Assisting Whole-Farm Decision-Making through Stochastic Budgeting

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ASSISTING WHOLE-FARM DECISION-MAKING THROUGH STOCHASTIC BUDGETING

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ABSTRACT

Stochastic budgeting is used to simulate the business and financial risk and the performance over a six-year planning horizon on a Norwegian dairy farm. A major difficulty with stochastic whole-farm budgeting lies in identifying and measuring dependency relationships between stochastic variables. Some methods to account for these stochastic dependencies are illustrated.

The financial feasibility of different investment and management strategies is evaluated. In contrast with earlier studies with stochastic farm budgeting, the option aspect is included in the analysis.

INTRODUCTION

In assessing any business investment, particularly for a family business such as a farm, there are two aspects to consider. One is the profitability of the investment, which is often a fairly long-run matter. The future is shrouded in uncertainty so such decisions often involve a high degree of intuition or strategic thinking. The other aspect is financial feasibility. Usually large investments involve borrowing substantial amounts of money, implying a significant increase in financial risk of the business. For example,

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a couple of bad years in production and an unexpected rise in the interest rates can send the business bankrupt. This risk is most severe in the first years after the investment when the debt is at a peak. In this paper a model of the business and financial risk of the farm over such a shorter time horizon is presented.

A typical farm in Eastern Norway is used as a case study. In the planning year the farm has dairy and some beef production, cereal crops and some forestry. The (male) farmer is thinking about five alternative investment and management strategies, but is very uncertain which he should choose.

In making a decision about a business investment or future strategic choice farmers have to account for many aspects. Among other things, they have to make up their minds about the following questions: What future activity gross margins (GMs) are realistic to use in farm planning? Will the present subsidy scheme change in the future, and if so how? When borrowing money, will there be any changes in the interest rates over the next few years? What about the labour requirement for different activities - how many hours will be required per unit? Will there be a need to hire labour, and if so, how much? What price might be obtainable if milk quota could be sold in the future? These and other similar uncertainties imply use of stochastic budgeting.

Richardson and Nixon (1986) developed the stochastic whole-farm budgeting model FLIPSIM (Farm level income and policy simulator). FLIPSIM simulates, under price and yield risk, the annual economic activities of a representative farm over a multiple-year-planning period. It has been used for policy analysis (e.g. Knutson et al., 1997), comparing risk management strategies (e.g. Knutson et al., 1998), technology assessment, financial analysis etc.

Milham et al. (1993) developed a stochastic whole-farm budgeting system, called RISKFARM. RISKFARM was originally developed to enable the appraisal of the financial performance and risk effects of alternative farm and non-farm investments and potential changes in the financial structure of Australian farms (Milham, 1992). Compared with FLIPSIM, RISKFARM has several stochastic variables and the stochastic dependency is specified in another way (multivariate empirical probability distribution in FLIPSIM vs. hierarchy of variables approach in RISKFARM).

In this analysis a whole-farm stochastic budgeting model is used which includes stochastic GMs, interest rates, fixed costs, labour requirements for activities and milk quota price. The model simulates the farm performance and the business and financial risk over a six-year planning horizon. Risky strategies are evaluated by cumulative distribution functions (CDFs) and by stochastic dominance. In concept, the model draws on the work of Milham et al. (1993). In contrast with earlier studies using stochastic farm budgeting, the option value of a 'wait and see' strategy is included in the analysis.

OVERVIEW OF THE FARM SYSTEM AND INVESTMENT STRATEGIES

The case farm used in this study is in the lowlands of Eastern Norway. Winters are long in this area, normally with snow and temperatures many degrees Celsius below zero. The climate gives high farm business costs compared to most other countries. Farm size is 33 ha of arable land and 50 ha of forest. The main activity on the farm in the planning year 1999 was milk production, with a milk quota of 100 000 litres. The area not used to grow fodder crops was used for cereal production, mainly wheat and barley.

For the past several years the prices of farm products in Norway have mainly been decided through annual negotiations between the two farmers’ unions and the Government. As a result, prices for almost all enterprise have been administrated. Despite this price regulation, the GM per unit for each enterprise within a farm is uncertain. This uncertainty is caused by factors such as weather and plant and animal diseases causing yield and product quality uncertainty. With increased deregulation more price volatility is expected in future causing still higher GM volatility. The prices of forest products largely follow the world market prices and also vary between years.

