An Application of Target-MOTAD Programming to the Analysis of Downside Business and Financial Risk on Farms

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In this paper a description is provided of the development and use of a target-MOTAD model for use in consultative work with farmers who are under financial pressure. The analysis of downside risk and introduction of a trade-off between financial and business risks are key features of this model that make it especially applicable to such situations.

1. Introduction

Mathematical programming methods have been used as tools supporting farm advisory work for more than two decades. Early analyses included determination of optimal feed mixes (Dent and Casey 1967). The methods seemed successful in such partial applications, and enthusiastic modellers set off to extend the approach to whole-farm decision making. Although some progress was achieved with such models in a more aggregate agricultural policy analytic role (Hazell and Norton 1986; Heady and Srivastava 1975), the benefits from using whole-farm mathematical programming models have been less clear in a farm management role.

Deterministic programming models overlooked the significant variability in farm operations. While this is less of a problem in the analysis of single farm enterprises, where the objective is to approximate the best level of use of an input or combination of inputs, variability generally is the kernel of the issue where, in the presence of risk-averse behaviour, multiple enterprises (including financing activities) are being considered in a whole-farm setting.

There are various whole-farm programming models that incorporate risk. They include risk programming (Hazell 1971; Hazell and Scandizzo 1974), safety-first methods (Roy 1952; Boussard and Petit 1967; Kennedy and Francisco 1974) and game theoretic approaches (McInerney 1967). To represent the risky farm-level situation with any of these models requires a large data gathering exercise and a complex model. Furthermore the type of financial risk exposure that we wished to analyse demanded the avoidance of downside risk. This tended to make the most-used risk programming approaches such as MOTAD (Hazell 1971) inappropriate because of their equal weighting of positive and negative variations in outcomes.

Our objective in this study was to test target-MOTAD (Pederson and Bertelsen 1986) against these criticisms in a realistic on-farm context. As a safety-first approach, it was hypothesised that it would provide a reasonable theoretical basis for aiding farm decision making in circumstances where downside risk was the concern of the decision maker, possibly where survival was at risk. However, an empirical test in an actual farm situation was the only way to judge its tractability as a farm management tool. In the process of its application to a case-study farm a bound on the method was discovered which suggested that a safety-first criterion may not be appropriate where non-survival of the farm business has a reasonably high probability.

Finally given that on actual farms downside risk is most often associated with financing the business, it was desirable to use a method that incorporated financial risk. Pederson and Bertelsen (1986) have

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used a target-MOTAD model to examine the 'trade-off' between paying off the farm debt as quickly as possible to reduce financial risk (*i.e.* reducing the level of fixed financial obligations) and spreading business risks through diversification of enterprises (*i.e.* adoption of flexible strategies). Our task was to include within the target-MOTAD framework the type of financial risk-business risk trade-off which was possible on the farms that we were dealing with.

2. Theoretical Background

2.1 Target-MOTAD

The target-MOTAD model has its roots in the mean variance (E-V) analysis developed in the 1950s (Markowitz 1952; Tobin 1958), and many commentaries have been made about the suitability of E-V analysis as a decision criterion (*e.g.* Tsiang 1972, 1974). The optimal solution to an E-V problem can be obtained using quadratic programming. Mean-absolute deviation analysis or MOTAD is a linear technique designed to approximate this quadratic result (Hazell 1971) and can be solved using linear programming. MOTAD is built on the assumption that risk is perceived as the absolute deviations from the mean. Unlike the quadratic programming technique of E-V analysis in which deviations are squared, larger deviations are not given extra weight with mean-absolute deviation analysis. However, when the outcomes are approximately normally distributed the MOTAD efficient set closely resembles the E-V efficient set (King and Robison 1984).

Adaptations of the above two efficiency criteria, which account for the safety-first approach, include those by Porter (1974), Tauer (1983) and Watts, Held and Helmers (1984). Porter developed a target-semivariance analysis while the remaining authors were involved in the development of a target-negative deviation approach.

Target-semivariance analysis assumes that decision makers perceive risk as deviations below a critical, target level of income. The squaring of deviations below the target level results in quadratic programming being used, as in E-V analysis, so that larger deviations are given more weight (Bertelsen 1985). Larger deviations below the mean are therefore penalized more than smaller deviations. However, this characteristic is unlikely to be an important influence in a time of economic hardship, and seems unwarranted as a justification of target-semivariance analysis.

