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Trade-off between Return and Risk in Farm Planning: MOTAD and Target MOTAD Approach

INTRODUCTION

Indian agriculture achieved an impressive growth following green revolution but risk in agriculture has also increased during the period. At micro level risk in agriculture affects farmers' decisions and often results in technically and allocatively inefficient level of resource use. It emphasises the need for incorporation of risk in farm decisions. Accordingly, various risk programming techniques have been suggested. Most of the applications in agriculture deal with either the Mean-variance or MOTAD (Minimisation of Total Absolute Deviation) decision criteria. The Mean-variance analysis requires a quadratic programming algorithm which is expensive to run for large models. MOTAD provides reasonably similar results which can be generated by a linear programming algorithm (Hazell, 1971). This characteristic of MOTAD has popularised it amongst the researchers.

However, MOTAD results do not necessarily fulfil the second-order stochastic dominance (SSD) test, i.e., cannot rank alternate farm plans. Tauer (1983) proposed an alternative mathematical programming model called Target MOTAD which is computationally efficient and generates solutions meeting SSD test. Further, Target MOTAD measures risk as negative deviation from target return, while MOTAD measures risk as negative deviation from mean. Although it may be important for policy makers, yet from a farmer's point of view it is the negative deviation from a fixed level of acceptable target which poses threat. Thus Target MOTAD appears to be theoretically a more plausible approach for planning under risk. The empirical evidences comparing MOTAD and Target MOTAD solutions are limited. The comparative study done by Watts *et al.* (1984) is based on hypothetical data from Hazell (1971). However, the present study is based on actual farm data. In the Indian context, although there are numerous studies involving MOTAD (Mruthyunjaya and Sirohi, 1979; Singh and Jain, 1983; Randhir and Krishnamoorthy, 1993), yet a comparative account of MOTAD and Target MOTAD is not reported. Therefore, the present study has been undertaken with the farm level data from the green belt of Haryana, India.

METHODOLOGY

The risk efficient farm plans using MOTAD and Target MOTAD have been formulated for an average farm of 12.3 acres. The specifications of Target MOTAD and MOTAD models are:

Target MOTAD

$$\text{Maximise } Z = \sum_{i=1}^{n} f_i X_i \qquad \ldots(1)$$

Subject to following constraints:

$$\sum_{i=1}^{n} a_{ij} X_i \leq b_j \quad (\text{where } j = 1.....m) \qquad \ldots(2)$$

$$\sum_{i=1}^{n} C_{hi} X_i + Y_h^- \geq T \quad (\text{where } h = 1.....s) \qquad \ldots(3)$$

$$\sum_{i=1}^{n} Y_h = U \quad (\text{where } U = Z\text{----->}0)$$

$$X_i \geq 0 \qquad \ldots.(4)$$

where Z = total expected return to fixed farm resources from farm activities,
f_i = expected gross margin coefficient of i-th activity,
X_i = level of i-th production activity,
a_{ij} = requirement of j-th resource per unit of i-th activity,
b_j = availability of j-th resource,
C_{hi} = gross margin of i-th activity in h-th year,
Y_h^- = absolute value of the negative total gross income deviation in h-th year from the target return,
T = target level of gross income,
U = a constant parameterised from Z to 0, it is the absolute value of expected negative deviation from the target return level.

The first equation of Target MOTAD model maximises expected return of the solution set. The second equation fulfils the technical constraints, whereas the third equation measures the revenue of a solution under state 'h' if return is less than target return(T), the difference is transferred to the fourth equation via variable Y_h^-, and it sums the negative deviation. The last equation is non-negativity constraints.

