Economic simulation to support investment decisions in pig farming

G.B.C. Backus

STELLINGEN

1. Het vaststellen van de risicohouding van landbouwers is nog steeds niet mogelijk op basis van de huidige besluitvormingstheorie.
   Dit proefschrift

2. Voor een juiste afweging van de consequenties van alternatieve investeringsbeslissingen is de in de voorlichting gebruikelijke tijdshorizon van 1 jaar onvoldoende.
   Dit proefschrift

3. Bedrijfsexpansie is voor de meeste vleesvarkensbedrijven in Nederland een aantrekkelijke strategie, zelfs bij hogere toekomstige mestafzetkosten.
   Dit proefschrift

4. Ten onrechte wordt er een positief verband aangenomen tussen de mate van complexiteit van strategisch management en het benodigde aantal variabelen om dit management te modelleren en te ondersteunen.
   Dit proefschrift

5. Veldtesten zijn nodig om de waarde van beslissingsondersteunende computersystemen voor organisaties te bepalen.
   Dit proefschrift

6. Het zich bewust zijn van de economische positie van het individuele varkensbedrijf is zowel voorwaarde als stimulans om te komen tot strategische verandering.
   Dit proefschrift

7. Er is veel literatuur over de oorzaken van schaalvergroting in de landbouw. Maar zelfs grote landbouwbedrijven zijn klein vergeleken met bedrijven in andere sectoren. De vraag waarop nog geen bevredigend antwoord bestaat, is waarom landbouwbedrijven zo klein zijn.
   Ruttan, V.R., 1988. Scale, size, technology and structure: a personal perspective. Robison, L.J. (ed.) Determinants of farm size and structure. Michigan Agricultural Experiment Station Journal Article No 12899.

8. Dwaasheid of verdorvenheid is de mens zozeer eigen, dat we ons kunnen afvragen waarom we van regeringen iets anders zouden verwachten.
Tuchman, B. 1984. De mars der dwaasheid: bestuurlijk onvermogen van Troje tot Vietnam. Knopf: New York.

9. Ook als een bisschop een lezing houdt, moet daarover vrij gediscussieerd kunnen worden.
Mgr. Bekkers. 1964. Leven, wonen en werken in noord-brabant. Verslag sociale studiedagen Gemert 17-18-19 juli 1964.

10. Gezien de mate van autonomie van sociaal-economische ontwikkelingen in Nederland dienen beleidmakers zich meer te baseren op scenario-analyse dan op het ontwikkelen en doorrekenen van beleidsalternatieven.

11. De vrijwel unanieme opvatting dat voor een correcte merkentoets van kruisingsprodukten in de varkenshouderij een grote steekproef nodig is, veronderstelt impliciet een hoge mate van variatie in de prestaties van elk van deze produkten.

12. Sommigen veronderstellen dat fotomodellen in tegenstelling tot computermodellen wel werken. Deze opvatting staat meer model voor hun verwachtingspatroon dan voor de werkelijkheid.

G.B.C. Backus
Economic simulation to support investment decisions in pig farming
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ECONOMIC SIMULATION TO SUPPORT INVESTMENT DECISIONS IN PIG FARMING

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Abstract

Economic simulation to support investment decisions in pig farming

Economische simulatie ter ondersteuning van investeringsbeslissingen op varkensbedrijven

Backus, G.B.C., 1994.

The study described in this thesis focuses on the development and use of a model that simulates the consequences of long-term investment decisions in pig farming. The thesis is composed of six parts. Chapter 1 deals with a basic review of the literature on strategic planning under risk and uncertainty. A computer-based model for strategic pig farm planning, the Investment Simulation Model (ISM) was developed and described in chapter 2. ISM is a stochastic simulation model, which uses data of the individual farm and also data representing the average Dutch pig farm. Chapter 3 analyzes the effects of the input variables on the outcome of the response variable for the distinguished strategies, using a stochastic approach for these inputs in the experimental design. They were formalized in a regression metamodel for each replacement strategy. Chapter 4 describes an evaluation procedure that was developed for testing ISM under operational use. In chapter 5 the expected economic consequences of farm expansion plans on future economic viability were estimated for 24 pig farms, using ISM. The concluding chapter provides a general discussion about the choices that were made in modelling the strategic planning process, the experiences gained, and the possibilities for future research.

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Voorwoord

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GENERAL INTRODUCTION

1. Introduction

The need for research in the field of strategic management is obvious when examining both the unpredictability and complexity of the environment in which farms must operate. Jalvingh (1993) developed a computerized decision support system for tactical planning. External factors such as manure legislation lead towards an increasing need for farmers to get a better insight into the expected consequences of their plans at a strategic level.

The aim of this project was to develop and test decision support systems for swine farmers, offering them the possibility of gaining insight into the possible economic consequences of alternative strategic plans.

Within the farmer's strategic planning function several decisions can be distinguished (Boehlje and Eidman, 1984). In the ISM-project (Investment Simulation Model), attention was mainly paid to long-term investment decisions: replacement of existing pig farm buildings and buying others. This project intended to put the decision support system into practice. Therefore, the models should be able to carry out farm-specific simulations quickly. Moreover, they should be able to focus on relevant decision problems.

2. Outline of the thesis

Research for this thesis was carried out within the ISM-project. Attention was focused on the design and use of decision support systems based on a computer-based simulation model to simulate the economic consequences of strategic plans related to investment decisions in swine farming.

The theoretical framework for individual farm decision making is outlined in chapter 1. This chapter deals with the farmers' possible use of the theory of decision analysis in particular.

A computer-based model that simulates both an individual pig farm and an average 'reference' farm was developed and described (Chapter 2). The approach used for simulating the pig farm was stochastic modelling involving random numbers (i.e. Monte Carlo simulation), and was used to evaluate several strategic planning features of selected performance measurements on pig farms.

The computer-based simulation model was modified and transformed to support individual pig farmer decisions (Chapter 3), the inclusion of a regression metamodel within the decision support system being a new feature. In addition, the decision support system was used to study the impact of risk preferences and personal planning horizons on farmer decisions.

Reports on testing pig farm decision support systems are rare (Huirne, 1990). Therefore, an evaluation procedure was developed for testing the decision support system under operational use (Chapter 4). The advice of extension officers with and without use of the decision support system was compared. The expected economic consequences of farm expansion plans for 24 individual pig farms were determined using the decision support system (Chapter 5). Results were compared for farmers with and without expansion plans.

The concluding chapter focuses on the choices made at the beginning of the project, and the experiences gained during the project. In addition opportunities for further research are presented.

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Chapter 1

Farm decision making under uncertainty

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Abstract

This paper aimed at identifying risk and uncertainty within the strategic farm planning process. The concept of decision making under risk was discussed by reviewing the theory of Subjective Expected Utility and its limitations. The Subjective Expected Utility model failed as a descriptive model. After discussing techniques for measuring risk preferences, an overview of applied risk models was presented. Examination of the literature on empirical research on farm risk models revealed much attention for risk responses, especially for enterprise diversification. However, it was doubtful whether decision makers could be classified according to their risk preferences. The major factors determining uncertainty within the strategic decision-making proces were outlined for pig farmers. Multiple scenarios could be used within Decision Support Systems to analyze changes in the social and political environment. However, appropriate guidelines in developing multiple scenarios were rare. For both risk and uncertainty, serious problems remained in making the theory of decision analysis available in such a way that it could be used by farmers.

Key words: decision making, risk, uncertainty, utility, scenario.

1. Introduction

The consequences of decisions are generally not fully realized the moment these decisions are made. External changes in technology, markets and legislation as well as internal changes in production contribute to the risky environment for farmers. Farmers still farm because many risky situations are also potentially profitable. Farmers' responses to risky but potentially profitable situations are part of the farm management process (Boehlje and Eidman, 1984). Typically, farmers have some information on the possible outcomes and some feeling for those that are more likely to occur. Appropriate decisions must consider the possible outcomes and the individual's attitude towards bearing risk: both are considered in this paper.

Risk management skills are an important component of good management. During the last decades, quantifying and managing risk in agriculture has been a topic of continuing interest to agricultural economists, especially in the United States and Australia. The contributions made by agricultural economists to firm level risk research have been summarized by

Anderson et al. (1977), Barry (1984) and Robison and Barry (1986).

Patrick et al. (1985) provide results which indicate that farmers regard weather, output prices and input costs as the more important sources of variability in both crop and livestock production.

Uncertainty can be defined as the stochastic variation in prices and performances, given constant underlying technical and economic relationships. In the longer run, these underlying relationships may change as well. For developing scenarios or alternative futures, therefore, it is important to characterize those factors of change in a useful way with respect to farmers' decision making. This paper aims at identifying risk and uncertainty to be implemented within the strategic pig farm planning process. First, the concept of decision making under risk is discussed by describing the theory of Subjective Expected Utility and its limitations. After discussing techniques for measuring risk preferences and approaches to quantifying risk, an overview of applied risk models is presented. The empirical research is examined with respect to applied research methods and alternative risk responses. In the following section the major factors determining uncertainty within the strategic pig farm decision-making proces are outlined. Finally, the main issues to consider in future applied farm level risk research are formulated.

2. Risky decisions

People face decision problems when they have alternatives in choosing, each with significant consequences, and when they are unsure about which particular choice is best. When uncertainty exists about the consequences of a particular choice because of stochastic states of nature, the decision problem is said to be risky (Anderson et al., 1977). Knight (1921) divided decision-making situations into risk and uncertainty. He defined the risk situation as one in which the decision maker knows both the alternative outcomes and the probability associated with each outcome. Under uncertainty, the decision maker does not know the probability of alternative outcomes. Furthermore, he may or may not know the different outcomes that can occur. This distinction between risk and uncertainty is relevant for the knowledge of the probability of an event is by itself a very rich information about it, and, therefore, has a certain value.

According to Shackle (1961), decisions aim at the experiences most preferred, using the freedom of imagination only constrained by judgement of what is possible. For decision makers, the solution of a decision problem involves four steps (Simon, 1960): (1) Perception of decision need or opportunity; (2) Formulation of alternative courses of action; (3) Evaluation of the alternatives; and (4) Choice of one or more alternatives.

According to Von Winterfeldt and Edwards (1986), most difficulties in decision making become apparent with the identification and recognition of the available alternatives, the determination of relevant attributes, and the collecting of relevant information. A non-trivial difficulty, however, is in the compounding of events. If A is unlikely, and if B is likely if A occurs, what is the likelihood of B? Probabilities are made use of in deriving such implications, but it is by no means evident that relying upon the probability calculus mechanics is correct in such a circumstance. Moreover, appropriate choice criteria are considered a major component of risky decision making (Anderson et al., 1977).

2.1. Subjective Expected Utility

The major theory of decision making under risk is the theory of Subjective Expected Utility. According to this theory, the decision maker's expected utility depends on the individual's utility function and the dispersion of the outcome. The expected utility of a risky prospect to the individual is given by

$$EU(X) = \int U(X)dF(X)$$

where U is the utility of money X and dF(X) is the probability distribution of wealth (X). Exchanging a risky prospect between two decision makers can create utility because of the difference in wealth between them.

Von Neumann and Morgenstern (1944) proved that if an individual's behaviour conformed to certain axioms his preferences for two or more outcomes of a risky prospect could be determined. These axioms were: ordering of choices, transitivity, substitution of choices (independence axiom), and certainty equivalent of choices.

In the Subjective Expected Utility theory, risk preferences are related to the curvature of the utility of money function U (Pratt, 1964; Arrow, 1971). Common measures of risk preferences are the absolute risk aversion coefficient $\alpha = -U''(X)/U'(X)$ and the relative risk aversion coefficient $r = X(-U''(X)/U'(X))$. Thus, $\alpha = r / X$, with α and r being coefficients when they are calculated for a particular X. They can also be functions, however, to describe the individual's risk preference over a range of X. Risk aversion coefficients are derived from a Taylor series expansion, and thus are local measure of risk aversion.

With outcomes measured in dollars, an absolute risk aversion coefficient of, for example 0.00125 indicates that near the outcome level at which α was elicited, the decision maker's marginal utility drops at a rate of 0.125 % per dollar change in income. Because α varies with changes in the units of measurement, a scale-free measure like the relative risk aversion coefficient can be useful. The value assumed for r may be two or three if the decision maker is considered fairly risk averse, and four if he is extremely risk averse. Values as small as 0.5 may be assumed if an individual is regarded as hardly being concerned about risk.

The mathematical representation of utility is related to the actual decision makers' risk aversion. According to Zuhair et al. (1992), decision makers may be classified as risk averse, risk neutral or risk preferring, depending on the utility function chosen by the researcher. If the second derivative of the quadratic utility function is less than zero, it implies risk-averse behaviour. If it is positive, it implies risk-preferring behaviour over the entire range of income. The second derivative of the negative exponential utility function is less than zero, thus implying constant risk aversion over all income levels (Pratt, 1964). This is one of its major limitations (Zuhair et al, 1992). Evidence for diminishing absolute risk aversion by individuals is provided by Hildreth and Knowles (1982). The question is, however, whether it is possible to classify decision makers. Are the risk aversion coefficients constant over a wide range of possibilities? When buying a lottery ticket, do I have the same risk aversion if the price is 1 $ or 10000 $ (whatever the size of the lottery outcome)?

Kimball (1992) reported on the analogy between risk aversion and the sensitivity of optimal choices to risk. He showed the usefulness of the third derivative of the utility function, which sign governed the presence or absence of a precautionary saving motive just as the sign of the second derivative governed the presence or absence of risk aversion.

Applying Subjective Expected Utility theory raises the problem of accurately measuring utility functions and the probabilities of outcomes and choices. However, applications in decision theory using efficiency criteria are still possible. Efficiency criteria consider the trade-off between the expected outcome and its dispersion. Consideration of the dispersion reduces the ability to select a preferred action, but may reduce the number of actions a decision-maker must compare in making a choice. Efficiency criteria provide a partial ordering of risky alternatives, given certain assumptions concerning either peoples' preferences or the distribution of risky outcomes. Most commonly, risk analysis involves returns from individual enterprises and a measure of their variability expressed as variance

(Markowitz, 1952) or mean absolute deviation (Hazell, 1971). Stochastic dominance with respect to a function is an evaluation criterion that orders choices without requiring an exact utility function or specified characteristics of risk attitudes (Meyer, 1977).

Much research has been focused on empirical evidence concerning the reliability of the Subjective Expected Utility theory. In an early study, Officer and Halter (1968) found that farmers' decisions were more accurately predicted by expected utility maximization than by expected profit maximization.

Schoemaker (1982) reviewed evidence concerning the Subjective Expected Utility theory. According to him, the Subjective Expected Utility theory fails as a descriptive model because (1) people do not structure problems as holistically and comprehensively as the theory suggests, (2) they do not process information, especially probabilistic, according to the Subjective Expected Utility theory, and (3) Subjective Expected Utility theory as an "as if" model poorly predicts choice behaviour in laboratory situations.

Tversky and Kahneman (1974) considered three heuristics of thinking under uncertainty which can lead to systematic and predictable errors in probabilistic judgments: representativeness, availability and anchoring. Representativeness refers to the resemblance between an event and its population. Availability is the ease with which relevant information comes to mind, for example, recent dry years. Anchoring implies an available relevant value, which is the starting point for additional probability judgments. Although these three heuristics lead to systematic errors, they are usually effective.

With respect to the prescriptive perspective, an important problem concerns the construction of utility functions. From the fact that changes in the context or framing of a problem may lead to different preferences, the question arises in which context the "true" risk attitude is measured. Tversky and Kahneman (1981) introduced the terminology of framing for referring to the effects of different descriptions on choice.

Grether (1978) and Grether and Plott (1979) reported on inconsistencies in the choice between two available prospects, i.e. the Preference Reversal Phenomenon. With this, people generally prefer prospect A (high probability of winning) over B (high reward in case of winning), but bid more for B than for A.

Kahneman and Tversky (1979) presented an alternative for the Subjective Expected Utility model, called the Prospect Theory. In this theory, value is assigned to gains and losses rather than to final assets and outcomes are weighted according to their probability. The Prospect Theory is able to take anchoring into account. From the descriptive perspective, therefore, it is an improved version of the Subjective Expected Utility model.

Machina (1982) presented the generalized expected utility model as an alternative for the Subjective Expected Utility model. He showed that expected utility analyses do not depend on the independence axiom. However, the generalized expected utility model does not provide solutions for the Preference Reversal Phenomenon and for framing effects (Machina, 1987).

Other aspects concerning Subjective Expected Utility theory are the aspect of time, and the fact that in decision making several attributes are involved. Because Subjective Expected Utility theory is cast in a timeless setting in which a single choice is made, rather than a sequence of choices, the distinction between terminal wealth and annual income is vague (Machina, 1984). In multi-attribute decision making, the decision maker is faced with the problem of trading off the achievement of one objective for the other. Multi-variate decision making includes single-period decisions concerned with more than one performance measure, and decisions involving optimization of a single attribute over a multi-period time horizon. Maximizing terminal wealth implicitly assumes additive utility, and the decision maker to be indifferent to the temporal rate of wealth accumulation as long as the overall level is the same (Jeffrey and Eidman, 1991).

According to Jungerman (1983) there are two possible interpretations of the deviations from the Subjective Expected Utility model. The first interpretation is that divergences from the Subjective Expected Utility model are caused by the way in which people make decisions: errors of judgment may be made by using heuristics, decision problems may be wrongly interpreted, and information processing may be defective because of motivational factors.
The other interpretation is that the examined deviations from the Subjective Expected Utility model are caused by the way in which the research is conducted: the cognitive costs of being rational are not taken into account, decision experiments are conducted with decision problems as discrete events without giving any feedback, and the way in which the decision problem is structured is seldom explicitly checked.

There is evidence that decision makers often violate some of the axioms that underlie the Subjective Expected Utility model. But interpretation of the evidence is complicated. Furthermore, the fact that people do not always make the most rational choices under uncertainty is a necessary condition for the Subjective Expected Utility model to have prescriptive power.

3. Risk

3.1. Measuring risk preferences

A decision maker can be said to be more risk averse than another at all values of X if, and only if, for every risk, his risk or insurance premium is higher than that of the other decision maker (Pratt, 1964). The risk premium is equal to the amount he is willing to pay for insurance against risk. Therefore, adequate rankings of individuals according to their attitude toward risk can only be made if their risk aversion - over their entire utility function - is known. Risk preferences appear only partly to be a stable feature of an individual decision maker. March and Shapiro (1987) reviewed several treatments of context-dependent risk taking.

Using simple statistical tests, Pope and Just (1991) found strong evidence congruent with constant relative risk aversion, and against constant absolute risk aversion and constant partial relative risk aversion. Young's (1979) survey of risk studies of Australian and American farmers revealed that approximately 50% of the sampled individuals showed risk-preferring attitudes over at least some ranges. Wilson and Eidman (1983) found that 69% of a sample of Minnesota swine producers had almost risk neutral risk-aversion coefficients ranging from -.0002 to .0003 . In general, most empirical results indicate that farmers are risk neutral to slightly risk averse with respect to mean annual income.

Several field studies have been carried out to measure farmers' attitudes toward risk within the context of Subjective Expected Utility models. Risk attitudes have been determined by various techniques: (1) direct elicitation of utility functions; (2) the experimental approach; (3) the observed economic behaviour approach; (4) the risk interval approach.

Early attempts to measure risk attitudes were based on utility functions derived from certainty equivalents of hypothetical lotteries (Officer and Halter, 1968). Estimates of risk attitude were derived by asking individuals to provide either points of preference or indifference in various hypothetical risky situations (Bond and Wonder, 1980).

Direct elicitation of utility functions involves direct questioning the decision makers to specify their risk attitudes. According to Anderson et al. (1977), the simplest method is based on considering an Equally Likely risky prospect and finding its Certainty Equivalent. In using the so-called ELCE-method, utility points are established continuously until sufficient Certainty Equivalents are elicited specifying the utility function. Smidts (1990) applied two techniques for measuring risk attitude, the lottery or midpoint chaining technique and the conjoint measurement. The midpoint chaining technique was judged to be the easiest one.

Because of the lack of realism in the game setting, possible interviewer bias, and the lack of time for respondents to study the hypothetical choices, direct elicitation of utility functions was criticized (Binswanger, 1980; Robison et al., 1984).

In a study of risk attitudes of rural households in India, Binswanger (1980) used an experimental approach, involving lotteries with real money payoffs. Dillon and Scandizzo (1978) used mind experiments involving choice between risky and sure farm alternatives. They concluded that most farmers are risk averse, and that income level, and maybe also socio-economic variables influence risk attitude.

The interval approach was developed by King and Robison (1981a, 1981b). This approach assumes that, over small interval ranges, an average risk aversion measure is a good measure of the Arrow-Pratt function of absolute risk aversion. The procedure requires the decision maker to choose between pairs of probability density functions of monetary outcomes. It calculates the boundary levels of absolute risk aversion that would make the decision maker indifferent to the two distributions. The individuals' response indicates whether their level of risk aversion is above or below the boundary levels. By asking the decision maker to choose between appropriately selected pairs of distributions, the range that includes the decision maker's risk aversion function is determined. The interval can be of any width. The wider the interval, the greater the likelihood of type II errors, i.e. failure to order pair-wise comparisons, and the smaller the type I error, i.e. rejection of the preferred action choice (Fleisher and Robison, 1985).

When using the interval approach for estimating the effect or response over time by decision makers, the interaction between interval width and income range is an important consideration (Love and Robison, 1984).

Risk is incorporated into the Subjective Expected Utility model by assigning probability distributions to relevant variables. The Subjective Expected Utility model requires estimates of probability distributions of the outcome of risky prospects. Spetzler and Stael von Holstein (1975) referred to the process of extracting and quantifying individual judgment about uncertain quantities as probability encoding. A number of procedures were developed and applied for assessing subjective probabilities (Anderson et al., 1977). These procedures assume that the decision makers' judgment of probabilities is correct.

Methods quantifying risk are based on empirical data, elicited distributions, or are logically derived. According to Carter and Dean (1960), the use of empirical data for encoding risk requires careful examination of the length of the historical period from which data should be used, the source of the data, and the method for processing the data. Debrah and Hall (1989) concluded that mathematical models using aggregate yield and price data seriously underestimated the income variability faced by individual farmers.

Personal probabilities directly elicited from the decision makers express the individuals' degree of believing in an event. Hogarth (1975) concluded that people, as selective, step-wise information processing systems with limited capacity, are ill-equipped for assessing subjective probability distributions. According to March and Shapiro (1987), managers are quite insensitive to estimates of the probabilities of possible outcomes. This is again the problem of expectations which Shackle (1961) reported about. The question is when the use of probabilities is legitimate? Shackle (1961) distinguished unique decisions on the one hand and recurring decisions on the other. Its application to unique decisions is doubtful.

3.2. Risk reponses

Many empirical studies on methods for managing risk were mentioned by Barry (1984) and Eidman (1989). Most studies do not try to calculate expected utilities directly. Instead efficiency criteria are used.

Available evidence indicates that farmers use a combination of methods to manage risk on their individual farms. According to Patrick et al. (1985), obtaining market information and pacing investments are the most important managerial responses to variability. Other important management responses to risk are diversification, production practices, maintaining eligibility for government programs, forward contracting, spreading sales, insurance, and maintaining financial, feed, and credit reserves. Wilson and Luginsland (1988) reported that 66 Arizona dairy farmers mentioned communication with hired agricultural labourers, the use of consultants, and the use of management information systems most frequently as relevant management responses to variability. Other risk responses were forward contracting, maintaining feed reserves, debt management, pacing investments and holding credit reserves. In addition to individual risk responses, the role of public policy must be recognized, both in the need for risk management and in the opportunities available to respond to uncertainty.

Many efforts with respect to modelling decision making under risk were directed toward single-period, single attribute models. The attribute is net income which is risky. Most of the literature examined did not take the consequences of a sequence of events into account, nor the existence of conflicting goals.

A few studies incorporated sequences of events, but did not allow the decision maker to re-evaluate the decision strategy (Kaiser and Apland, 1987). The existence of conflicting goals in farm decision making was explicitly recognized in studies by Berbel (1989) and Patrick (1979). In Table 1, an overview of empirical research on farm risk management is presented.

Major topics of interest were the diversification of the enterprise (Boehlje et al., 1991; Jeffrey, 1988; Johnson and Boehlje,1983; Johnson and Rausser, 1977; Rawlins and Bernardo, 1989; Turvey and Driver, 1987; Young and Barry, 1987) and the diversification of production practices (Berbel, 1989; Hatch et al., 1989; Rawlins and Bernardo, 1989; Vandeveer et al., 1989; Williams et al., 1990; Van Zijl and Groenewald, 1986).

Diversification may reduce risk if the farmer includes a sufficient number of activities. However, constraints for this way of eliminating risk at the individual farm level include the objectives of the farm, management skills, compatibility of activities with the resources available, and economies of scale.

Farm size as a risk response was studied by Held and Helmers (1980), Jeffrey (1988) and Johnson and Boehlje (1983). According to Held and Helmers (1980), expansion by purchase may be advantageous. However, a higher rate of business failure may occur. Increasing the herd size in conjunction with the elimination of some or all crop enterprises is preferred to more traditional expansion strategies (Jeffrey, 1988).

