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Economic value of management information systems in agriculture: a review of evaluation approaches

Jos A.A.M. Verstegen [a,*], Ruud B.M. Huirne [a], Aalt A. Dijkhuizen [a],
Jack P.C. Kleijnen [b]

[a] *Wageningen Agricultural University, Department of Farm Management, Hollandseweg 1, 6706 KN Wageningen, Netherlands*
[b] *Tilburg University, Department of Information Systems and Auditing, and Center for Economic Research, School of Business and Economics, Tilburg, Netherlands*

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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.

Keywords: Evaluation research; Economics of management systems; Farm computer systems

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 aries 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.,

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* Corresponding author. Fax: +31 8370 84763.

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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 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 (1995) 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. Investment evaluation

2.1. Benefit–cost analysis

The standard procedure for investment evaluation is benefit–cost analysis. For example, a labour-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 labour 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 parlour, 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. Extensions of traditional benefit–cost analysis

The problem of MIS evaluation is addressed in many publications outside agriculture (Kleijnen, 1980, 1984; Hamilton and Chervany, 1981; Banker and Kauffman, 1989; Kauffman and Weill, 1989) and inside agriculture (King et al., 1990; Streeter and Hornbaker, 1995). Two main types of research approaches can be identified: normative and positive approaches (Fig. 1).

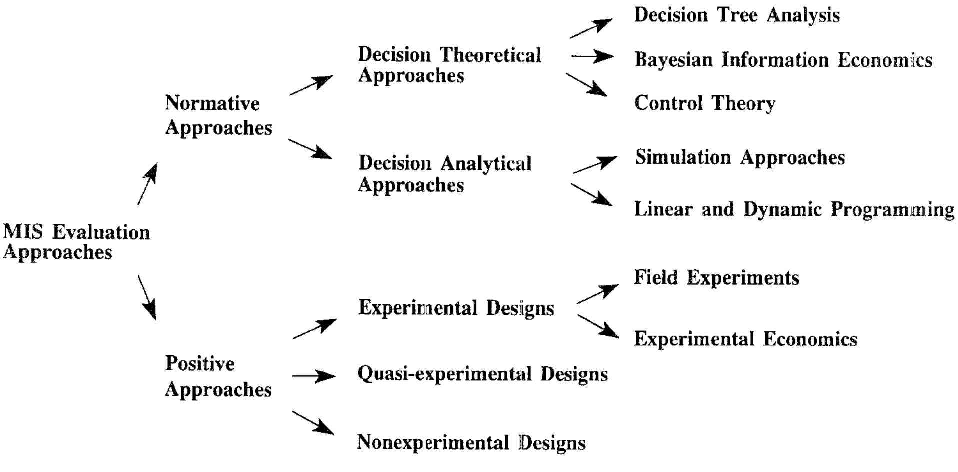

Fig. 1. A classification of evaluation approaches to the determination of the economic value of MIS.

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, labour savings), and according to some predefined decision making criteria (Kleijnen, 1980). In Fig. 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 (Fig. 1).

3. Normative MIS evaluation approaches

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 (Fig. 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). Fig. 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. 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 ($0.1 \times -100 + \ldots + 0.1 \times 120 = -1.0$). 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

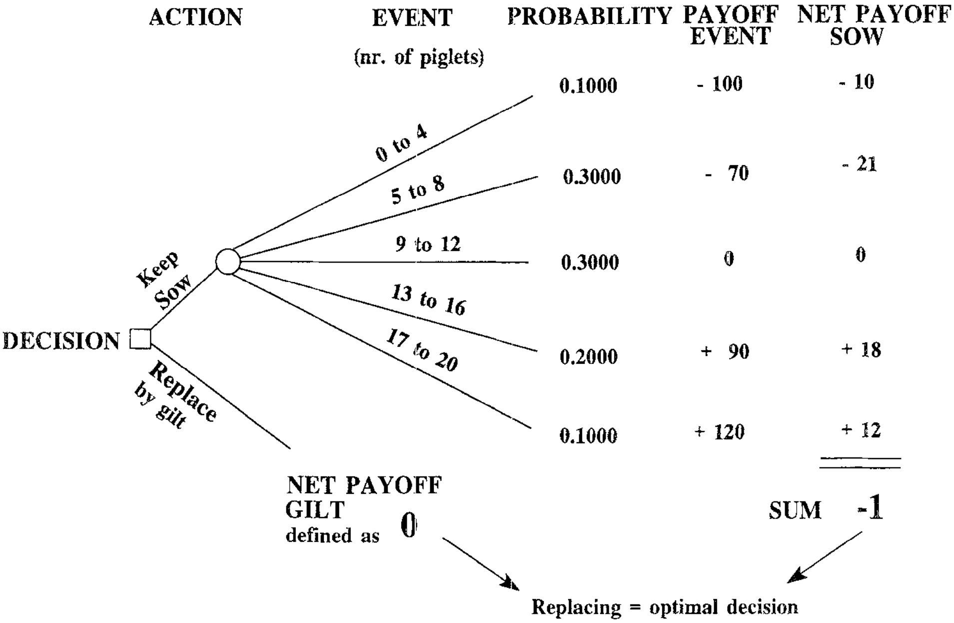

Fig. 2. An example of the use of decision tree analysis in analyzing the sow culling problem.

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):

$$P(\Theta_i \mid z_k) = \frac{P(\Theta_i) \times P(z_k \mid \Theta_i)}{P(z_k)}$$

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

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 1
Revision of probabilities using Bayes Theorem

Θ_i [a]	$P(\Theta_i)$ [b]	$P(z \mid \Theta_i)$ [c]	$P(z \cap \Theta_i)$ [d]	$P(\Theta_i \mid z)$ [e]	$ [f]	$P(\Theta_i \mid z) \times \$$
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 [g]

[a] Uncertain event = number of piglets in next litter of third-parity sow.
[b] Prior probability of uncertain event i.
[c] Likelihood of prediction z, given uncertain event i; z = one piglet extra in next litter.
[d] Joint probability.
[e] Posterior probability of uncertain event i, given z.
[f] Payoff with uncertain event i.
[g] Expected payoff of sow in next cycle.

Based on the information and expectations the farmer had in the decision tree example (Fig. 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 Fig. 2 is a third-parity sow and the management information system indicates 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 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.

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 Fig. 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 labour 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 behaviour 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.

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 behaviour. 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).

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 (Fig. 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, where internal validity diminishes from

Table 2
Classification of research designs[a] 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

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

the upper left corner towards the lower right corner. "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.

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).

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.

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). The PO design can hardly be labelled 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: TS) is the only "no control" design that may give reliable conclusions.

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: NTS) were found (Alpar and Kim, 1990; Lazarus et al., 1990; Carmi, 1992).

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[1]. 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.

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: 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).

4.7. Experimental economics

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

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

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 (*and* 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.

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.

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