H. Edward Trainor (1988). *Information Economics: Linking Business Performance to Information Technology*. Englewood Cliffs NJ: Prentice-Hall. 287 pp.

Putler, Daniel S., and David Zilberman (1988). "Computer Use in Agriculture: Evidence from Tulare County, California." *American Journal of Agricultural Economics*, 70(4): 790-802.

Raemakers, Peter J. L., Jan H. Huiskes, Martin W.A. Verstegen, Leo A. den Hartog, Peter C. Vesseur, and J. (Han) W.G.M. Swinkels (1995). "Estimating Individual Body Weights of Group-Housed Growing-Finishing Pigs Using a Forelegs Weighing System." *Computers and Electronics in Agriculture*, 13: 1-12.

Simon, Herbert A. (1979). "Rational Decision Making in Business Organizations." *American Economic Review*, 69(4): 493-513.

Smith, Julian E. (1990). “Gearing IT in the Office to Business Needs.” In: *Managing Information Systems for Profit*. T.J. Lincoln, ed. New York: Wiley. p. 199-240.

Tomaszewski, Michael A., Aalt A. Dijkhuizen, Ruud B.M. Huirne and Albert Otten (1997). “Determining the Effect of a Dairy Management Information System on Production and Performance Parameters in Texas DHI Herds.” Working Paper Wageningen Agricultural University.

Van Asseldonk, Marcel A.P.M., Ruud B.M. Huirne, and Aalt A. Dijkhuizen (1997). “Effects of Information Technology on Dairy Farms: An Empirical Analysis of Milk Production Records.” Working Paper Wageningen Agricultural University.

Vos, H. (Fred) J.P.M., and Gerrit-Jan F. Koekkoek (1997). “Het gebruik van handcomputers in de varkenshouderij” [The use of hand-held computers in pig farming]. *Agro-Informatica*, 10(4): 10-12.

Weiss, Carol H. (1972). *Evaluation Research: Methods of Assessing Program Effectiveness*. Englewood Cliffs, NJ: Prentice-Hall. 160 pp.

Zachariasse, Levinus C. (1991). “Farm Management Information Systems Planning and Development in the Netherlands.” Paper presented at a Symposium "Harmonization of Information Systems: A Farm Business Model Approach", 1991 meeting of the American Agricultural Economics Association, Manhattan NY, August 1991, 11 pp.

SUMMARY

Introduction

Developments in commercial pig farming are generally characterized by extended herd sizes and narrowed income margins. Minor differences in productive performance have an increasing impact on economic results. Therefore, good management becomes more and more important for farmers to stay in business.

In the last decades, many efforts have been made to develop electronic tools to support management on pig farms. Before 1970, recording of yearly farm data, if any, was done manually. In the seventies, the Dutch state advisory service started automated data processing at herd level. Quarterly herd data were processed on a central mainframe computer. From the eighties onward, sow-herd management information systems (MIS) have been developed that can provide daily or weekly production information at the level of the individual sow. Farmers can operate these MIS on their farms or use the mail-in services of the MIS providers. In the nineties, computerized pig management support continues with the development of simulation models, optimization models and expert systems.

Although much effort is put in the development of advanced computer systems, a thorough evaluation of the added value of using MIS in pig farming is lacking. Insight into this value is useful to farmers making investment decisions and to companies that design and market MIS.

Problem definition

The overall objective of the research project was to develop and test methods to determine the profitability of MIS in livestock farming. The methods should first be applied to evaluating MIS in pig farming.

Determining the profitability of MIS is difficult because of the specific product of MIS, i.e., processing of animal data into useful management information.

Costs of MIS are relatively easy to determine. They include costs for interest and depreciation related to the investments in hardware and software (updates), and operating costs, such as labor costs, MIS training costs, and help desk costs.

Benefits of MIS, however, are more difficult to evaluate, because of the wide range of decisions and activities that can be affected by MIS and the crucial role of the MIS user in creating MIS benefits. Sow-herd MIS, for instance, designed to support production management, check for incorrect data entries, calculate key ratios, provide sorted sow overviews, and offer opportunities for (simple) farm analyses. Added value of these MIS thus depends on the number of data recording errors and the number of calculations that

were made before MIS adoption, and the actual use of MIS figures and MIS analysis opportunities in livestock management. The added value originates from the fact that farmers have limited time, motivation, or skills to decide in a way that is consistent with their farm goals. Economic value of MIS arises from *improvements* in decision making, which includes:
(1) higher benefits because MIS cause farmers to choose other decision alternatives, (2) higher benefits because MIS cause farmers to make decisions more timely, and (3) loss-avoidance because MIS allow farmers to control larger herds with the same decision quality as before farm expansion.