Tauer (1985), Williams et al. (1990), and Young and Barry (1987) presented research examples of reserves, either feed or financial reserves. Carrying reserves is, like diversification, a method for limiting the impact of unfavourable events on the firm, but the reserves cannot affect the events themselves. (Fleisher, 1990).

Alocilja and Ritchie (1990), Bosch and Eidman (1987), and Vantassel (1987) studied specific production practices as possible risk responses. Specific production practices as a risk method are more likely to affect the occurrence of an event.

The correct use of information supports farmer's decision making with respect to defining and estimating the expected outcomes of these decisions and therefore directly influences the selection of risk methods. A few empirical studies report on the value of information in farm decision making (Bosch and Eidman, 1987; Byerlee and Anderson, 1982).

Bosch and Eidman (1987) used simulation and Generalized Stochastic Dominance for estimating the value of information under uncertainty for an expected-utility-maximizing decision maker. They presented empirical evidence that additional information has diminishing marginal results for a given level of risk aversion, and that the value of information increases

Table 1. Overview of empirical research on farm-level risk responses.

Study	Field of interest	Research method	Classification of risk response
Alocilja and Ritchie (1990)	Adoption of high-yielding technologies	Simulation, Pareto optimization	Specific production practice
Bailey and Richardson (1985)	Marketing strategies for grain sale considering hedging and cash sales	Simulation, Stochastic Dominance	Market information, hedging
Berbel (1989)	Cropping pattern, farm size	Optimization	Production practice diversification
Boehlje et al. (1991)	Farm and non-farm diversification	Calculation of several portfolios	Enterprise diversification
Bosch and Eidman (1987)	Value of soil, water and weather information to irrigators	Simulation, Stochastic Dominance	Specific production practice
Byerlee and Anderson (1982)	Value of rainfall predictor to Australian sheep producers	Calculation of Quadratic Utility Function	Feed reserves
Dayton and Baldwin (1989)	Marketing alternatives for grain farmers	Simulation	Government programs, hedging, forward contracting
Hatch et al. (1989)	Risk-income trade-offs associated with buying, selling, and producing at alternative catfish growth stages	Safety-First Stochastic Dynamic Programming	Production practices diversification
Held and Helmers (1980)	Purchasing and/or renting land	Simulation	Purchasing and/or renting land
Jeffrey (1988)	Farm expansion, changes in crop mix, specialization in dairy	Simulation, Stochastic dominance	Enterprise diversififcation, farm size
Johnson and Boehlje (1983)	Firm expansion, portfolio activities, storage and hedging options	Mean-Variance analysis (Quadratic Programming)	Enterprise diversification, storage and hedging, firm expansion
Johnson and Rausser (1977)	Land purchase, diversification, insurance	Simulation	Enterprise diversification, insurance Government programs, hedging, forward contracting
Kaiser and Apland (1987)	Participation in farm commodity programs relative to other risk strategies	MOTAD (*) (Discrete Stochastic Sequential Programming)	Government programs

Table 1. Continued

Study	Field of interest	Research method	Classification of risk response
Karp and Pope (1984)	Rangeland management as a control problem, choice of treatment and stocking rate	Stochastic Dynamic Programming	Control of stocking rate and treatment of rangeland
Patrick (1979)	Purchasing and/or leasing land with different loan repayments	Simulation	Debt management
Plain (1982)	Production and marketing flexibility	Simulation (deterministic)	Hedging, spreading sales, flexibility
Rawlins and Bernardo (1989)	Forage diversification, herd size	MOTAD	Enterprise diversification Production practices diversification
Reidy (1988)	Evaluation of tillage/grass vs. tillage	Simulation	Enterprise selection
Smidts (1990)	Marketing strategies of potato producers	Utility Function based on linair regression	Spreading sales, forward contracting
Tauer (1985)	Life insurance vs. installment payments for farm purchase	Stochastic dominance	Financial reserves
Turvey and Driver (1987)	Diversification	Capital Asset Pricing Model	Enterprise diversification
Vandeveer et al. (1989)	Irrigating as a risk management strategy	Safety-first Target MOTAD	Production practices diversification
Vantassel (1987)	Grazing strategies, mesquite controlling	Simulation, Stochastic Dominance	Specific production practices
Williams et al. (1990)	Two tillage systems, five crop rotations	Stochastic Dominance	Production practices diversification, feed reserves, Government programs
Young and Barry (1987)	Financial assets as a risk response	Mean-Variance analysis	Enterprise diversification, financial reserves
Van Zijl and Groenewald (1986)	Maize cultivar strategies	Simulation, Stochastic Dominance MOTAD	Production practices diversification

(*) MOTAD : Mean of total absolute deviations with the level of risk aversion.

Byerlee and Anderson (1982) estimated the value of a rainfall predictor to Australian sheep farmers. The risk averse decision makers attached more value to the information than the risk prone ones did, but, among risk averse decision makers, the value of information declined slightly with the degree of risk aversion, as a result of the higher preposterior variance associated with the use of information. Thus, the decision to acquire new information is in itself often a risky one.

King et al. (1988) and Frankemolle (1987) presented models that allow the decision maker to "learn from experience". These studies can be regarded as first attempts to develop computer-based systems for supporting decision making under risk. But they do not provide empirical results with respect to using the model in this way.

4. Uncertainty

Successful farms, those that continue to produce profitably, survive. A farm can change its operations to respond to changes in the external environment. Identifying changes in the environment is part of the strategic decision making proces. Contingency planning can be used as a method to test strategies against major sources of uncertainty. Usually strategies are tested incrementally against only one or two key uncertainties such as the inflation rate or the price of oil (Porter, 1985).

Strategic decision making involves assumptions about the future external environment. The external environment of the farm has several dimensions, five of which are major ones: natural, technological, social, economic, and political factors.

A major uncertainty factor of the natural environment for crop farmers is the weather. Present day pig farming means the use of confinement systems with process automation to regulate environmental control decisions. Therefore, weather is not an important source of uncertainty for pig farmers in Western Europe. Of course, in the long run global warming may also affect pig farming.

Technological advance continues to create new breakthroughs in technology. In the 1960s and 1970s, technological innovations were directed towards the reduction of labour, making increases in farm size possible. One of the recent advances in the field of biotechnology is the production of the growth hormone porcine somatotropin (PST). Adoption of technological advance, however, depends on other social, political and economic factors.

An important aspect of the social environment of pig farming in Western Europe is the ongoing process of urbanization, leading to changing consumer attitudes with respect to intensive animal husbandry, and thus influencing the production methods operators of pig farms may use. This influence occurs through social pressure and through changes in laws and regulations affecting pig farming.

The economic environment of EU pig farming can be described as a market which is not in the interest of the EU price and market policy. The development of pig meat prices has a cyclical character. Periods with significant expansion of production are automatically followed by periods with low prices. Total consumption level remained almost constant in the 1980s (Wisman, 1991). Another development as a corollary of the halt to the growth of the EU budget expenses is the change in agricultural price and market policy towards reduction of price support for agricultural products like milk, sugar, and grain. Other sources of uncertainty are changes in inflation and interest rates.

Some public policy measures, such as subsidies and price guarantees, are directly aimed at providing stability. However, more changes to encourage the use of more environmentally friendly technology are probably forthcoming. Because the type and magnitude of such changes are unknown, this is a major source of uncertainty. As a consequence of the ongoing urbanization process, the political environment for pig farmers is becoming more and more unfavourable.

Since agricultural markets do not reflect the social costs of production, pig farming in the livestock production areas in the European Community has evolved to a state where it is in conflict with the environment. Governments are developing environmental policies that try to take into account environmental costs and benefits as well as income consequences (Backus et al., 1993). However, it is difficult to determine the social cost and benefits of agricultural products. The goals of environmental policy are aimed at the adoption of environmentally friendlier production technology, and have had a more or less floating character over time. This creates an important source of uncertainty for the farmer.

4.1. Multiple scenarios

The strategic management literature recommends the use of scenario analysis to evaluate the desirability of alternative strategies. A scenario is a set of statements about a possible future state of the environment and of the events and other changes that will lead to the future state. Multiple scenarios or alternative futures emerge as internally consistent views of the future industry structure under one set of assumptions (Willis, 1987). A problem is that scenarios need to consider the full range of environmental factors. The large number of factors makes the number of potential scenarios very large, while there is a need to develop a small number of good scenarios (Beck, 1982).

Porter (1985) suggested to examine each element of industry structure and classify them under one of the three categories: constant, predetermined and uncertain. Constant elements of industry structure are those aspects of structure that are very unlikely to change. Predetermined elements of structure are areas where structure will change, but the change is largely predictable. Constant and predetermined structural variables are part of each scenario, while uncertain structural variables actually determine the different scenarios (Porter, 1985).

Technological advance and the existence of a market mechanism for pork are said to be constant elements of the pig industry structure. The floating character of environmental legislation is assumed to be an uncertain variable, as well as inflation and relative input prices.

Willis (1987) suggested evaluating scenarios on their responsiveness, comprehensiveness, documentation and plausibility. Scenarios should be responsive to the need of evaluating alternative strategies. They should be comprehensive enough to develop the time line of events which lead to the future situation described. Finally plausibility refers to the need for the scenario to be internally consistent.

The time line of events which leads to the future situation described must begin with the present situation. The shift toward the future situation must therefore have a gradual character, unless abrupt changes are expected.

For strategic pig farm decision making the following uncertain structural variables that are used to define scenarios are suggested: (1) Inflation; (2) Labour costs; (3) Feed price; (4) Investment costs; (5) and Environmental costs.

In the Western world, inflation levels vary from time to time as a consequence of structural changes in the economy. The impact pattern of inflation, however, is highly unpredictable. Changes in labour costs are a consequence of changes in wealth. For the farmer this implies both higher labour costs and higher levels of family living expenditure. Changes in feed price depend mainly on the EU price and market policy, including both the grain price and the possibilities of using other products than grain for feed. Changes in investment costs reflect changes in building costs. Finally, changes in environmental costs depend on national and international legislation to protect the environment.

5. Discussion and outlook

According to Schoemaker (1982), the Subjective Expected Utility model fails as a descriptive model. When violations of some axioms imply the impossibility of eliciting utility functions representing the decision maker's preferences, the impracticability of the Subjective Expected Utility model causes an important limitation of the theory. Still, the Subjective Expected Utility model provides a good framework for thinking systematically through complex issues of the decision-making process.

Examination of the literature on empirical research on farm risk models revealed much attention for risk responses, especially for enterprise diversification. Too little attention was paid to the evaluation of risk methods by an integral assessment of individual risk preferences and other constraints based on values of the farmer such as family expenses, labour input, and willingness to borrow money. Moreover, farm diversification limited the possibilities of creating cost savings by cost price strategies.

Rapidly changing environments ask for a decision framework that takes price and production variability into account, as well as uncertainty caused by changes in the social and/or political environment. For the latter, scenarios can be used. The use of multiple scenarios is not only aimed at identifying the major factors behind the changing farm environment, but must also wean decision makers from their dependence on single-line forecasts (Beck,1982). The time horizon of scenario analysis probably depends on the type of industry. The lifetime of farm assets is a certain requirement for deciding on a time horizon.

Developing software to support farmer decision making is necessary to make the theory of decision analysis available for use at the farm level (Eidman, 1989). Decision Support Systems can be defined as interactive computer-based systems that help decision makers to use data and models in order to solve unstructered problems (Sprague and Carlson, 1982). In developing decision support systems for farm level risk management the way in which people make decisions should be emphasized. For widespread use of interactive Decision Support Systems, not only the performance with respect to calculations is a requirement, but also the necessary time for the input of specific farm data.

Another critical success factor in stimulating farmers to consider risk and uncertainty in a quantitative way is the type of decision problems to which decision analysis is applied. Farmers are more receptive to decision analysis when it is applied to problems they consider important.

For strategic decision making estimating long-run risk and uncertainty is important. The more distant the future time horizon under consideration, the more vague the alternative futures are. Then, uncertainty becomes more important than risk. The use of multiple scenarios is a way to deal with uncertainty. However, appropriate guidelines in developing multiple scenarios are rare, if any.

It also appears to be doubtful whether decision makers can be classified according to their risk preferences. Are the risk aversion coefficients constant over a wide range of possibilities? In conclusion, for both risk and uncertainty, serious problems remain in making the theory of decision analysis available in such a way that it can be used by farmers.

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Chapter 2

A computer-based model for strategic planning on pig farms

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Abstract

In this paper, first a conceptual approach for strategic planning on pig farms is discussed. Based on this approach a personal computer system, the Investment Simulation Model (ISM), was developed to analyze the impact of long-term investment decisions on individual farm performance. ISM is a stochastic simulation model which uses data from individual farms and also average data representing Dutch pig farms. Individual pig farms are characterized by their resources, such as land, buildings and loans, and their production plans. Two aspects were considered in formulating strategic plans: farmer's objectives and the relevant farm environment. The model can help individual farmers and advisors to determine objectives by identifying the impact of strategic plans on ending net worth and family expenditures over a maximum period of 240 months. The simulated results indicated that a higher meat price disparity of 0.02 Dfl per kg of carcass decreased the relative net worth of the farm by 14.9%. The individual farm parameters, especially the rate of turnover, the feed conversion rate, and the original loan had a strong influence on the relative net worth in month 240. What-if scenarios with higher labour costs hardly influenced the relative ending net worth. A what-if scenario with higher feed prices had a significant negative impact on relative ending net worth, while higher replacement values of pig buildings influenced relative ending net worth positively. Inflation had a strong negative influence on relative ending net worth. A maximum impact value for manure disposal costs equal to Dfl 0.05 per kg forced the farm out of business.

Key words: pig farming, strategic planning, scenario, simulation model

1. Introduction

The unpredictability of changes in the technological, economic and political environment in which farms operate makes it important for farmers to possess strategic management skills. Farmers use distinct strategic plans to respond to these changes. Moreover, the economic success or failure of any firm depends on competitive advantage. As a consequence of the homogeneous nature of most farm products, farmers generally try to create and sustain a competitive advantage in costs and not in differentiation (Porter, 1985).

Most strategic plans are developed manually, which is time-consuming. These plans, therefore, have been kept simple (i.e. are static and deterministic in their approach) and include limited sensitivity analysis. For many parts of the strategic planning process computer-based systems could be used, if available. A conceptual approach for strategic farm planning underlying such systems is presented in the second section, and illustrated for pig farms.

In the third section, a model is presented that can be used to simulate the strategic planning on pig farms, the Investment Simulation Model (ISM). ISM uses data from individual farms and average data from Dutch pig farms. The model is aimed at supporting strategic planning on swine farms by giving insight into the relation between plans and their expected outcome. The (desired) future situation gets significance by relating the outcome of the individual farm to the outcome of the average Dutch farm.

Capital investment decisions are among the most important strategic decisions taken by the farmer. Important reasons for investment are modernizing the farm, generation change, fiscal reasons, farm expansion, and lowering costs (Amrobank, 1990 ; see also LaDue and Kwiatkowsky, 1989). The strategic decisions in ISM deal with the relation between farmer's characteristics and long-term investment decisions on the farm. The model behaviour and research results about this relation are outlined in the fourth section. In section five, the Investment Simulation Model and some illustrative results are discussed.

2. A conceptual approach for strategic planning

2.1. Basic concepts

The primary functions of management are planning, implementation and control. Planning is designing the bridge between the actual situation and a desired situation in the future. Plans become reality by implementation. During the control process the demand for a (strategic) change is analyzed (Boehlje and Eidman, 1984).

Strategic planning decisions involve the purchase of durable inputs such as land, buildings, and equipment. A strategic plan includes the mission statement indicating the kind of business the firm is in, the objectives and the strategy (Thompson and Strickland, 1992). The strategic plan consists of a pattern of actions which will lead to a predicted outcome, based on forecasts of future events. This formal description of the strategic decision-making process is not always followed by the farmer. Often, decisions are made less aware and in a less formalized manner.

Determining a suitable strategy begins with identifying the opportunities and risks in the environment (Andrews, 1971). Farmers should develop a strategic contingency plan that can be adopted when basic assumptions on which the strategy was built change (Hofer and Schendel, 1977). The contingency approach is often used for strategic choices. With this scenarios and strategies are matched. Thus, different strategies can be chosen for a number of important what-if scenarios.

2.2. The relevant environment

Most farms can be characterized as small business firms that have to act as price takers. The individual farmer has few possibilities of influencing his environment, making it more important to anticipate changes in the environment of the farm correctly and in time. This makes information about external conditions important for strategic planning.

Distinct aspects of the relevant farm environment are: (1) the process of technological advance, (2) the economic environment, (3) the monetary environment, and (4) the legislative environment. These aspects are the underlying factors that determine the structure and the competitive forces within the pig industry.

Technological advance deals with adopting and implementing new technologies. Major areas in which technological advance has been realized in Dutch pig farming are housing and automation. Both have led to large scale climatized confinement systems with more or less automated feeding and climate control systems.

Markets constitute the relationship between the pig farm and its economic environment. This relation can be specified in terms of prices for available farm inputs and farm products. The prices reflect the relative scarcity of products. Farm input markets can be distinguished into: labour, pig farm buildings, land, feed, piglets, and miscellaneous input products. The development of prices over time is not only characterized by trends. Prices of fattening pigs and piglets are well known for their cyclic behaviour.

The monetary environment enables farmers: (1) to deposit money as savings, (2) to purchase and sell goods, and (3) to acquire capital for capital investments.

Legislation can be aimed at all members of society, or particular groups. All members of society, for instance, face tax legislation. The revenues of this legislation can be used to finance public expenditure. Other forms of legislation are aimed at specific groups within the society. In the Netherlands, the Soil Conservation Act, the Nuisance Act and the Act on Manure and Fertilizers constitute a legislative framework aimed at protecting the environment and directed at agricultural producers (Backus et al., 1993).

The Dutch tax system and the manure regulations constitute external conditions for pig farmers and have a profound impact on the planning process. Income tax has to be paid on the family income, and has three different rates. The higher the income the higher the tax rates. Property tax has to be paid on the family net worth, after deduction of a certain tax free value. There is only one rate for property tax.

Within the legislative framework to protect the environment, a levy on surplus manure production has been introduced, which is based on the amount of phosphate in kg, and is only imposed on farms with a manure surplus. To be able to determine the manure surplus on individual farms, farmers have to keep manure records. Only those farmers with sufficient land to apply the manure to without exceeding predetermined maximums for arable land, grassland, and maize land respectively, are exempt from paying the surplus levy. In addition to paying the manure surplus levy, farmers who have surplus manure will also have to pay the full price for disposing surplus manure from their farms as well as manure storage costs (Backus et al., 1993).

2.3. Objectives

Objectives can be defined as specified targets over a period of time to meet the goals of the farmer. They are related to the economic position of the firm and the level of cash withdrawals for family expenditures. Family and business objectives are often in conflict.

The objectives of the farmer are consistent with his personal values, e.g. leisure preference, and the willingness to borrow money. Personal values are established by past experiences, and direct the development of the strategic plan, while strategies reflect its contents.

Important business objectives that individual farmers have are those that maximize profit or increase net worth. Personal objectives may be the possibility of using part of the farm income for family expenditure. The ratio of the family net worth of the individual farm compared with the family net worth of the average Dutch farm can be used as an indicator for the relative wealth position. The average ratio over the entire period of family expenses of the individual farm compared to the family expenses of the average Dutch farm can be used as an indicator for consumed wealth.

3. Description of the Investment Simulation Model for pig farms

3.1. General outline

The computer-based model was developed using Object Oriented Programming in Turbo Pascal 6.0. It contains about 9,000 statement lines, and 140 input variables. The model is stochastic by nature and uses Monte Carlo simulation to determine monthly meat prices and interest rates.

Major object types in the program are: SYSTEM, SCENARIO, FARM, STRATEGY, and BUILDING. The SYSTEM class contains all the constant values. They are retrieved in an object to be able to vary system constants without changing the sources. SCENARIO represents the firm environment such as what-if scenarios, trends, and the implication of these values for prices and cost prices. The object type FARM has two variants, the average and the individual farm. The average farm is a lifeless trend follower, the farm parameters of which automatically follow the trend in the market (scenario). The individual farm develops itself, which is a consequence of specified decision rules (strategies), and by increase in experience. STRATEGIES are linked to individual farms. An object BUILDING represents a pig house. An object FARM contains 0, 1, or more objects of the type BUILDING. The main features of the Investment Simulation Model are presented in Figure 1.

The length of the time horizon can be defined as the number of months that the decision-maker evaluates the consequences of alternative strategic plans. The maximum is set at 240 months. According to Curtis (1983), decision makers may find that their time horizons are much shorter than the planning period, which can be defined in terms of the lifetime of durable inputs. As experience in planning is gained, the time horizon can be stretched with each planning cycle.

Experience

The effect of experience on costs is an important factor for businesses. The costs of products decline with increasing experience in producing and selling them. Experience can be defined as the cumulative number of units produced to date (Abell and Hammond, 1988).

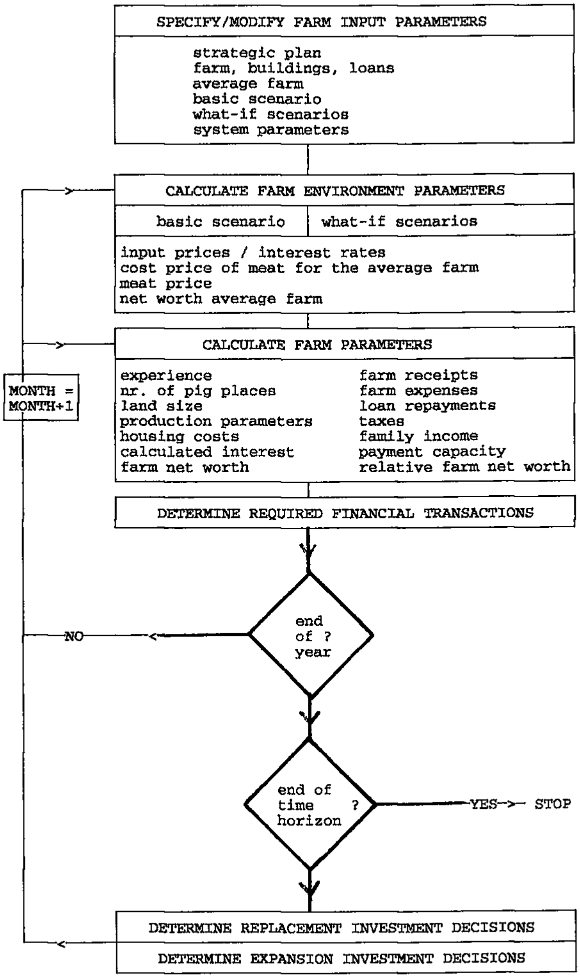

Figure 1. Flow chart of the Investment Simulation Model.

The experience effect in ISM is described as follows:

experience effect = (1.0 + max experience_effect) * experience(i) / (experience(i) + max experience_effect * average experience) (1)

where "max experience effect" is the maximum effect of experience; "experience(i)" is the experience expressed in months; and "average experience" is the months of experience, the experience factor of which equals 1.0.

The experience effect can be calculated as a function of the number of months the farm produces pigs. For the average farm, the experience effect is assumed to be constant, and equal to 1.0. On the individual farm, growth of the animal, meat percentage and the number of pig places per hour of labour are divided by the experience effect while feed conversion and mortality rate are multiplied by the experience effect. Growth and mortality rate can be integrated into the rate of turnover which is defined as the number of pigs delivered per pig place per year.

```
rate of turnover= {(1-mortality) * days / (growth traject / growth)} / experience effect      (2)
```

The variable "days" is constant and equal to 365.25.

Determining the meat price

The market price of pig meat in the model is assumed to be determined by: (1) the long-term cost price, (2) payments according to quality, (3) income disparity, and (4) cyclical movements.

The long-term development of pork prices is influenced by the process of farm technological advance. The development of the average cost price for all pig farms indicates at which long-term development in market prices farmers will stay in business. The cost price of fattening pigs consists of labour costs, housing costs, interest, feed costs, manure costs, cost of mortality, miscellaneous costs, and overhead. The average cost price for all pig farms, excluding manure costs, over the last 12 months is regarded as equal to the long-term meat price. Dutch manure costs are excluded because they are not representative of European pig production, contrary to other cost factors such as the price of labour and the price of feed. Only those cost factors are included whose factors are representative of European levels of the pork market.