Target-semivariance analysis requires a covariance-semivariance matrix to be specified. This involves a necessary level of data accumulation uncharacteristic at a farm level. In contrast, target-negative deviation analysis, or target-MOTAD, avoids the need for such a matrix and can be solved using linear programming. This is because it is the absolute (rather than squared) level of negative deviations that are operable in the risk constraint, which is the probability weighted sum of deviations below the target income level.

> "No numerical index of risk preference is required in target-negative deviation analysis. The level of constraint on negative deviations from target is inversely related to the degree of risk aversion. The risk-efficient set of actions is derived by maximizing expected income at varying levels of risk constraint. A trade-off occurs between expected income and deviations below the target income level" (Bertelsen 1985, p. 15).

Further theoretical support for target-MOTAD comes from Fishburn (1977) who demonstrated that target-negative deviation analysis produces an efficient set which is a subset of the second degree stochastic efficient set.

2.2 Financial and Business Risk

An aspect, often given cursory treatment in mathematical programming analyses, is the influence of the farm-firm's financial position on production activities. Such treatment seemed to contradict our observation that the debt position of the farm was of central importance, particularly where downside risk was of concern to the farmer. In this context, it is necessary to define financial risk and business risk. Financial risk is defined as the added variability of the net cash flows relative to owner's equity that results from the fixed financial obligation associated with debt financing (Weston and Brigham 1978). Business risk is the inherent uncertainty of the farm business resulting from production variability and input and product price uncertainty. Uninfluenced by the method(s) of finance, business risk is commonly defined by the coefficient of variation s_a/r_a, where the expected net operating income is r_a and the standard deviation is s_a.

Total risk (TR) faced by the equity holders of the farm-firm is then the product of business risk (BR) and financial risk (FR) where risks are measured in terms of coefficients of variation:

$$TR = BR * FR \tag{1}$$

Barry (1983) developed an extended portfolio model, shown in equation 2, to explain the impact of leverage on total risk:

$$TR = (S_a / R_a) * \{R_a P_a / (R_a P_a - I_d P_d\} \tag{2}$$

where S_a is standard deviation of return on risky assets,
R_a is expected return to the risky assets,
I_d is interest rate on debt,
P_a is proportion of risky assets in the portfolio, and
P_d is proportion of risk-free asset (debt) in the portfolio.

Noting that the first term on the right of equation 2 is business risk (S_a/R_a), then it is observed that leverage (or change in P_d) is the mechanism which amplifies business risk. Importantly, the size of the multiplicative risk effect caused by the final term of equation 2 (which measures financial risk) depends on its denominator, which measures the amount by which expected return on business assets exceeds the cost of borrowed funds. Also, "since variability of returns to assets (S_a) and the index of financial leverage (P_d) are both positively related to the level of total farm risk, a strategic trade-off could occur between financial management strategies which modify business risk exposure and scale adjustments in leverage" (Pederson and Bertelsen 1986, p. 68).

It was hypothesised by Gabriel and Baker (1980) that farmers adjust the production mix and marketing methods in order to reduce business risk when they are faced with greater financial risk and vice versa. A change in the business or financial portfolios may occur as a compensatory action to cope with a forced change in the other portfolio in an attempt to keep total risk stable. Gabriel (1979) observed a strong financial response to changes in business risk on Central Illinois grain farms. In addition the impacts were found to vary between the different groups of farmers categorised according to their level of risk aversion.

3. The Model

The target-MOTAD model used in this analysis examining trade-offs between business and financial risks is represented by the following system:

$$\text{Maximize } E(R) = R\,X \tag{3.1}$$

Subject to:

$$A\,X < B \tag{3.2}$$
$$R^* X + d- > T \tag{3.3}$$
$$Pd- < D \tag{3.4}$$
$$X,\ d- > 0 \tag{3.5}$$

R = 1 x n vector of expected returns for each activity;
X = n x 1 vector of activity levels;
E = expectation;
A = k x n matrix of resource requirements;
B = k x 1 vector of resource constraints;
R* = series of m 1 x n vectors of simulated net returns;
T = m x 1 vector with each element equal to the target;
d- = m x 1 vector of negative deviations from target;
P = 1 x m vector of probabilities for each observation (i), Pi=1/m;
D = a scalar parameterised from zero to a large number;
n = number of activities;
m = number of observations, (simulated years); and
k = number of resource constraints.

Equation 3.1 is the objective function in which expected revenue is maximized. Resource constraints are specified by equation 3.2. In equation 3.3, the deviation from the target level of income is defined as 'd-'. The sum of the simulated net revenues (R*X) and the permitted number of deviations (d-) must exceed the target income level

(T). The permitted number of deviations in equation 3.3 is defined according to equation 3.4 in which the probability weighted sum of deviations (Pd-) must be less than the defined acceptable deviation from the target (D). Parameterisation of D provides the risk-efficient frontier.