MIS evaluation methods

Chapter 2 describes various methods that could be used to determine the economic value of MIS in agriculture. Two main types of research approaches are identified: normative and positive approaches. Normative approaches provide a theoretical pre-audit measure of what the profitability of MIS could be or should be, based on the net returns of their functions (e.g. improved decision making, labor savings), and according to some predefined (consistent) decision making criteria. In Figure 2.1, normative approaches are further split up into decision theoretical approaches (decision tree analysis, Bayesian Information Economics, Control Theory) and decision analytical approaches (simulation approaches, linear programming, dynamic programming).

Positive approaches determine what the profitability appears to be through empirical studies (post-audit). Examples include experimental, quasi-experimental, and nonexperimental designs. Within the group of experimental designs, a further distinction can be made between field experiments and experimental economics.

Normative approaches are considered to have limited potential in practice. MIS value originates from the fact that most farmers have limited time, motivation, or skills to decide consistently. The consequence of the incorrectness of the consistency assumption is a low external validity; the estimates on the value of MIS obtained with normative approaches will differ from its real value in practice. The value of positive approaches, on the other hand, depends very much on the availability and quality of (longitudinal) field data and the type of research design. Experimental economics was identified as a means to obtain data on decision making in a highly controllable environment and was, therefore, considered to be an interesting alternative to MIS evaluation in agriculture. Two positive approaches were applied in this thesis.

MIS evaluation using panel data

One issue that arises in an MIS evaluation study is whether good managers are more likely to use MIS; therefore, a concern is how to sort out the effect of "better management" from the actual benefits of MIS. Computer users tend to be better educated, operate large farms, are younger, and typically have more contacts with colleagues using computers, or have children interested in computers. Panel data - time-series from several farmers - can overcome this self-selection problem by within-farms investigation (before and after MIS adoption).

Chapter 3 describes a study, set up to quantify the economic effects of MIS in pig farming using panel analysis. A panel data set was created by combining data of a survey study conducted in 1983 and a survey study conducted on the same farms in 1992. The relationship between MIS use and economic results of 71 sow farms was investigated in a quasi-experimental nonequivalent time-series design. Data were collected on animal recording practice, year of MIS adoption, and annual herd performances from 1982 to 1991. Panel analysis in a mixed-effects model using ordinary least-squares procedures allowed for a separation in farm-specific and (common) trend effects. Adjusted for other effects in the statistical model, production on farms adopting MIS increased by 0.56 piglets per sow per year ($p = 0.09$), indicating a return on investment of between 220% and 348%. This means that, through MIS use, net returns to labor and management on an average 165-sow farm would increase by 7.7% to 8.7%. Tests for autocorrelation, influential observations, and nonequivalent control time-series indicated that this outcome is robust. Another outcome of the study was that effects of MIS use differed significantly between farms ($p \leq 0.001$).

Impact of farm characteristics

An in-depth analysis of the impact of farm characteristics on MIS profitability was executed in the study reported on in Chapter 4. Profitability of sow-herd management information systems (MIS) arises from improved managerial decision making and, therefore, will vary from farm to farm. The impact of farm characteristics on MIS profitability was investigated, comparing two conceptually different farm classification methods within the same research population: the sociological "style of farming" approach and the farm-economic "management level" approach. The sociological style of farming concept is defined as the specific structuring of farm aspects and is based on a complex of opinions of what farming should be like, shared by a group of farmers. It emphasizes the strategic component of farming and assumes that farmers have freedom to structure their farms according to their goals, instead of being the result of past experiences or governmental rules and laws. A typical characteristic of the style of farming concept is that it entailed self-classification of farmers. The management level classification is based on an index method for scoring management that originally was developed for glasshouse horticulture in the Netherlands. With help of pig farming experts and a questionnaire, management of farmers was scored on six management factors, i.e., education and training, modernity of facilities, firm policy, tactical planning, operational planning, and social aspects. For the purpose of the study, the "management level" approach was considered superior to the "style of farming" approach, because management levels could explain part of the variation in MIS profitability between farms whereas styles of farming could not. Management levels of pig farmers were positively correlated with MIS profitability ($r = 0.35$, $p = 0.02$). Although farmers with high management levels tend to be better informed than farmers with low management levels, they derive more added value from MIS.