Prices of feed, labour, and new building places are calculated monthly using a linear formula with a base value and a monthly trend. All input prices are made nominal by multiplying them by the inflation rate. Output prices of meat and piglets are not multiplied by the inflation rate because these prices are composed out of the nominal input prices and derived from the cost price for all pig farms.

```
cost price hog    = labour costs + housing costs + interest costs + feed costs + cost dead pigs +   (3)
                    overhead + (miscellaneous costs * inflation) + manure costs
labour cost       = nominal labour costs * hours / delivered hogs                                  (4)
housing costs hog = depreciation + interest + maintenance                                          (5)
  depreciation      = (nominal replacement value / average lifetime) / rate of turnover            (6)
  interest          = 0.5 * interest on loans * nominal replacement value / rate of turnover       (7)
  maintenance       = farm maintenance / delivered hogs                                            (8)
interest costs    = average hog value * interest on loans / rate of turnover                       (9)
feed costs        = nominal feed price * growth traject * feed conversion                          (10)
cost dead pigs    = ( mortality / ( 1 - mortality ) ) * average hog value                          (11)
overhead          = farm overhead * inflation / delivered hogs                                     (12)
cost price meat   = ( cost price hog + cost price piglet ) / carcass weight                        (13)
cost price piglet = f(cost price hog)                                                              (14)
piglet price      = f(meat price)                                                                  (15)
```

The cost price of a piglet and its market price can be estimated using a linear regression formula based on historical data for the cost price of hogs and the meat price.

The additional payment for carcass quality is based on the quality payment scheme, as advised by The Dutch Commodity Board for Meat and Livestock Products.

The degree of income disparity is expressed as the average difference between the market price and the cost price of meat. This variable reflects the existence of the agricultural treadmill, where farmers are forced to adopt new technologies or will otherwise be forced to wind up the business due to too low a productivity.

Cyclical movements of meat prices are caused by farmers' adjustments to changes in aggregate supply and demand. These adjustments lead to lower prices in case of high price levels, and higher prices in case of low price levels respectively. The response period for these changes is determined by how easily the resources can be adjusted. Cyclical price fluctuations imply fluctuating receipts for the individual farmer. This may lead to situations, where planned investments cannot be realized, due to insufficient financial reserves and/or insufficient additional debt capacity.

The stochastic nature of the Investment Simulation Model is represented by the calculation method for monthly meat prices and interest rates. For the meat price and the interest rate a cyclical component is assumed. This cyclical component is represented by a sine function. The expected monthly cycle values for the price of meat and subsequently the meat price itself are calculated as follows:

```
cycle      = ( a * amplitudo * sin(( month * 2π ) / ( b * wave length )) * inflation     (16)
meat price = average cost price meat + cycle + additional price + disparity               (17)
```

where a and b are non-correlated stochastic parameters having an average value of 1.0. Each time the function value of cycle equals zero, a and b are generated again. This implies that the wave length and amplitudo of the meat price cycle fluctuate during the time horizon. In Figure 2a and 2b the meat price and the national cost price of pig meat is shown for two different random numbers. The simulations are based on values as given in the appendix for the average and standard deviation of amplitudo and wave length.

Interest rates are also characterized by fluctuating movements. In the Investment Simulation Model, amplitude and wave length of interest rate cycles are fluctuating according to the same sine formula as the variable cycle.

Loans

For long-term loans it is assumed that interest and principal payments are charged monthly. Loans can be acquired when the additional debt capacity of the farm is sufficient. The term of the loan is equal to the lifetime of the assets for which the money is borrowed, except a loan in the case that the farm would otherwise not be able to meet payment conditions. In the latter case a fixed loan term of 72 months is assumed. Loans are of the constant principal payment type, implying a constant principal payment each period. As a result, interest costs and total loan payment decrease over time.

For self-liquidating loans on live animals it is assumed that the amount of debt per pig is used at the beginning of the fattening period. At the end of the fattening period, interest is charged on the debt on live animals per pig delivered.

3.2. The average pig farm

The average Dutch pig farm serves as a reference for the individual pig farm, and is described in similar terms. Where the individual pig farm develops itself based on decision rules outlined in the strategic plan, however, the average farm is a dead entity and develops itself based on time series for the main parameters characterizing farm structure and productivity. In Figure 3, the main differences in calculating the parameters of the individu al and the average Dutch farm are summarized.

The average value of a pig farm consists of the value of the pig farm buildings, financial reserves, land, and the livestock value. In addition to changes in nominal value due to inflation and the replacement value of farm buildings, the annual increase in the average value

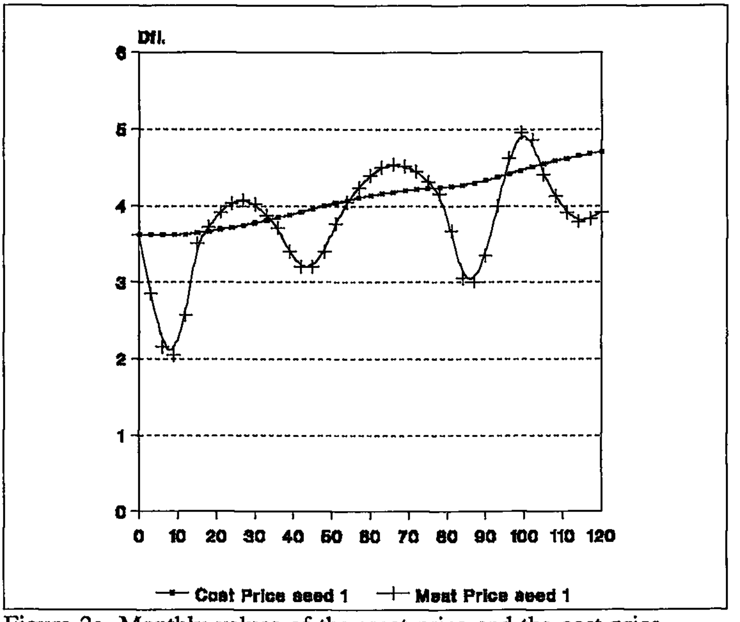

Figure 2a. Monthly values of the meat price and the cost price.

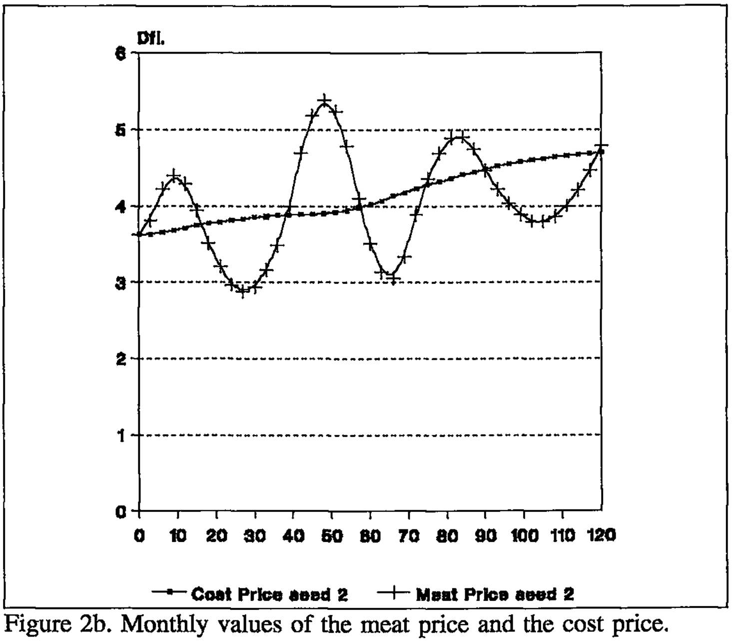

Figure 2b. Monthly values of the meat price and the cost price.

of the pig farm depends on the level of replacement investments and expansion investments.

Assuming that the national average age of the pig farm buildings is constant, defining the average value of replacement investments as being equal to the annual depreciation of pig farm buildings is made possible. The calculation of annual expansion investments for the average farm is derived from time series, and based on historical data for the national average

	Average pig farm	Individual pig farm
unpaid labour (hrs)	constant	f(additional pig places)
paid_hours (hrs)	constant	f(unpaid labour, additional pig places)
age framework	constant	f(time)
age inventory	constant	f(time)
age equipment	constant	f(time)
pig places	linear trend	f(expansion strategy, additional debt capacity)
growth	linear trend	f(replacement/expansion strategy, experience)
feed conversion	linear trend	f(replacement/expansion strategy, experience)
mortality	linear trend	f(replacement/expansion strategy, experience)
meat percentage	linear trend	f(replacement/expansion strategy, experience)
carcass type payment	linear trend	f(replacement/expansion strategy, experience)
arable land	linear trend	f(expansion strategy, fraction land investment)(*)
grassland	linear trend	f(expansion strategy, fraction land investment)(*)
maize land	linear trend	f(expansion strategy, fraction land investment)(*)
principal payments	linear trend	f(debt, loan term)
interest payments	linear trend	f(debt, interest on loans)

(*) Fraction land investment is the fraction of investments in purchasing land relative to investments in purchasing pig farm buildings.

Figure 3. Main differences in calculating parameters for the individual and the average Dutch pig farm.

number of pig places, multiplied by the nominal replacement value for the month over which the value has to be calculated.

For the average farm, principal payments and interest payments are calculated as follows:

$$\text{principal payment} = (\text{debt} / \text{family net worth}) * \text{pig farm value} / \text{average lifetime assets} \quad (18)$$

$$\text{interest payment} = (\text{debt} / \text{family net worth}) * \text{pig farm value} * \text{interest rate loans} \quad (19)$$

3.3. The individual pig farm

The individual pig farm can be characterized by the farmer's values on leisure, the maximum leverage, the relation between farm income and family expenditures, the assets in land and pig farm buildings including its productivity and the loans.

One of the reasons to be a farmer is the possibility of being independent. However, in order to keep the farm viable, the farmer often depends on others in making decisions. As a result of the strong increase in average farm size, the capital structure of agricultural firms has developed toward an increasing use of non-equity capital in the past decades. In addition to economic and financial reasons, the use of non-equity capital can be limited by those farmers who wish to be independent. This wish for independence can be expressed by the maximum leverage ratio. The leverage ratio is defined as the ratio of debt to equity.

With increasing farm size, more hired labour is necessary. It depends on the farmer's wish for independence whether and how much hired labour he allows on the farm. The maximum number of hours unpaid labour per farm per year depends on the priorities of income and leisure, respectively.

The relation between the farmer's household and the farm is important. Besides keeping the farm viable, the farmer needs to use part of the family income for family expenditures. In the model, the minimum and maximum level of family expenditures has to be specified. The minimum level of family expenditures depends on the farmers preferences for income and expenditure, respectively. This is determined by the family size and the age of the family members. The minimum and maximum level of family expenditure have to be defined for a specific interval of family income. Within this interval family expenditures are calculated by linear intrapolation. Outside this interval, family expenditures are assumed to be constant.

```
nominal_min_expenses = inflation * labour_price_increase * min_expenses                                (20)
nominal_max_expenses = inflation * labour_price_increase * max_expenses                                (21)
nominal_max_income_for_min_expenses = inflation * labour_price_increase * max_income_for_min_expenses (22)
nominal_min_income_for_max_expenses = inflation * labour_price_increase * min_income_for_max_expenses (23)
```

The development in the nominal price of labour can be used as an indicator for the development in overall wealth. The increase in labour costs is calculated as the cumulative value of the increase in the price of labour from month 1 to the actual month in the model.

The individual pig farm is also characterized by the pig farm buildings and the loans. The pig farm buildings are characterized by the number of pig places, their production levels, and age. Loans are characterized by the amount, the number of principal payments, and the starting month. Interest rates are assumed to be variable. The loan term is equal to the average lifetime of the assets for which the loan is required.

Financial transactions are governed by the level of financial account; pig revenues, land income, off-farm income, purchase of feed and other farm inputs, family expenses, interest and principal payments.

If the level of the financial account exceeds the maximum, money is transferred to the savings account. Four solutions are possible to manage a shortage on the financial account: (1) transferring money from the savings account, (2) acquire a new loan, (3) selling land, and (4) selling buildings. Subsequently, those four solutions are evaluated monthly and eventually carried out, until the financial problem is solved.

Farmers may increase their future income level with increased leverage. If this income is partly reinvested in the farm, saved, or used to repay loans, net worth will increase. The financial possibilities of the individual farm are then estimated for the buildings for which possible replacement investments are evaluated. Therefore, the additional debt capacity should be known. The additional debt capacity depends on the payment capacity of the farm, the interest rate, and the lifetime of the asset for which the loan is required. The additional debt capacity of the farm for a specific investment alternative is equal to the minimum value of the formulas 27 and 28:

```
adjusted pre tax family income   = pre tax family income-(delivered hogs * carcass weight * cycle) (24)
adjustedted after tax family income = adjusted pre tax family income - (income tax + property tax) (25)
payment capacity  = adjusted after tax family income - adjusted family expenditures +            (26)
                    depreciation - principal payment
add debt capacity = payment capacity / ((1 / remaining lifetime) + interest)                      (27)
add debt capacity = maximum leverage * equity - debt                                              (28)
```

The formula for payment capacity (26) represents the structural payment capacity of the farm, and the pre tax family income is adjusted for cyclical meat price influences. Subsequently, the family expenditures adjusted for cyclical meat price influences can be calculated subsequently using the adjusted after tax family income.

The willingness of the bank to lend additional money to the farmer is represented by formula 27, and depends on payment capacity of the firm, the interest level as well as the remaining lifetime of the asset for which the loan is required.

The amount of additional money the farmer is willing to borrow depends on the actual financial leverage, and on the maximum leverage the farmer wants to deal with.

The necessary calculations for determining the family net worth are:

```
hog margin             = ( meat price * carcass weight - piglet price - interest costs - feed costs (29)
                         - cost dead pigs - nominal miscellaneous costs ) - labour costs
                         - housing costs - overhead - manure costs
pig farm income year   = delivered hogs * hog margin + nominal labour costs * (hours-paid hours) +  (30)
                         pig places * ( interest + interest costs) - interest payment
nominal land income    = inflation * (arable income + grass income + maize income)                 (31)
farm income            = pig farm income year + nominal land income                                 (32)
off farm income        = interest on savings * savings_account                                      (33)
pre tax family income  = farm income + off farm income                                              (34)
```

```
taxable income         = pre tax family income - income limit tax free                 (35)
after tax family income = pre tax family income - (income tax + property tax)          (36)
savings                = after tax family income - family expenses                     (37)
```

Manure costs are calculated by adding disposal costs to the manure surplus levy. To be able to calculate the manure disposal costs, the average quantity of manure that cannot be applied on the own farm, must be calculated first. The manure surplus levy is calculated by multiplying the amount of manure surplus levy by the appropriate levies. Dividing the farm manure costs by the number of hogs delivered results in the manure costs.

```
pig farm value        = pig places * (equipment value + inventory value + framework value)   (38)
total pig farm value  = pig farm value + ( pig places * average hog value )                   (39)
farm net worth        = nominal land value + total pig farm value                             (40)
reserve               = savings account + financial account                                   (41)
family net worth      = farm net worth + reserve                                              (42)
```

Distinct types of investments in the Investment Simulation Model are replacement and expansion of durable capital assets. With this, pig farmers can either replace their existing buildings or buy existing buildings from other farmers. It is assumed that pig farmers are also able to buy land from other farmers.

When replacement investments are based on the technical lifetime of the assets, the framework, equipment and inventory are replaced when they have fully depreciated. Depreciation is a function of the lifetime of the assets.

When a replacement investment is realized, it is assumed that the production results of growth, feed conversion, mortality, meat percentage, and carcass type payment, improve together with the labour productivity for that building. The magnitude of the improvement depends on type and age of the replaced asset: equipment, equipment plus inventory, equipment plus inventory plus framework. The improvement in production results and labour productivity for a building as a result of a replaced asset is calculated as a linear function of the decrease in age of the replaced asset and the average national improvement in production results per month.

If the additional debt capacity and the financial reserve are sufficient, all desired replacement investments are realized directly in ISM. If the reserves are not sufficient to realize the replacements, additional debt possibilities are used.

3.4. What-if scenario's

The use of what-if scenarios is helpful to gain insight into the consequences of differences in time and magnitude of changes in the relevant farm environment.

In ISM, what-if scenarios can be formulated for: the cost of labour, the replacement value of pig farm buildings, the price of feed, inflation, and the manure disposal costs.

For each relevant aspect of the farm environment, the future external conditions can be formulated as follows:

$$Yi = Fi + Ii \tag{43}$$

where Yi represents the expected future external conditions; Fi represents the expected future external conditions based on historical data; Ii is the what-if scenario; and i is the actual month.

What-if scenarios in the model have (1) a gradual impact pattern of temporary duration, where the duration of the increasing impact is equal to the duration of the decreasing impact; or (2) a gradual impact pattern of temporary duration, where the increase is of a long duration and the decrease of a short duration. Possibility (1) makes use of the properties of the normal distribution function. The expected monthly additional values for the what-if scenario variable can be calculated using the following formula:

$$Ii = e^{(-(4*(1-i))/2)^2} \tag{44}$$

where Ii are the expected additional values for the what-if scenario variable; and i is the month number. The maximum value for the density of the normal distribution function is 0.3989, which serves as a scale factor for the maximum impact value.

For a non-symmetric gradual impact pattern the properties of the Beta (3, 1.5) distribution function can be used. Beta (3, 1.5) is a skewed function. The interval over which I increases is four times the interval over which I decreases. For example, when the duration of the what-if scenario equals 10 years, the maximum impact is reached in year 8. The what-if scenario for inflation is assumed to have a gradually long increasing and after that a gradually short decreasing impact of temporary duration. The variable can be calculated using the formula which represents the density function of the beta distribution function Beta (3, 1.5):

$$Ii = (105/16) * ((i-i0)/d)^2 * \sqrt{(1-((i-i0)/d))} \tag{45}$$

where Ii are the expected additional values for the what-if scenario variable; i is the month number; i0 is the starting month of the what-if scenario; and d is the duration of the what-if scenario. The maximum value of Ii for Beta (3, 1.5) is 1.8783 which serves as a scale factor for the maximum impact value.

4. Model behaviour

4.1. Basic outcome

Model behaviour can be studied by evaluating simulation results of one specialized Dutch pig farm for a specified set of parameters over a time horizon of 240 months. In the appendix, values for the major input variables are given. The specified pig fattening farm can be characterized as having: (1) two pig farm buildings together requiring almost a full-time labour place; (2) no land; (3) high family expenditures; and (4) slightly above average productivity.

The simulation results of 10 independent replications over a time horizon of 240 months are presented in Table 1. Farm expansion gave the highest values for relative net worth after 240 months, compared to no expansion, because the family expenditures and other overhead decrease per pig place.

Table 1. Comparison of two expansion strategies for different iterations (different random numbers)

	Family net worth after 240 months (Dfl.)		
Iteration	No expansion	Expansion = 1000 places (*)	Difference
1	1,586,298	3,895,960	2,309,662
2	2,636,078	4,116,753	1,480,675
3	2,155,403	2,984,095	828,692
4	2,560,866	3,450,782	889,916
5	2,416,989	3,190,456	773,467
6	4,013,758	6,785,332	2,771,577
7	2,195,159	3,843,269	1,648,110
8	3,239,286	4,728,313	1,489,027
9	2,780,927	4,643,240	1,862,313
10	2,237,988	3,927,976	1,689,988

(*) Starting month of the expansion strategy = 1

The presented differences in relative net worth depend not only from differences in interest rates and in the pig price cycle. For most random numbers, the average value over the entire time horizon of the variable cycle differs from zero. This difference adds up to the already specified meat price disparity. Thus, the presented differences in relative net worth for different iterations are also partly due to differences in meat price disparity.

The outcome values for the two expansion strategies for the different random numbers vary in a similar way. The results suggest that if one is not so much interested in the absolute values of the outcome, but more in the ranking of the strategies to be chosen, one iteration is sufficient for this farm.

In Table 2, a log-book of an example of a simulation of the individual pig farm for 240 months is presented. The first line in the log-book contains the following information: in month 12, the farm has 1280 pig places with an average age of 99 months; the financial and savings accounts are equal to Dfl 16,391 and 214,076 respectively; the debt level equals Dfl 812,101 with a remaining loan term of 117 months; the ratio of realized family expenditures to the realized family expenditures of the average farm is 1.161; the family net worth equals Dfl 1,200,275; and the ratio of family net worth to the family net worth of the average pig farm is 0.99.

Table 2. Log-book of important investment and financial decisions (1)

Month	pig places	average age (2)	financial account	savings account	debt	loan term(3)	family expenses ratio	family worth	relative net worth
12	1,280	99	16,391	214,076	812,101	117	1.161	1,200,275	0.99
24	1,884	113	-37,815	111,776	942,353	92	1.131	1,392,866	1.07
36	1,884	101	-55,320	0	1,297,349	79	1.096	1,431,124	1.03
48	1,884	113	1,561	114,051	1,157,488	68	1.105	1,513,767	1.02
60	2,321	123	-86,303	0	1,342,154	56	1.084	1,623,358	1.02
72	2,321	135	36,317	141,752	1,165,265	47	1.094	1,741,926	1.03
84	2,321	138	102,090	131,143	1,075,386	38	1.100	1,844,999	1.02
96	2,321	107	-89,186	0	2,007,821	66	1.088	2,063,664	1.07
108	2,321	119	22,764	0	2,003,409	58	1.082	2,028,567	0.99
120	2,321	131	71,353	149,714	1,786,224	48	1.089	2,160,497	0.99
132	2,321	135	-31,654	0	1,932,951	43	1.080	1,975,565	0.85
144	2,321	147	47,974	0	1,654,394	33	1.083	1,942,942	0.79
156	2,321	159	70,293	318,018	1,411,962	25	1.089	2,204,334	0.84
168	2,321	144	-42,838	0	1,546,356	33	1.085	2,118,412	0.76
180	2,321	141	-165,970	0	2,352,108	52	1.080	2,272,903	0.77
192	2,321	153	-35,283	0	2,304,420	46	1.076	2,175,361	0.69
204	2,321	165	116,991	432,720	1,959,872	37	1.082	2,615,354	0.78
216	2,321	153	16,713	207,188	1,789,323	31	1.084	2,600,563	0.73
228	2,321	165	-2,877	918	1,567,916	24	1.083	2,258,985	0.60
240	2,321	130	155,777	691,267	2,300,693	91	1.087	3,895,960	0.98

(1) applied expansion strategy is 1000 pig places
(2) average age : average age of the pig farm framework, inventory, and equipment (months)
(3) loan term : average remaining loan term (months)

The pig farm started slightly above average productivity. This farmer had an expansion strategy of 1000 pig places in month 1, and each guilder invested in pig farm expansion was immediately followed by 0.20 guilders investment in land purchase. A technical replacement strategy was applied for the pig farm buildings.

Every 12th month, the possible replacement investments were evaluated first. When a replacement investment was carried out by borrowing money, no second loan was allowed in that month for other replacement and expansion investments. Another possible reason for expansion investments not to be realized in a certain year was that the model assumed a minimum number of pig places to expand. This number was a fraction of the national average farm size. Here, this fraction was assumed to be equal to 0.4 .

When a replacement investment was necessary, the financial possibilities of realizing this investment were evaluated, and were based on the available reserve and the additional debt capacity. When a planned replacement investment in a certain year was not possible due to a lack of financial possibilities, the financial possibilities with respect to that replacement investment are evaluated each next year. The log-book results also show that the financial reserve can vary significantly.

4.2. Sensitivity analysis

A sensitivity analysis was carried out to analyze the impact of various input values on the relative ending net worth of the farm under study. The input variables selected for the sensitivity analysis represent major factors characterizing the relevant farm environment and economic performance of the farm itself. Only one variable is modified at a time, while for the other variables the basic values are used. Results of the sensitivity analysis are presented in Table 3. The alternative values, for which this analysis was made, are at a 5% higher and a 5% lower level than the basic values. It appears that meat price disparity is a very influential system parameter. A higher disparity of 0.02 Dfl per kg of carcass decreases the relative net worth of the farm by 14.9%. This result makes the simulation model dependent on the assumptions with respect to meat price disparity. Of the individual farm parameters, especially the rate of turnover, feed conversion rate, and the debt have a strong influence on the relative net worth in month 240.

Table 3. Results of the sensitivity analysis.

Variable	Input values			Relative ending net worth(*) for different input values	
	Low	Basic	High	Low	High
System parameters					
Maximum experience effect	0.0475	0.05	0.0525	-0.021	0.040
Overhead average pig farm (Dfl.)	9,500	10,000	10,500	-0.052	0.000
Miscellaneous cost per hog (Dfl.)	9.5	10	10.5	-0.001	0.001
Meat price disparity (Dfl./kg)	-0.36	-0.38	-0.40	0.149	-0.079
Individual farm parameters					
Savings Account (Dfl.)		0.0	50,000	not calculated	0.020
Maize Land (ha)	4.75	5.0	5.25	-0.065	0.012
Minimum Expenses (Dfl./yr)	57,000	60,000	63,000	0.004	-0.058
Initial Experience (months)	142	150	158	0.007	-0.060
Rate of turnover	2.74	2.88	3.02	-0.036	0.176
Feed conversion rate	2.64	2.78	2.92	0.162	-0.301
Original loan (Dfl)	570,000	600,000	630,000	0.140	-0.060

(*) Values are presented as the difference from the basic situation (alternative minus basic). Relative net worth after 240 months in basic situation is equal to 0.980.

4.3. Results: what-if scenario analysis

To analyze the impact of what-if scenarios, starting month, duration, and maximum impact value were specified for the variables: (1) inflation, (2) feed price, (3) labour costs, (4) manure disposal costs, and (5) replacement value of pig places. In the what-if scenario analysis, the starting values for the variable under study were the same for the basic scenario and for the what-if scenario.