Table 1 is a schematic matrix of the linear programming model used. Linear resource constraints are represented mathematically in the first set of rows of the matrix (R_{01} to R_{0k}). The entries $R_{1,1}$ to $R_{50,10}$ are 50 simulations of net revenue for each of the production activities. Then each of the constraints OBS_1 to OBS_{50} has an associated prespecified target income (T) shown in the right hand side (see Section 5.2 for the derivation of T). If the difference between the sum of the revenues of the enterprises in the basis and the target income is negative, then deviation activities enter the solution (DEV_1 to DEV_{50}). Finally, the row labelled SUMDEV accumulates the negative deviations and weights them by their probabilities (P_1 to P_{50}), equal to 0.02. By parameterising the right hand side of this matrix for a given level of target income, different basic solutions to the target-MOTAD problem are obtained, each varying according to the probability of achieving a given target income. The series of solutions from such a parameterisation is the risk-efficient frontier.

4. Farming Background

In order to demonstrate the use of the target-MOTAD model, a case-study of a farm in the Mallee in Victoria is presented. It has wheat as a principal activity together with sheep and beef enterprises. It is fairly typical of farms in the area, and at 1456 hectares it is close in area to the average Mallee farm of 1507 hectares (Hall 1988a, p.34). The 20 per cent clay-loam, 60 per cent loam, and 20 per cent sandy loam soils, combined with an average rainfall of 350 millimetres, results in a typical district 'conservative' stocking rate of between two and two and a half dry sheep per hectare.

Water supply for stock is adequate with good dams

Table 1: Schematic Tableau of the Target-MOTAD Model

Row	Production Activities	Other Activities	Dev_1..........Dev_{50}	RHS	INC
OBJ	ER_1 ER_2 ER_3 ......ER_{10}			max	
R_{01}	– – – ......–	–............–		B_1	
R_{02}	– – – ......–	–............–		B_2	
.....				.....	
R_{0k}	– – – ......–	–............–		B_k	
OBS_1	$R_{1,1}$ $R_{1,2}$ $R_{1,3}$ ......$R_{1,10}$		1	T	
...	....		...	...	
...	....		...	...	
...	....		...	...	
OBS_{50}	$R_{50,1}$ $R_{50,2}$ $R_{50,3}$ .....$R_{50,10}$		1	T	
SUMDEV			P_1 P_2........ P_{50}	D	-10

OBJ is the objective function to be maximised.
RHS is the right hand side for the resource restriction (B) or target (T).
INC is the increment by which the right hand side is parameterised.
B, R and m are as defined for equation system 3.1 to 3.5.
P is 0.02 (1/m) times the value of any negative deviation from the target income.
D is a parameterised value.

servicing the three blocks making up the farm. The three blocks are separated by approximately five kilometres. Shedding and silos on the two larger blocks result in no shortage of shed or storage space, while sheep yards exist on each block. Facilities on one block such as the shearing shed can service the whole farm. Established sheep handling facilities are typical of farms in the Mallee.

Like many wheat growing farms, the case-study farm had borrowed heavily several years ago, when interest rates were low, to finance the purchase of new machinery. Unlike many, however, the farmer had managed to pay off much of this debt. Thus, some minor debt was still outstanding, and although not as severe a drain on financial resources as on some farms, it was still of some concern given that very high interest rates seemed to be a continuing feature of the business environment. Hooke (1988, p. 94) compared the debt position of different farm types across Australia and found that the severest problems were on cereals and cereals-livestock farms.

Deregulation of financial markets and higher costs of debt servicing had heightened the case-study farmer's awareness of financing issues, and discussions with him suggested that the influence of fixed financial obligations on the production mix of farm enterprises was an issue worthy of study. The objectives of our work with him became to (a) identify the efficient set of risk management strategies from alternative cropping and livestock activities, and (b) compare the effects of various levels of equity and hence financial obligations on risk-efficient sets. This analysis provided a means by which the suitability of the target-MOTAD model could be tested.

5. Data for the Case-Study Farm

The data set describing the case-study farm can be categorised into the three areas of production constraints, the target income, and simulated net revenues and objective function.