The Norwegian government has assigned relatively large subsidies to the agriculture sector compared with other countries. Even if both the national and international agricultural policy environments change in the future, it seems almost certain that the Government will be obliged to continue making high transfer payments to the Norwegian agricultural sector so long as it is considered desirable to retain a substantial number of people in agriculture. Hence, it was assumed in this paper that the subsidy per farmer will be at the same level in the planning period as in the planning year 1999.

Since 1983, production quotas have regulated the production of cow milk. From 1996, the Government introduced a system for administrative redistribution of milk quotas. Farmers can apply to purchase quotas up to 20% of the total quota they had the previous year, although not more than the farm area allows. The farmer only gets an offer if other farmers are selling their quotas. If a farmer wishes to sell quota, he must sell the whole quota.

The floating interest rate on borrowed funds is rather uncertain. A farmer with large investments and high debt is normally rather dependent on the interest rate level over the next few years. It is possible to get a loan at a fixed interest rate to avoid some risk, but in the long run the cost is naturally higher.

Maximum family labour available on the farm is 2600 h, on the basis of one full-time owner operator. If the labour requirement on the farm exceeds this limit, the farmer must hire labour at a fixed cost per hour.

The plan was prepared in 1999 for the planning period 2000 to 2005. In 1999 the farmer was concerned that existing level of production was too low to return an adequate level of profit in future, but he was very uncertain what strategy he should then chose. The choice was among the following five strategies:

1. Continue as today. This choice implies continuing to produce milk to the level of the quota of 100 000 litres and use the arable land not under fodder crops for cereals.
2. Continue as today, but invest in a new farm building for chicken production. The new building would be for 80 000 chickens per year and was estimated to cost NOK 1 440 000.
3. Invest in improvements of the present farm building and combine milk production with beef production in addition to cereal production. A new cowshed would reduce the labour needed for milk production. This released time would be used for beef production. In addition to producing the milk quota of 100 000 litres, the improved building would make it possible to keep 30 beef cows. The total investment cost was estimated to be NOK 2 700 000.
4. Abandon the milk production, sell the milk quota for NOK 5.50/litre (that is what the sellers are offered for the first 100 000 litres) today and only produce cereals. It was assumed that 50% of the available family labour per year (1300 h) would be devoted to half-time paid off-farm work at a fixed wage of NOK 125 000 per year. If the labour requirement on the farm were to exceed 1300 h, labour would be hired at a fixed cost. No investment cost was required.
5. Same as strategy 4, except wait to sell the milk quota until the quota price eventually get above NOK 7.00/litre.

If the farmer does not invest in farm improvements, 300 m^3 of forestry will be felled every second year. If the farmer does invest, 1000 m^3 of forestry will be felled in the investment year and 500 m^3 the first year after the investment.

THE MODEL

Traditional whole-farm budgeting is done on the basis of fixed-point estimates of production, prices and financial variables to predict point estimates of financial results. In reality, the events and conditions planned for will not turn out as assumed. A common response to this problem is to conduct sensitivity analysis as part of the planning exercise in order to determine the range of possible results. In a sensitivity analysis it is customary to consider changes in only one variable at time. The effects on the performance measure of combinations of errors in different variables are, therefore, largely ignored (Hull, 1980). And, when many variables are uncertain, sensitivity analysis of the effect on financial performance for more than just few variables becomes tedious and difficult to interpret. Moreover, the sensitivity analysis gives no indication of the likelihood of a particular result being achieved.

To overcome these problems an alternative approach is stochastic budgeting, which accounts for some of the main uncertainties in the evaluation and then gives an indication of the distribution of outcomes. In this framework uncertain variables can be expressed in stochastic terms, and many combinations of variable values can be analysed to provide a full range of expected outcomes (Milham et al., 1993).

The model in this paper was built up from a deterministic whole-farm budgeting model, formulated in an Excel spreadsheet. The model operates over a year-to-year strategic level, and produces annual financial reports over a six-year time horizon. The financial reports are derived from functional equations linking the farm production activities, subsidy schemes, capital transactions, consumption activities and financing and tax obligations.

Stochastic features were introduced into the budget by specifying probability distributions for variables assumed to be most important in affecting the riskiness of the selected measure of financial performance.