For a technical replacement strategy and a planned expansion by 1000 pig places, simulation results of the individual pig farm in the basic scenario were compared with those in the what-if scenario. Results are presented in Table 4.

Maximum impact values of what-if scenarios for the labour costs hardly influenced the relative ending net worth. A what-if scenario for feed price had already a significant negative influence on relative ending net worth, while higher replacement values of pig buildings influenced relative ending net worth positively. For this highly leveraged farm, inflation had a strong negative influence on relative ending net worth. A maximum impact value for the manure disposal costs equal to Dfl 0.050 per kg of manure forced the farm out of business. This what-if scenario implied an average increase in manure disposal costs of approximately Dfl 0.020 per kg of manure, compared to Dfl 0.015 per kg of manure in the basic scenario.

Table 4. Impact of what-if scenarios on relative ending net worth (1).

	Maximum impact value	Relative ending net worth
Feed price (Dfl/kg)	0.40	0.862
Labour costs (Dfl/hr)	20	0.993
Inflation (fraction/month)	0.005	0.293
Replacement value (Dfl/pig place)	800	1.160
Manure disposal costs (Dfl/kg)	0.050	0.000

(1) Starting month = 1 ; Duration = 240 months.
Relative net worth after 240 months in basic situation is equal to 0.980.

5. Discussion and outlook

The main determinant of profitability for individual pig farms was represented by the variable "meat price disparity". This variable had a strong impact on the simulation outcome. Future research should focus on the factors determining "meat price disparity". Important factors to take into account are: differences in environmental legislation between European pig production areas, economies of scale, switching costs, geographical concentration, forward and backward integration, and threat of substitution.

The simulation results reveal that expansion strategies have a positive impact on the relative economic position of the simulated pig farm. In ISM, the reason for expansion of scale being a key to economic success was that economies of scale existed for the variables family expenditures and overhead per farm. However, additional calculations showed that this conclusion did not hold for low-productive farms. These farms had neither enough additional debt capacity nor reserves to buy additional pig places. When legislative barriers to building and buying pig farm buildings increased, expansion was less feasible. The current system of production rights within the legislative framework to protect the environment increased the purchase price of farms, and therefore made expansion also less profitable.

When the constraints on labour and financial leverage remained unchanged, and when there was no planned expansion, it was difficult to improve the relative economic position of the farm. The farm's position at the beginning of the planning (simulation) period determines to a large extent its position at the end of the period.

All farmers have plans for their business. These differ in quality, not in whether or not they exist. The choice is not whether to plan, but whether to plan effectively (Curtis, 1983). Among the barriers that can inhibit effective planning are a lack of knowledge of the true relative firm position and the environment in which the farm operates. The use of computer-based simulation models can help to support farmers in this respect. In the case of ISM, however, the large number of possible combinations is a problem.

The use of simulation models has several advantages. Simulation allows estimating future performances of an existing farm under a projected set of operating conditions. Alternative strategies can be compared via simulation in order to see which of the strategies gives the best results. In using simulation, much better control over experimental conditions can be obtained than will generally be possible when experimenting with the system itself. Simulation also allows studying farm economics in compressed time (Law and Kelton, 1991). However, developing simulation models is also associated with disadvantages and pitfalls. One disadvantage is the time-consuming nature of the research. More often, one has to speak of "man years" than of "man months". It is also very dangerous to develop a simulation model on one's own. At regular times, the concepts developed must be discussed with other experts in the field. Furthermore, determining input values for some variables can be tricky. For example, how does one quantify the experience level of young farmers. And last but not least, it is very important to distinguish between developing and programming a simulation model. It must be recognized that in most cases simulation modelling has the character of prototyping, so that the software must be able to incorporate adaptations of the model during later stages.

Possibilities for future research in modelling strategic pig farm planning are relevant environmental factors that influence the choice of geographical location, differentiation, and vertical integration.

It must be taken into account that modelling the farm and its environment makes it necessary to define important parameters that are mostly implicit in reality. Farmers are aware of their labour input and financial leverage being restricted to a certain level, but they do mostly not have a clear opinion about the maximum level for these parameters. When using the model for decision making, high priority must therefore be given to the relationship between objectives derived from personal preferences and their outcome.

As long as one is interested in differences in the relative economic position of farms as a consequence of different input values rather than in the ranking of strategies taking into account different risk attitudes, one iteration of the model is allowed. If one is interested in the development of the absolute outcome values over time, preferably a time horizon should be chosen such that the meat price cycle has just reached its end.

To support individual farmers in making decisions a stochastic approach using Monte Carlo simulation is preferable, taking into account their attitudes toward risk. The outcome of each iteration can be seen as an observation. After performing several iterations, farmers can choose from strategies by evaluating cumulative distributions of outcome for each strategy. Research to examine this aspect is under way.

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Appendix: Major input values

System parameters		
Piglet weight (kg)	25.0	
Carcass weight (kg)	86.0	
Income tax free upper income level (Dfl.)	11,538	
Low income tax rate (%)	38.4	
Low tariff upper income level (Dfl.)	43,267	
Mid income tax rate (%)	50.0	
Mid tariff upper income Level (Dfl.)	85,930	
High income tax rate (%)	60.0	
Property tax free upper Net Worth (Dfl.)	561,000	
Property tax rate (%)	0.8	
Replacement timing (months)	12	
Fixed loan term (months)	72	
Experience average farm (months)	180	
Maximum experience effect	0.05	
Overhead per farm (Dfl.)	10,000	
Framework lifetime (months)	360	
Inventory lifetime (months)	180	
Equipment lifetime (months)	90	
Framework salvage fraction	0.0	
Inventory salvage fraction	0.2	
Equipment salvage fraction	0.5	
Maximum maintenance costs (% of replacement value)	2	
Amplitude monthly interest: average (st. dev.)	0.0015	(0.0005)
Wave Length Interest: Average (st. dev.)	60	(25)
Amplitude Meat Price: Average (st dev.)	0.80	(0.30)
Wave Length Meat Price: Average (st. dev.)	36	(10)
Base Interest on loans (per month)	0.0067	
Margin between interest on savings and loans	0.0002	
Base inflation rate (perc./month)	0.0030	
Meat price disparity (Dfl./kg)	-0.38	
Additional meat price (Dfl./kg)	0.10	
P2O5 limit free of levy (kg/ha)	125	
P2O5 limit low levy (kg/ha)	200	
Low P2O5 levy (Dfl./kg)	0.25	
High P2O5 levy (Dfl./kg)	0.50	
P2O5 allowance arable land (kg/ha)	125	
P2O5 allowance grass land (kg/ha)	175	
P2O5 allowance maize land (kg/ha)	125	
Manure disposal costs (Dfl./kg)	0.015	
Growth (kg/day): base (trend)	0.713	(0.0005)
Feed conversion rate: base (trend)	2.85	(-0.002)
Mortality: base (trend)	0.021	(-0.00001)
Meat percentage: base (trend)	55.4	(0.0)
Land value (Dfl./ha): base (trend)	40,000	(200)
Labour costs (Dfl./hr): base (trend)	32.52	(0.048)
Feed price (Dfl./kg): base (trend)	0.47	(0.0)
Building places: base (trend)	1200	(3.0)
Labour hours per pigplace: base (trend)	1.6	(-0.001)
Replacement value pigplace (Dfl.): base (trend)	800	(0.34)
Miscellaneous costs per hog (Dfl.)	10	

Appendix continued

Farm parameters	Average Farm Base (Trend)	Individual Farm
Financial Account (Dfl.)	10,000 (0)	51,000
Savings Account (Dfl.)	100,000 (0)	0.0
Maximum Unpaid Labour (Hrs./yr)	2,348	3,000
Maximum Hours (Hrs./yr)		5,000
Maize Land (ha)	4.0 (0)	5.0
Grass Land (ha)	3.0 (0)	0.0
Arable Land (ha)	2.0 (0)	0.0
Maximum Expenses (Dfl./yr)	60,000	70,000
Minimum Expenses (Dfl./yr)	60,000	60,000
Min. Income With Max. Family Expenses	70,000	120,000
Max. Income With Min. Family Expenses	40,000	50,000
Family Income Last Year (Dfl.)	60,000	70,000
Initial Experience (months)		150
Maximum Leverage		5.0
Fraction Land Investment		0.0
Minimum Financial Account (Dfl.)		-100,000
Maximum Financial Account (Dfl.)		100,000
Aim Financial Account (Dfl.)		0
Debt live hog (Dfl)	190	190
Pig Places		1,280
Last Update Framework		-96
Last Update Inventory		-96
Last Update Equipment		-72
Rate of turnover		2.88
Feed conversion rate		2.78
Meat Percentage		55.4
Carcass Type Payment (Dfl./kg)		0.00
Solvency	0.72	
Original loan (Dfl)		600,000
Number of principal payments		180
Starting month loan		-1

Chapter 3

A decision support system for strategic planning on pig farms

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Abstract

This paper reported on a Decision Support System (DSS) for strategic planning on pig farms. The DSS was based on a stochastic Simulation Model of investment decisions (ISM). ISM described a farm with one loan and one building by 23 variables. The simulation model calculated the results of a strategic plan for an individual pig farm over a time horizon of maximal 20 years for a given scenario. For the distinct replacement strategies the regression metamodel described the outcome of the response variable as a function of the farm variables. Regression results indicated that a linear function with only 9 or 10 farm variables already gave a reasonable estimate of the results of the simulation model. Turn over ratio, feed conversion ratio, percentage of meat, farm size, family expenses, and experience were the main parameters determining future relative farm position. Risk attitudes played a minor role for the simulated farm, because one strategy was preferred to another, regardless of risk preference. To analyze the attractiveness of a chosen strategic plan for different what-if scenarios, the visual method using graphical representations offered sufficient information about the results of what-if scenario analysis. The number of years ahead, that the decision maker evaluates the consequences of simulated strategic plans influenced the strategy to be preferred.

Key words: decision support, scenario, pig farm, metamodel, strategic planning

1. Introduction

Decision Support Systems (DSS) are an important application of Management Information Systems (Davis and Olson, 1985). According to Keen and Scott Morton (1978), DSS imply the use of computers to improve decision making, and allow the user to retrieve data and evaluate alternatives based on models fitted for the decisions to be made. Reports on DSS for strategic planning on pig farms are lacking.

A computer-based simulation model of the strategic planning process on pig farms was developed, the Investment Simulation Model (ISM). ISM gives insight into the strategic planning on pig farms, in terms of the relation between strategic plans and their simulated outcome (Backus et al., 1994). A short description of the pig farm model is presented in the second section.

A method to help determine the optimal replacement strategy for specific combinations of input values is presented in the third section. When using ISM to search for the optimal strategic plan, the user has to choose from among 6 discrete combinations of replacement and anticipatory strategies. Because one single iteration requires 1 minute computation time, and because there are numerous possible combinations of strategic plans and what-if scenarios, it is time-consuming to develop an optimal strategic plan. Therefore a regression metamodel was applied to describe the outcome of the response variable as a function of the farm variables.

To support farmers in developing strategic plans, the stability of the optimal strategy can be analyzed for several what-if scenarios. Three distinct methods are compared in section four.

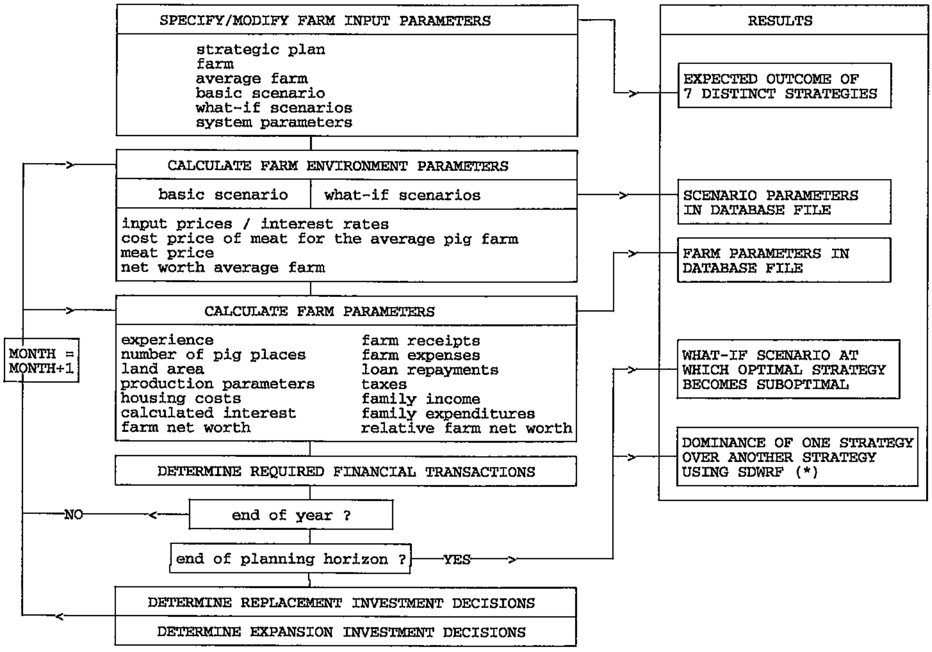
In the fifth section, the economic impact of constraints on unpaid labour and capital are described. In the sixth section, the risk interval approach for measuring individual risk preferences is applied to specify the impact of risk preferences on the attractiveness of strategies. The impact of the personal time horizon on the chosen strategy is discussed in section seven. Finally, the Decision Support System and its potential for use in strategic planning is discussed in section eight.

2. Short description of the Investment Simulation Model

The Investment Simulation Model (ISM), was developed to analyze the impact of long-term investment strategies on individual performance of farms with fattening pigs. To serve as an individual DSS for pig farmers, additional features are implemented. A flow chart of the main aspects of the DSS is presented in Scheme 1. The DSS uses data from the individual farm and also average data representing the Dutch pig farms. The average pig farm serves as a reference for the individual pig farm, and is described in the same terms as the individual farm. The average farm develops itself based on time series for parameters characterizing farm structure and productivity. All input parameters can be modified to suit other countries and farm conditions.

The individual pig farm can be described in terms of investment strategies, maximum labour, maximum leverage, years of experience, family expenditures as a function of farm income, assets in land, and pig farm buildings including their productivity, as well as the loans.

Pig farm buildings are characterized by the number of pig places, age of facilities and the productivity parameters daily growth, feed conversion ratio, meat percentage, and carcass



(*) SDWRF : Stochastic Dominance With Respect to a Function

Scheme 1. Flow chart of the Decision Support System.

type payment. Loans are described by the amount of money, the number of principal payments, and the starting month of the loan.

To describe a pig farmer with 1 pig farm building and 1 loan the model uses a total of 23 input variables: 3 variables describing the loan, 8 variables describing the pig farm building, and 12 variables representing the farm. Moreover, 2 additional variables are required to represent the farmer's risk attitude[1].

Farmer's objectives are numerous and often conflicting. In ISM, the relative ending net worth and the relative family expenses ratio are used as the major outcome variables. Relative ending net worth is the ratio of the ending net worth of the individual farm to the ending net worth of the average pig farm. Relative family expenses ratio is the average ratio over the entire simulation period of monthly family expenditures of the individual farm to monthly family expenditures of the average farm. Relative ending net worth is regarded as a measure

1. The two variables representing risk attitude are not always used, and need therefore not always be specified.

of potential future utility, while the relative level of family expenses can be regarded as a measure for consumed utility. ISM makes it possible to analyze the relation between potential future utility and consumed utility, as well as the trade-off with other farmer's objectives like leisure, and the wish to be independent of banks.

3. The optimal strategy

A strategic plan developed with ISM consists of a combination of decision rules. In ISM, a strategic plan consists of replacement strategies, anticipatory strategies, and expansion strategies. Replacement strategies can be based on the technical or the economic lifetime of farm assets. In case of an economic replacement strategy, every 12th month, four alternatives are evaluated with respect to their expected outcomes: (1) no replacements, (2) replacement of the equipment, (3) replacement of equipment and inventory, or (4) replacement of the entire building. To choose from those four activities, the estimated margin per pig place in that building is calculated for each activity for the next month. The activity with the highest estimated margin per pig place is chosen. This margin is calculated as follows:

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margin = ( meat price * carcass weight - ( labour cost + interest costs + feed costs +        (1)
       cost dead pigs ) ) * rate of turnover - ( depreciation + interest + maintenance )
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where labour cost, interest costs, feed costs and cost of dead pigs are expressed per pig delivered; rate of turnover is the number of pigs delivered per pig place per year. Depreciation, interest and maintenance are expressed per pig place per year.

If no investments are made the cost of the buildings are calculated against their salvage value. The complementary maintenance costs are expressed as a linear function of the age of the framework, equipment and inventory. The expected net margin in case that the equipment is replaced, is calculated as if no investments are made in inventory and framework. Thus, the housing costs of equipment are based on the replacement value and of inventory and framework on the salvage value. The maintenance costs of equipment are based on the expected average lifetime, while the calculated maintenance costs of inventory and framework are based on age. The expected net margin in case the entire building is be replaced, is based on its replacement value. Maintenance costs are based on the average expected maintenance cost for its technical lifetime.

ISM assumes that within a replacement investment, a farmer can also apply anticipatory or timing strategies: (1) a non-cyclical investment strategy, (2) a cyclical investment strategy, or (3) an anti-cyclical investment strategy. For specialized pig farms, timing of investment may be a possible flexible strategy which responds to new information or changing conditions. The timing strategy is implemented in ISM by the variable timing, which has the values 0, 12, or -12. Before the age of a specific asset (expressed in months) is adjusted, age is corrected for the variable timing, because this depends on whether the pig meat price is low, high, or normal. A low price means that the meat price is lower than the average cost price for all farms minus twice the disparity; a high price means that the meat price is higher than the average cost price for all farms. For a cyclical investment strategy the variable timing equals -12 when meat prices are low, and +12 when meat prices are high. The opposite holds for cases of anti cyclic investment strategies. Thus, anticipating the pig meat price cycle can be realized by delaying or accelerating investments with respect to the equipment and/or inventory and/or framework.

Farm expansion can be represented by a continuous aspect, i.e. the number of additional pig places. Thus, a strategic plan is specified by two discrete aspects and one continuous aspect. For the effective use of the model as a decison support system it must be able to guide the DSS-user in his search for the optimal strategy, without taking too much of his time.

The expansion strategy which is expected to be optimal has to be determined first. Because of the presence of economies of scale in the model, it is assumed that for most farms it is attractive to expand, such that the limits of maximum labour and maximum leverage are reached. The size of the farm on which these two constraints are fully used, is calculated as the minimum of the following two formulas.

$$x1 = x2 / x3 \tag{2}$$

$$x1 = \{ (x4 - x5) * x6 / x7 \} + x8 \tag{3}$$

where

x1 = number of pig places at which constraints on labour and leverage are fully used

x2 = maximum hours (hours/year)

x3 = hours per pig place

x4 = maximum financial leverage (Debt/Equity)

x5 = financial leverage

x6 = equity (Dfl.)

x7 = replacement value of a pig place (Dfl.)

x8 = actual number of pig places

The optimal expansion strategy is assumed to be determined by the number of building places, where the constraints of maximum labour and maximum leverage have just been fulfilled.

Regression models are an effective way to approximate the relative ending net worth surface for alternative strategies. A simulation experiment has to be carried out, the results of which are used for the specification of the regression models. Kleijnen (1992) reported on the use of such metamodels.

Based on 140 simulation runs with different observations (farms), the relation between the relative ending net worth for a strategic plan and the 23 variables describing the farm, the loan, and the pig farm building was estimated for each of the 6 combinations of replacement and anticipatory strategies. The estimation is based on a relatively simple linear relationship between farm variables and relative ending net worth, and can serve as a substitute for the input/output behavior of the simulation model. If this function is known for each of these 6 combinations, determining the optimal strategic plan for an individual farm comes down to choosing that combination of replacement and anticipatory strategies, where the corresponding function value is the maximal one.

Using regression metamodels in a DSS by determining the strategy which is likely to be optimal improves performance with respect to response time, and makes it possible to limit the number of alternative strategies to be further analyzed by the DSS user. Based on a statistical analysis of the outcome of these simulations, a regression model must be specified for each of the 6 discrete combinations of replacement and anticipatory strategies. These regression functions will be incorporated in the decision support system.

In case of only one pig house and one loan per farm, an individual pig farm can be described by 23 input variables, excluding 2 variables representing the farmer's risk attitude[2]. The farmer's risk attitude is not taken into account within the regression metamodel, because these two variables do not influence the dependent variable in the regression metamodel, relative ending net worth. Relative ending net worth Y is a function of the simulation results of an individual farm described by the set $\{X_1,...,X_k,...X_{22}\}$. The relative ending net worth (Y) can also be approximated as a linear function of these input variables:

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2. Within the regression metamodel, an individual pig farm can be described by 22 instead of 23 input variables, because the number of principal payments for long-term loans was set constant at 240.

$$Y_{ij} = \sum_{k=1}^{22} a_{ijk} X_k + \varepsilon \, , \qquad (4)$$

where

Y = relative ending net worth

X_k = input variable k; k = 1,...,22

i = replacement strategy i (technical or economic) (i = 1,2)

j = anticipatory strategy j (non-cyclical, cyclical, anti-cyclical) (j = 1,2,3)

a_{ijk} = estimate of effect of input variable X_k in replacement strategy i and anticipatory strategy j

ε = error term.

It was assumed that expected values for ε equal 0 and are independently distributed.

The procedure for determining what initial situations will be simulated, starts with a random determination of the 22 input variables for a certain number of simulations. The determination of these 22 values was carried out stochastically because then the maximum amount of information could be gained, assuming that the impact on the outcome of the 22 input variables was not equal (Timmer, 1984). Minimum and maximum values for the 22 input variables are presented in the appendix. For each of 140 generated initial situations, the optimal expansion strategy was also determined, given a specific replacement strategy, and given the maximum quantity of labour and the maximum leverage.

Six discrete strategies were distinguished (remember: i=1,2 and j=1,2,3): (1) technical, non-cyclical replacement; (2) economic, non-cyclical replacement; (3) technical, cyclical replacement; (4) economic, cyclical replacement; (5) technical, anti-cyclical replacement; and (6) economic, anti-cyclical replacement. For each of these six strategies, regression analysis was applied. First, six regression metamodels based on 140 observations each, were specified with all the 22 inputs as independent variables. After that, variables which did not contribute significantly to the regression model, were excluded, and for each distinct strategy regression metamodels were specified again, but now with the remaining 9 or 10 significant variables.

Adjusted R-square, Pearson correlation coefficients, and the degree of significance are presented in Table 1.

Table 1 also presents the standardized parameter estimates of the independent variables for the dependent variable relative ending net worth for each of the six strategies. A standardized regression coefficient is calculated by dividing a parameter estimate a_k by the ratio of the sample standard deviation of the dependent variable to the sample standard deviation of the regressor (SAS, 1990).

Table 1. Standardized estimates of the significant regression parameters (a_k) and their significance levels (p-levels) (*).

Strategy (**)	TN	TC	TA	EN	EC	EA
starting loan (month)	-0.132c	-0.122b	-0.107b	-0.090b	-0.092b	-0.100b
number of pig places	0.371c	0.299c	0.308c	0.366c	0.282c	0.285c
rate of turnover	0.239c	0.231c	0.227c	0.254c	0.229c	0.223c
feed conversion rate	-0.287c	-0.296c	-0.282c	-0.269c	-0.295c	-0.287c
meat percentage (%)	0.361c	0.391c	0.386c	0.355c	0.352c	0.351c
land area (ha)	0.198c	0.228c	0.246c	0.203c	0.236c	0.253c
savings account (Dfl.)	0.134c	0.105b	0.097b	0.085b	a	a
initial experience (month)	-0.417c	-0.430c	-0.438c	-0.436c	-0.453c	-0.451c
maximum hours (hours/yr)	a	a	a	a	0.088b	0.087b
max. family expenses (Dfl.yr)	-0.099b	-0.087b	-0.089b	-0.094b	a	a
max_inc_min_exp (***) (Dfl./yr)	0.111b	0.103b	0.088b	0.119b	0.111b	0.108b
Adjusted R-square(****)	0.68	0.66	0.69	0.69	0.65	0.64
R(Y1/Y2)	0.55	0.56	0.56	0.55	0.55	0.54

(*) a: p-level ≥ 0.1000 ; b: 0.0100 ≤ p-level < 0.1000 ; c: p-level < 0.0100 .
(**) Replacement: TN=technical, non-cyclical; TC=technical, cyclical; TA=technical, anti-cyclical
EN=economic, non-cyclical; EC= economic, cyclical; EA=economic, anti-cyclical.
(***) The maximum income level where the family expenditures are still constant and at a minimum.
(****) Adjusted for degrees of freedom.
R(Y1/Y2) Pearson correlation coefficients for relative ending net worth and relative family expenses ratio.