MIS evaluation using experimental economics

Chapter 5 reports a pilot experiment intended to yield insight into whether laboratory economics experiments can be used as an alternative to surveys for determining the profitability of MIS in sow farming. Compared with survey studies, economics experiments have better control of intervening variables and require fewer historical data. If the experimental economics approach proves to be a good alternative to a survey study, it may be used for (ex-ante) evaluation of new MIS systems and, possibly, other information services. Instead of linking MIS use to farm results directly, the effect of different information levels on decision making was investigated under controlled laboratory conditions. An investment project selection problem was constructed to be an abstract experimental economics analogue of the sow replacement problem, and 86 pig farmers were used as subjects in the experiment. Many of the farmers also participated in the above-mentioned survey study. The individual decision-making experiment was executed in a quasi-experimental, nonequivalent control, pretest-posttest design. In an MIS group, MIS estimates were derived by within-subjects comparisons of decision quality with and without MIS features. A baseline group was included to control for learning or exhaustion effects during an experimental session (Table 5.1). Decision quality of subjects in the MIS group significantly improved when offered MIS features ($p = 0.02$). Furthermore, a comparison was made between experimental and survey MIS estimates, both derived from the same pig farmers. An overall effect of MIS was found in both the experiment ($p = 0.02$) and the survey study ($p = 0.09$). However, the two MIS estimates were not significantly correlated ($r = -0.35$; $p = 0.14$). It was concluded that the most likely explanations for these uncorrelated estimates include problems with the experimental design and/or biases in survey MIS estimates due to exogenous changes on farms other than MIS use, and differences between the laboratory and the natural environment in levels of communication and decision making routine.

Discussion and conclusions

Chapter 6 discusses a general framework of MIS profitability in livestock management (Figure 6.1). The research approaches applied are evaluated using the framework. Application of the methods in other fields of livestock farming is discussed. Furthermore, an outlook for farm developments, MIS developments, and other IT (information technology) developments is presented together with their implications for future MIS evaluation research. The chapter ends with the main conclusions of the thesis.

The main conclusions of the thesis are:

- Because MIS benefits arise from the fact that farmers have limited time, motivation or skills to decide consistently, positive research approaches that derive MIS benefits from actual decision making of farmers have more potential for MIS evaluation than normative approaches that assess MIS benefits with predetermined decision criteria.
- The combination of panel data and a statistical model with a dummy variable per individual farm is very powerful in MIS evaluation because effects can be estimated both within and between farms at the same time, separating farm-specific and common (trend) effects.
- In our study, average production of sow farms using MIS increased by 0.56 piglets raised per sow per year, from the second year of MIS use onward. Converted to economic terms, MIS use resulted in a profit of US$ 15 to US$ 17 per sow per year, meaning a return on investment of 220 to 348% and 7.7 to 8.7% of the typical Dutch income per sow per year.
- MIS value is positively correlated with the management level of the farmer; although farmers with high management levels tend to be better-informed than farmers with low management levels, they derive more added value from MIS.
- Providing subjects in an economics experiment with MIS features, such as processed data and sorted overviews, significantly improved their decision making, whereas subjects' decision making without MIS features did not.
- Individual MIS estimates derived from the same farmers in the survey study and economics experiment did not correlate significantly. Further research using a refined experimental design is necessary to decide whether an economics experiment can be an alternative to a field study in determining the profitability of MIS in sow farming.

SAMENVATTING

Inleiding

Ontwikkelingen in de varkenshouderij gaan gepaard met continue schaalvergroting en afnemende winstmarges per dier. Het gevolg hiervan is dat een klein verschil in dierproductiviteit sterk doorwerkt in het economisch bedrijfsresultaat. Een goed management is daarom noodzakelijk om de continuïteit van het bedrijf te waarborgen.

De afgelopen decennia waren vele inspanningen gericht op de ontwikkeling van electronische hulpmiddelen die het management op varkensbedrijven kunnen ondersteunen. Vóór 1970 werden bedrijfsgegevens niet of alleen handmatig (doorgaans eenmaal per jaar) bijgehouden. Het Consulentschap voor de Varkens- en de Pluimveehouderij startte begin jaren zeventig met een geautomatiseerde administratie van gegevens op bedrijfsniveau. Kwartaalgegevens werden daarbij verwerkt door een centrale "mainframe" computer. Vanaf begin jaren tachtig worden er zeugen-managementinformatiesystemen (MIS-en) ontwikkeld die de varkenshouder (naar keuze wekelijks of dagelijks) voorzien van management-informatie op dierniveau. De varkenshouder kan zijn of haar diergegevens thuis op de p.c. administreren en verwerken of gebruik maken van een van de centrale verwerkingsbureau's. De ontwikkelingen op het gebied van de gecomputeriseerde management-ondersteuning gaan door in de jaren negentig. Simulatiemodellen, optimalisatiemodellen en expertsystemen zijn ontwikkeld om de varkenshouder van de toekomst te kunnen ondersteunen.