Objective probabilities based on historical data alone can seldom reflect the uncertainty about future situations in stochastic analysis (Hull, 1980; Hardaker et al., 1997; Milham, 1998). The subjective expected utility theorem leads to the conclusion that the right probabilities to use for decision analyses are the decision maker's subjective probabilities. The probability distributions used in the model in this paper were partially based on historical data (objective frequencies) and partially based on elicited subjective judgments.

One aspect that is important to consider in stochastic budgeting is the question of the stochastic dependency between variables (Hull, 1980; Hardaker et al., 1997). The distribution of performance variables will be seriously compromised if important stochastic dependencies are ignored. For example, if yield and price are positively correlated, an analysis that assumes zero correlation will under-estimate variance of revenue, and will over-estimate it if they are negatively correlated. Stochastic dependency between variables was built in to the model either by use of the stochastic dependency embodied in the discrete historical data matrix or by use of the 'hierarchy of variables approach' (Hardaker et al., 1997).

With Palisade's @Risk add-in software a Monte Carlo sampling procedure was used to evaluate the budget for a large number of iterations. In the simulation, values of parameters entering into the model were chosen from their respective probability distributions by Monte Carlo sampling and were combined according to functional relationships in the model to determine an outcome. The process was repeated a large number of times to give estimates of the distributions of the performance measures which can be expressed as cumulative distribution functions (CDFs), or summarised in terms of moments of the distributions. The appropriate number of samples to draw in the Monte Carlo sampling exercise depends on the required degree of stability of the simulation results. To ensure stability, 1500 sample simulation experiments were used. The random generator used in the simulation process was seeded to ensure that the same set of random samples would be sampled for each strategy evaluated.

In financial analyses such as this it is not always obvious which performance measures one should use; the choice depends on the purpose of the analysis. Milham (1992) used net worth and net cash flow at the end of the planning period as objectives in appraisal of financial performance of alternative farm and non-farm investments on Australian farms. The purpose of this analysis is to compare different investment and production strategies with respect to financial feasibility, and the measure of performance used is equity at the end of the last (sixth) planning year. Equity is a measure of financial solidity, and a large equity promises the ability to survive losses in the future. A farmer is technically bankrupt if the equity is negative. One problem with this measure is in case when the equity is positive at the end of the planning period yet in some of the years between the start and end of the period the equity was negative, and the farmer was therefore insolvent. To prevent this scenario an extra high interest rate on loans was built in to apply if the equity became negative at any year during the planning period. In practise, banks also require a higher interest rate for loans with high risk. Private consumption was assumed fixed every year in the planning period, independent of bad or good years.

Specification of stochastic variables in the model

As already noted, the stochastic variables in the model include fixed costs, activity GMs, interest rates, labour requirement for activities and milk quota price.

The fixed costs are assumed normally distributed around a stochastic time trend, and the hierarchy of variables approach (Hardaker et al., 1997; Milham, 1998) was used to account for this. The hierarchy of variables approach is a means of avoiding the need to directly determine the relationship between each pair of co-related variables. The approach requires selection of a macro-level variable to which all types of fixed costs can be expected to be correlated. The macro-level variable used was the price index of agricultural means of production and production services, *PC*, maintained by Statistics Norway (1986-99) over the period 1985 to 1998. The hierarchy of variables approach involved the following steps. First, the time trend was derived by regressing the price index of agricultural means of production and production services, *PC*, against time, *t*:

$$PC_t = \gamma + \delta t + e_{PCt} \qquad e_{PCt} \sim N\left(0, \sigma^2_{PC}\right), \;\; t = (1, \ldots, 14) \tag{1}$$

Second, equation (1) was used to predict the price index agricultural means of production and production services, *PC*, for every year in the farm plan period. The predicted means from equation (1) were assumed to be the means of a normal distribution, with the standard deviation of error component, σ_{PC}, used as the standard deviation of the normal distribution:

$$\hat{PC}_t = \hat{\gamma} + \hat{\delta} t + N\left(0, \sigma^2_{PC}\right) \qquad t = (16, \ldots, 21) \text{ for the planning years 2000 to 2005} \tag{2}$$