The results in table 1 indicate that all signs of the parameter estimates were as expected, which supports the validity of the regression metamodel (4). The variable "starting loan" represents the number of months prior to the moment the loan was applied. For example, for a loan starting 60 months ago "starting loan" is equal to -60. and is expressed as a minus variable. Therefore, a negative sign of the parameter estimate for "starting loan" is to be expected, as it is also for feed conversion ratio, initial experience, and maximum family expenditures. Presented differences in standardized parameter estimates for different replacement strategies indicate that the attractivity of the replacement strategies mainly depended on the variables "starting loan", savings account", "maximum hours", and "maximum family expenses". Compared with an economic replacement strategy, the more long-standing the loan and/or the higher the savings account, the more attractive the technical replacement strategy was; the higher the maximum number of hours and/or the maximum family expenses, the less attractive the technical replacement strategy was. Most significant for each distinct strategy were the variables representing the farm size (number of pig places and land size), the variables representing farm productivity (turnover ratio, feed conversion ratio, and meat%), and initial experience.

For each distinct strategy, R-squares adjusted for degrees of freedom are also presented in Table 1. Adjusted R-squares ranged from 0.64 to 0.69 for the different strategies. Pearson correlation coefficients between relative ending net worth and the ratio of individual family expenditures compared with family expenditures of the average Dutch farm varied for the different strategy aspects from 0.54 to 0.56. Thus, there was a positive relationship between potential future utility and consumed utility.

4. Stability of the optimal strategy

To specify expected future external conditions, quantitative information from official sources is used to specify relevant trends. However, such official sources do mostly not incorporate important developments which are either recent or difficult to formalize. Because of these limitations it is desirable to develop what-if scenarios for important aspects of the farm environment. The development of what-if scenarios enables the farmer to develop contingency plans based on different sets of forecasts.

The strength of the optimal strategy, given a certain starting situation, depends on the influence of changing environmental variables. In the model what-if scenarios are defined for five variables: inflation, labour costs, feed price, replacement value of pig places, and manure disposal costs.

What-if scenarios for the variables labour costs, feed price, pig farm replacement value, and manure disposal costs are defined as having a gradual impact pattern of temporary duration, where the duration of the increasing impact is equal to the duration of the decreasing impact.

During the 1970s, inflation rates increased gradually until the beginning of the 1980s when a coordinated international monetary policy strongly decreased inflation rates. Therefore, the what-if scenario for inflation was defined as having a gradual impact pattern of temporary duration, where the increase had a long duration and the decrease a short duration.

Theoretical distribution functions can be used to represent the gradual impact pattern of what-if scenarios. Using the properties of the normal distribution function, the duration of what-if scenarioss can be specified in terms of the standard deviation. The impact can have a positive or negative value. The expected additional impact values can be calculated for each month, when the starting month of the what-if scenario, its maximum impact value and its duration are specified.

The what-if scenario for inflation can be represented by the density function of the beta distribution function Beta(3; 1.5).

What-if scenarios can influence the simulation outcome. The question is whether this influences the strategy to be chosen. Therefore, for each of the five mentioned variables a one-dimensional search method was applied. The method searched maximum impact values where the strategy which was initially optimal, becomes suboptimal. Strategies were compared pairwise. The methods were compared with respect to their effectiveness in determining the attractiveness of the optimal strategy with a changing environment. The methods were: (1) the bisection method, (2) the intersection method, and (3) the visual method.

Sub (1): The bisection method is a search procedure which begins with 2 starting points for the maximum impact value, namely 0 (point a) and a value which can be specified by the ISM-user (point b). If for both points the same strategy appears to be optimal, it is assumed that there is no other optimal strategy within the interval [a;b]. If the optimal strategy for point a differs from the optimal strategy in point b, it is assumed that there is a turning point at which the initially optimal strategy becomes suboptimal. The best estimator of the turning point is in the middle of the two points for maximum impact value. If for that new point (c) the optimal strategy still appears to be optimal, the interval in which the turning point is, is half as long as before, and the procedure repeats for the interval [c;b]. The procedure is repeated until the number of bisections, specified in advance, is realized.

Sub (2): The intersection method differs only from the bisection method in that it uses information of the function values when estimating the turning point. Turning points were estimated based on the relation between the differences in function value (relative ending net worth) and for the strategies compared. If the difference in function value at b was four times greater than the difference in function value at a, the intersection point was expected to be at one fifth of the interval [a;b]. As in the bisection method, the number of repeated estimations for the intersection method was defined in advance.

Sub (3): The visual method, using graphical representations, is an alternative if it is not possible to summarize results of what-if analyses for a specific variable in a single turning point. This may occur when function values show a stepwise pattern with varying what-if scenarios. The visual method began with 2 starting points for the maximum impact value namely 0 (point a) and a value which can be specified by the ISM-user (point b). Next, the function values were calculated for the middle in between the two starting points, point c. Then, the procedure was repeated and function values were calculated for the middle points of both intervals [a;c] and [c;b]. Each next iteration, all distinct intervals were divided into two intervals of equal size, and function values were calculated for the new middle points.

The DSS presents the results of the analysis graphically in an interactive mode. The number of repeated simulations is not known in advance. The DSS user can stop the procedure any time.

Simulation results were based on one particular pig farm. The pig farm had four relatively new pig buildings, with a total of 2250 pig places and average results. The farmer owned 5 ha of land and had a long-term debt of Dfl. 665,000 with 98 remaining monthly loan repayments.

In Figures 1a-1e the values of relative ending net worth for different what-if scenarios for five distinct variables were presented for 2 different strategies. Strategy TN0 can be characterized as a technical, non-cyclical replacement strategy without expansion. Strategy EN0 differs from strategy TN0 in applying an economic replacement strategy.

The results presented in Figure 1a indicate that for this farm increasing nominal replacement values had in general a positive influence on the relative ending net worth, but did not alter the dominance of strategy TN0 over strategy EN0. In general, for this farm, it can be concluded that compared with the technical replacement strategy the economic replacement strategy was less stable for what-if scenarios for manure disposal costs, inflation, and feed price. Economic replacement led to earlier replacement of buildings and therefore better productivity. This made the farm less vulnerable to changes in the environment.

More than 1.5% additional inflation above the base inflation rate of 3.6% per year (Figure 1b) had a strong negative influence on this farm in case of strategy TN0. The relative ending net worth was only affected by more inflation at an additional inflation rate of 6.0%. Figure 1c shows that higher labour costs hardly affected the value of the response variable of the farm. In Figure 1d it is shown that higher feed prices made strategy TN0 unfavourable compared with strategy EN0. With strategy EN0 buildings were replaced earlier, leading to better feed conversion ratios. The economic importance of better feed conversion ratios increased with increasing feed prices. In Figure 1e, the severe impact of increasing manure disposal costs on the relative ending net worth of this farm with only 5 ha of land is presented. The negative impact was strongest when strategy TN0 was applied.

The results presented show that the impact of the simulated what-if scenarios on the relative ending net worth could be considerable, depending on the type and magnitude of the what-if scenario. However, instead of looking at the absolute values of the response variables, one might be more interested in the influence of what-if scenarios on the choice to be made. The results in Figures 1a-1e indicate that for the simulated individual farm the choice of the optimal strategy was sensitive for changes in the relevant future farm environment, especially

Figure 1A. What-if scenarios for Nominal Replacement Value
Technical (TNO) versus economic (ENO) replacement

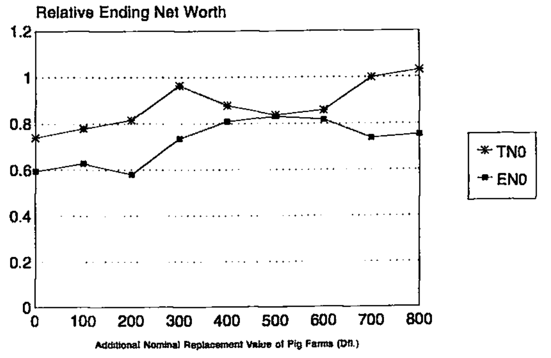


Figure 1B. What-if scenarios for Inflation
Technical (TNO) versus economic (ENO) replacement

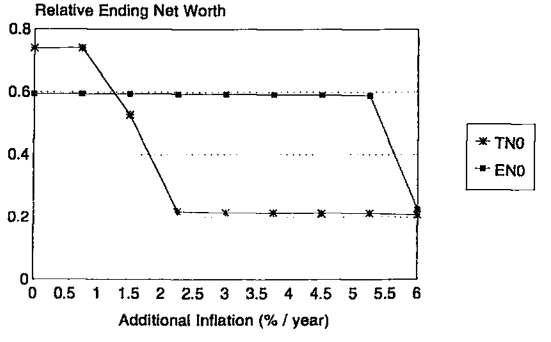


Figure 1C. What-if scenarios for Labour Costs
Technical (TNO) versus economic (ENO) replacement

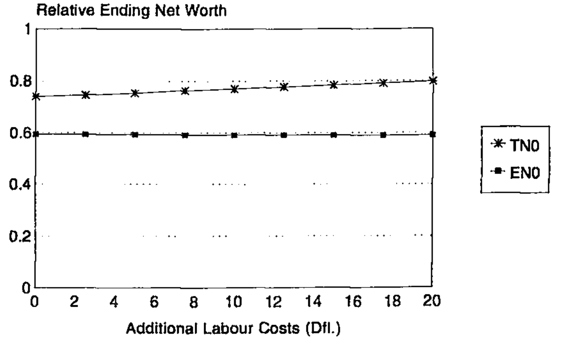


Figure 1D. What-if scenarios for Feed Price

Technical (TNO) versus economic (ENO) replacement

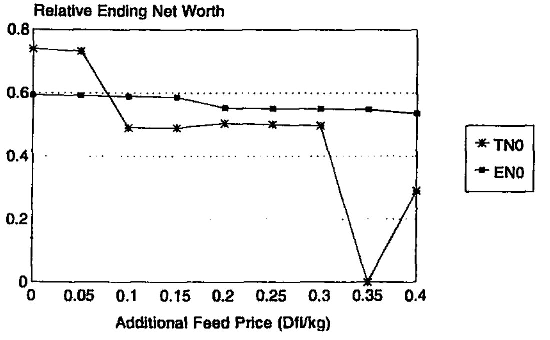
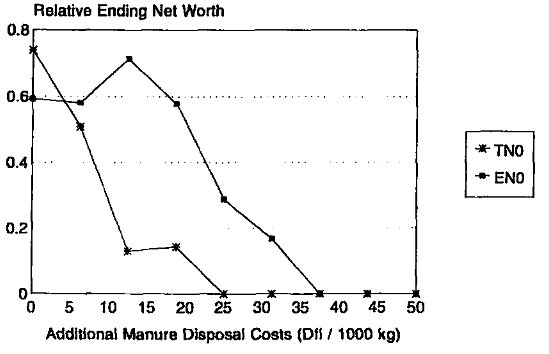


Figure 1E. What-if scenarios for Manure Disposal Costs

Technical (TNO) versus economic (ENO) replacement



for what-if scenarios for inflation, and replacement value of pig farm buildings.

The non-smooth behaviour of the function values with varying maximum impact values makes use of the visual method preferable, because it summarizes all relevant information. However, also the visual method does not prescribe which alternative strategic plan to choose.

5. Constraints on unpaid labour and capital

Using computer-based models for farmer decision support requires explicit descriptions of the strategic plan. Personal values are mostly not explicitly specified by the farmer. Farmers do not know whether their actual perception of the maximum number of hours available and their maximum leverage will actually influence future relative ending net worth. The DSS provides the user with information on whether the constraints are binding and on the impact of that limitation on the relative ending net worth, as well as the strategy to be preferred. The economic impact of constraints on available unpaid labour and on capital was calculated as:

$$v1 = f(x9 + 52) - f(x9) \tag{5}$$

$$v2 = f(1.1 * x4) - f(x4) \tag{6}$$

where

v1 = marginal labour value

v2 = relative capital value

x4 = maximum financial leverage

x9 = maximum unpaid labour (hours/year)

The marginal value of a constraint for available unpaid labour was calculated as the change in relative ending net worth due to an increase of available unpaid labour with one unit (one unit = 52 hours). The economic impact of a constraint on capital was calculated as the change in relative ending net worth due to an increase in maximum leverage by 10%. Labour and capital can be limiting factors in case of substantial firm growth. For farms with above-average zootechnical performance, particularly the marginal labour value can be quite high. For these farms, the relative capital value is often low, due to the improvement in financial leverage during the simulation period, as a consequence of the above-average zootechnical productivity.

6. The impact of risk attitude

What-if scenarios, the marginal value of unpaid labour, the relative value of capital, and comparison of strategies are features of ISM which so far have been applied for one iteration. This approach is sound for ISM, if one is not so much interested in the functional value itself, but in the strategy to be chosen (Backus et al., 1994).

The choice from among risky alternatives depends on the risk preferences of the decision maker towards different distributions of expected outcome. When individuals express non-neutral risk preferences, a stochastic approach using more than one iteration was applied in ISM. This is relevant as one focuses on the ranking of strategies. Based on the comparison of distributions of outcomes for simulated strategies, the preferred strategy can be selected.

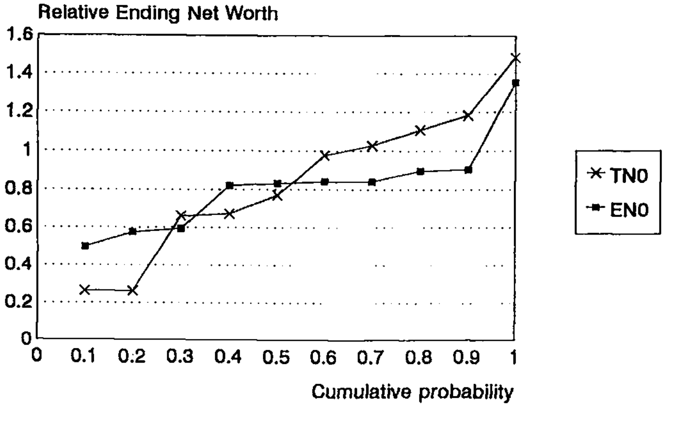
The impact of risk attitude on the attractiveness of strategies can be taken into account within ISM by applying Stochastic Dominance With Respect to a Function (SDWRF), developed by Meyer (1977). SDWRF is an evaluation criterion that orders choices without requiring an exact utility function or specified characteristics of risk attitude. King and Robison (1981) applied the so-called Interval Approach to the Measurement of Decision Makers Preferences. This approach is a preference measurement technique designed to be used in conjunction with SDWRF. It utilizes a lower bound R1(x) and an upper bound R2(x) of the absolute risk aversion function. The absolute risk aversion function R(y) represents local measures of the degree of concavity or convexity expressed by a decision maker's utility function u(y). A negative value of R(y) implies local convexity of the utility function and risk preferring behaviour. The absolute risk aversion function should be stable, unless the individual's wealth, health, education or other basic characteristics change. Lower and upper bounds of a decision maker's absolute risk aversion function define an interval measurement of his preferences.

Depending on R1(y) and R2(y), ISM can evaluate alternative strategies, for up to 200 observations per strategy. Relative ending net worth was used as the outcome variable on which the strategies are ordered. The result was about being dominant or the preference for one strategy over the other(s). It was considered appropriate using relative ending net worth as utility measure, because of the positive relationship between relative ending net worth and the ratio of relative family expenditures.

To analyze the impact of risk attitude on the strategy preferred for the pig farm, its simulation results over 240 months were compared for two distinct strategies. The two distinct strategies were: (TN0) technical, non-cyclical replacement, no expansion, and (EN0) economic, non-cyclical replacement, no expansion. In Figure 2, simulation results are presented for ten iterations. For the lower outcomes, an economic replacement strategy performed better, whereas for higher outcomes a technical replacement strategy performed better.

The impact of different risk attitudes on the preferred strategy was analyzed for this case by applying Stochastic Dominance with Respect to a Function (SDWRF). Using SDWRF led to TN0 as the preferred strategy for risk neutral decision makers, and for individuals with lower bounds of risk aversion equal to or higher than 0.0006 and upper bounds of risk aversion equal to or higher than 0.0010. It seems in congruence with the literature to classify the latter risk aversion coefficients from strong to very strong risk averse (Raskin and Cochran, 1986). It can be concluded that in this case differences in risk preference did not lead to a different choice of strategy.

Figure 2. Relative Ending Net Worth for different strategies



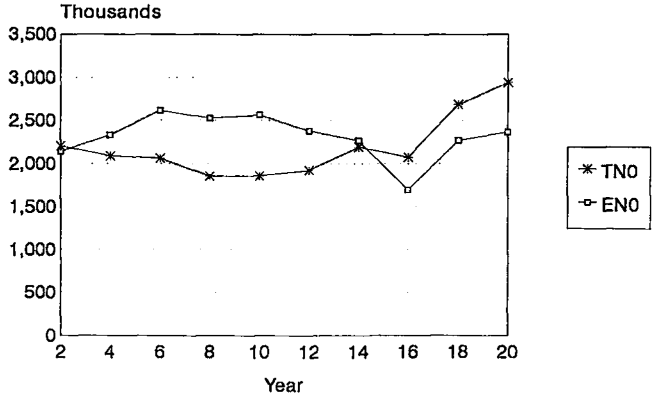
TN0 = technical, non-cyclical replacement
EN0 = economic, non-cyclical replacement

7. The impact of time horizon

The length of the personal time horizon is an important aspect of farm management. The number of years ahead over which the decision maker evaluates the consequences of alternative strategic plans possibly influences the choice of the preferred strategy. For replacement strategies, this also depends on the age of the assets at the beginning of the simulation and on the lifetime, because the consequences of alternative replacement strategies can become visible only if replacements have actually been realized. In Figure 3, the simulation results of a comparison of a technical, non-cyclical replacement strategy without expansion (TNO) with an economic, non-cyclical replacement strategy without expansion (ENO) are presented for varying time horizons.

The results clearly indicate the need for time horizons of sufficient length. Based on a personal time horizon of 4 to 12 years, this farmer would be advised to choose an economic replacement strategy, while after 14 years there was hardly any difference in outcome, and after 15 to 20 years, strategy TNO gave better results for this particular farm. Pig farm extension organizations usually calculate the results of investment alternatives one to five years ahead. According to the latter results, this may lead to wrong conclusions.

Figure 3. Ending Net Worth with varying time horizons (Dfl.)



TNO = technical, non-cyclical replacement
ENO = economic, non-cyclical replacement

8. Discussion

Learning from mistakes can be an effective educational tool. But learning from strategic management mistakes may be too expensive. Provided with sufficient realism, Decision Support Systems can help farmers in exploring strategic management matters without having to pay for possible mistakes. A prerequisite for using DSS in practice, however, is the required time for collecting necessary information and for data entry. To use the Investment Simulation Model (ISM), developed in this research, 23 variables have to be collected.

It appeared that linear functions with 9 or 10 independent variables gave a reasonable estimation of the results of the simulation model. The complexity of strategic management matters does not automatically imply that hundreds of variables must be taken into account.

Due to the long-term consequences of strategic investment decisions, it takes several years before people can see the full effect of their decisions. The longer the personal time horizon of the farmer, the higher the chances are that he takes all consequences of his strategic choices into account. However, this conclusion does not imply that a chosen strategy will remain optimal for the whole time horizon. There is a fair chance that by the time the effects of a particular strategy are fully known, the environment is different from that in which the strategy was choosen. Therefore, the DSS must be used frequently, for example each year, to evaluate the strategy to be implemented for the next year, and evaluating alternative strategies with a time horizon of 20 years.

According to Hogarth (1975), individual decision makers are selective, sequential information processing systems with limited capacity. They are ill-suited to deal with the increasing complexity of our socio-economic system, which makes strategic planning more difficult. Decision Support Systems for strategic planning have therefore become even more necessary. An important aspect of exploring strategic planning matters deals with uncertainty. Assessing uncertainty and its consequences is one of the main tasks of the farmer as a manager. ISM with its stochastic features can support farmers in performing this task.

Although the future cannot be predicted, there are ways to deal with this limitation. The use of what-if scenarios within Decision Support Systems helps the decision maker to evaluate the attractiveness of his strategy with changing external conditions. With this, the farmer's main goal of analyzing multiple scenarios should be to learn the relevance of what he knows and does not know.

Besides complexity and uncertainty, risk attitude is the third important issue in discussing strategic management. Within the framework of the theory of Stochastic Dominance as it was applied in ISM, risk attitudes played only a minor role, because for the simulated farm, one strategy was dominated by first degree stochastic dominance over another, regardless of risk preference. Moreover, when risk attitudes influenced the choice of a strategy, this was only the case when the difference in results of compared strategies was small.

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Appendix. Minimum and maximum values for the random generation of observations within the experimental design.

		minimum	maximum
LOAN	starting loan (month)	-240	0
	loan (Dfl.)	0	1,000,000
BUILDING	last update framework (luf)(month)	-360	0
	last update inventory (lui)(month)	Max(-180,luf)	0
	last update equipment (month)	Max(-90,lui)	0
	number of pig places	0	6,000
	rate of turnover	2.5	3.3
	feed conversion rate	2.6	3.2
	meat percentage	52	56
	carcass type payment (Dfl./kg)	0.00	0.05
FARM	land (ha) (1)	0	10
	financial account (Dfl.)	0	50,000
	savings account (Dfl.)	0	200,000
	initial experience (month)	5	360
	family income (Dfl./yr)	0	10,000
	maximum hours (hours/yr)	2,000	10,000
	maximum leverage	0.5	4.0
	fraction land investment	0	0.5
	minimum family expenses (Dfl./yr)	20,000	50,000
	maximum family expenses (Dfl./yr)	50,000	80,000
	max. income with min. fam. exp. (2)	40,000	70,000
	min. income with max. fam. exp. (3)	70,000	100,000

(1) This value is the same for the area of arable, grass, and maize land.
(2) The maximum income level at which the family expenditures are still constant and at a minimum (Dfl/yr).
(3) The minimum income level at which the family expenditures are still constant and at a maximum (Dfl/yr).

Chapter 4

The impact of a decision support system for strategic pig farm planning on the advice of extension officers

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Abstract

This paper assessed the impact of a decision support system, the Investment Simulation Model (ISM), on recommendations given by extension officers to pig farmers. ISM gives insight into the relation between strategic investment decision rules and their simulated outcome. An evaluation procedure was developed for testing ISM under operational use. The model was put to the test on three farms and with three extension officers. For each farm, three sets of recommendations were prepared: 1) without using ISM, based on a farm visit to collect data; 2) with using ISM, based on a farm visit to collect data; and 3) with using ISM, but where data had been collected by another advisor. The field test resulted in striking differences between recommendations based on ISM and those not based on ISM. In the latter recommendations, immediate farm expansion was regarded as not feasible for 2 of the 3 farms. When using ISM, a farm expansion strategy was advised for all 3 farms, however, not immediately. Without using ISM, replacement strategies for the buildings, manure costs, and family expenditures were largely ignored in the advice, contrary to the advice based on ISM. Adjusted for the difference in travelling time, the time required for preparing advice using ISM equaled 80% of the time required for preparing advice not using ISM. Whether or not the extension officer himself collected the farm data did not influence the advice.

Keywords: pig farming, decision support, investment strategy, field test

1. Introduction

Determining the consequences of concrete investment alternatives is an important part of the work of extension officers in pig farming. However, determining consequences of investment alternatives is only part of the strategic planning process. A strategic plan is a result of a - more or less conscious - process in which personal attitudes, individual opinions on relevant future farm conditions, and alternative strategies are weighed against each other (Boehlje and Eidman, 1984). The better the strategic plan fits within the individual capacities of the farmer, the better future viability of the farm will be ensured.

A strategic plan is the result of a choice process based on personal judgements. People have limited capacities to process information and to make correct judgements. To improve strategic farm management skills, the process of weighing the different elements of the strategic plan has to be improved (Andrews, 1971; Porter, 1980 and 1985). Therefore, decision support systems can be a useful tool (Keen and Scott Morton, 1978; Sprague and Watson, 1986), but results supporting their merits are usually lacking (Adelman, 1991). Huirne (1990) reported a field test with a decision support system with 2 extension officers and on 10 farms, which resulted in a full test agreement between the system and human experts of about 60%. In only 4% of the cases, system and experts fully disagreed. No report was given on who was right in case of a disagreement.

Measurement of the effectiveness of decision support systems has generated much interest over the years. Among the approaches to measuring system effectiveness are: usage estimation, user satisfaction, decision making performance, cost-benefit analysis, and information economics (Srinivasan, 1985; Hamilton and Chervany, 1981A). System users are not the only relevant functional group for evaluating system effectiveness (Hamilton and Chervany, 1981B). Management should evaluate systems regarding their contribution to the organization as a whole.

DSS usage says something about user acceptance, but the relation with decision making quality is weak and possibly even misleading (Srinivasan, 1985; Davis, 1989). Users who, on average, spend more time per working session on a computer often have a positive opinion of the problem solving capacity of the system. However, such sessions are not necessarily directed towards the most important aspects of the job to be done.

The relation between the features of a system and the decision maker's need for information also influences system effectiveness. Srinivasan and Kaiser (1984) reported that an increase in functionalities led to both a more frequent as well as a more extensive use of the system. A negative relation existed between the number of functionalities and the perception of the relevance of a system. So, when developing DSS it is better to analyze which specific functionalities support the user most, and try to implement these in the system.