Veel studies zijn en worden gericht op het ontwikkelen van steeds geavanceerdere computersystemen; weinig studies houden zich bezig met de vraag wat de toegevoegde waarde van een MIS is voor de varkenshouderij. Het antwoord op deze vraag is niet alleen van belang voor varkenshouders die overwegen om in een MIS te investeren, maar ook voor bedrijven die MIS-en ontwikkelen en vermarkten.

Probleemafbakening

Het doel van deze studie is het ontwikkelen en testen van methodieken ter bepaling van het rendement van MIS-en in de veehouderij. Hiertoe worden MIS-en in de varkenshouderij geëvalueerd. De bepaling van het rendement van MIS-en is moeilijk vanwege hun ietwat eigenaardige product, d.i. het vertalen van ruwe diergegevens in nuttige informatie ten behoeve van het management.

De kosten van een MIS kunnen doorgaans relatief gemakkelijk worden vastgesteld. Deze bestaan uit rente en afschrijving op hardware- en software, cursussen om met een MIS te leren omgaan, arbeid bij gebruik van een MIS en kosten voor de begeleiding (helpdesks). De opbrengsten van een MIS zijn daarentegen veel moeilijker te bepalen. Dit komt door de brede range van beslissingen en activiteiten die door een MIS kunnen worden beïnvloed en de invloed van de gebruiker hierop. MIS-en in de zeugenhouderij bijvoorbeeld controleren de data-invoer, berekenen kengetallen, produceren allerlei overzichten en bieden mogelijkheden voor (eenvoudige) bedrijfsanalyses. De waarde van dergelijke systemen hangt daarom enerzijds af van het aantal registratiefouten en typen berekeningen die varkenshouders voor de aanschaf van het MIS maakten, en anderzijds van het daadwerkelijke gebruik van de mogelijkheden die het MIS biedt.

De toegevoegde waarde van een MIS komt voort uit het feit dat boeren te weinig tijd, motivatie of vaardigheden hebben om beslissingen te nemen die echt overeenkomen met hun bedrijfsdoelstellingen. De economische waarde van MIS-en ontstaat daarom door *verbeteringen* van managementbeslissingen, welke bestaan uit:

(1) hogere opbrengsten omdat varkenshouders door een MIS betere beslissingsalternatieven kiezen;
(2) hogere opbrengsten omdat varkenshouders door een MIS tijdig (c.q. sneller dan voorheen) beslissingen nemen;
(3) het vermijden van verliezen omdat varkenshouders door gebruik van een MIS een grotere bedrijf kunnen "managen" zonder op de productiviteit per dier in te hoeven leveren.

MIS-evaluatiemethodieken

Hoofdstuk 2 beschrijft diverse methodieken die gebruikt kunnen worden om de economische waarde van een MIS te bepalen. Twee groepen van benaderingen zijn onderscheiden: normatieve en positieve benaderingen. Normatieve benaderingen leveren een theoretische ex-ante maat die aangeeft wat het rendement van een MIS kan of zou moeten zijn, op basis van vooraf veronderstelde besluitvormingscriteria en de potentiële opbrengsten van MIS-opties (bijv. verbeterde besluitvorming en arbeidsbesparing). In Figuur 2.1 worden de normatieve benaderingen verder onderverdeeld in "decision theoretical approaches" (decision tree analysis, Bayesian Information Economics, Control Theory) en "decision analytical approaches" (simulation approaches, linear programming, dynamic programming).

Positieve benaderingen stellen via empirische studies (ex-post) vast wat het rendement van een MIS in de praktijk blijkt te zijn. Voorbeelden hiervan zijn experimentele, quasi-experimentele en niet-experimentele proeven. Binnen de groep van experimenten kan nog een verdere onderverdeling gemaakt worden naar veld-experimenten en economische experimenten (Figuur 2.1).

Normatieve benaderingen worden van weinig waarde geacht voor deze studie, omdat hier het daadwerkelijke rendement in de praktijk wordt onderzocht. De waarde van

MIS komt voort uit het feit dat varkenshouders te weinig tijd, motivatie of vaardigheden hebben beslissingen te nemen die consistent zijn met hun doelstellingen, terwijl normatieve benaderingen juist uitgaan van consistente besluitvorming. Daardoor kunnen normatieve schattingen van het rendement van een MIS behoorlijk afwijken van het rendement in de praktijk. Daarentegen hangt de waarde van positieve benaderingen sterk af van de proefopzet en de beschikbaarheid en kwaliteit van de gegevens. Experimentele economie biedt de mogelijkheid om gegevens over daadwerkelijke besluitvorming van de varkenshouder te verkrijgen in een controleerbare omgeving en wordt daarom in dit kader beschouwd als een interessante methode.. In dit proefschrift worden twee positieve benaderingen toegepast, namelijk een enquête-studie en experimenteel-economische studie.