MOTAD Model

$$\text{Minimise} \quad Z_0 = \sum_{h=1}^{s} Y_h^- \qquad \ldots.(1)$$

Subject to following constraints:

$$\sum_{i=1}^{n} a_{ij} X_i \leq b_j \quad (\text{where } j = 1\ldots\ldots..m) \qquad \ldots.(2)$$

$$\sum_{i=1}^{n} (C_{hi} - g_i) X_i + Y_h^- \geq 0 \quad (\text{where } h = 1\ldots\ldots..s) \qquad \ldots.(3)$$

$$\sum_{i=1}^{n} f_i X_i = \lambda \quad (\text{where } \lambda = 0 \text{----------} \rightarrow Z) \qquad \ldots.(4)$$

$$X_i \geq 0 \qquad \ldots.(5)$$

where Z_0 = sum of the absolute value of the negative of the gross income of various enterprises from their mean value,
Y_h^- = absolute value of the negative total gross income deviation in the h-th year from the mean return,
X_i = level of i-th production activity,
a_{ij} = requirements of j-th resource per unit of i-th activity,
b_j = available supply of j-th resource,
C_{hi} = gross margin of i-th activity in h-th year,

g_i = mean value of the gross return of the i-th crop/dairy activity,
f_i = expected gross margin coefficient of i-th activity,
λ = a constant parameterised from Z to 0; it is the total expected gross return.

The MOTAD model measures risk as linear deviation from the mean income (equation 3). The risk is considered undesirable (assumption of risk aversion) and hence is minimised (equation 1). The trade-off occurs between mean income (λ) as in equation 4 and deviation (Y_h^-). The risk-return frontier is developed by parametrically running the model with regard to mean income and minimising deviation from the mean income.

The MOTAD and Target MOTAD risk-return frontiers were derived for the representative mixed farm (crop-dairy) in the green belt of Haryana (Kurukshetra district). The synthetic/model farm in the study could produce different paddy varieties (3), potato, *toria*, wheat, lentil, sunflower, summer pulse, sugarcane and fodder crops(2). The resources: land (6 for bimonthly seasons), labour (12 restrictive periods for human labour), working capital (2 for *kharif* and *rabi)*, and medium-term capital acted as constraints. The interdependence of crop and dairy enterprises were incorporated in the model with fertiliser nutrients (nitrogen, phosphorus), and fodders (berseem, jowar) tie rows. At times of shortage, constrained resources were supplemented through hiring/borrowing/purchasing. Hence, in addition to real crop and dairy activities, labour hiring, capital borrowing, fertiliser purchasing activities were incorporated in the model. A linear programming model leads to specialisation. Therefore, the profitable levels of a few crops, viz., basmati paddy, potato, summer paddy, summer pulse, fodders and sugarcane were restricted according to economic and institutional circumstances. Apart from these, enterprise returns of the previous six years were incorporated in Target MOTAD while deviations from the mean returns in the previous years were incorporated in MOTAD to consider risk in enterprises.

RESULTS AND DISCUSSION

The risk-return pairs and associated enterprise combinations, as generated by MOTAD model for a synthetic farm, are presented in Table I and risk-return trade-off with Target MOTAD has been presented in Table II. In order to make comparison, Target MOTAD results were generated by using MOTAD expected return as target and parameterising the maximum total negative deviation from target return. The comparison is illustrated graphically in Figure 1 with 'AF' as Target MOTAD frontiers and 'af' as MOTAD frontiers with common return reference points. In MOTAD solution for every change in parameterised return enterprise combinations changed (Plan 1 to Plan 6); but in Target MOTAD model expected gross return and the enterprise-mix did not change with every change in target return and downside risk. However, a target return of Rs. 1,12,000 with constrained negative deviation or downside risk of Rs. 500, Rs. 333 and zero changed the enterprise-mix on the farm. Similar changes were observed with a target return of Rs. 1,17,000 and presented in Table II. These risk-return trade-offs with target return of Rs. 1,17,000 and Rs. 1,12,000 are illustrated graphically in Figure 1 with 'mn' and 'pr' as risk-return frontiers. The Target MOTAD solution shows that at higher target return, viz., Rs. 1,32,000, Rs. 1,27,000 and Rs. 1,22,000 there was no change in the enterprise-mix reduction in negative deviation or downside risk. Thus at a lower target return with constrained downside risk only there were changes in the enterprise-mix.