5.1 Production Constraints

The land and capital constraints were treated together. The property size is 1456 hectares. To cope with the farm decision maker's preferences, limits were placed on the number of hectares which can be allocated to the production of wheat, barley and peas. Such restrictions help cope with barley's timeliness-of-harvest requirement, since barley will damage more readily than wheat and has a shorter optimal time before it lies flat, sprouts or drops to the ground. The area allocated to peas is limited to cope with the specific disease problems which could build up if the area of peas in a crop rotation is enlarged. Similarly, the maximum area of wheat helps stop the build up of diseases such as Cereal Cyst Nematode and Takeall. Wheat, barley, and peas are limited to eight hundred, four hundred, and two hundred hectares respectively. Medic pastures also break life cycles of grass-born diseases so it is assumed that the area not cropped is given to medic pastures.

Turning to labour, in order to allow for the hours spent on general farm activities, repairs, maintenance and other miscellaneous work, a total labour constraint was imposed. The constraint is in the form of seasonal labour restrictions and allows for the fact that the farm operator's wife is active in assisting with various activities. A 'hire labour' activity was included in the target-MOTAD matrix to give flexibility with respect to labour in selection of optimal management programs, and account for the availability of casual labour and the farm operator's willingness to use casual labour. Labour requirements specific to the different activities defined for the farm were obtained from Department of Agriculture and Rural Affairs farm management surveys of the region adjusted in consultation with the operator.

In calculating feed availabilities, crop rotations had to be considered to cope with various diseases as well as to maintain adequate soil nutrients. An assumption therefore was made that at least 20 per cent of medic pastures will be in their first year. Another assumption with respect to feed availability is that there is autonomous feed production at a level of 0.05 Live Stock Months (LSM) (Rickards and Passmore 1971) per hectare in Summer and Winter and 0.10 LSM in the Autumn and Spring. The autonomous feed production is designed to account for natural grass germination and growth. Feed produced by various types of pasture and crops, and feed required by livestock, were derived from White and Bowman (1981) and Oram (1985).

No limits were placed on the number of sheep and cattle possible in the production mix apart from those restrictions imposed through other constraints such as feed and labour. The preference of the farm operator was that there will be only one sheep breeding activity in the production mix. No additional computations were needed to cope with this preference as only one sheep activity entered any production mix in the results obtained.

5.2 Target Income

The target income level (T in Table 1) is the amount required to meet the demands for family consumption, fixed farm costs and fixed financial obligations. The target income for the typical 1500 hectare Mallee wheat/sheep farm with a debt problem can be formulated according to the method in Table 2. The family living expenses were those considered by the case-study farmer to be the minimum necessary to support the household. The fixed farm costs are those which are unavoidable, and the fixed financial obligations are dependent on the level of equity as shown in Table 3.

A broadacre farm, such as the case-study farm, would typically be facing a debt problem at equity levels of 60 to 70 per cent (Burgess and Carne 1989, personal communication). Table 3 was constructed

Table 2: Formulation of Target Income when Debt is $329 000

	$	$
Family Living Expenses [a]		26 000
Fixed Farm Costs [b]		
-administration	6036	
-rates	5622	
-insurances	3385	
-rent	1575	
-wages and contracts(autonomous)	3640 [c]	20 258
Fixed Financial Obligations [d]		78 684
Total		124 942

a Estimated figure approaching that necessary to support one household on the case-study farm.
b Derived from Hall (1988b).
c Casual labour assumed autonomous.
d Derivation given in detail in Table 3.

Table 3: Likely Debt Servicing Obligations at Various Levels of Equity[a]

Equity (%)	Debt($)	Commercial interest rate plus 1.0% margin (%)	Fixed financial obligation ($)[b]
71.99	263 260	20.75[c]	62 954
65.00	329 000	20.75[c]	78 684
57.26	401 710	20.75[c]	96 060

a A 10-year loan with quarterly repayments.
b The sum of four equal quarterly repayments.
c This rate implies an effective annual rate of 23.91 per cent.

to show possible debt servicing obligations at a range of equity levels between 57 and 72 per cent. The case-study property is valued at \$625 per hectare or \$940 000 in total (Simpson 1989, personal communication). A 10-year loan with quarterly repayments is assumed for the debt outstanding with a one per cent margin placed on an interest rate of 19.75 per cent (Burgess and Carne 1989, personal communication). Hence, the three target incomes to be examined in this study to express different financial risks through different fixed financial obligations were \$109 000, \$125 000 and \$142 000.