MIS-evaluatie met panel-gegevens

Een belangrijke handicap bij MIS-evaluatie is dat het waarschijnlijk de betere managers zijn die een MIS gebruiken. De moeilijkheid is dan om het effect van dat betere management te onderscheiden van het effect van een MIS. Uit Amerikaanse studies in de landbouw blijkt dat computergebruikers in zijn algemeenheid beter zijn opgeleid, grotere bedrijven bezitten, jonger zijn en meer contacten hebben met collega's. Daarnaast speelt ook het feit of ze kinderen hebben die geïnteresseerd zijn in computers een rol.

Dit zogenaamde zelfselectieprobleem kan worden vermeden indien uitgegaan wordt van panelgegevens - tijdreeksen van verschillende bedrijven - en analyses uitgevoerd worden binnen een bedrijf (vóór en na aanschaf van een MIS). Hoofdstuk 3 beschrijft een studie die uitgevoerd is om het economisch effect van MIS te analyseren via panel-analyse. Door data van een enquête uit 1983 te combineren met data van een enquête op dezelfde bedrijven in 1992 werd een panel-dataset verkregen. De relatie tussen het gebruik van een MIS en de economische resultaten van 71 zeugenbedrijven was onderzocht in een zogenaamd "quasi-experimental nonequivalent time-series" proefopzet (zie hoofdstuk 2). Gegevens werden verzameld over de wijze van registreren op een bedrijf, het jaar van aanschaf van een MIS en de productieresultaten van 1982 tot en met 1991. Een scheiding in bedrijfsspecifieke en trend-effecten werd bereikt door panelanalyse uit te voeren met een "mixed effects" model, een dummy-variabele voor ieder afzonderlijk bedrijf en gebruikmakend van kleinste-kwadraten-methodieken (OLS).

De productie op de zeugenbedrijven steeg vanaf ongeveer één jaar na aanschaf van een MIS en gecorrigeerd voor interveniërende variabelen, gemiddeld met 0,56 grootgebrachte big per zeug per jaar (p = 0,09). Dit betekende een extra netto-opbrengst van 30 tot 34 gulden per zeug per jaar. Het jaarlijkse rendement van de investering in MIS bedraagt hiermee tussen de 220 en 348% en de arbeidsopbrengst op een gemiddeld bedrijf met 165 zeugen stijgt hiermee met 7,7 tot 8,7%. Aanvullende autocorrelatietesten, testen op invloedrijke waarnemingen en testen op de invloed van de controlebedrijven op de uitkomst gaven aan dat de schatting robuust is. Een andere belangrijke uitkomst van de panelanalyse was dat er duidelijke verschillen tussen bedrijven waren in het effect van een MIS ($p \leq 0,001$).

De invloed van bedrijfskarakteristieken

Een verdere studie naar de invloed van bedrijfskarakteristieken op het rendement van een MIS werd uitgevoerd in de studie beschreven in hoofdstuk 4. Het rendement van een MIS ontstaat door een verbeterde besluitvorming en kan daarom van bedrijf tot bedrijf verschillen. In hoofdstuk 4 worden dezelfde zeugenbedrijven als in hoofdstuk 3 op twee fundamenteel verschillende manieren geclassificeerd, namelijk met behulp van de sociologische bedrijfsstijlenbenadering en met behulp van de bedrijfseconomische managementniveau-benadering. De bedrijfsstijlenbenadering is gedefinieerd als de specifieke ordening van allerlei bedrijfsaspecten op grond van een geheel van door boeren gedeelde opvattingen omtrent de wijze waarop er geboerd dient te worden. De nadruk ligt hierbij op de strategische aspecten van de bedrijfsvoering en verondersteld wordt dat boeren op basis van hun doelstellingen zelf hun bedrijf kunnen inrichten. Een typische eigenschap van de bedrijfsstijlenbenadering is dat boeren zichzelf classificeren.

De managementniveaubenadering is oorspronkelijk ontwikkeld voor de Nederlandse glastuinbouw maar is voor deze studie omgezet voor gebruik in de varkenshouderij. Met behulp van varkenshouderij-experts en een enquête werden de 71 varkenshouders gescoord op zes managementfactoren. Deze waren “onderwijs en opleiding”, “moderniteit van de gebouwen”, “beleidsvoorbereiding en -uitvoering”, “tactisch management”, “werkvoorbereiding en voortgangscontrole” en “sociale aspecten”.