This paper aims at determining the impact of a decision support system, the Investment Simulation Model (ISM), on advice given by extension officers to pig farmers. ISM gives insight into the relation between strategic investment decisions and their simulated outcome (Backus et al., 1994A and 1994B). ISM incorporates a simulation model and a regression metamodel. The simulation model simulates results of a strategic plan for an individual pig farm and of the average pig farm for a particular scenario over a time horizon of maximal 20 years. The regression metamodel predicts the relative ending net worth of the farm for 6 distinct replacement strategies as a function of 9 or 10 farm input variables, depending on the chosen replacement strategy.

In the second section the organizational design of the field test and the participating farms are described. Results of the field test are presented in the third section where the advice without the use of ISM and the advice with the use of ISM is compared. Also, the plans with a without a farm visit are compared. Moreover, results on the time required for preparing the advice are presented. Finally, the results are discussed in the fourth section.

2. Materials and method

2.1. Design of the field test

The contribution of ISM to extension work depends to a great extent on the impact on the plan recommended. Also, the time required for learning the system and preparing the plan in an operational environment are important aspects of the value of ISM. To gain insight into the practical relevance of ISM for use in extension, a field test was carried out.

By aiming the field test at determining the impact of ISM on the plan, instead of determining subjective user opinions, objective results can be obtained. This allows organizations to determine the potential costs and benefits of introducing ISM in their organization.

The field test was carried out in cooperation with the Dutch National Extension Service for Pig Husbandry. In three meetings with representives of the National Extension Service, the organization of the field test, the qualifications of the extension officers, and the functionalities of ISM were discussed. The extension officers participating in the field test had to prepare written plans. Besides that, they had to record the time required for preparing the plan. Written plans are part of the daily work of extension officers. Mostly, these plans are prepared at a farmer's request for advice with respect to long-term investment decisions, for which the farmer has to pay.

It was decided to limit the functionalities of ISM within the field test to determining the influence of (1) family expenditures; (2) farm expansion; (3) changes in manure disposal costs; (4) the willingness to borrow money and to increase unpaid labour; (5) varying price conditions; and (6) replacement strategies. The influence of the willingness to borrow money is calculated as the change in relative ending net worth per 10% increase in maximum leverage. The influence of the willingness to increase own labour was calculated to be the change in relative ending net worth per additional hour of unpaid labour per week.

Other functionalities of ISM, such as determining individual risk preferences and analyzing its impact on the strategy to be chosen, as well as analyzing the results of strategies for various what-if scenarios regarding feed prices, labour, investment costs, and inflation were not included in the ISM version used in the field test. Only for manure disposal costs, a what-if scenario analysis was applied.

Three extension officers, together representing 40 years of experience, were selected to participate in the field test, each of them representing a different region. The participating extension officers had a joint session in which the aim of the field test was discussed. It was explained that they first had to prepare a plan without using the DSS, before they received more information about ISM. Finally, the qualifications for the farms participating in the field test were discussed. It was agreed that farmers with at least 1200 places for fattening pigs, and younger than 50 years of age should participate. A description of the design of the field test is presented in Table 1.

Table 1. Description of the field test (*).

Extension officer	without ISM with farm visit	with ISM with farm visit	with ISM without farm visit
X	A,X,x,t1	B,X,x,t2	C,X,y,t2
Y	B,Y,y,t1	C,Y,y,t2	A,Y,z,t2
Z	C,Z,z,t1	A,Z,z,t2	B,Z,x,t2

(*) C,X,y,t2 : a plan for farm C prepared by extension officer X, using ISM, where extension officer Y had collected the data on the farm.

The field test was carried out as follows: Three extension officers (X, Y, and Z) and three farms (A, B, and C) took part. Also two time periods were distinguished (t1 and t2). Officers X, Y, and Z had not been instructed how to use ISM and had not worked with ISM at t1. The beginning of t2 was marked for X, Y, and Z by a joint introduction to the operational use of ISM. The other distinction was about visiting the farm to collect data and to discuss the strategic plan which had to be simulated.

First, the extension officers prepared a recommendation without knowledge/use of ISM within a maximum period of three weeks after visiting their selected farm. This was followed by an instruction session which lasted an entire day, and marked the beginning of period t2. During the morning session, the main features of ISM regarding strategic farm planning concepts were explained. During the afternoon session ISM was demonstrated. Subsequently, the extension officers had to visit the second farm within two weeks, previously visited by their colleague, to collect the necessary data. Thus, data are collected twice. Next, data entry and calculations with ISM were performed at the office on the same day, after additional instruction of one hour. Assistance with the use of ISM was available to the extension officers throughout the session. At the end of this session, each extension officer gave copies of the data entered and the calculated output to a second officer, to enable him to prepare a plan with the use of ISM results, without visiting a farm. Within a week, all three extension officers had prepared 2 written plans with ISM. The field test was carried out within a period of 6 weeks.

2.2. Farms participating in the field test

Basic information of the three participating farms and of a typical Dutch fattening pig farm is presented in Table 2.

Table 2. Farm input data for the decision support system

	A	B			C				Typical Farm
Arable land (Ha)	0	0			0				2
Grass Land (Ha)	0	0			0				3
Maize Land (Ha)	2.5	0			0				4
Financial account (Dfl)	51,000	0			-285,000				10,000
Savings account (Dfl)	0	0			0				100,000
Experience (Months)	120	216			150				180
Maximum total labour (Hrs)	5,000	5,400			9,000				
Maximum unpaid labour (Hrs)	3,000	3,400			4,000				2,348
Family income last year (Dfl/month)	6,100	5,400			7,000				5,000
Minimum Family Expenses (Dfl)	24,000	63,000			40,000				60,000
Max. Inc. for Min. Exp. (Dfl) (1)	50,000	50,000			35,000				40,000
Maximum Family Expenses (Dfl)	72,000	70,000			80,000				60,000
Min. Inc. for Max. Exp. (Dfl) (2)	125,000	70,000			80,000				70,000
Minimum Financial Account (Dfl)	-230,000	-100,000			-285,000				
Aim Financial Account (Dfl)	0	0			0				
Maximum Financial Account (Dfl)	100,000	100,000			25,000				
Land Investment Fraction (Dfl)	0.0	0.0			0.0				
Maximum Leverage	5.0	4.0			3.0				
Pig Buildings (Nr)									
Pig PLaces (Nr)	1.400	300	480	960	640	180	800	810	1,236
Last Update Framework (Months)	-96	-228	-192	-108	-156	0	-108	-12	
Last Update Equipment (Months)	-96	-24	-156	-36	-84	0	-84	-12	
Last Update Inventory (Months)	-72	-24	-84	-36	-24	0	-24	-12	
Turnover Ratio	2.88	2.97	2.75	2.88	3.01	3.01	3.01	3.01	2.77
Feed Conversion Ratio	2.70	2.83	2.80	2.80	2.80	2.80	2.80	2.80	2.84
Meat (%)	55.1	54.2	53.8	54.0	55.0	55.0	55.0	55.0	55.4
Carcass Type Payment (Dfl/kg)	0.0	0.00	0.00	0.00	0.14	0.14	0.14	0.14	0.0
Loans									
Actual Debt (Dfl)	600.000	660.000			641.000		265.000	175.000	
Monthly Repayments (Nr)	180	180			180		180	240	
Starting month of the Loan	0	-17			-9		-22	-156	

(1) Maximum income level where family expenses are still constant and at a minimum.
(2) Minimum income level where family expenses are still constant and at a maximum.

Farmer A started pig farming 10 years ago. He is married, and has no children. His wife has a job outside the farm. Farmer A's goal is to raise enough farm income now and in the future, and to maintain continuity of the farm. He plans to create a facility for storage and mixing of wet feed by-products. It is possible that in the near future a neighbouring pig farm will be sold. Farmer A is interested in buying this farm, if there is an opportunity.

Farmer B started with pig farming 18 years ago. He is married and has several children. Farmer B questions the long-term continuity of his farm. He has relatively old buildings. Is a farm of this size capable of adapting to possible environmental costs? Farmer B's goal is to exploit a farm with a farm size large enough to ensure long-term continuity for himself, and, if possible, for one of his children.

Farmer C started pig farming 12 years ago. He had asked for a plan because he wanted to know whether his farm would be able to survive. He knows that his farm has a good economic position at the moment, but he questions whether it is necessary to make adjustments or expand his farm in the near future. Although it is unlikely that one of his children will take over the farm, the farmer wants to maintain the farm as a viable economic unit.

The data in Table 2 were required as input for ISM. ISM also required information about the replacement strategy, the anticipatory strategy, and the expansion strategy the farmer preferred.

The extension officers succeeded in collecting the required input data for ISM. Extension officer Z faced a problem because farm C used a large installation for feeding wet by-products, and participated in a vertical coordination program with special price conditions. Feeding wet by-products can decrease the cost price per kg of carcass, but is also associated with annual depreciation and interest costs for the required equipment. The extension officer solved the problem by setting the costs and benefits of feeding wet by-products at Dfl. 0.05 and Dfl. 0.15 per kg of carcass respectively. The benefit of Dfl. 0.10 per kg of carcass was added to the carcass type payment. Participating in the vertical coordination program resulted in an addition to the meat price of Dfl. 0.04 per kg. This price benefit was also added to the carcass type payment for farm C.

The farmers were asked to specify the relation between their income and the corresponding family expenditures. This appeared to be difficult. All farmers stated that they would not use part of their money that was available for investment for purchasing land. The "land investment fraction" was therefore equal to 0 for all three farms. The variables "last update equipment" and "last update inventory" had to be estimated because they contained several assets (feed installation, drinking water installation, crates, ventilation system, isolation) with different lifetimes, which were replaced in different time periods. Also the distinction between inventory and equipment was vague for some assets.

For each pig building, the productivity parameters (turnover ratio, feed conversion rate, percentage of meat, and carcass type payment) which were used as start values for ISM, had to be estimated. Extension officers X and Z both used three-year-farm averages as start values for ISM. These averages were calculated by the information system of farm A and farm C respectively. In specifying the start values per pig building, extension officer Z did not differentiate between the four pig buildings with respect to their productivity level, although these buildings were not the same as to modernity. Extension officer Y estimated the start values per pig building for farm B by using the calculated results from a technical record system for each building separately.

As shown in Table 2, the number of pig places per farm varied from 1,400 to 2,430. The three participating farms had a larger than average herd size. The age of the buildings also varied considerably. Technical performance parameters were: number of fattening pigs delivered per pig place (rate of turnover); kg of feed per kg growth (feed conversion ratio); percentage of meat; and carcass type payment. All farms were financially highly leveraged, with relatively recent loans.

For those characteristics in Table 2 where the average pig farm presented no information, ISM used either system parameters or trend values. It was assumed that the framework, inventory and equipment of the average pig farm building were 100 months old on average, and that solvency of the average pig farm remained at 72% over time.

3. Results of the field test

In the field test, the advice without using ISM was compared with the advice using ISM. In using ISM, the calculated farm worth in the first year for farms B and C differed 5% and 1% respectively from the calculated farm value in the same year without using ISM. If for farm A the farm house value Dfl. 200,000 was subtracted from the farm value of Dfl. 1,260,000, farm A would have a value of Dfl. 1,060,000. ISM calculated a net worth of Dfl. 960,000 for farm A.

The farm results in month 12 calculated by ISM indicated a large relative net worth for farm C, a slightly below average relative net worth for farm B, and a small relative net worth for farm A. Relative net worth was defined as the ratio of the net worth of the individual farm compared with the net worth of the average Dutch farm at the same time. Farms A and B had a very low solvency at the end of year 1, and farm C had a high financial leverage. In Table 4 it is shown that for all three farms solvency in month 12 was lower than in the first year in Table 3. This was due to the fact that in Table 3 calculations were based on a meat price adjusted for the hog price cycle, while in Table 4 calculations were made including the effect of an initially decreasing meat price for the first year of the simulation period.

Farms A and B had less modern buildings compared with farm C. Moreover, farms A and B had loans with a relatively long remaining average loan term. Farm A, however, had good technical results.

A summary of the plans prepared with ISM and plans prepared without ISM, is presented in Table 3 and Table 4. The results were derived from income and balance sheets which were added as appendices to the written plan. The calculations in Table 3 represent expected values for the next year (year 1), assuming "normal" meat prices. Extension officers did not use time horizons longer than 1 year in their calculations. This is the reason for having results in Table 3 presented for the next year. With ISM it is possible to calculate results over a time horizon of up to 20 years. The calculated farm results for year 20 using ISM are presented in Table 4. Calculations in Table 4 are based on the assumption of fluctuating meat prices.

Main differences in the calculations in Tables 3 and 4 are that in Table 3 extension officer X categorizeded for farm A the value of the farm house under "Farm value", and that in Table 3 for farm B extension officer Y included the "off-farm" income of the farmer's wife under the heading "Other income". Both assumptions are contrary to the calculations in Table 4. Also farmer A's wife had a job outside the farm. But extension officer X did not include this in his calculations without ISM.

Further examination of the results in Table 4 reveals that the expected relative net worth did not differ much for the three first ranking strategies. Generally, technical, non-cyclical; economic, non-cyclical; and economic, cyclical replacement strategies realized the best economic results. Increasing the willingness to borrow money had a positive influence on relative ending net worth. Increasing the willingness to increase unpaid labour on farm A had mixed results for the simulated strategies. For all three farms, expansion had a positive influence on the relative ending net worth. The relative ending net worth varied with varying price conditions. Farms A and C were able to bear unfavourable price conditions. However, farm B would be forced out of business if unfavourable price conditions occurred. The other aspects presented in Table 4 were simulated with 1 iteration, representing normal price conditions.

Increasing manure disposal costs with an average of Dfl. 20 per m^3 over the entire simulation period had a strong negative impact on all three farms. For farm B it meant going out of business even. An increase in both the minimum and maximum level of family expenditures by Dfl. 10,000 led to an increase in the average monthly ratio of the farmers'

Table 3. Summary of calculated results without using ISM.

Farm	A	A-alternative	B	C
FARM RESULTS IN YEAR 1				
Number of pig places	1,400	2,400	1,740	2,450
Hog margin per pig per year	190	184	138	204
Expected farm margin	246,434	410,000	228,515	506,869
Housing costs	162,130	290,370	160,450	310,173
Miscellaneous farm Costs	14,000	14,000	15,000	22,000
Manure Disposal Costs	38.000	60,000	30,000	68,000
Labour Income	32,304	45,630	23,065	106,696
Calculated Interest	72,306	116,253	49,530	118,217
Paid Interest	74,854	177,529	52,800	95,660
Farm Income	29,756	-15,646	19,795	129,253
Other Income	0	0	25,000	7,400
Family Expenses	20,000	20,000	55,000	48,000
Income Tax	0	0	0	76,000
Estate tax	0	0	0	0
Miscellaneous expenses	10,000	10,000	5,000	11,500
Savings	-244	-45,646	-15,205	1,153
Depreciation	83,950	142,350	92,710	168,044
Loan repayment	36,500	105,000	44.000	66,000
Available for Investment	47,206	-8,280	33,505	103,197
Farm value	1,260,000	2,417,000	1,085,000	2,036,000
Long term loans	600,000	1,650,000	660,000	1,081,000
Solvency (%)	33	15	30	38

Table 4. Summary of calculated results with using ISM.

Farm	A		B		C	
FARM RESULTS IN YEAR 20						
Relative net worth per strategy (*)						
- technical,non-cyclical (TN_MAX)(**)	3.39 (1)		0.61 (3)		3.30 (2)	
- technical, cyclical (TC_MAX)	2.98 (6)		0.19 (6)		3.20 (4)	
- technical, anti-cyclical (TA_MAX)	3.13 (5)		0.20 (5)		2.88 (6)	
- economic, non-cyclical (EN_MAX)	3.38 (2)		0.61 (2)		3.30 (3)	
- economic, cyclical (EC_MAX)	3.37 (3)		0.66 (1)		3.37 (1)	
- economic, anti-cyclical (EA_MAX)	3.20 (4)		0.41 (4)		3.13 (5)	
Chosen strategy (***)	EN1000		TN1000		EC1750	
- relative net worth	1.83		0.86		2.65	
- expansion effect (****)	0.22		0.28		0.46	
- relative value of capital	0.1044		-0.1285		0.0403	
- marginal value of labour	-0.0201		0.0009		0.0214	
Relative net worth for varying meat price conditions - very low	1.44		0.00		1.75	
- low	1.77		0.00		2.13	
- normal	1.83		0.86		2.65	
- reasonable	2.41		0.97		3.73	
- good	2.64		1.32		3.71	
Impact What-if scenario manure costs	-0.42 (-23%)		-0.86 (-100%)		-0.85 (-32%)	
Impact family expenses						
- minimum/maximum expense level	24/72	34/82	63/70	53/60	40/80	50/90
- family expenses ratio	1.08	1.24	1.13	0.96	1.25	1.40
- relative net worth	1.83	1.70	0.86	1.03	2.65	2.47

(*) Numbers between () represent ranking order.
(**) MAX means the additional pig places allowed by the maximum leverage and the maximum hours per farm per year. The expansion strategy is in some cases presented by a fixed number of pig places.
(***) EN1000 means economic, non-cyclical replacement with an expansion strategy of 1000 pig places
TN1000 means technical, non-cyclical replacement with an expansion strategy of 1000 pig places
EC1750 means economic, cyclical replacement with an expansion strategy of 1750 pig places
(****) Increase in relative net worth compared with the same replacement strategy, but without expansion.

own family expenditures compared with the family expenditures of the average Dutch farm over a period of 20 years. The increase ranged from 1.08 to 1.24 for farm A and from 1.25 to 1.40 for farm C. Due to this increase in family expenditures, relative net worth decreased from 1.83 to 1.70 for farm A, and from 2.65 to 2.47 for farm C. For farm B the impact of lower, instead of higher, family expenditures was calculated.

The contents of the advices prepared by the extension officers participating in the field test is presented in Table 5. The results in Table 5 reveal several differences between plans using ISM and plans without using ISM. A minor difference occurred between the advice using ISM with farm visit compared with the advice using ISM without farm visit with respect to the general opinion on the economic position of the farm. However, this may be caused by differences in wording.

Table 5. Summary of items mentioned within the written plan.

Farm	Without ISM With farm visit A			With ISM With farm visit A			With ISM Without farm visit A		
	A	B	C	A	B	C	A	B	C
General opinion of the farm									
- good	x		x			x	x		x
- reasonable				x					
- bad		x			x			x	
Advice on strategies									
- farm expansion: expand immediately			x			x			x
expand later				x	x		x	x	
do not expand	x	x							
- replacement strategies: no replacement									
technical					x			x	
economic				x		x	x		x
- anticipatory strategies: non-cyclical				x	x		x	x	
cyclical						x			x
anticyclical									
Mentioning impact on economic position:									
- family expenditures	x			x	x	x	x	x	x
- changes in manure costs			x	x	x	x	x	x	x
- willingness to use unpaid labour				x	x	x	x	x	x
- willingness to borrow money						x	x	x	x
- influence varying meat prices			x		x	x		x	x
Other: start using information system		x							
improve technical results	x	x			x				

Without the use of ISM, immediate farm expansion was regarded as not feasible for 2 of the 3 farms. Using ISM, a farm expansion strategy was advised for all 3 farms. However, this did not mean that immediate expansion was advised. It meant that the expected results over a time horizon of 20 years were better if an expanding strategy was applied. According to ISM results, farms A and B were not able to expand during the first few years of the simulation period. Due to too small an additional debt capacity, farms A and B were not able to buy a pig farm building before years 5 and 10 respectively. But with and without ISM, an immediate expansion was not advised for farms A and B. For the plan on farm expansion, without using ISM, the extension officers extrapolated only one year ahead in time. Using ISM, a time horizon of 20 years was applied.

Within ISM, economies of scale were built in through the existence of overhead. However, the profitability of farm expansion using ISM also depended strongly on the productivity level of the simulated farm. The more the productivity level of the farm sank below the productivity level of the average farm, the higher chances were that farm expansion was not profitable. On all participating farms, productivity level was at least equal to or above productivity of the average farm.

Without using ISM, replacement strategies for the buildings were not dealt with in the plan not using ISM, contrary to the plan drawn up by using ISM.

Without using ISM, the extension officers mentioned the impact of family expenditures and of changes in manure disposal costs on relative ending net worth only once. When using ISM, these issues were mentioned in all the plans, together with mentioning the impact of the farmer's willingness to provide more unpaid labour. The advice resulting from using ISM covered more aspects, and was better supported by quantitative information.

When making a plan when using ISM, the plan "with a farm visit" only differed slightly from the plan "without a farm visit". When not using ISM, extension officers included more miscellaneous aspects in their recommendations, for example, the suggestion for starting to use a system for herd recording.

During the field test, all three extension officers recorded the time they spent on distinct activities for preparing the advice. The time required, for preparing the written plan for the pig farmers, excluding PC text editing, is presented in Table 6. The results presented in Table 6 indicate that preparing a plan without using ISM took 13.83 hours on average per farm. Preparing a plan with using ISM took on average 12.83 hours "with a farm visit" and 3.17 hours "without a farm visit". It must be mentioned that the time required for preparing a plan with using ISM "with a farm visit" cannot be compared directly with the time required for preparing a plan without using ISM. In case ISM was not used, the extension officers had to visit a farmer in their region, whereas the extension officers using ISM who had to visit a farm had to travel to another region, leading to on average 1.84 additional hours of travelling time. One reason the plan with using ISM required less time was that ISM had been designed to use as few data as possible. Furthermore, the output was designed to present only essential information without all details. Adjusted for the difference in travelling time, the time required for preparing advice using ISM equaled 80% of the time required for preparing advice not using ISM.

Table 6. Time required for preparing a written plan (Hours).[1]

DSS	Without ISM			With ISM			With ISM		
Farm Visit	With farm visit			With farm visit			Without farm visit		
Officer	X	Y	Z	X	Y	Z	X	Y	Z
Farm	A	B	C	C	A	B	B	C	A
Collecting data on farm	2.5	3.0	2.5	2.5	2.0	2.0			
		(2.67)			(2.17)				
Travelling	1.0	0.5	1.0	2.0	3.0	3.0			
		(0.83)			(2.67)				
Data entry and calculating	5.0	5.0	4.5	4.0	4.0	4.0			
		(4.83)			(4.0)				
Analyzing/formulating plan	5.5	7.0	4.0	4.0	4.0	4.0	3.5	3.0	3.0
		(5.5)			(4.0)			(3.17)	
Total	14.0	15.5	12.0	12.5	13.0	13.0	3.5	3.0	3.0
		(13.83)			(12.83)			(3.17)	

1. Numbers between () are average values for the three extension officers.

When using ISM without visiting the farm, the necessary time to analyze the results and to formulate the written plan did not differ much from the time required for these activities using ISM after having visited the farm. However, it must be mentioned that someone still has to collect the input data, with the risk of not collecting all the information required.

4. Discussion

It is difficult to define a framework with which a system's performance can be compared. Organizations have difficulties in specifying which systems they want to use within their organization. Only a method for comparing the way extension officers actually work is left.

For evaluating the impact of a decision support system for strategic pig farm planning on the plan of extension officers, a field test was carried out. For practical reasons, only 3 farms and 3 extension officers participated in the field test. However, using small case studies is considered a feasible empirical method to evaluate decision support systems in an operational environment. This conclusion was also drawn by Adelman (1991).

In the recommendations without the use of ISM, immediate farm expansion was regarded as infeasible for 2 of the 3 farms. When using ISM, a farm expansion strategy was advised for all 3 farms. Without using ISM, replacement strategies for the buildings, what-if scenarios, and family expenditures were hardly mentioned in the advice, contrary to the advice when ISM was used. The differences reported regarding whether or not to expand were due to the fact that ISM had a longer time horizon, compared with the plan drawn up without using ISM.

Adjusted for the difference in travelling time, the time required for preparing advice using ISM equaled 80% of the time required for preparing advice not using ISM. This may be partly due to the fact that at the beginning of the field test the extension officers had been instructed how to use ISM. This recommended a use of the system in a specific way, without deviating the subject, or considering detailed aspects of the farm.

The extension officers needed not only less time when they used ISM, but they also proceeded in a more uniform way. Without using ISM, there were differences in the advice of whether or not to take off-farm income into account and the value of the farm house. Equity increases due to off-farm income represent "unearned growth". Such an increase is not related to the performance of the pig farm itself, and should not be incorporated in the calculations. When they used ISM, the value of the farm house could not be included in the farm net worth. This was a disadvantage, because it was difficult to split up the loans into a part relating to the farm house and a part relating to the farm land and buildings.