Third, each price index for farm buildings, FC_1, machinery and equipment, FC_2, hired labour, FC_3, and other fixed costs, FC_4, was regressed against *PC*:

$$FC_{it} = g_i + h_i PC_t + e_{FC_i t} \qquad e_{FC_i t} \sim N\left(0, \sigma^2_{FC_i}\right), \; t = (1,\ldots,14), \; i = (1,\ldots,4) \tag{3}$$

where i is type of fixed costs index, FC_i. Fourth, the predicted stochastic time trend in equation (2) was used in equation (3) to forecast price indexes of future fixed costs for each i. The error component from equation (3) with mean zero and standard deviation, σ_{FC_i}, was included to account for normally distributed fixed costs for each i:

$$\hat{FC}_{it} = \hat{g}_i + \hat{h}_i \hat{PC}_t + N\left(0, \sigma^2_{FC_i}\right) = \left(\hat{g}_i + \hat{h}_i \hat{\gamma}\right) + \hat{h}_i \hat{\delta} t + N\left(0, \hat{h}_i^2 \sigma^2_{PC} + \sigma^2_{FC_i}\right),$$
$$t = (16,\ldots,21) \tag{4}$$

From equation (4) we observe that the predicted price index of each fixed cost i has: a different constant term, a different drift term and different variance but the constant term, drift term and variance for each price index of fixed cost depend partly on the predicted trend in the macro variable PC. An implicit simplifying assumption is that all stochastic effects derived from national costs data are applicable to the individual case farm. For this analysis the standard deviation of the error component, σ_{FC_i}, was assumed to increase linearly by 2.5% a year over the planning period.

The estimation of parameters of the probability distributions for the stochastic GM variables and their stochastic dependency was partially empirically based and partially based on elicited subjective distributions. Since no suitable data for the case farm exist, the Farm Business Survey (driftsgranskingsdata) from the Norwegian Agricultural Economics Research Institute (NILF, 1992-99) was used to estimate historical GM variation of activities within farms between years. Both national and international developments (WTO and European Union) imply that Norwegian agricultural policy will be changed in the future. In that case historical data are not relevant in our decision model. I therefore elicited from an expert (a national agricultural economics adviser) his subjective marginal distributions of the individual activity GMs, and the historical GM series was reconstructed. To estimate historical GM variation of activities within farms between years and reconstruct this historical GM series I followed exactly the method used in Lien and Hardaker (2001: 24-26).

The reconstructed series in Table 1 have the subjectively elicited means and standard deviations while preserving the cross-section stochastic dependencies embodied in the historical data. Then, the 'state of nature'-matrix in Table 1 is a discrete distribution of expected activity GMs for the first year in the planning model.

Table 1. Distribution of activity GMs in NOK per unit[a] by state for the first planning year in the model

State	1	2	3	4	5	6	7	8	Mean	Std.dev.
Prob.	0.13	0.09	0.09	0.16	0.16	0.16	0.09	0.13		
Barley	8392	5164	6885	5759	5997	6943	6826	7145	6633	1068
Wheat	9540	6127	9068	5873	7643	7551	7902	8669	7733	1414
Milk cow	13056	13795	12015	11273	12156	14233	12192	13124	12720	1051
Beef cow	5659	6013	5288	5606	4755	5363	6118	5674	5507	398
Chicken	2974	3072	2822	2809	2750	2880	2966	3033	2900	122
Forestry	207	200	185	194	209	202	199	198	200	8

[a] Barley and wheat are per hectare. Milk and beef cows are per head. Chicken is per 1000 head. Forestry is per m^3 sold spruce roundwood.

As with fixed costs, stochastic trend in the different activity GMs in the state of nature-matrix (Table 1) were also accommodated using the hierarchy of variables approach. The macro-level variable used was the price index of total farm products for the period 1985 to 1998, provided by Statistics Norway (1986-99). The hierarchy of variables approach used for the stochastic trend in activity GMs follows the same steps as described for fixed cost earlier. The only difference was that the stochastic noise term from step 3 was not included in step 4, since the stochastic noise in the activity GMs was described by the state of nature matrix. The predicted stochastic trend index for each year from the hierarchy of variables approach was multiplied by the corresponding activity GM in the state of nature matrix. This procedure implies an assumption that the stochastic time trend in the total farm products experienced between 1985 to 1998 will continue. It also assumes that the time trend, which was derived from national price data, was applicable to activity GMs on the farm analysed.

It was assumed that the uncertainty increases with the planning horizon. A linear increase in the subjective standard deviation of the activity GMs with ± a specified percentage (2.5% used in this paper) for each year represents increased uncertainty. This adjustment, in addition to the stochastic trend adjustment, gives a different state of the nature matrix for every year in the plan. To account for the cross-section stochastic dependency, in each iteration of the simulation the sampling procedure was programmed so that the same state of nature was used for all activities.