Variatie in het rendement van een MIS kon voor een deel worden verklaard door de verschillen in managementniveau’s, maar niet door de verschillen in bedrijfsstijlen van varkenshouders. Geconcludeerd wordt dan ook dat voor het doel van deze studie de managementniveau-benadering beter geschikt is dan de bedrijfsstijlenbenadering. Managementniveau’s van varkenshouders bleken positief gecorreleerd te zijn met het rendement van een MIS ($r = 0,35$, $p = 0,02$). Alhoewel varkenshouders met een hoog managementniveau over het algemeen al over meer informatie beschikken dan varkenshouders met een laag managementniveau, blijken ze toch meer toegevoegde waarde van een MIS te krijgen.

MIS-evaluatie met experimentele economie

Hoofdstuk 5 beschrijft een pilot-experiment dat opgezet is met het doel om te onderzoeken of economisch experimenten, uitgevoerd in een laboratorium, gebruikt kunnen worden als een alternatief voor enquêtes bij de bepaling van het rendement van een MIS. Economische experimenten hebben, in vergelijking met enquêtestudies, een betere controle op interveniërende variabelen en zijn minder afhankelijk van de beschikbaarheid van historische gegevens. Wanneer uit deze studie zou blijken dat een experimenteel-economische benadering een goed alternatief kan zijn voor enquêtestudies, dan zou het ook ingezet kunnen worden voor (ex-ante) evaluatie van nieuwe MIS-en of andere informatie of diensten. In plaats van het onderzoeken van een directe relatie tussen MIS-gebruik en bedrijfsresultaten, wordt bij experimentele economie het effect van verschillende niveau's van informatievoorziening op de besluitvorming onderzocht onder gecontroleerde laboratoriumomstandigheden.

Een investeringsselectieprobleem werd geconstrueerd, zijnde een abstracte variant van het zeugenvervangingsprobleem. Zesentachtig varkenshouders namen deel aan het experiment. Eenenvijftig van deze deelnemers kwamen van een bedrijf dat deel uitmaakte van de voorgaande enquêtestudie. Het individuele- besluitvormingsexperiment werd uitgevoerd in een zogenaamde "quasi-experimental, nonequivalent control, pretest-posttest" proefopzet. In de MIS-behandeling werden MIS-schatters verkregen door beslissingen van dezelfde deelnemers te vergelijken vóór en na beschikbaarheid van de MIS-opties. Een controlegroep (zonder MIS-opties) werd opgenomen om te kunnen controleren of er gedurende het experiment verstorende leer- of vermoeidheidseffecten zouden optreden (Tabel 5.1). De besluitvorming van de deelnemers in de MIS-behandeling bleek significant te verbeteren wanneer MIS-opties werden geboden ($p = 0{,}02$). Bij de deelnemers in de controlegroep was dit niet het geval. Bij een vergelijking van de MIS-schattingen van varkenshouders die zowel aan de enquête als aan het experiment hadden deelgenomen, bleek dat er geen significante correlatie was tussen beide schatters ($r = -0{,}35$; $p = 0{,}14$). Dit ondanks dat het feit dat zowel bij de enquêtestudie als in het experiment een MIS-effect gevonden werd (significanties resp. $p = 0{,}09$ en $p = 0{,}02$). Problemen met de opzet en uitvoering van het experiment (verschillen met de praktijk in de hoeveelheden communicatie en besluitvormingsroutine) en ruis in de enquête-schattingen (veranderingen op varkensbedrijven die onterecht aan het gebruik van een MIS zijn toegewezen) zijn de meest waarschijnlijke verklaringen voor de ongecorreleerdheid van de schatters. Verder onderzoek met een verder verfijnde opzet van het experiment is nodig om te zien of een economisch experiment een alternatief kan zijn voor enquêtes bij de bepaling van het economisch rendement van MIS-en.

Discussie en conclusies

In hoofdstuk 6 wordt een conceptueel raamwerk voor MIS-en in de veehouderij geïntroduceerd (Figuur 6.1) aan de hand waarvan de in dit proefschrift toegepaste onderzoeksbenaderingen worden geëvalueerd. Toepassing van de evaluatie-methodieken in andere sectoren van de veehouderij wordt uiteengezet. Verder bevat hoofdstuk 6 een blik op de toekomst. De consequenties voor toekomstige MIS-evaluaties van bedrijfsontwikkelingen en ontwikkelingen op het gebied van MIS-en en andere IT (informatie-technologie) toepassingen worden bediscussieerd. Het hoofdstuk wordt besloten met de belangrijkste conclusies van dit proefschrift.