The Target MOTAD suggested a decline in the area under basmati paddy, potato, *toria*, lentil and increase in the area under *kharif* paddy, wheat, sunflower for relatively stable return. With respect to scarce land resources, *kharif* paddy replaces basmati paddy while

wheat substitutes toria and lentil for stability in farm return. During autumn and late autumn seasons potato was found profitable, but its area decreased as concern for risk increased in the subsequent plans. Sunflower, grown during winter and spring seasons provided stable farm return as its acreage increased in the successive farm plans with low return and risk. MOTAD solution also suggests similar changes in the cropping pattern but it advocates an increase in the area under *toria*-sunflower at the cost of wheat for stability in farm return; while wheat is one of the most stable crops of the green belt. However, a higher covariance of wheat with other crops may be the possible explanation for this disconcerting result. This may also be due to difference in concepts of risk. In terms of deviation per unit mean, a more accurate measure of risk, wheat is less risky but MOTAD measures risk as linear deviation from mean. Wheat is associated with higher average return as well as negative deviation. But deviation per unit return, a better measure of risk, is not high for wheat. The MOTAD solution does not, however, consider the latter measure of risk. Thus it can be inferred that measurement of risk under MOTAD framework is not as convincing as Target MOTAD. As discussed earlier, the change in the enterprise-mix was not frequent in Target MOTAD but parameterisation of target returns and downside risk present expected return and also distribution of downside risk in different years/situations. Finally, it indicates the magnitude of returns in different years/situations, with a given enterprise-mix.

Figure 1 illustrates that the Target MOTAD frontiers (AF) are substantially different