In the year 1999, when the plan was done, the following levels of interest per year were assumed: short-term loan interest rates 9%, long-term loan interest rate 7.5%, deposit interest rate 6%. The probability distributions and trends over the planning horizon in the stochastic interest rate on financial assets and liabilities were forecasted with an autoregressive model. The reason for using an autoregressive model and not a simple regression model is that interest rate often has a mean reversion trend, i.e. the interest rate normally reverts to a long-run trend. The forecasting model was estimated using annual average rates on Governments bonds of ten years maturity for the period 1985 to 1999. Interest on Governments bonds was assumed to be the macro-level variable affecting all interest rates. It was assumed that the interest rates on short- and long-term loans and deposit are all perfectly correlated. After identification, estimation and diagnostic checking, a simple first-order autoregressive model, AR(1) was identified. In this model interest rate this year depends only on interest rate last year plus a random disturbance, which was assumed normally distributed. The forecast values and their standard deviations from the estimated AR(1) equations were used as indexes for the stochastic distribution and stochastic trends of all interest rates used in the budgeting model.

Labour requirements of activities were assumed stochastically independent of the other groups of variables. The uncertainty about the labour requirements per unit was specified by triangular probability distributions. An expert (a national agricultural economics adviser) specified the minimum, maximum and most likely labour requirements for each activity on the farm. It was assumed that these probability distributions remain the same over the six years modelled.

The milk quota price was assumed fixed for the year 2000 (NOK 5.50/litre) and for the years 2001 to 2005 was assumed to follow a discrete distribution, stochastically independent of the other groups of variables. The lowest assumed quota price was zero (the case when the redistribution of milk quota is removed) and the highest assumed price were NOK 9.00/litre.

In this subsection some approaches to dealing with stochastic specification are illustrated. Which method should be chosen in a particular application will depend on the nature and causes of the dependency between the stochastic variables and data and information available. The hierarchy of variables approach and the autoregressive model require relevant historical data. In cases where historical data not are relevant, as for the GMs in this paper, some combination of subjective probabilities, estimates of historical correlation between activities and simulation of stochastic trend combined with the hierarchy of variables approach may be a suitable method.

Ranking risky strategies

The term risk is used in different ways. Three common interpretations are the chance of bad outcomes, the variability of outcomes and uncertainty of outcomes. Following Hardaker (2000) risk is best formalised as uncertainty of outcomes, e.g., as the whole distributions of outcomes.

To present the financial feasibility of alternative strategies CDFs of the performance measure are informative. For example, from the CDF for equity we can find the likelihood for each of the analysed strategies that the farmer will be insolvent at the planning horizon.

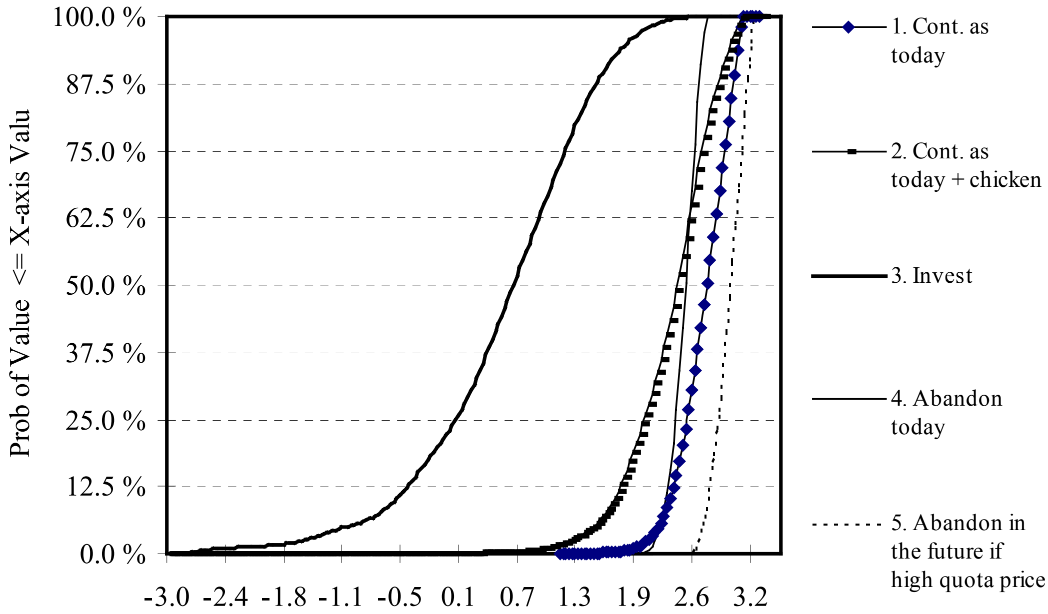
Stochastic dominance analysis is often used to order risky prospects for which whole distributions of outcomes are available (e.g. Milham, 1992). A stochastic dominance criterion is a decision rule that provides a partial ordering of risky prospects for decision-makers whose preferences conform to a specified set of conditions. First- and second-degree stochastic dominance are often not discriminating enough in empirical work. A more powerful criterion, stochastic dominance with respect to a function (SDRF), was introduced by Meyer (1977), and was used in this analysis. The decision making class is defined by upper and lower bounds on the absolute risk aversion coefficient, r_a. In this paper the software computer program developed by Goh et al. (1989) was used for the computational task of ranking the prospects using the SDRF-approach.