De belangrijkste conclusies van dit proefschrift zijn:

- Positieve onderzoeksbenaderingen die MIS-effecten afleiden van daadwerkelijke beslissingen van agrariërs hebben meer potentie dan normatieve onderzoeksbenaderingen die MIS-effecten afleiden met behulp van veronderstelde beslissingscriteria.
- Het gecombineerd inzetten van panelgegevens en een statistisch model met een "dummy" variabele voor ieder afzonderlijk bedrijf is erg nuttig bij MIS-evaluatie omdat tegelijkertijd effecten binnen en tussen bedrijven kunnen worden geschat. Hierbij worden bedrijfsspecifieke en trend-effecten gescheiden.
- In de onderhavige studie steeg de gemiddelde productie op zeugenbedrijven met 0,56 grootgebrachte big per zeug per jaar, vanaf ongeveer één jaar na aanschaf van een MIS. Vanaf dat moment resulteerde het gebruik van een MIS in een extra netto-opbrengst van 30 tot 34 gulden per zeug per jaar. Het rendement op de investering in MIS bedraagt 220 tot 348% en de arbeidsopbrengst per zeug per jaar stijgt hiermee met 7,7 tot 8,7%.
- Het effect van een MIS is positief gecorreleerd met het managementniveau van een varkenshouder. Alhoewel varkenshouders met hoge managementniveau's over het algemeen over meer informatie beschikken, krijgen ze toch meer toegevoegde waarde van een MIS.
- Varkenshouders in de MIS-behandeling van het economische experiment verbeterden hun besluitvorming significant nadat ze waren voorzien van MIS-opties (zoals verwerkte data en gesorteerde overzichten). In de controlegroep kregen de deelnemers geen MIS-opties en trad ook geen verbetering op in de besluitvorming.
- De MIS-schattingen van dezelfde varkenshouders in de enquête en het economische experiment bleken niet te correleren. Verder onderzoek met een verder verfijnde opzet van het experiment is nodig om te zien of een economisch experiment een alternatief kan zijn voor enquêtes bij de bepaling van het economisch rendement van MIS-en.

RELATED PUBLICATIONS

1992

Verstegen, J.A.A.M.; Huirne, R.B.M.and Dijkhuizen, A.A. (1992). Research outline to determine the profitability of management information systems. Proceedings of the 4th international congress for computer technology in agriculture, Versailles, France, June, 1-3, p. 233-237.

Verstegen, J.A.A.M. en Van den Tillaart, H.J.M. (1992). Varkens houden in Noord-Brabant en Zeeland. Proefverslag p3.91 Proefstation voor de Varkenshouderij, Rosmalen.

1993

Verstegen, J.A.A.M.; Huirne, R.B.M. and Dijkhuizen, A.A. (1993). The profitability of management information systems in livestock production. Poster paper of the 7th EAAE congress, Stresa, Italy, 6-10 September, 1992.

Verstegen, J.A.A.M.; Huirne, R.B.M. en Dijkhuizen, A.A. (1993). Het rendement van management-informatiesystemen in de varkenshouderij. In: (J.M. van Berlo, A. Hoogerwerf, M.P. Reinders en P.J.M. Wijngaard, eds.) Informatica toepassingen in de agribusiness; Voordrachten VIAS - Symposium 1993, Agro-informaticareeks nr. 7 (mei 1993): 71-80.

Verstegen, J.A.A.M.; Huirne, R.B.M.; Dijkhuizen, A.A. en Backus, G.B.C. (1993). Bepaling van het economisch rendement van management-informatiesystemen. Praktijkonderzoek Varkenshouderij, 7(3): 13-16.

Verstegen, J.A.A.M.; Dijkhuizen, A.A.; Huirne, R.B.M. and Renkema, J.A. (1993). Determining the profitability of management information systems: methods and empirical results. (ed. H. Hogeveen) Proceedings of the Symposium on Herd Health Decision Support, Utrecht, The Netherlands, June 15-16, SKBS/B2/93-13: p. 89-107.

Verstegen, J.A.A.M., Huirne, R.B.M.and Dijkhuizen, A.A. (1993). The profitability of management information systems in livestock production. Proceedings of the 7th EAAE congress, Stresa, Italy, 6-10 September 1992. Poster paper abstract no. 13.

1994

Reilink, A.; Huirne, R.B.M.; Verstegen, J.A.A.M.; en Dijkhuizen, A.A. (1994). Stijl van boeren bepaalt milieugedrag: duurzaam bedrijf langs vele wegen haalbaar. Boerderij Veehouderij, 79(5), 1 maart 1994: 16VE-17VE.

Verstegen, J.A.A.M., Huirne, R.B.M., and Dijkhuizen, A.A. (1994). Economic profitability of veterinary management information systems in swine farming. ISVEE conference, Nairobi Kenya, August 15-19, 1994. The Kenya Veterinarian, 18(2): 442-444.