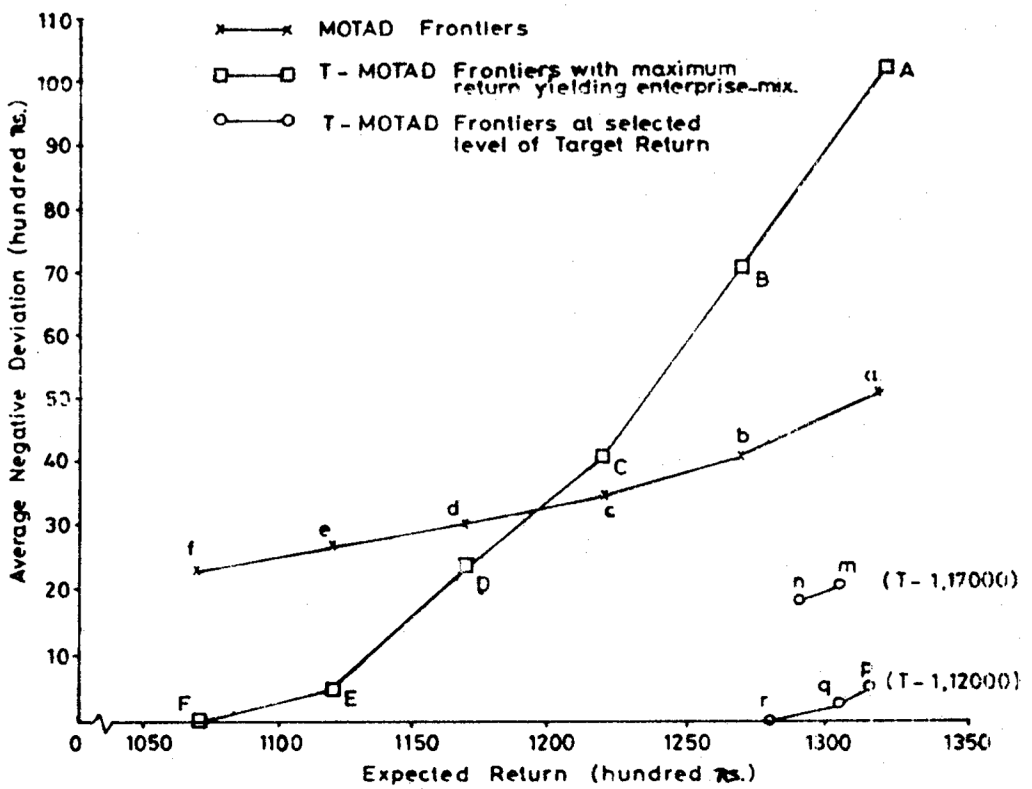

Figure 1. MOTAD and Target MOTAD Risk-Return Frontiers

TABLE I. RISK-RETURN TRADE-OFF WITH MOTAD FOR A SYNTHETIC FARM (12.3 ACRES), KURUKSHETRA DISTRICT

Sr. No.	Particulars	Existing plan	Risk efficient plans for medium (12.3 acres) farm					
			Plan 1	Plan 2	Plan 3	Plan 4	Plan 5	Plan 6
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
1.	Gross return (Rs.)	1,17,414	1,32,000	1,27,000	1,22,000	1,17,000	1,12,000	1,07,000
2.	Minimised risk (Rs.)	-	5,087	4,005	3,415	2,990	2,670	2,370
3.	Return per unit risk (per cent)	-	26.0	31.7	35.7	39.1	42.0	45.7
4.	Crop enterprises (acres)							
	Paddy *kharif*	5.9	2.1	2.0	2.0	2.0	2.0	2.0
			(7.4)	(7.2)	(7.0)	(7.2)	(8.1)	(8.3)
	Paddy summer	2.3	2.5	2.5	2.5	2.5	2.5	2.5
			(8.8)	(8.9)	(8.7)	(9.0)	(10.1)	(10.4)
	Paddy basmati	3.1	4.0	4.0	3.4	2.9	2.5	2.0
			(14.1)	(14.3)	(11.9)	(10.4)	(10.1)	(8.3)
	Toria	0.6	0.5	2.2	2.2	4.8	5.6	6.3
			(1.8)	(7.9)	(7.7)	(17.2)	(22.6)	(26.1)
	Potato	0.8	2.0	0.3	0.4	0.2	0.2	0.2
			(7.0)	(1.1)	(1.4)	(0.7)	(0.8)	(0.8)
	Wheat	9.2	5.2	4.0	2.2	2.0	2.0	2.0
			(18.3)	(14.3)	(7.7)	(7.2)	(8.1)	(8.3)
	Lentil	0.2	-	-	-	-	-	-
	Sunflower	0.9	2.5	3.4	6.3	7.6	5.9	5.0
			(8.8)	(12.1)	(22.0)	(27.2)	(23.8)	(20.8)
	Summer pulse	0.8	4.0	4.0	4.0	1.5	-	-
			(14.1)	(14.3)	(14.0)	(5.4)		
	Sugarcane	0.3	2.0	2.0	2.0	0.8	0.5	0.5
			(7.0)	(7.1)	(7.0)	(2.9)	(2.0)	(2.1)
	Jowar	1.4	1.8	1.8	1.8	1.8	1.8	1.8
			(6.3)	(4.4)	(6.3)	(6.4)	(7.2)	(7.5)
	Berseem *rabi* fodder	1.5	1.8	1.8	1.8	1.8	1.8	1.8
			(6.3)	(6.4)	(6.3)	(6.4)	(7.2)	(7.5)
	Total cropped area	-	-	-	-	-	-	-
			(100.0)	(100.0)	(100.0)	(100.0)	(100.0)	(100.0)
5.	Dairy enterprises							
	Milch buffalo (Nos.)	4.1	5.5	5.4	5.5	5.5	5.5	5.6
	Draught animal (Nos.)	1.4	1.0	1.0	1.0	1.0	1.0	1.0
6.	Land utilisation (per cent)	90.8	97.0	94.3	93.5	86.5	76.8	74.9
7.	Labour utilisation (man-days)	1,403.6	1,376.0	1,322.3	1,307.4	1,252.8	1,196.2	1,173.8
8.	Working capital (Rs.)	70,215.0	73,529.0	71,973.0	71,294.0	70,766.0	70,242.0	68,028.0
9.	Risk per unit capital (per cent)	-	6.9	5.6	4.8	4.2	3.8	3.5