5.3 Simulated Net Revenues and Objective Function

The objective function entry for each activity is the mean of the simulated net revenues $\Sigma R_{ij}/50$. Hence by describing the estimation of simulated net revenues, the objective function is automatically considered. Each element (R_{ij}) has a value equal to revenue ($p_{ij}y_{ij}$) minus variable costs (VC_{ij}), where p_{ij} is defined as the real effective returns to growers per unit and y_{ij} the yield:

$$R_{ij} = p_{ij}\, y_{ij} - VC_{ij} \qquad (4)$$

R_{ij} = simulated net revenue;
p_{ij} = price;
y_{ij} = yield;
VC_{ij} = variable costs;
i = 1 to 50 simulated observations; and
j = 1 to 10 production activities.

In general in the simulation, subjective data were used for levels of yields and prices while objective data were used for variable costs and for estimating correlations in yields and prices. Incorporation of subjective beliefs of likely price and yield distributions is considered vital for the analysis to accurately define the decision context of the farm operator. The information gathered from the farm operator was obtained in the form with which he was most familiar; in the case of yields, bags per acre were recorded and subsequently converted to tonnes per hectare. The collection of data in this way is consistent with dealing with some of the problems highlighted by Anderson, Dillon and Hardaker (1977) regarding the elicitation of distributions. In an appeal to parsimony, triangular probability density functions of yields and prices were elicited

Table 4: Triangular Distributions of Production Activities

Activity	Price			Yield		
	Maximum	Most Likely	Minimum	Maximum	Most Likely	Minimum
Wheat	168.7	153.4	153.4	3.27	1.84	0.51
Malt Barley	200.0	180.0	170.0	1.93	1.23	0.35
Feed Barley	150.0	140.0	130.0	3.34	1.76	0.88
Field Peas	250.0	180.0	150.0	1.84	0.82	0.41
	Price of wool per head			**Price per head put off**		
Wool/weth's	32.0	30.0	26.0			
1X Lamb A	28.0	25.0	12.0	38.0	30.0	20.0
1X Lamb S	28.0	25.0	12.0	38.0	30.0	20.0
2X Lamb A	18.0	15.0	13.0	41.0	29.0	20.0
2X Lamb S	18.0	15.0	13.0	38.0	27.0	20.0
wf Weaners				350.0	300.0	230.0

1X = first cross, 2X = second cross.
A = Autumn drop lambs, S = Spring drop lambs.
wf = winter fatten.
Yield in tonnes per hectare, Price in \$ per tonne or \$ per head.

from which cumulative distributions were created and from which random samples were taken using a variation of Monte Carlo random sampling. The resulting distributions are shown in Table 4.

A complicating feature of the simulated net revenues is that there are correlations between the various activities in their yields and prices. Yield correlation clearly exists as the Mallee is highly susceptible to climatic variations which affect all crops. To account for this, historical yield information generated by various trials conducted in the Mallee was used (see Cumming 1989 for details).

Historical price information was also generally used to estimate the price correlations between crops. The price correlation between wheat and feed barley was 0.79, wheat and malt barley 0.78, and feed barley and malt barley 0.97. Because the current market structure for peas has only recently developed, a price correlation with wheat of 0.25 had to be assumed. This correlation reflects the comparatively low substitutability of wheat and field peas due to their different protein contents and different uses.

Correlations between wool prices and the prices paid for lambs were recognised. However, lack of data again prevented estimation of the correlation. The assumed correlation between first-cross lambs and the price of wool was 0.3 and between second-cross lambs and the price of wool was 0.2. These figures reflect the influence that wool prices have on the willingness of producers to pay for stock.

Net revenues for crops were obtained after subtracting expenses from the gross revenues calculated by multiplying the 'price generated' with the 'yield generated'. A statistical description of the net revenues associated with each enterprise, given the correlations discussed above and given the farm operator's subjective distributions, is presented in Table 5.

6. Results

The study shows that target-MOTAD provides results which are valuable for farm planning and to researchers. In particular, it provides a valuable means of analysing farm debt issues.

6.1 Risk Efficient Solutions

Figure 1 shows risk efficient frontiers for the case-study farm given equity levels of 71.99, 65.00 and 57.26 per cent, with corresponding target incomes of \$109 000, \$125 000 and \$142 000. Movement up any of these frontiers involves increases in both expected returns and riskiness. Such movements involve the types of changes in farm plan shown in

Table 5: Statistical Description of Simulated Net Revenues of Production Activities (\$ per ha, or \$ per grown sheep)

