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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 using 23 variables. The simulation model calculated the results of a strategic plan for an individual pig farm over a time horizon of a maximum of 20 years for a given scenario. For six distinct replacement strategies, regression metamodels were specified to describe the outcome of the response variable as a function of the farm variables. The regression results indicated that a linear function with only nine or ten farm variables gave a reasonable estimate of the results of the simulation model. Turnover ratio, feed conversion ratio, percentage of meat, farm size, family expenses, and experience were the main parameters determining future relative farm position. For farms with high levels of family expenditures and/or financial leverage an economic replacement strategy was optimal. Risk attitudes played a minor role in the choice of the optimal strategy, 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. The number of years ahead for which the decision maker evaluated the consequences of simulated strategic plans influenced which strategy was preferred.

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, the investment simulation model (ISM), was developed. ISM gives insight into strategic planning on pig farms, in terms of the relation between strategic plans and their simulated outcome (Backus, 1994). It was developed to analyze the impact of long-term investment strategies on the individual performance of farms with fattening pigs. Replacement strategies of breeding sows and boars are not considered. Based on the results of a field

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test, ISM was considered useful for extension officers by the Dutch Extension Office for Pig Husbandry (Backus et al., 1995).

With ISM, the individual pig farm can be described in terms of investment strategies, maximum labor, 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 loans. To describe a pig farmer with one farm building and one loan the model uses a total of 23 input variables: three variables describing the loan, eight describing the pig farm building, and 12 representing the farm. Moreover, two additional variables are required to represent the farmer's risk attitude. Relative final net worth, the ratio of the final net worth of the individual farm to the final net worth of the average pig farm, is used as the major outcome variable.

2. From ISM to DSS

A model ought to be a representation of the main characteristics of reality. This is a reason to limit the number of input variables, the relationships, and the strategies described in ISM. For the effective use of ISM as a DSS it must be able to guide the DSS user in his search for the optimal strategy. Also, the possible impact of rapidly changing environments has to be taken into account. To serve as an individual DSS for pig farmers, additional features were implemented.

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 lifespan of farm assets. A farmer can also apply anticipatory strategies: (1) a non-cyclical investment strategy, (2) a cyclical investment strategy, or (3) an anti-cyclical investment strategy. For a cyclical investment strategy, replacement investments are delayed when meat prices are low, and accelerated when meat prices are high. The opposite holds for cases of anti cyclical investment strategies.

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. Because of the presence of economies of scale in the model, it is assumed that expansion will be attractive in order to reach the limits of maximum labor and maximum leverage. The assumption that expansion provides an opportunity for scale economies, given sufficient managerial span of control, is consistent with Brewster (1950).

Regression models are an effective way to approximate the relative final net worth surface for alternative strategies. A simulation experiment has to be carried out in order to derive input data that can be used for specification of the regression models. Kleijnen (1992) reported on the use of such regression metamodels. Relative final net worth for each strategy was regressed on 23 input variables describing the farm, the loan, and the pig farm building. Each estimation was based on 140 simulation runs with different observations (farms). The estimation is a relatively simple linear relationship between farm variables and relative final net worth. The estimated equations can be used to predict the performance of the six strategies on other pig farms. If this function, the regression metamodel, is estimated for each of these six combinations, determination of the optimal strategy for an individual farm amounts to choosing that combination of replacement and anticipatory strategies, where the corresponding function value is maximal.

Relative final net worth Y is a function of the simulation results of an individual farm described by the set $\{X_1,\ldots,X_k,\ldots X_{22}\}$. The relative final net worth (Y) can also be approximated as a linear function of these input variables

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

where Y is relative final net worth; X_k is input variable k ($k = 1,\ldots,22$) (within the regression metamodel, an individual farm can be described by 22 instead of 23 variables, because the number of principal payments for long-term loans was set constant at 240); i is replacement strategy i (technical or economic) ($i = 1,2$); j is anticipatory strategy j (non-cyclical, cyclical, anti-cyclical) (j = 1,2,3); a_{ijk} is an estimate of the effect of input variable X_k in strategy ij; ϵ is an error term.

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

The simulation for each of the 140 farms was based on a random selection of the values of the 22 input variables. The selection 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 (see appendix A). 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 labor and the maximum leverage.

Six discrete strategies were distinguished (remember: i = 1,2 and j = 1,2,3). Regression analysis was applied for each of these six strategies. First, six regression metamodels based on 140 observations each, were specified with all 22 inputs as independent variables. Then, variables which did not contribute significantly to the regression model were excluded, and for each distinct strategy regression metamodels were specified again, but this time with the remaining nine or ten significant variables. Table 1 presents the standardized parameter estimates and the degree of significance of the independent and significant variables for each of the six strategies.

The results in Table 1 indicate that all signs of the parameter estimates were as expected, which supports the validity of regression metamodel (1). Table 1 also presents R^2 values adjusted for degrees of freedom; these ranged from 0.64 to 0.69 for the different strategies. Most significant for each distinct strategy were the variables representing farm size (number of pig places and land size), farm productivity (turnover ratio, feed conversion ratio, and meat percentage), and initial experience.