RESULTS

Figure 1 show the graphs of CDFs generated for equity for each of the five strategies, while Table 2 contains a summary of the final results of the stochastic dominance analysis.

Figure 1 show that strategy 3 has about 25 %chance that the farmer will be insolvent by the end of the planning period. The lower tails of the CDFs for strategies 1, 2, 4 and 5 all lie to the right of the point representing zero equity, implying zero probability of insolvency at the planning horizon. Note that accounting for the wait and see option value of milk quota sale increases the equity measure at the end of the planning horizon considerably (strategy 5 c.f. strategy 4).

Figure 1. Cumulative distribution of equity in millions NOK for different investment and management strategies.



The relation between absolute and relative risk aversion is $r_a(w) = r_r(w)/w$ where w is wealth. With an equity of NOK 2 450 000 (the farmers equity at the beginning of the planning period) a value of absolute risk aversion, $r_a(w)$, in the range 0.0000002 to 0.0000016 correspond to relative risk aversion, $r_r(w)$, in the range 0.5 (hardly risk avers at all) to 4 (very risk avers). These bounds on $r_a(w)$ were used in the SDRF analysis. The main results from Goh et al.'s (1989) SDRF program ranked the 5 strategies as follows: strategy 5 dominates strategy 1 dominates strategy 4 dominates strategy 2 dominates strategy 3 (Table 2). In other words, SDRF analysis, in this case, leads to a risk-efficient set with only one member - strategy 5 - and this was the option recommended to the farmer.

Table 2. Pairwise comparison matrix[a] to investigate SDRF for a set of bounds for the investment and management problem

Range	$0.0000002 \leq r_a(w) \leq 0.0000016$				
	Strategy				
Strategy	1	2	3	4	5
1. Cont. as today	-	1	1	1	0
2. Cont. as today + chicken	0	-	1	0	0
3. Invest	0	0	-	0	0
4. Abandon today	0	1	1	-	0
5. Abandon in the future if quota price is high	1	1	1	1	-

[a] 1 = win, 0 = loss, - not compared

CONCLUDING COMMENTS

Since farming is a risky business it is important in planning to account for risk. Information from an ordinary deterministic budgeting model done on the basis of point estimates of uncertain variables may not tell the whole story for future investment and management decisions on a farm. A stochastic budgeting approach may give more realistic and more useful information about alternative decision strategies.

Great flexibility in planning can be represented using stochastic budgeting. In this paper business risk, financial risk and the option aspect are integrated, and different investment and management strategies are evaluated. Many other applications are possible. Available special-purpose software (e.g. @Risk) allows stochastic budget models to be constructed and used much more easily than in the past.

Experiences gained in this study suggest some principles for similar work. First, the model should be kept as simple as is judged reasonable. It is important to be critical in choice of stochastic variables in the model - too many make it complicated to account for stochastic dependencies between variables. The intention with budgeting models is not to give exact answers, but to highlight consequences of different strategies. Second, it is critical to make good estimates of the distributions of key uncertain variables. Unrealistic estimates make the analysis a waste of time. Third, it is important to identify and measure stochastic dependencies between variables satisfactorily, at least if this is thought to be important. Some methods to build in these dependencies are illustrated in the paper.

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BIBLIOGRAPHICAL SKETCH

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