Activity	Mean	Variance	Minimum	Maximum
Wheat	146	4932	7.8	287
Malt Barley	104	1814	18.9	183
Feed Barley	144	1976	50.8	213
Field Peas	98	2249	4.4	218
1st Cross S	37	27	25	46
1st Cross A	37	20	25	45
2nd Cross S	28	14	22	38
2nd Cross A	25	13	18	34
Merino Wool	20	2	18	23
wf Weaners	40	532	3	89

wf = winter fatten, A = Autumn lambing, S = Spring lambing

Figure 1: Risk Efficient Production Frontiers

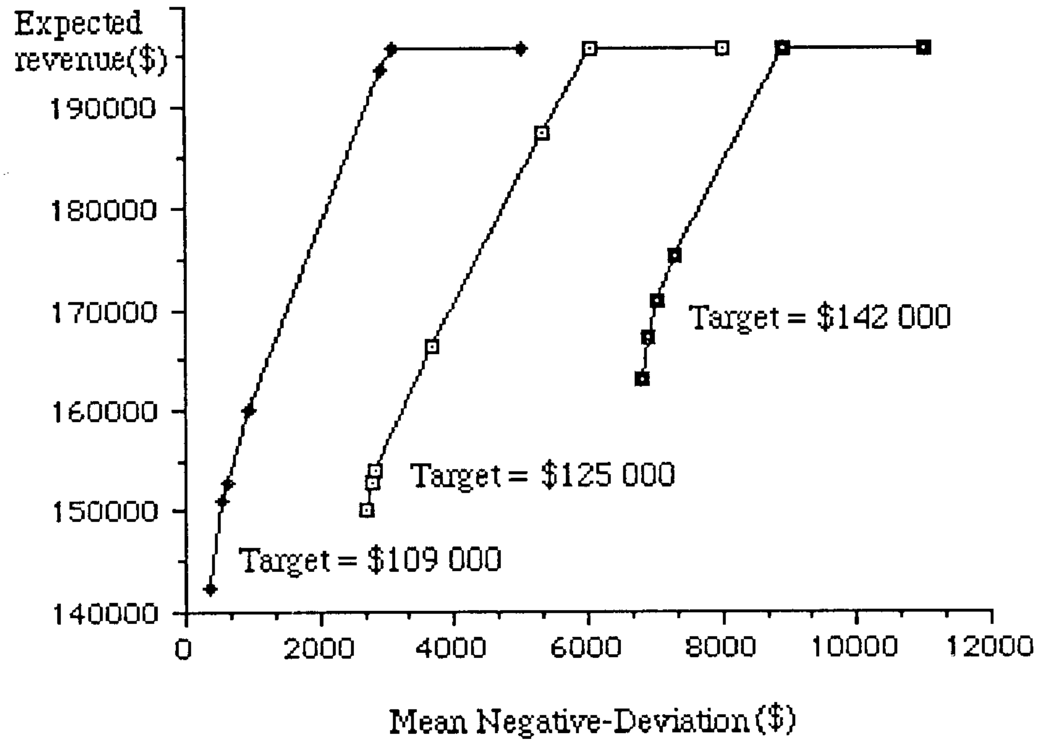
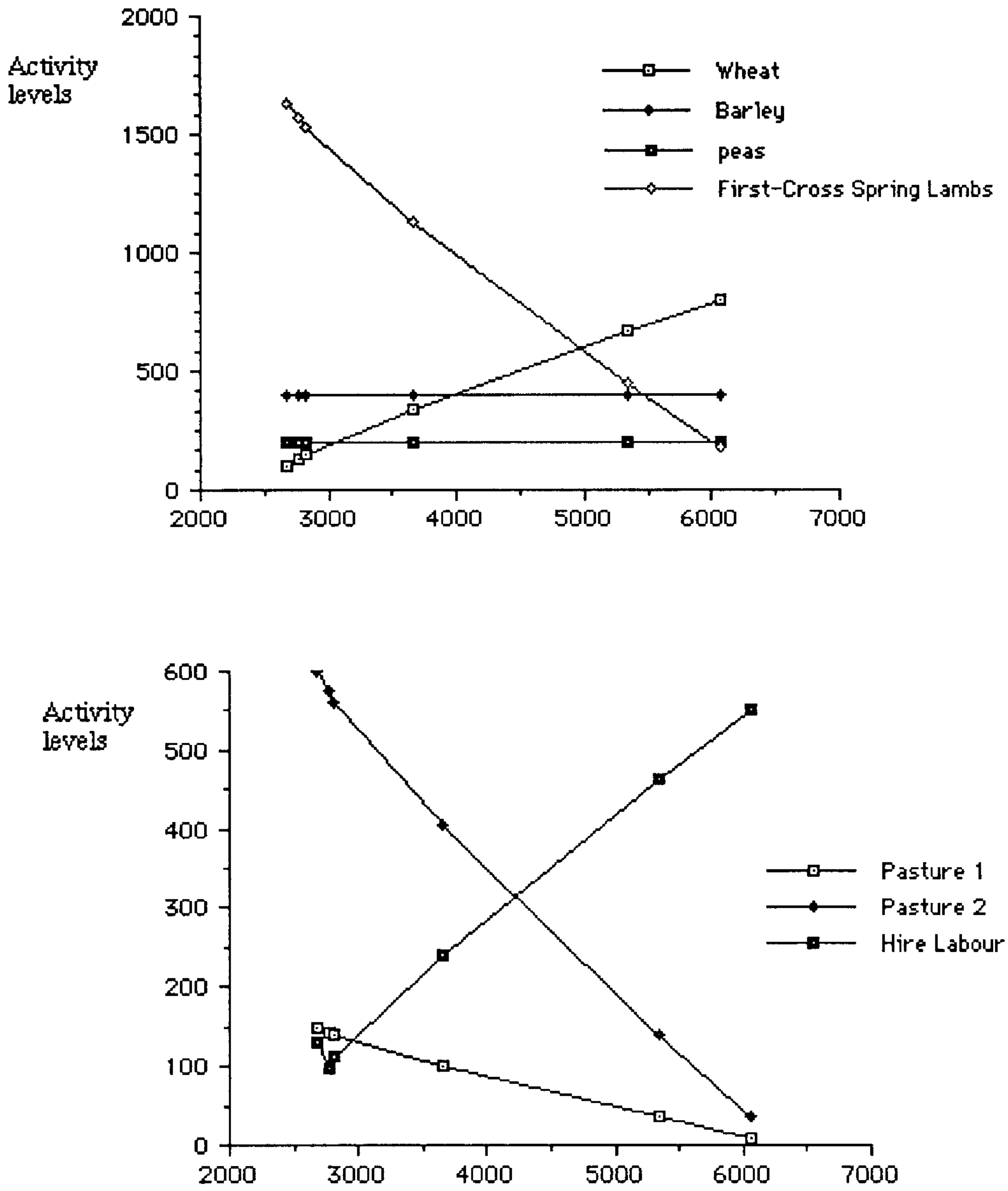