Note: Figures in parentheses are percentages to the total cropped area.

from MOTAD frontiers (af) based on Tables I and II respectively. It is evident that Target MOTAD solutions (A) through (C) resulted in higher negative deviation and hence higher risk. In the remaining solutions, Target MOTAD resulted in lower negative deviation from target return or risk. The Target MOTAD frontier (AF) presented the magnitude of negative deviations from target return for a given enterprise-mix. The risk-return frontiers 'mn' and 'rp' with fixed target returns of Rs. 1,17,000 and Rs. 1,12,000 are a compromise between the earlier two frontiers. However, one common characteristic about all these frontiers was a relatively faster increase in risk with increase in the return. In fact, the increase in the return requires simultaneous increase in the utilisation of resources; and with increased

scarcity of resources risk per unit return has increased. Again, the increase in risk was more with target return. It emphasises the effect of considering deviations from a fixed risk reference point or target versus a moving risk reference point or mean.

TABLE II. RISK-RETURN TRADE-OFF WITH TARGET MOTAD FOR A SYNTHETIC FARM (12.3 ACRES), KURUKSHETRA DISTRICT

Sr. No.	Particulars	Risk efficient plans with different target returns and downside risk						
		Plan 1	Plan 2	Plan 3	Plan 4	Plan 5	Plan 6	Plan 7
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
1.	Target return (Rs.)	1,32,000 1,27,000	1,22,000	1,17,000	1,17,000	1,12,000	1,12,000	1,12,000
2.	Downside risk (Rs.)	10,333 7,000	4,000	2,000	1,833	500	333	0
3.	Gross return (Rs.)	1,31,220	1,31,060	1,30,470	1,29,270	1,31,550	1,30,410	1,28,050
4.	Crop enterprises (acres)							
	Paddy *kharif*	2.1	2.1	2.4	3.4	2.1	2.8	4.1
		(7.2)	(7.3)	(8.7)	(12.4)	(7.4)	(10.0)	(14.9)
	Paddy summer	2.5	2.6	2.5	2.5	2.5	2.5	2.5
		(8.5)	(9.0)	(9.1)	(9.1)	(8.8)	(8.9)	(9.1)
	Paddy basmati	4.0	4.0	3.7	2.6	4.0	3.3	1.8
		(13.7)	(13.8)	(13.5)	(9.5)	(14.0)	(11.7)	(6.6)
	Toria	1.6	1.4	0.5	0.5	0.5	0.5	0.7
		(5.5)	(4.8)	(1.8)	(1.8)	(1.7)	(1.8)	(2.5)
	Potato	0.9	1.1	2.0	2.0	2.0	2.0	2.0
		(3.1)	(3.8)	(7.3)	(7.3)	(7.0)	(7.1)	(7.3)
	Wheat	4.1	4.5	5.9	5.9	4.7	5.3	5.7
		(14.0)	(15.5)	(21.5)	(21.5)	(16.5)	(18.9)	(20.7)
	Lentil	2.0	1.6	0.2	0.2	1.3	0.8	0.2
		(6.8)	(5.5)	(0.7)	(0.7)	(4.6)	(2.8)	(0.7)
	Sunflower	2.5	2.5	2.5	2.5	2.5	2.5	2.7
		(8.5)	(8.6)	(9.1)	(9.1)	(8.8)	(8.9)	(9.8)
	Pulse summer	4.0	3.6	2.2	2.2	3.3	2.8	2.2
		(13.7)	(12.4)	(8.0)	(8.0)	(11.6)	(10.0)	(8.0)
	Sugarcane	2.0	2.0	2.0	2.0	2.0	2.0	2.0
		(6.8)	(6.9)	(7.3)	(7.3)	(7.0)	(7.1)	(7.3)
	Jowar fodder	1.8	1.8	1.8	1.8	1.8	1.8	1.8
		(6.1)	(6.2)	(6.5)	(6.6)	(6.3)	(6.4)	(6.6)
	Berseem fodder	1.8	1.8	1.8	1.8	1.8	1.8	1.8
	Total cropped area	29.3	29.0	27.5	27.4	28.4	28.1	27.5
		(100.0)	(100.0)	(100.0)	(100.0)	(100.0)	(100.0)	(100.0)
5.	Dairy enterprises							
	Buffaloe (Nos.)	5.0	5.0	5.0	5.0	5.0	5.0	5.0
	Draught animal (Nos.)	1.0	1.0	1.0	1.0	1.0	1.0	1.0
6.	Land utilisation (per cent)	97.9	97.7	96.9	96.4	97.4	97.2	95.3
7.	Labour utilisation (man-days)	1,374.5	1,366.2	1,348.4	1,337.8	1,358.5	1,351.0	1,277.4
8.	Working capital (Rs.)	73,520.0	73,110.0	72,510.0	72,250.0	72,840.0	72,580.0	71,110.0