Larger differences in standardized parameter estimates for different replacement strategies were mainly present for the variables 'starting loan', 'savings account', 'maximum hours', and 'maximum family expenses'. These variables were the least significant. Differences in attractiveness

Table 1
Standardized estimates of the significant regression parameters (a_k) and their significance (P) levels [a]

	Strategy [b]					
	TN	TC	TA	EN	EC	EA
Starting loan (month) [c]	−0.132c	−0.122b	−0.107b	−0.090b	−0.092b	−0.100b
No. 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
Max. hours (h $year^{-1}$)	a	a	a	a	0.088b	0.087b
Max. family expenses (Dfl. $year^{-1}$)	−0.099b	−0.087b	−0.089b	−0.094b	a	a
$Max._{inc}-min._{exp}$ (Dfl. $year^{-1}$) [d]	0.111b	0.103b	0.088b	0.119b	0.111b	0.108b
Adjusted R^2 [e]	0.68	0.66	0.69	0.69	0.65	0.64

[a] a, $P > 0.1000$; b, $0.0100 < P < 0.1000$; c, $P < 0.0100$. 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 (Statistical Analysis Systems Institute Inc., 1990).
[b] Replacement: TN, technical, non-cyclical; TC, technical, cyclical; TA, technical, anti-cyclical; EN, economic, non-cyclical; EC, economic, cyclical; EA, economic, anti-cyclical.
[c] The variable 'starting loan' represents the number of months prior to the moment the loan was applied.
[d] The maximum income level where the family expenditures are still constant and at a minimum.
[e] Adjusted for degrees of freedom.

of the distinguished strategies were therefore small. Compared with an economic replacement strategy, the more long-standing the loan and/or the higher the savings account, the more attractive was the technical replacement strategy. Return on investment appeared to be better for savings than for improving farm productivity. The higher the maximum number of hours and/or the maximum family expenses, the more attractive was the economic replacement strategy. Especially for farms with high levels of family expenditures and/or financial leverage, an economic replacement strategy was optimal. Such farms need to make timely investments to improve the profitability of their pig farm operation to avoid limitation on further investment, imposed by loan capacity.

The stability of the optimal strategy depends on the influence of changing environmental variables. In the DSS 'what-if' scenarios are defined for five variables: inflation, labor costs, feed price, replacement value of pig places, and manure disposal costs.

'What-if' scenarios for the variables labor costs, feed price, pig farm replacement value, and manure disposal costs are defined as having a gradual impact 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 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' scenarios 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 has an influence on the strategy to be chosen. Therefore, a one-dimensional search method, using graphical representations, was applied. The method searched maximum impact values where the strategy which is initially optimal, becomes suboptimal. Strategies were compared pairwise. This visual method can be used as an alternative to the bisection method (Press et al., 1989) when 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 begins with two starting points for the maximum impact value, namely 0 (point a) and a value which can be specified by the DSS user (point b). Next, function values are calculated for the point occupying the central position between the two starting points, point c. The procedure is then repeated and function values calculated for the middle points of both intervals [a;c] and [c;b]. For following iterations, all distinct intervals are divided into two intervals of equal size, and function values 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 with 2250 pig places, average productivity, and a long-term debt of Dfl. 665.000. Fig. 1 presents the values of relative final net worth for different 'what-if' scenarios for inflation and for two different strategies. Strategy TN0 can be characterized as a technical, non-cyclical replacement strategy without expansion. Strategy EN0 differs from strategy TN0 in that it applies an economic replacement strategy.

The results indicate that more than 0.75% additional inflation above the base inflation rate of 3.6% per year had a strong negative influence on this farm in the case of strategy TN0. The relative final net worth was only affected by infla-

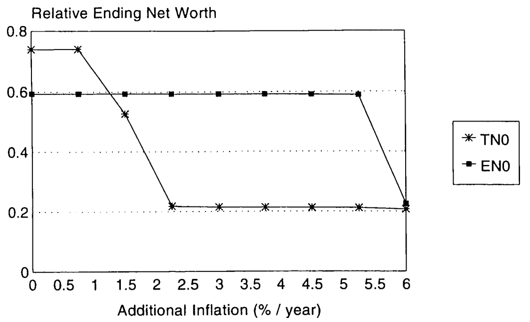

Fig. 1. What-if scenarios for inflation. Technical (TN0) vs. economic (EN0) replacement. TN0 is technical, non-cyclical replacement. ENO is economic, non-cyclical replacement.

tion above the base rate at an additional inflation rate of 5.25–6.0%.

The impact of the 'what-if' scenarios on the relative final net worth was 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 indicate that for the simulated individual farm the choice of the optimal strategy was sensitive to changes in the relevant farm environment.

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

In conclusion, the results presented show that despite the complexity of strategic planning, a regression metamodel with only nine or ten farm variables gave a reasonable estimate of the results of the simulation model, and therefore of the choice of the best strategy. This choice, however, is made given a base scenario with assumptions about the future farm environment. Rapidly changing environments demand a decision framework that takes alternative scenarios into account. Therefore, ISM is still necessary, because with different 'what-if' scenarios, different outcomes are possible.