Figure 2. As expected an increase in risk is associated with a higher proportion of wheat in the plan and a lower proportion of first-cross spring lambs. There are accommodating adjustments in labour and pasture activities.

These results suggest that the risk efficient frontier shifts to the right in response to increased financial pressure caused by higher debt levels. To discover whether different farm plans result from these different levels of equity requires the farmer's preferred position on each frontier to be defined. This is equivalent to finding points of tangency between his utility contours and the risk efficient frontiers of Figure 1.

It is possible to envisage a more comprehensive utility analysis which could be used to discover the preferred equity percentage for a given rate of interest. Conceptually, this would involve subtracting, from net revenue, fixed costs and the costs of debt and equity, so that the risk efficient frontiers of Figure 1 would shift down. The extent of the downward shift caused by the introduction of fixed costs other than the costs of debt would be the same for all frontiers, while the downward shift resulting from equity (debt) costs would be higher the higher the equity (debt) percentage. The preferred equity percentage would then be indicated by the point on these amended risk efficient frontiers that achieves the highest point on the utility surface. Hence, in theory, the target-MOTAD model could be extended to consider the optimal equity level. However, this analysis was considered beyond the scope of the

Figure 2: Activity Changes with a Target of $125 000



present study, particularly given the difficulties related to the estimation of equity costs.

6.2 Information for the Farmer

The next challenge was to present the results in a way that the farmer would find useful. To provide most farmers with the required understanding of the distributions involved, the mean-negative deviation is probably not sufficient. From an inspection of the output file for a given target income, the critical information of the number of years in which revenue fell below target was recorded, and the range and average of those shortfalls in revenue could be obtained. This was used to generate the information presented to the farmer which is reproduced in Table 6.