After the field test was finished, extension officer X mentioned that he had felt uneasy about preparing advice without knowing anything else of the farm and the farmer than input and output data from ISM. It should be borne in mind, however, that user perceptions do not necessarily reflect the evaluation criteria of the organization the user works for (Davis, 1989). Based on the results from the field test, it can be concluded that extension officers can produce written advice based on required input data collected by someone else, while at the same time they have no knowledge of the farm and the farmer. This offers opportunities of benefiting from further specialization of extension officers. But, that depends on the organisation. The extension officer collecting the farm data can discuss the strategic plan of the farmer, based on a written plan produced by a colleague familiar with ISM. The question, however, is whether the officer will be able to explain the written plan to the farmer. Another alternative is to train a selected group of extension officers as strategic management experts. A more thorough set of recommendations without using more time per written recommendation may be one of the benefits.

Extension officer Y expressed that he had the feeling he should know more of ISM to be able to use it more effectively. Possible improvements are estimating the productivity level for each pig building separately, and the use of ISM in comparing specific investment alternatives like extension officer X did for farm A without using ISM.

In a meeting with representatives of the National Extension Service for Pig Husbandry the results of the field test were discussed. It was concluded that ISM can be useful for extension officers. Three extension officers will be selected to start working with ISM. Together with the three officers, one or more "extension products" will be specified in which ISM can be used as a DSS. To meet the necessary requirements with respect to strategic management skills, the three extension officers will receive training.

The study was aimed at the written advice to the farmer. The advice based on ISM contained several elements dealing with personal values. The extension officer who will discuss this advice with the farmer needs to be a farm management specialist, but requires also good communicative skills and practical experience in pig farming to identify problems at an early stage. If the ISM-user takes the ambitions and capacities of the pig farmer into account, ISM can be a useful tool .

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Chapter 5

The expected economic consequences of expansion plans for individual pig farms

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Abstract

This research assessed the economic consequences of pig farm expansion strategies using the Investment Simulation Model (ISM). ISM gives insight into the relation between strategic investment decisions and their simulated outcome. The expected economic consequences of expansion were determined for 24 pig fattening farms. Twelve of the 24 farms had further expansion plans. Compared with the initial situation, the simulation results over a period of 20 years showed an increase in average relative net worth of 30% for the 12 farms without expansion plans, 94% for the 6 farms with realized expansion plans, and a decrease of 39% for the 6 farms that did not realize expansion. With the change in relative net worth over the entire simulation period as a dependent variable in a regression analysis, adjusted R-square was 0.85. The independent input variables, i.e., maximum expenditures, payment capacity, average age of the assets, and two of the three variables representing the expansion strategy contributed significantly to the simulation outcome. With the difference between the relative ending net worth in the basic scenario and in the what-if scenario as a dependent variable, adjusted R-square was 0.99. Parameter estimates of the independent input variables representing family expenditures, farm size, willingness to provide labour and capital, expansion strategy, income per pig place, and debt and asset characteristics were significant. Farms that expanded showed to be more sensitive to changes in manure costs than farms without expansion plans, but still their relative ending net worth was higher than the farms without expansion plans.

Keywords:pig farming, expansion, investment, simulation, strategy, scenario

1. Introduction

Capital investment decisions are important for the future viability of individual farms. Important investment motives are modernizing farm facilities, intergenerational transfer, fiscal tax considerations, farm expansion, and lowering cost price (NN, 1990). Firm expansion provides an opportunity for scale economies (Porter, 1985). A prerequisite for successful expansion is a sufficient managerial span of control. In this study, it was assumed that the span of control formed no limitation on the size of a specialized pig farm. The assumption that specialized farms can grow very large is consistent with Brewster (1950).

According to LaDue et al. (1991) farms that do not invest are most likely to be either small or operated by older farmers. This conclusion was based on an ex-post comparison with respect to farm investments. Our study, however, used an ex-ante distinction of farm investment decisions, based on the expansion strategy of 24 farmers participating in the study.

This paper was aimed at determining the expected economic consequences of expansion strategies for individual pig fattening farms. For this study, a computer-based simulation model, the Investment Simulation Model (ISM) was applied. ISM is a computer system that analyzes the impact of long-term investment strategies on individual pig farm performance (Backus et al., 1994A and 1994B). The model simulates results of a strategic plan for an individual pig farm and the average Dutch pig farm over a time horizon of maximal 20 years for a given scenario. Simulated results are analyzed for a basic and a what-if scenario with respect to future manure disposal costs.

Jeppesen (1990) and Jacobsen and Skærlund (1991) reported on computer-based planning tools supporting pig farmers. They mentioned the importance of involving farmers during the planning stage. Also in ISM, much attention was paid to the type and amount of data required from the farmer.

In the second section, the selection of participating farms and the applied evaluation criteria are described. In the third section, the results of the simulation are presented and compared with the expected results for farms with different expansion strategies and scenarios. In the fourth section, the results are discussed.

2. Materials and methods

The simulation study was based on 24 starting situations with 35 input variables and 8 output variables. Each starting situation was based on input data collected on a single farm. The farm was simulated in one run over a period of almost 20 years ahead. Each simulation run resulted in one observation. In ISM, monthly meat prices and interest rates have a cyclical character. The period did not exactly equal 20 years. For the specific "random" seed number used for the simulation of the participating farms, the meat price cycle equalled zero after 221 months. Using a simulation run of 221 months offered the possibility comparing starting values of the variables with final values, without variation in meat prices disturbing the comparison.

2.1. Participating farms

Determining the expected economic consequences of farm expansion requires production and financial data of individual farms. The data were derived from 24 fattening pig farms that used the services from a Dutch farm accountancy organisation.

In compiling a suitable data set for this study, only farms with production records and certified income statements over the year 1992 were selected, which ensured that the input data had carefully been screened and edited by professional field staff. For farm data to be certified as usable, non-farm assets and liability data must be complete. In order to be able to participate in the study, a significant part of farm income must be derived from the production of fattening pigs.

Based on these criteria, the data set used in this study consisted of 24 farms. All 24 farms were visited individually for data gathering. First, data on income statements were gathered at the regional offices of the accountancy firm, followed by individual farm visits during which production data and information on expansion plans were collected. The average interview lasted 2 hours, with a minimum of 45 minutes and a maximum of 4 hours. The duration of the interviews varied because of different interests of the participating farmer.
Six of the participating farms had raised the number of fattening pigs recently. Eight farms owned no land at all. Half the number of participating farms had no plans for further expansion in fattening pig production, and only one of the 12 farms without expansion plans had expanded its fattening pig enterprise in the past two years. All farms with expansion plans would try to expand within the two coming years, except one farmer who had defined a planned expansion, starting five years after the interview visit.

Table 1 presents average input data for the simulation, representing typical Dutch pig farms. On average, the farms had less than 4 ha of land. The variables "max labour" and "max debt equity ratio" represent farmers' willingness to provide labour and to borrow money for realizing necessary replacement investments and/or planned expansion investments. If one of these constraints cannot be fulfilled, investments will not be realized within ISM.

Table 1. Average inputs of the 24 selected pig farms

Input Variable	Average	Standard Deviation
Arable land (ha)	1.35	4.25
Grassland (ha)	1.17	2.57
Maize land (ha)	1.74	2.75
Value house (Dfl)	196,020	106,878
Debt live hog (Dfl)	63	91
Income last year (Dfl)	51,456	55,485
Max. labour (Hrs/yr)	2,211	1,129
Min. expenditures (Dfl/yr)	28,335	20,436
Max. expenditures (Dfl/yr)	38,227	25,829
Max. inc. min.exp (Dfl/yr) (1)	36,093	25,954
Min. inc. max. exp(Dfl/yr) (2)	46,011	32,824
Max. debt equity ratio	1.62	0.94
Pig places	1,119	529
Expansion planned immediately (pig places)	143	245
Expansion planned later (pig places)	147	377
Starting month expansion later	5.5	14.2

(1) Maximum income where family expenditures are still at a minimum
(2) Minimum income where family expenditures are still at a maximum

Family expenditures are sensitive to price changes (Carriker et al., 1993). Brake (1968) reported on the danger of neglecting important cash withdrawals in firm growth models. In ISM, the four variables representing the family expenditures pattern as a function of farm income are: minimum expenditures (min. expenditures), maximum expenditures (max. expenditures), the maximum income where family expenditures are constant and still at a minimum (max. inc. min. exp.), and the minimum income where family expenditures are constant and still at a maximum (min. inc. max. exp). The minimum and maximum level of expenditures must be defined for a specific interval of family income. Within this interval, monthly family expenditures are calculated by linear intrapolation.

The average values of minimum and maximum expenditures were corrected for off-farm income and for other income sources. Family expenditures were corrected for other income according to the average contribution of that income over the years.

For each farm, detailed information was collected about the pig farm buildings and the loans. Per building data on the number of pig places, rate of turnover, feed conversion ratio, percentage of meat, carcass type payment, and age of equipment, inventory, and framework were collected. Per loan information about starting month, number of repayments and initial loan amount was obtained.

2.2. Evaluation criteria

In order to identify the attractiveness of farm expansion, evaluation criteria are needed to differentiate between expected future farm results that are successful and less successful. However, future farm results are also determined by actual farm performance and financial structure. The study aimed at using a limited number of evaluation criteria to be able to give the participating farmers a clear explanation of the simulation results. Evaluation criteria that can be used are performance measures, asset and debt characteristics.

Performance measures

Performance measures that were used in this study are: (1) family income per pig place, (2) payment capacity, and (3) relative net worth.
The family income per pig place can be used as a performance measure to compare pig farming with other economic activities. With this, a pig place represents the capital input required for the corresponding economic activity.

The additional debt capacity of the farmer depends on the payment capacity, the interest level as well as the expected lifetime of the asset for which the loan is required. The payment capacity is calculated using the formula:

Payment capacity = after tax family income - family expenses + depreciation - principal payment (1)

Relative ending net worth is defined as the ratio of the ending net value of the individual family farm to that of the average Dutch family farm. For technical productivity measures (rate of turnover, feed conversion, percentage of meat, carcass type payment), average data of Dutch pig fattening farms were used as a reference. For data on farm financial structure and family expenditures (solvency, family expenditures, value of the farm house), average data of Dutch family farms were used.

Debt and asset characteristics

To know the average age of pig farm buildings is useful in combination with other characteristics in the field of debt management. It is also helpful in evaluating investment patterns over time. A high average age of pig farm buildings indicates the necessity of new investments in the near future.

Debt management characteristics used in the study are solvency, long-term debt, and the remaining loan term. Solvency is a financial ratio characteristic and defined as the ratio of equity to total asset value. Long-term debt is a characteristic representing all loans excluding short-term loans and debt on live animals. The remaining loan term in months indicates the average number of monthly repayments for the actual debt.

3. Results

Simulations for 24 different farms were performed for eight different performance measures: relative net worth, farm value, family income per pig place, debt asset ratio, long-term debt, age of the remaining loans, payment capacity, and age of the pig farm buildings.

The evaluation criteria farm value, family income per pig place, long-term debt, and payment capacity are expressed in nominal Dutch guilders. Annual inflation was assumed to be 3.6%, so that the value of one guilder at the beginning of the simulation period equaled two guilders at the end.

3.1. Basic scenario

The simulation results in the basic scenario are presented in Table 2. The farms were divided into farms with and without expansion plans. Based on the simulation results, the farms with expansion plans were further divided into farms that indeed expanded during the simulation period and farms that did not.

On average, the farmers without expansion plans were less prepared to provide labour and to borrow money for investments than farmers with expansion plans. Both groups of farms had approximately the same number of pig places.

At the beginning of the simulation period, the group of farms with expansion plans could be characterized as having a lower relative net worth, an almost equal family income per pig place, a higher long-term debt with a higher remaining loan term, a lower payment capacity, and a lower average age of the pig farm buildings. The lower payment capacity was mainly a result of the higher debt level.

The group of farms with expansion plans was further divided into farms that managed to expand and farms that did not. The debt level of the farms that did not manage to expand was very high. Taking into account short-term debt, average solvency was below zero even. Also the average income per pig place at the beginning of the simulation period was much lower than farms that managed to expand. This resulted in a low payment capacity, and therefore, expansion was hardly possible for these farms.

The results presented in Table 2 clearly indicate an overall improvement of the relative net worth during the simulation period. On average, relative net worth improved by 30% for the 24 participating farms. However, it must be recognized that these farms were a biased sample. Average family income per pig place in the first year for the 24 farms was Dfl 61, compared with Dfl 40 for the average Dutch pig farm.

Also the ratio of equity to the total asset value improved. Long-term debt levels were very low at the end of the simulation period. Short-term debt, including debt on live animals, was higher at the end of the simulation period than long-term debt.

At the end of the simulation period, the group of farms that initially had expansion plans but were not able to expand could be characterized as having

Table 2. Simulation results in the basic scenario: for farms without and with expansion plans, the latter subdivided into farms, the plans of which were realized and were not.

Simulation results Mean values	Farms without expansion plans (N=12)	Farms with expansion plans (N=12) realized(N=6)	not realized(N=6)	total(N=12)
INPUT VALUES				
Maximum labour (hours)	1,801	3,347	1,898	2,623
Maximum debt equity ratio	1.03	2.37	2.07	2.22
Expansion planned immediately	0	188	383	286
Expansion planned later	0	588	0	294
Pig places before expansion	1,130	1,198	1,021	1,109
SIMULATION RESULTS MONTH 0				
Relative net worth	0.826	0.759	0.703	0.731
Farm Value (Dfl)	1,148,308	1,055,231	978,473	1,016,852
Income / place (Dfl)	62	65	53	59
Solvency	0.58	0.14	-0.03	0.06
Long term debt (Dfl)	359,511	536,682	540,337	538,509
Remaining loan term (months)	144	203	188	195
Payment capacity (Dfl)	4772	4,943	2,350	3,647
Age of the assets (months)	96	101	75	88
FINAL SIMULATION RESULTS				
Relative net worth	1.072	1.475	0.437	0.956
Farm Value (Dfl)	4,442,024	6,113,960	1,813,149	3,963,555
Income / place (Dfl)	244	212	143	177
Solvency	0.91	0.95	0.86	0.90
Long term debt (Dfl)	32,575	0	116,150	58,075
Remaining loan term (months)	28	1	30	16
Payment capacity (Dfl)	16,655	32,568	8,918	20,743
Age of the assets (months)	116	137	170	153
Realized expansion (places)	0	795	0	398
Relative net worth increase(%)	30	94	-39	31

still a lower relative net worth, a much lower family income per pig place, a lower payment capacity, and a higher average age of the pig farm buildings than the farms without expansion plans. The farms with expansion plans that did realize these had a much higher payment capacity than the farms that did not expand. Also the average increase in relative net worth of 94% was highest for these farms. The income per pig place did not improve compared with the farms without expansion plans. In ISM, farm expansion can only be realized by buying other pig farm buildings with technical results equal to the national average. So, in the simulation model applied it was not possible to buy farm buildings with a relative high income per pig place.

The Pearson correlation coefficients between the simulation results in simulation month 0 and the final simulation results are presented in Table 3. Correlation coefficients between relative ending net worth and the relative beginning net worth, the initial farm value, and the payment capacity in month 0 were high compared with correlation coefficients between relative ending net worth and debt characteristics. The final income per pig place was mainly correlated with the payment capacity, solvency, and the income per pig place in month 0.

Table 3. Pearson Correlation Coefficients between starting and ending values for selected variables.

Ending Values: / Starting Values:	Relative Net Worth	Farm Value	Income per Pig Place	Solvency	Debt	Remaining Loan Term	Payment Capacity	Asset Age
Relative Net Worth	0.65	0.65	0.34	-0.03	0.28	0.31	0.42	-0.40
Farm Value	0.65	0.65	0.34	-0.03	0.28	0.31	0.42	-0.40
Income Per Pig PLace	0.37	0.37	0.54	0.46	-0.16	-0.30	0.21	-0.13
Solvency	0.35	0.35	0.45	-0.05	0.10	0.13	0.15	-0.79
Debt	-0.28	-0.28	-0.19	0.16	0.03	0.07	-0.13	0.29
Remaining Loan Term	-0.14	-0.14	-0.04	0.53	-0.18	-0.20	0.01	0.22
Payment Capacity	0.87	0.87	0.60	0.21	-0.05	-0.15	0.77	-0.35
Asset Age	0.32	0.32	0.30	0.36	-0.39	-0.23	0.35	0.29

Final solvency was mainly correlated with the income per pig place and the remaining loan term in month 0. The correlation with solvency and debt levels in month 0, however, was low.

Table 4 shows the results of a regression analysis with the increase in relative net worth as the dependent variable. The regression analysis was based on the 24 participating farms (observations). R-square, adjusted for degrees of freedom, was 0.85. Maximum expenditures, payment capacity, average age of the assets, and two of the three variables representing the expansion strategy were highly significant.

Table 4. Results of regression analysis with increase of relative net worth during the entire simulation period as dependent variable (Adjusted R-square = 0.85).

Parameter estimates Variable	Parameter Estimate	Standard Error	T for H0: Parameter=0	Prob > |T|
Intercept	-32.818703	23.47442975	-1.398	0.1791
Maximum expenditures (Dfl)	-0.001049	0.00035774	-2.932	0.0089
Payment capacity (Dfl)	0.014135	0.00319447	4.425	0.0003
Average asset age (months)	0.390141	0.17444769	2.236	0.0382
Expansion planned later	0.348166	0.04187712	8.314	0.0001
Month later expansion planned	-6.800583	1.23125289	-5.523	0.0001

3.2. What-if scenario manure disposal costs

In the basic scenario, manure disposal costs were assumed to be Dfl. 15 per m^3. The what-if scenario for manure disposal costs was based on the assumption that these costs are gradually increasing until a specified maximum additional value, and thereafter decreasing until a value equal to the value for the basic scenario is reached. In what-if scenarios 1 and 2 manure disposal costs are on average respectively Dfl. 10 and Dfl. 20 higher than in the basic scenario.

The results presented in Table 5 indicate the negative influence of a what-if scenario with higher manure disposal costs on the relative ending net worth, for farms both with and without expansion plans. Farms that did expand faced a much stronger negative impact of the what-if scenarios than non-expanding farms. Yet, their relative ending net worth was higher than the farms without expansion plans. The absolute values of the decrease in relative ending net worth due to the what-if scenarios were equal for non-expanding farms whether they had expansion plans or not. But the relative ending net worth in the basic scenario was 2.5 times higher for the farms without expansion plans than the farms that had expansion plans but did not succeed.

Table 5. Simulated relative ending net worth for basic and what-if scenarios for manure disposal costs.

Simulation results Mean values	Farms without expansion plans (N=12)	Farms with expansion plans (N=12) realized(N=6)	not realized(N=6)	total(N=12)
What-if scenario 1				
absolute value	0.922	1.212	0.308	0.760
difference with basic scenario	-0.149	-0.263	-0.130	-0.197
What-if scenario 2				
absolute value	0.828	0.941	0.191	0.556
difference with basic scenario	-0.244	-0.533	-0.246	-0.390

What-if scenario 1: Manure disposal costs are on average 10 Guilders higher during the simulation period compared to the base scenario.
What-if scenario 2: Manure disposal costs are on average 20 Guilders higher during the simulation period compared to the base scenario.

Table 6 presents results of a regression analysis on the difference between the relative

Table 6. Results of regression analysis with the difference in relative ending net worth for the basic and the what-if scenario as dependent variable (Adjusted R-square= 0.99).

Parameter estimates Variable	Parameter Estimate	Standard Error	T for H0: Parameter=0	Prob > |T|
Intercept	0.148793	0.03666468	4.058	0.0036
Maximum labour (hrs)	-0.000154	0.00001708	-8.995	0.0001
Minimum expenditures (Dfl)	-0.000018543	0.00000162	-11.429	0.0001
Maximum expenditures (Dfl)	0.000019360	0.00000148	13.051	0.0001
Maximum debt equity ratio	-0.055457	0.00987455	-5.616	0.0005
Pig places	0.000248	0.00006869	3.605	0.0069
Area arable land (ha))	0.012316	0.00305436	4.032	0.0038
Area grassland (ha)	0.025187	0.00356992	7.055	0.0001
Area maize land (ha)	0.036504	0.00470832	7.753	0.0001
Farm value (Dfl)	-0.000000481	0.00000008	-6.244	0.0002
Income per pig palce (Dfl)	-0.003035	0.00032063	-9.465	0.0001
Remaining loan term (months)	0.000797	0.00011074	7.197	0.0001
Average asset age (months)	-0.001009	0.00025740	-3.919	0.0044
Expansion planned immediately	0.000180	0.00003996	4.502	0.0020
Expansion planned later	0.000109	0.00004045	2.683	0.0278
Month later expansion planned	-0.002900	0.00087393	-3.319	0.0106

ending net worth in the basic scenario with the relative ending net worth in what-if scenario 2. R-square, adjusted for degrees of freedom, was 0.99. The p-levels of the parameter estimates for all 15 independent variables were smaller than 0.03. A significant contribution to the specified regression model was given by the variables representing family expenditures, farm size, willingness to provide labour and capital, expansion strategy, income per pig place, and debt and asset characteristics.

4. Discussion

Collecting input data required for this study learned that specifying the minimum and maximum level of family expenditures did not cause any problems for the farmers who participated. Most farmers had difficulties in specifying the relation between family expenditures and family income, however. Specifying input values with respect to family expenditures also appeared to be difficult for farms that were not fully specialized in pig fattening.

The income per pig place at the end of the simulation had increased on average by 248% for the 24 farms, 200% of which was due to inflation and increased labour costs. A possible reason for the other 48%-increase may be that the participating farms represented a select group.

In this study, the framework in which expansion investments are evaluated was based on an ex-ante distinction of expansion plans. Compared with an ex-post distinction of expansion based on realized investment, the ex-ante distinction has a specific advantage. Within the ex-post distinction, farmers who did want to expand but, for whatever reason, were not able to realize this could not be distinguished from farmers who did not want to expand. The average results of farmers who did not want to expand were better than those farmers who were not able to expand. It should be borne in mind that farm sizes of both groups were approximately the same. So, the farmers who did not want to expand could not be characterized as farmers who had already expanded more than the farmers with expansion plans.

Ruttan (1988) argued that the optimal size of the farm is smaller in an environment characterized by high natural or institutional risk than in a low-risk environment. The study results do not contribute to this hypothesis. Although higher future manure disposal costs had a negative impact on the expected economic gains resulting from farm expansion, farm expansion still remained attractive under such a what-if scenario. There was no turning point at which expansion was no longer attractive.

Within these scenarios with increased manure disposal costs, farmers who were not able to expand faced a marginal existence as pig fattening farmers. Adjusted for inflation and labour costs, their income per pig place did not improve during the simulation period, and the existing buildings at the end of the simulation period were relatively old. For these farmers, specializing in other farm activities may be an option. If the other farm activities are also non-competitive, selling the entire farm business may be the best solution.

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GENERAL DISCUSSION

1. Introduction

This thesis deals with economic simulation to support investment decisions in pig farming. Five chapters were centred around a model of the strategic pig farm planning process. First, a basic review of the literature on strategic planning under risk and uncertainty was given (Chapter 1). In the second chapter, a computer-based model for strategic pig farm planning, the Investment Simulation Model (ISM) was developed and described. ISM is a stochastic simulation model which uses data of the individual farm and also average data representing Dutch pig farms. In the third chapter, effects of the input variables on the outcome of the response variable were analyzed for various strategies, using a stochastic approach for these inputs in the experimental design, and formalized in a regression metamodel for each replacement strategy. An evaluation procedure was developed for testing ISM under operational use and described in chapter 4. Finally, for 24 pig farms, the expected economic consequences of farm expansion plans on future economic viability were estimateded using ISM (Chapter 5).

This general discussion deals with the following topics: the model of the strategic planning process (section 2), experiences (section 3), the potential use of ISM (section 4), and possibilities for further research (section 5). In section 6, the main conclusions of the study are presented.

2. The model of the strategic pig farm planning process

The use of simulation models allows investigating farm economic results in little time. Progress in information technology created the possibility of more extensive research on strategic farm planning by using computer-based models. Models should describe relevant aspects of reality for specific questions of interest (Law and Kelton, 1991). Developing simulation models is also associated with choices among the concepts developed and specified input variables. This section deals with a critical reflection on the choices made in this study.

Development of ISM was aimed at supporting evaluation and choosing among alternative decisions. ISM enables pig farmers to gain insight into the consequences of long-term investment decisions on individual farm performance, taking into account their attitudes towards risk, personal expenditures, borrowing money and providing labour. Steps in solving a decision problem are the perception of decision need or opportunity, the formulation of alternative courses of action, identifying the consequences of these alternatives, and choice (Simon, 1960). ISM was developed to support the planning function of farm management, related to identifying the consequences of alternatives, and choice.

ISM focuses mainly on production and financing decisions. For farm decision making, production, finance and marketing decisions can be distinguished. An alternative risk management tool is buying and selling on the futures and/or options market. But since banks are willing to bear the risk of meat price fluctuations for viable pig farms by temporary arrangements of existing loans, there is less need to use this alternative.

ISM describes a pig farm with 25 input variables. A model ought to be a representation of the main characteristics of reality. That is a reason for limiting both the number of input variables and the relationships described in ISM. An additional reason for developing ISM with only essential farm specific input variables was that a limited number of input variables is considered a necessity for use in the field. Potential user organizations focus attention on the time required for instruction and use in the field and direct benefits. Pig farmers may have additional criteria for the willingness to use ISM, such as the learning effect and the availability of experienced guidance.