Braakman, E.H.J.; Verstegen, J.A.A.M.; Huirne, R.B.M. en Dijkhuizen, R.B.M. (1994). Managementsystemen betalen zichzelf. Boerderij/Varkenshouderij 79(12), 14 juni 1994: 20VA-21VA.

Verstegen, Jos A.A.M.; Huirne, Ruud B.M. and Dijkhuizen, Aalt A. (1994). De waarde van management-informatiesystemen in de praktijk. PHLO cursus "Informatiemanagement en managementondersteuning op melkvee- en varkensbedrijven", november 1994.

Huirne, Ruud B.M.; Verstegen, Jos A.A.M. and Dijkhuizen, Aalt A. (1994). Methoden voor het bepalen van informatiebehoeften. PHLO cursus "Informatiemanagement en managementondersteuning op melkvee- en varkensbedrijven", november 1994.

Verstegen, Jos A.A.M., Sonnemans, Joep, Braakman, E.H.J., Huirne, Ruud B.M. and Dijkhuizen, Aalt A. (1994). Survey Studies and Experimental Economic Methods to Investigate Farmers Decision Making and Profitability of Management Information Systems. in: B.H. Jacobsen, D.E. Pedersen, J. Christensen and S. Rasmussen (Eds.) Proceedings of the 38th EAAE Seminar "Farmers' decision making - a descriptive approach", October 3-5, 1994, Copenhagen, Denmark, pp. 333-344.

1995

Verstegen, J.A.A.M.; Dijkhuizen, A. A.; Huirne, R.B.M.and Renkema, J. A. (1995). Determining the profitability of management information systems: methods and empirical results. in: R.B.M. Huirne, S.B. Harsh, A.A. Dijkhuizen (eds.) Proceedings of the 1993 meeting of the North Central Regional Research Project NC-191, farm level information systems, Zeist, The Netherlands, May 10-14, p. 269-281.

Verstegen, Jos A.A.M.; Sonnemans, Joep; Huirne, Ruud B.M.; and Dijkhuizen, Aalt A. (1995). The Economics of Management and Management Information Systems in Agriculture. Selected Paper Abstracts 1995 AAEA Annual Meeting, August 6-9, 1995, Indianapolis, IN. In: Amer. J. Agr. Econ. 77(5), December 1995, p. 1361.

1996

Verstegen, Jos A.A.M., Sonnemans, Joep, Huirne, Ruud B.M. and Dijkhuizen, Aalt A. (1996). Evaluating Management and Management Information Systems Using Experimental Economics. in: G. Beers, R.B.M. Huirne, and H.C. Pruis (eds.) Proceedings of the 43rd EAAE Seminar "Farmers in small-scale and large-scale farming in a new perspective", October 16-18, 1995, Zeist, The Netherlands. LEI-Onderzoeksverslag 143, January 1996, p. 326-340 (367 pp.).

Verstegen, Jos A.A.M., Sonnemans, Joep, Huirne, Ruud B.M. and Dijkhuizen, Aalt A. (1996). Evaluating Management and Management Information Systems Using Experimental Economics. In: Gerhard Schiefer (ed.) Abstract Proceedings of the 1996 Bonn-Wageningen Workshop on Farm and Agribusiness Management Research, Bonn, July 10, 1996, pp. 9-10.

CURRICULUM VITAE

Johannes Antonius Arnoldus Maria Verstegen werd op 22 september 1967 geboren in Nistelrode (Noord-Brabant). In 1985 behaalde hij zijn VWO-diploma aan het Kruisherencollege te Uden. In september 1985 werd begonnen met de studie Zoötechniek aan de Landbouwuniversiteit Wageningen. De studie werd afgerond in maart 1991 met als afstudeervakken Veehouderij, Veevoeding, Agrarische Bedrijfseconomie en Voorlichtingskunde. Zijn stage werd uitgevoerd bij het Statens Husdyrbrugsforsøg (National Institute of Animal Science) in Foulum, Denemarken. Vanaf april 1991 tot en met april 1995 was hij als assistent in opleiding verbonden aan de vakgroep Agrarische Bedrijfseconomie van de Landbouwuniversiteit Wageningen, alwaar hij werkte aan de totstandkoming van dit proefschrift. Een gedeelte van deze periode bracht hij door bij het Proefstation voor de Varkenshouderij te Rosmalen en het Economic Science Laboratory van de Universiteit van Arizona. Zijn bijdrage aan de onderzoekscommissie van de vakgroep Agrarische Bedrijfseconomie werd gecompenseerd met een tijdelijke aanstelling als toegevoegd onderzoeker. Sinds september 1995 is hij werkzaam bij het Landbouw-Economisch Instituut (LEI-DLO) als onderzoeker agrarisch management, projectleider diergezondheid en coördinator van het LEI-DLO detachement Wageningen.