3. Impact of risk attitude

Comparisons of strategies and 'what-if' scenarios are a feature of the DSS which, so far have been applied to one iteration. This approach is usually sound for the DSS, if one is not so much interested in the functional value itself, but in the strategy to be chosen (Backus, 1994).

To examine the impact of risk attitude, a stochastic approach using more than one iteration was applied in the DSS. Based on the risk preferences of the decision maker towards compared 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 the DSS by applying the so-called interval approach to the measurement of decision makers' preferences (King and Robison, 1981). This approach is a preference measurement technique designed to be used in conjunction with stochastic dominance with respect to a function (SDWRF), developed by Meyer (1977). It utilizes a lower bound $R1(x)$ and an upper bound $R2(x)$ of the absolute risk aversion function. Depending on $R1(y)$ and $R2(y)$, the DSS can evaluate two alternative strategies. Relative final net worth was used as the criterion variable on which the strategies are ordered. The result concerned dominance or preference for one strategy over the other(s).

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

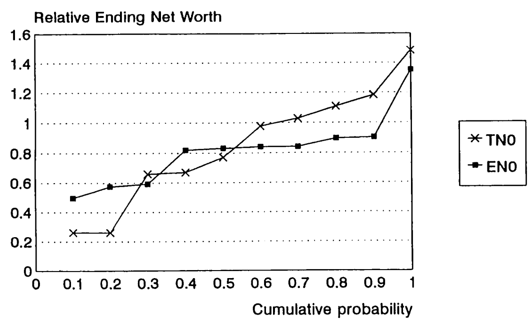

Fig. 2. Relative ending net worth for different strategies.

distinct strategies: (TN0) and (EN0). In Fig. 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. 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.

4. 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 may influence 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 their lifespan, because the consequences of alternative replacement strategies can become visible only if replacements have actually been realized. In Fig. 3, the simulation results of a comparison of a technical, non-cyclical replacement strategy without expansion (TN0) with an economic, non cyclical replacement strategy without expansion (EN0) are presented for varying time horizons.

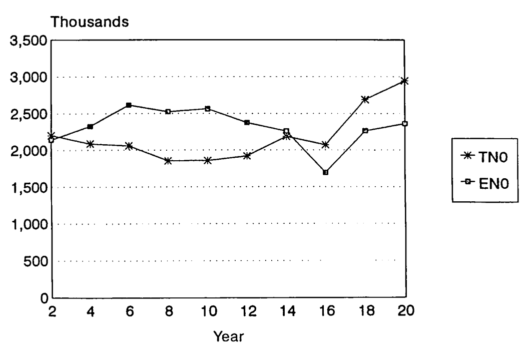

Fig. 3. Ending net worth with varying time horizons (Dfl.).Technical (TN0) vs. economic (EN0) replacement.

The results clearly indicate the need for time horizons of sufficient length. Based on a personal time horizon of 4–12 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 15–20 years, strategy TN0 gave better results for this particular farm. Pig farm extension organizations usually calculate the results of investment alternatives 1–5 years ahead. According to the latter results, this may lead to wrong conclusions.

5. 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 to explore strategic management matters without having to pay for possible mistakes. However, a prerequisite to using DSS is having the time necessary to collect information and enter data. To use the investment simulation model (ISM), developed in this research, 23 variables have to be collected.

It appeared that linear functions with nine or ten 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.

Owing 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. The objectives of the farmer may change over time. Moreover, there is a fair chance that by the time the effects of a particular strategy are fully known, the environment has become different from that in which the strategy was chosen. Therefore, the DSS must be used repetitively and frequently, for example each year, to evaluate the strategy to be implemented the following year, and to evaluate alternative strategies with a time horizon of 20 years.

According to Hogarth (1975), decision makers are selective, sequential information processing individuals 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 of dealing 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.

Appendix A

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	1000000
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	6000
	Rate of turnover	2.5	3.3
	Feed conversion rate	2.6	3.2
	Meat percentage	52	56
	Carcass type payment (Dfl. kg^{-1})	0.00	0.05
Farm	Land (ha)[a]	0	10
	Financial account (Dfl.)	0	50000
	Savings account (Dfl.)	0	200000
	Initial experience (month)	5	360
	Family income (Dfl. $year^{-1}$)	0	10000
	Max. hours (h $year^{-1}$)	2000	10000
	Max. leverage	0.5	4.0
	Fraction land investment	0	0.5
	Min. family expenses (Dfl. $year^{-1}$)	20000	50000
	Max. family expenses (Dfl. $year^{-1}$)	50000	80000
	Max. income with min. fam. exp.[b]	40000	70000
	Min. income with max. fam. exp.[c]	70000	100000

[a] This value is the same for the area of arable, grass, and maize land.
[b] The maximum income level at which the family expenditures are still constant and at a minimum (Dfl. $year^{-1}$).
[c] The minimum income level at which the family expenditures are still constant and at a maximum (Dfl. $year^{-1}$).

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