To make interpretation of the simulation results of ISM possible, the number of stochastic variables was limited to the pig meat price and the interest rate. The unpredictability of the environment in which pig farms must operate is to a large extent based on cyclical fluctuations in meat price and interest rates. Therefore, an approach was chosen using stochastic modelling involving random numbers (i.e. Monte Carlo simulation). Meat prices and interest rates have a fluctuating character within ISM, based on a sinus function with stochastic values for the wave length and the amplitudo of the cycle. Within a single iteration, several random numbers have to be generated sequentially. Each time that the function value of the sine equals zero, the wave length and the amplitudo of the next cycle are generated again.

The danger of omitting the sinus function in the model for the calculation of monthly meat prices and interest rates would be that for marginal farms some consequences of low prices and high lending rates are neglected; for example, the necessity to sell or buy land and buildings.

Production parameters have a deterministic character within ISM. Within present-day confinement systems, the level of production parameters within farms over years (e.g. rate of turnover, feed conversion rate) varies within much smaller intervals. Moreover, for strategic management matters, the focus is on average levels of production parameters for groups of animals rather than on individual animals, and over relatively long-term periods.

3. Experiences

Models are effective means to discuss strategic management matters. Instead of discussing assumptions about the outcome, it is possible to limit the discussion about assumptions to discussing the input. This makes it easier to discuss the subject in a way free from value judgments. Also, the model increases awareness with respect to the complexity.

Initial choices in the modelling process determine the potential value of specific applications. In ISM, different strategies have approximately the same standard deviations for the outcome variables. Different strategies were simulated under the same scenario each time. When these strategies have significantly different average outcome levels after several iterations, one strategy will be preferred, regardless of risk preference. When different strategies have almost the same average outcome level after several iterations, the choice of strategy may depend on risk preference, but its relevance is limited. In reality, however, a specific strategy may be associated with both a higher average and a higher standard deviation for the outcome variable than another strategy.

Using several iterations is the default situation in ISM, but using a single iteration may be sufficient in some cases. To describe the behaviour of the simulation outcome, a large number of iterations may be considered necessary. However, this also depends also on the field of interest. In chapter 2, it was concluded that when the interest did not so much focus on the absolute outcome values, but rather on the ranking of strategies, one iteration can give sufficient information. This conclusion holds for situations where the farm results for different strategies are simulated with the same cyclical, and stochastically determined fluctuations in meat prices and interest rates.

The use of a reference farm gives value to the simulation outcome. In the model, the average Dutch pig farm develops based on time series for parameters characterizing the monetary environment, farm structure and productivity. This approach makes easier interpretation of the simulation results for time periods up to 20 years possible.

The study revealed no decision rules that enabled individual pig farms to improve the relative economic position, except for changing personal values. In using ISM, to "beat the average farm" appeared not to be possible without providing more labour and capital or lowering family expenditures. If an individual pig farmer managed to beat the average farm by "just being smart" and if it became known to all pig farmers, then all pig farmers would alter their strategic plans, making the "smart" decision rule worthless.

The design applied to the field test, worked well. The extension organisation participating in the field test, favoured the idea of determining the potential value of Decision Support Systems for their own organisation through field tests, based on a few case studies. Using case studies can be a valuable tool in evaluating the value of Decision Support Systems (Adelman, 1991). The extension organisation accepted that to be able to compare results of an experimental group with a control group, additional effort had to be made. They stated that the instruction on ISM and its merits given to their employees was regarded as meaningful and valuable.

It is difficult to perform an overall evaluation of simulation models. Several functionalities of ISM were for practical reasons not yet included in the ISM version used in the field tests. These functionalities were 1) determining individual risk preferences and analyzing its impact on the strategy to be chosen, and 2) analyzing the results of strategies for various what-if scenarios regarding prices of feed, labour, investment costs, and inflation. Moreover, in the field tests, only direct users of ISM participated, and not chief executive officers from organizations such as extension, accountancy organizations, and lender organizations.

4. The potential use of ISM

Strategic planning gives insight into the long-term economic impact of farm expansion. According to Curtis (1983), the most important reason to do strategic planning is its close relation to the survival of the business. The test determining the economic consequences of expansion strategies for 24 pig farms (chapter 5) revealed that expansion was attractive, even when future manure disposal costs increased significantly.

Long planning horizons are necessary for strategic planning. The planning horizon varies with the issue under consideration. With respect to long-term investment decisions, the lifetime of pig farm buildings determines the planning horizon. The planning horizon should be of sufficient length to enable pig farmers to see the full effect of alternative long-term investment decisions. However, a long planning horizon does not mean that much attention should be focused on what should be done in year 20 or so of the simulation. The objectives of the farmer may change over time.

ISM needs to be used together with experienced guidance. The value of ISM lies in its possibility of supporting farmers with quantitative farm specific information. ISM gives information about the attractiveness of specific strategies, as well as their robustness for certain what-if scenarios. However, the test with pig farmers revealed that most farmers had difficulties in specifying constraints with respect to paid labour and maximum financial leverage under which they wanted to operate the farm. Experienced guidance is necessary to support farmers in specifying these input values. Furthermore, the formulation of alternatives received little attention when developing ISM. Thus, the pig farmer always needs to be aware of ISM focusing only on part of the decision process.

5. Further research

Further research is needed to incorporate the control function in ISM for assessing the viability of the individual farm. Differences observed in farm productivity and relative economic position were enormous (Chapter 5). Timely recognition of the need for a strategic change can be very beneficial for farmers. The need for a strategic change can be perceived by awareness of the farms' relative economic position in relation to personal objectives. Farmers are not always aware of the relative economic position of their farm. Moreover, the uncertainty of the farm environment requires a regular evaluation of the current farm position. Thus, the control function should be used on a regular basis. Doing so, it can support pig farmers in determining whether it is necessary to reconsider the current strategic plan.

Realistic personal and farm objectives require more consideration of personal issues and their relationship to the business (Curtis, 1983). The main issues to be considered for strategic pig farming are personal needs (expenditures, leisure, and independency) and personal attitude toward risk.

The difficulties in measuring risk preferences are tremendous. Recently-applied methods for eliciting subjective probability distributions contribute to solving the problem of overconfidence (van Lenthe, 1993). But it is still not easy to classify decision makers according to a specific preference. Individuals also change over time as does their way of decision making. Especially, for strategic management matters, where assessing the farm's environment has more relevance than at the operational level, further research on the use of what-if scenarios should have priority.

The main determinant of profitability for individual pig farms was represented by the variable "meat price disparity" (Chapter 2). This variable had a strong impact on the simulation outcome. Future research should focus on the factors determining "meat price disparity". Important factors to be taken into account are: differences in environmental legislation between European pig production areas, economies of scale, switching costs, geographical concentration, forward and backward integration, and threat of substitution.

When modelling the uncertain pig farm environment within ISM, aspects such as alternative actions with both very low probabilities and very high outcomes, either favourable or unfavourable, are neglected. An example of such a case is the outbreak of epidemic diseases on individual farms. Further research on this aspect is needed.

6. Main conclusions from the study

- The Investment Simulation Model defined and discussed in this study may be viewed as a comprehensive planning tool, allowing pig farmers and consultants to determine the consequences of alternative plans systematically. It also showed to be a valuable tool to support extension activities in this field.
- The complexity of strategic management matters does not automatically imply that hundreds of farm specific variables must be taken into account. A regression metamodel with 9 or 10 independent variables can give a reasonable estimation of the results of the Investment Simulation Model. This conclusion supports the assumption that describing one single pig farm within the Investment Simulation Model with 25 input variables is sufficient.
- Farm expansion can, in most cases, be regarded as an attractive strategy, even under a what-if scenario with higher future manure disposal costs.
- For both risk and uncertainty, serious problems remain in making the theory of decision analysis available in such a way that it can be used by farmers. Further research on this is required.
- Differences observed in farm productivity and relative economic position indicate the need for future research on the use of the control function in assessing the need for a strategic change.
- Field tests based on a few case studies to determine the potential value of Decision Support Systems for possible user organizations showed to be a valuable tool in assessing the value of Decision Support Systems.

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SUMMARY

Introduction

Learning from mistakes can be an effective educational tool. Provided with sufficient realism, Decision Support Systems can help farmers in exploring strategic management matters without having to pay for possible mistakes. In this thesis, a simulation model was developed for the support of strategic planning related to production and financial decisions on pig farms.

In chapter 1, a basic review of the literature on strategic planning under risk and uncertainty was given. The concept of decision making under risk was discussed by reviewing the theory of Subjective Expected Utility and its limitations. The Subjective Expected Utility model failed as a descriptive model.

After discussing techniques for measuring risk preferences, an overview of applied risk models was presented. Examination of the literature on empirical research on farm risk models revealed much attention for risk responses, especially for enterprise diversification. However, it was doubtful whether decision makers could be classified according to their risk preferences.

The major factors determining uncertainty within the strategic decision-making proces were outlined for pig farmers. Multiple scenarios could be used within Decision Support Systems to analyze changes in the social and political environment. However, appropriate guidelines in developing multiple scenarios were rare.

For both risk and uncertainty, serious problems remained in making the theory of decision analysis available in such a way that it could be used by farmers.

Pig farm model

In calculating the economic consequences of alternative strategic plans in pig farming, the simulation of investment decisions plays a central role. In the approach applied in this thesis, a stochastic simulation model was used which uses data from individual farms and also average data representing Dutch pig farms. Individual pig farms are characterized by their resources, such as land, buildings and loans, and their production plans. Two aspects were

considered in formulating strategic plans: farmer's objectives and the relevant farm environment. The model can help individual farmers and advisors to determine objectives by identifying the impact of strategic plans on ending net worth and family expenditures over a maximum period of 240 months.

The simulated results indicated that a higher meat price disparity of 0.02 Dfl per kg of carcass decreased the relative net worth of a simulated farm with high family expenditures and slightly above average productivity by 14.9%. The individual farm parameters, especially the rate of turnover, the feed conversion rate, and the original loan had a strong influence on the relative net worth in month 240. What-if scenarios with higher labour costs hardly influenced the relative ending net worth. A what-if scenario with higher feed prices had a significant negative impact on relative ending net worth, while higher replacement values of pig buildings influenced relative ending net worth positively. Inflation had a strong negative influence on relative ending net worth. A maximum impact value for manure disposal costs equal to Dfl 0.05 per kg forced the farm out of business.

Decision Support Systems

The Decision Support System for strategic planning on pig farms was described in chapter 3. The Decision Support System was based on a stochastic Simulation Model of investment decisions. The simulation model calculated the results of a strategic plan for an individual pig farm over a time horizon of maximal 20 years for a given scenario. For the distinct replacement strategies, a regression metamodel described the outcome of the response variable as a function of the farm variables. Regression results indicated that a linear function with only 9 or 10 farm variables already gave a reasonable estimate of the results of the simulation model. Turn over ratio, feed conversion ratio, percentage of meat, farm size, family expenses, and experience were the main parameters determining future relative farm position.

Risk attitudes played a minor role for the simulated farm, because one strategy was preferred to another, regardless of risk preference.

To analyze the attractiveness of a chosen strategic plan for different what-if scenarios, the visual method using graphical representations offered sufficient information about the results of what-if scenario analysis.

The number of years ahead, that the decision maker evaluates the consequences of simulated strategic plans influenced the strategy to be preferred.

Field tests

The model described in this thesis was designed for use in on-farm decision support. The description of the simulation model and the Decision Support System (DSS) in chapter 2 and 3 was focused on the technique for modelling pig farms. In chapter 4, attention was focused on the use of the Decision Support System in the field.

The impact of a decision support system on recommendations given by extension officers to pig farmers was assessed. An evaluation procedure was developed for testing the DSS under operational use. The model was put to the test on three farms and with three extension officers. For each farm, three sets of recommendations were prepared: 1) without using the DSS, based on a farm visit to collect data; 2) with using the DSS, based on a farm visit to collect data; and 3) with using the DSS, but where data had been collected by another advisor.

The field test resulted in striking differences between recommendations based on the DSS and those not based on the DSS. In the latter recommendations, immediate farm expansion was regarded as not feasible for 2 of the 3 farms. When using the DSS, a farm expansion strategy was advised for all 3 farms, however, not immediately. Without using the DSS, replacement strategies for the buildings, manure costs, and family expenditures were largely ignored in the advice, contrary to the advice based on the DSS. Adjusted for the difference in travelling time, the time required for preparing advice using the DSS equaled 80% of the time required for preparing advice not using the DSS. Whether or not the extension officer himself collected the farm data did not influence the advice.

In a second field test, the economic consequences of pig farm expansion strategies using the DSS were assessed. The expected economic consequences of expansion were determined for 24 pig fattening farms. Twelve of the 24 farms had further expansion plans.

Compared with the initial situation, the simulation results over a period of 20 years showed an increase in average relative net worth of 30% for the 12 farms without expansion plans, 94% for the 6 farms with realized expansion plans, and a decrease of 39% for the 6 farms that did not realize expansion. With the change in relative net worth over the entire simulation period as a dependent variable in a regression analysis, adjusted R-square was 0.85. The independent input variables, i.e., maximum expenditures, payment capacity, average age of the assets, and two of the three variables representing the expansion strategy contributed significantly to the simulation outcome. Farms that expanded showed to be more sensitive to changes in manure costs than farms without expansion plans, but still their relative ending net worth was higher than the farms without expansion plans.

Main conclusions from the study

- The Investment Simulation Model defined and discussed in this study may be viewed as a comprehensive planning tool, allowing pig farmers and consultants to determine the consequences of alternative plans systematically. It also showed to be a valuable tool to support extension activities in this field.
- The complexity of strategic management matters does not automatically imply that hundreds of farm specific variables must be taken into account. A regression metamodel with 9 or 10 independent variables can give a reasonable estimation of the results of the Investment Simulation Model. This conclusion supports the assumption that describing one single pig farm within the Investment Simulation Model with 25 input variables is sufficient.
- Farm expansion can, in most cases, be regarded as an attractive strategy, even under a what-if scenario with higher future manure disposal costs.
- For both risk and uncertainty, serious problems remain in making the theory of decision analysis available in such a way that it can be used by farmers. Further research on this is required.
- Differences observed in farm productivity and relative economic position indicate the need for future research on the use of the control function in assessing the need for a strategic change.
- Field tests based on a few case studies to determine the potential value of Decision Support Systems for possible user organizations showed to be a valuable tool in assessing the value of Decision Support Systems.

Samenvatting

Inleiding

Leren van gemaakte fouten kan een effectief leermiddel zijn. Beslissingsondersteunende systemen kunnen varkenshouders helpen inzicht te krijgen in strategisch management, zonder te veel te hoeven betalen voor mogelijk gemaakte fouten. In dit proefschrift is een simulatiemodel ontwikkeld ter ondersteuning van de strategische planning op varkensbedrijven.

In hoofdstuk 1 is een algemeen overzicht gegeven van de literatuur over strategische planning onder risico en onzekerheid. Methodische aspecten van besluitvorming onder risico en onzekerheid zijn beschreven aan de hand van de zogenaamde "Subjective Expected Utility" theorie en haar beperkingen. De "Subjective Expected Utility" theorie blijkt onvoldoende in staat te beschrijven hoe mensen in werkelijkheid beslissingen nemen.

Een overzicht van toegepaste risicomodellen is gepresenteerd. De meeste onderzoeken zijn gericht op risicomanagement middels diversificatie van de bedrijfsstructuur. Het is echter twijfelachtig of de risicopreferentie van individuen correct kan worden bepaald.

De belangrijkste bepalende factoren voor onzekerheid binnen het proces van strategisch management op varkensbedrijven zijn beschreven. Scenarios kunnen worden gebruikt in beslissingsondersteunende systemen om de invloed van structurele veranderingen in de sociale en politieke omgeving van het bedrijf te analyseren. Het ontbreekt echter aan richtlijnen voor het ontwikkelen van geschikte scenarios.

Zowel ten aanzien van risico als onzekerheid blijft het moeilijk de bestaande besluitvormingstheorie beschikbaar te maken voor gebruik in de praktijk.

Model van het varkensbedrijf

Bij het bepalen van de economische consequenties van alternatieve strategische plannen op varkensbedrijven speelt de simulatie van investeringsbeslissingen een centrale rol. De benadering in dit proefschrift gaat uit van een stochastisch simulatiemodel dat gegevens van individuele bedrijven gebruikt, alsmede referentie gegevens welke het gemiddelde Nederlandse varkensbedrijf voorstellen. Individuele varkensbedrijven worden gekarakteriseerd door hun produktiemiddelen, land, gebouwen en leningen, alsmede hun produktieplannen.

Ondernemersdoelstellingen en de relevante omgeving van het bedrijf zijn belangrijke aspecten van het strategisch plan. Het model kan varkenshouders en voorlichters helpen doelstellingen vast te stellen door de invloed van alternatieve strategische plannen op bedrijfswaarde en gerealiseerde gezinsuitgaven over een periode van maximaal 20 jaar te kwantificeren.

De simulatieresultaten geven aan dat een grotere dispariteit tussen vleesprijs en gemiddelde kostprijs over alle bedrijven van f. 0,02 per kg gepaard gaat met een afname van de relatieve bedrijfswaarde met 14,9% voor een bedrijf met zowel hoge gezinsuitgaven als een hoge produktiviteit. Vooral de kengetallen omzetsnelheid, voerconversie, en hoeveelheid vreemd vermogen hadden een grote invloed op de relatieve bedrijfswaarde in jaar 20. What-if scenarios met hogere arbeidskosten hadden nauwelijs invloed op de relatieve bedrijfswaarde in jaar 20. What-if scenarios met hogere voerprijzen, hogere mestafzetkosten en hogere inflatiepercentages hadden allen een negatieve invloed op de relatieve bedrijfswaarde in jaar 20, terwijl een what-if scenario met een hogere vervangingswaarde van de gebouwen de relatieve bedrijfswaarde in jaar 20 daarentegen positief beïnvloedde.

Beslissingsondersteunend systeem

Het beslissingsondersteunend systeem voor de strategische planning op varkensbedrijven is beschreven in hoofdstuk 3. Het beslissingsondersteunend systeem is gebaseerd op een stochastisch simulatiemodel van investeringsbeslissingen. Het simulatiemodel berekent de te verwachten resultaten van een strategisch plan, gegeven een bepaald what-if scenario, over een tijdshorizon van maximaal 20 jaren. Een regressiemetamodel beschrijft de simulatie-uitkomsten als functie van de bedrijfsvariabelen voor de onderscheiden vervangingsstrategieën. Resultaten van de regressieanalyse geven aan dat een lineaire functie met slechts 9 of 10 bedrijfsvariabelen reeds een redelijke schatting geeft van de resulaten van het simulatiemodel. Omzetsnelheid, voerconversie, vleespercentage, aantal varkensplaatsen, oppervlakte land, gezinsuitgaven, en aantal jaren ervaring bleken de belangrijkste invloed te hebben op de toekomstige economische positie van het bedrijf. Risicopreferenties speelden slechts een beperkte rol voor het gesimuleerde varkensbedrijf, omdat de keuze van de optimale strategie onafhankelijk bleek te zijn van de risicopreferentie.

Voor het analyseren van de aantrekkelijkheid van een strategisch plan voor verschillende what-if scenarios blijkt de visuele methode op basis van een grafische weergave voldoende informatie te verschaffen.

Het aantal jaren vooruit waarover de individuele varkenshouder de consequenties van alternatieve strategische plannen evalueert, is van invloed op het gekozen plan.

Veldtesten

Het in dit proefschrift beschreven model was ontwikkeld voor gebruik door individuele varkenshouders. De beschrijving van het simulatiemodel en het beslissingsondersteunend systeem in hoofdstuk 2 en 3 was gericht op het modelleren van varkensbedrijven. In hoofdstuk 4 was de aandacht gericht op het gebruik van het beslissingsondersteunend systeem in de praktijk.

De invloed van het beslissingsondersteunend systeem op het advies van voorlichters aan varkenshouders is bepaald. Een evaluatieprotocol was ontwikkeld voor het testen van het DSS onder praktijkomstandigheden. De veldtest werd uitgevoerd met drie voorlichters en drie varkensbedrijven. Voor elk bedrijf werden drie adviezen opgesteld: 1) zonder gebruik van het systeem, gebaseerd op een bedrijfsbezoek voor het verzamelen van gegevens; 2) met gebruik van het systeem, gebaseerd op een bedrijfsbezoek voor het verzamelen van gegevens; en 3) met gebruik van het systeem, waarbij de gegevens door een collega voorlichter werden verzameld.

De veldtest resulteerde in opvallende verschillen tussen de verstrekte adviezen. In het advies zonder gebruik van het systeem werd onmiddellijke uitbreiding voor 2 van de 3 bedrijven als niet haalbaar beschouwd. Echter, in geval van gebruik van het systeem werd een expansiestrategie, zij het niet direct, voor alle drie de bedrijven geadviseerd.

Zonder gebruik van het systeem werd de invloed op de resultaten van vervangingsstrategieën, mestafzetkosten, en het niveau van gezinsuitgaven niet gekwantificeerd. Gecorrigeerd voor verschillen in reistijd, bleek de benodigde tijd voor het opstellen van het advies met gebruik van het systeem 80% van de tijd benodigd voor het opstellen van het advies zonder gebruik van het systeem te vergen. Het al of niet zelf verzamelen van de bedrijfsgegevens bleek niet van invloed te zijn op de inhoud van het advies.

In een tweede veldtest werden de economische consequenties van expansieplannen met behulp van het systeem bepaald voor 24 varkensbedrijven. Twaalf van de vierentwintig varkensbedrijven hadden expansieplannen.

Vergeleken met de uitgangssituatie nam de relatieve bedrijfswaarde over een periode van 20 jaar met 30% toe voor de 12 bedrijven zonder expansieplannen, met 94% voor de 6 bedrijven met gerealiseerde expansieplannen, terwijl de relatieve bedrijfswaarde met 39% afnam voor de 6 bedrijven met expansieplannen die gedurende de simulatieperiode niet werden gerealiseerd. Met de verandering in relatieve bedrijfswaarde over de gehele simulatieperiode als afhankelijke variabele in een regressieanalyse bleek de gecorrigeerde R^2 gelijk te zijn aan 0,85. De onafhankelijke variabelen maximum gezinsuitgaven, betalingscapaciteit, ouderdom van de stallen, en de expansiestrategie bleken significant te zijn. Bedrijven die uitbreidden bleken gevoeliger te zijn voor veranderingen in mestafzetkosten dan bedrijven zonder expansieplannen. Echter hun relatieve bedrijfswaarde na 20 jaar was nog steeds hoger dan die van de bedrijven zonder expansieplannen.

Belangrijkste conclusies van het onderzoek

- Het simulatiemodel dat in dit proefschrift is beschreven kan worden beschouwd als een hulpmiddel bij de strategische planning op varkensbedrijven, door varkenshouders en voorlichters de mogelijkheid te bieden de consequenties van alternatieve strategische plannen op systematische wijze te bepalen. Het simulatiemodel bleek een waardevolle ondersteuning te zijn voor de huidige voorlichtingsactiviteiten.
- De complexiteit van strategisch management impliceert niet automatisch dat honderden bedrijfsvariabelen in beschouwing moeten worden genomen. Een regressiemetamodel met 9 of 10 variabelen geeft reeds een redelijke schatting van de uitkomsten van het simulatiemodel. Deze conclusie ondersteunt de veronderstelling dat het modelleren van een individueel varkensbedrijf op basis van 25 variabelen in ieder geval voldoende is.
- Bedrijfsexpansie kan in de meeste gevallen worden beschouwd als een aantrekkelijke strategie, zelfs onder een what-if scenario met hogere toekomstige mestafzetkosten.
- Voor zowel risico als onzekerheid resteren aanzienlijke beperkingen in het toepassen van de besluitvormingstheorie door landbouwers.
- Veldtesten waarin op basis van slechts enkele case studies de potentiële waarde van beslissingsondersteunende systemen voor organisaties wordt bepaald, blijken zinvol.
- Geobserveerde verschillen in produktiviteit en relatieve economische positie zijn een indicatie voor de noodzaak van verder onderzoek naar het evalueren door individuele varkenshouders van een eventuele noodzaak tot strategische verandering.

Curriculum vitae

Gerardus Bartholomeus Catharina Backus (Gé) werd op 12 juni 1956 geboren in Helden (Limburg). In 1975 behaalde hij aan het St. Thomascollege te Venlo het VWO diploma. In september 1975 werd een start gemaakt met de studie Landbouweconomie aan de toenmalige Landbouwhogeschool Wageningen. In september 1981 sloot hij deze studie af met als afstudeervakken Agrarische Bedrijfseconomie, Algemene Agrarische Economie en Agrarische Geschiedenis.

Na zijn afstuderen trad hij in september 1981 in dienst bij het Ministerie van Landbouw en Visserij, waar hij diverse functies heeft vervuld op het gebied van voorlichting en onderzoek. Sinds 1986 werkt hij als hoofd van de afdeling economie bij het Proefstation voor de Varkenshouderij te Rosmalen.