Note: Figures in parentheses are percentages to the total cropped area.

CONCLUSION

The basic purpose of risk-return analysis is to rank alternate farm plans on the basis of risk, to assess the returns under alternate risky situations and examine the trade-off between risk and returns. As discussed earlier, the MOTAD model was found to be unsatisfactory on two accounts. Target MOTAD fulfils the objectives of risk analysis. It also presents risk return trade-off but every change in target return does not present risk-return trade-off unless

negative deviation from target return is constrained. While MOTAD presents risk return trade-off with every change in parameterised return. The changes in the enterprise-mix was in accordance with the parameterised return while this was not the case with the Target MOTAD. Thus risk-return trade-off presented by MOTAD is more plausible.

Finally, the application of MOTAD and Target MOTAD models suggests a decline in the area under basmati paddy, potato, *toria,* lentil and an increase in the area under *kharif* paddy, wheat, sunflower for stability in farm return in the green belt of Haryana, India.

Brajesh Kumar Jha*

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REFERENCES

Hazell, P.B.R. (1971), "A Linear Alternative to Quadratic and Semivariance Programming for Farm Planning Under Uncertainty", *American Journal of Agricultural Economics,* Vol. 53, No. 1, February, pp. 53-62.

Mruthyunjaya and A.S. Sirohi (1979), "Enterprise System for Stability and Growth on Drought Prone Farms: An Application of Parametric Linear Programming", *Indian Journal of Agricultural Economics,* Vol. 34, No. 1, January-March, pp. 27-42.

Randhir, O. Timothy and S. Krishnamoorthy (1993), "Optimal Crop Planning under Production Risk in Tankfed South Indian Farms", *Indian Journal of Agricultural Economics,* Vol. 48, No. 4, October-December, pp. 678-686.

Singh, A.J. and K.K. Jain (1983), "Farm Planning under Risk and Uncertainty: An Application of Parametric Linear Programming", *Indian Journal of Agricultural Economics,* Vol. 38, No. 2, April-June, pp. 208-216.

Tauer, L.M. (1983), "Target MOTAD", *American Journal of Agricultural Economics,* Vol. 65, No. 3, August, pp. 606-610.

Watts, M.J.; L. Held and S. Helmers (1984), "A Comparison of Target MOTAD to MOTAD", *Canadian Journal of Agricultural Economics,* Vol. 32, No. 1, March, pp. 175-185.

* Post-Doctoral Fellow, National Centre for Agricultural Economics and Policy Research (ICAR), Pusa, New Delhi-110 012.

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