Table 6: Summary of Below Target Revenues ($)

No.	Expected Revenue	Mean Negative Deviation	Number of simulated years with revenue below target	Best below target outcome	Worst below target outcome	Mean value below target
Target = $109 000, 28.01% debt totalling $263 260, interest at 20.75%						
1	195 858	3 313	6	103 687	49 326	79 391
2	190 804	2 950	5	90 579	56 287	79 504
3	157 282	978	4	103 413	89 185	96 779
4	152 702	779	4	106 145	93 681	99 256
5	146 762	572	3	102 544	97 456	99 459
6	142 489	465	3	104 008	98 007	101 258
Target = $125 000, 35.00% debt totalling $329 000, interest at 20.75%						
7	195 858	6 065	9	122 684	51 326	91 304
8	187 489	5 347	8	111 866	59 539	91 580
9	166 392	3 654	7	112 058	80 245	98 900
10	153 894	2 815	7	117 821	92 510	104 895
11	152 702	2 763	8	123 584	93 681	107 732
12	150 269	2 678	8	121 257	95 606	108 264
13	150 211	2 677	9	124 962	95 651	110 130
Target = $142 000, 42.74% debt totalling $401 710, interest at 20.75%						
14	195 858	8 387	9	135 373	51 326	95 404
15	171 627	6 480	9	137 944	75 107	105 998
16	168 216	6 227	10	139 224	78 455	110 863
17	164 225	6 113	11	138 729	82 372	114 214
18	160 935	6 051	12	139 078	85 601	116 789

The farmer was shown the information in Table 6 and the underlying plans that supported it. Then after some discussion, he was asked to select his preferred solutions at each level of the target. In this way, the optimal position on each frontier was obtained and the impact of changes in the level of equity on farming activities was revealed.

With the $109 000 target income, the case-study farmer opted for production plan No.1 which would maximise his expected revenue. This plan included 800 ha of wheat and 179 first-cross lambs. As the target income was increased to $125 000 there was a shift from wheat (340 ha) into lambs (1130 first-cross) as production plan No.9 was considered optimal. Production plan No.15, with 480 ha of wheat and 840 first-cross lambs, was chosen as optimal under the $142 000 target income, under a "boom-or-bust" philosophy. Hence, for the two lower levels of debt financing the farmer's selection supports the use of a safety-first approach like target-MOTAD. This is evidenced by activities that have lower business risk entering the solution as financial risk is increased. However, at higher levels of debt (lower equity), a reversal is observed in which higher financial risk induces *higher* business risk, and a riskier overall solution is selected, seeming to contravene the safety-first criterion. Indeed, later in the interview it became clear that some other components of the model, including crop rotation constraints, would be ignored by the farmer if debt obligations reached these extreme levels. This final solution is one in which the farmer is so constrained by the target that he must almost profit maximize. This appears to coincide with actual behaviour observed on other farms which have been pushed hard by creditors so that soil degradation has occurred (Crabb 1989, p. 25). Thus at the empirical level, the target-MOTAD model seems to provide a reasonable description of behaviour at all but extreme equity levels. Its theoretical conditions were not fulfilled in the final position that was characterised by extreme debt-servicing pressure.

7. Conclusions and Study Implications

The target-MOTAD modelling work discussed in the paper generated risk efficient frontiers in a safety-first decision framework. The preferences of a case-study farmer for various positions across these frontiers showed that changes in equity, which affect the debt burden of the farm, can be expected to influence his farming activities.

From the authors' perspective the farm analysis demonstrated the usefulness of target-negative deviation analysis in modelling decision making in a risky environment. The target-MOTAD model was an easy-to-use method of incorporating the downside risk aspects of farm decision making under financial pressure. The results were understandable to the farmer and, being relevant to his current decision making, provided a useful vehicle for dialogue between the researcher and the farmer. An aspect of the study which is considered valuable is the on-farm decision context which was interwoven with the analysis. The farmer expressed satisfaction that his own estimates were used in the risk analysis.

The use of generated price and yield information in a cheap, easy-to-adjust fashion allows application of this process to other farms. The generated price and yield observations are based on the decision maker's most recent experiences and beliefs, while cost of production estimates based on accounting records further reflected the farming practices and financial system of the case-study farm. Furthermore it is more likely that farmers will be able to relate to a target return level which they set, and to their own tolerance of returns below the target level when deciding on a management system.

Biological simulation of farm production systems is currently evolving (White and Weber 1987; White, Weber, Bowman and McLeod 1989) along with an increasing number of, and competence in the use of, computers. A dynamic, user friendly, personal computer program which will consider both the financial and business risks, with weightings between predictions of biologically-derived mathematical relationships and the decision maker's own beliefs, taking into account the history of the property, could be developed with risk-efficient options expressed in an easily understandable form. All information used in the current study is readily accessible to a farm operator with reasonably accurate records; historical correlations would evolve over time along with the biological yield predictions.

The potential roles of new enterprises in a farm plan could be easily tested by inclusion of generated prices and yields in the simulated years and by including establishment costs in the fixed financial obligations. Because the target-MOTAD technique offers a way of modelling the effects of fixed financial obligations in a volatile business environment, it provides an important guide for farm survival.

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