Journal of Economic Cooperation Among Islamic Countries **18**, 4 (1997) 155-170

# A TRADE-OFF BETWEEN EXPECTED RETURNS AND RISK AMONG FARMERS OF RICE-WHEAT ZONE OF PUNJAB, PAKISTAN

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A target MOTAD risk-programming model was developed and used to analyse alternative farming systems for the central Punjab of Pakistan. The profit- maximising enterprise combination was found not to be significantly different from combinations that can achieve a desired target income with some given levels of risk. However, enterprise mix and levels of activities for profit-maximising LP model and risk-efficient target MOTAD was found to be significantly different. A comparison of MOTAD and target MOTAD was also made. Target MOTAD solutions always generated higher expected income with less negative deviations than those in the corresponding MOTAD solutions. If risk is conceived as deviations below target income, target MOTAD solutions will result in lower negative deviations and, thus, less risk. Moreover, the target MOTAD efficiency frontiers are above the MOTAD efficiency frontier everywhere.

## 1. INTRODUCTION

It is generally argued that small farmers in developing countries are "poor but efficient" (Schultz, 1983). The argument is that farmers allocate their resources efficiently in the given production environment and in the light of their life-long experiences. With the improved availability of rapidly changing new crop production technologies, however, modern inputs, and ever-changing government policies, farmers are now required to adjust and readjust their farm plans frequently with less information available than before. The argument of life-long experience does not seem valid anymore. Moreover, with commercialisation, the farming business is becoming more and more sophisticated and risky. Farm families who find a need to adopt new technology and/or intend to change their farm organisation need more information on the risk associated with the change in order to make the decision.

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Few would disagree that agricultural production is a risky process. Available literature suggests that most farmers are risk-averse and that risk aversion tends to be more common among small farmers (Dillon and Scandizzo, 1978). The inclusion of farmers' risk behaviour in farm planning models is well discussed in the literature. Given that small farmers are risk-averse in general, unless risk responses are adequately considered in agricultural planning models, the results generated in empirical analysis may be of little use either in direct decision-making or in policy analysis (Brink and McCarl, 1978, and Boisvert and McCarla, 1990). It is further stressed by Hazell (1982) that neglect of risk-averse behaviour of farmers can result into overstatement of the output levels of risky enterprises and overly specialised cropping patterns.

Conventional linear programming models are widely used as a method for determining profit-maximising resource allocation. But given the fact that these models ignore the potential risk associated with the enterprises considered for resource allocation and, thus, may provide misleading results where farmers tend to be risk-averse and considerable risk is involved in agricultural business, these deterministic models may yield farm plans that may not correspond to the real farm decision-making environment, and the use of risk-programming models to eliminate these problems seems therfore more appropriate.

## 2. OBJECTIVES OF THE STUDY

The main objective of this study is to analyse the selected farming systems of Punjab and to determine risk-efficient optimal farming systems given existing economic and financial conditions. The specific objectives of the study are to: a) determine profit-maximising farming systems given the current credit availability; b) determine the optimum farm resources allocation and enterprise combinations in a risky environment; and c) analyse the sensitivity of optimal farm plans to changes in target farm income

## 3. THE TARGET MOTAD MODEL

The target MOTAD model is a useful planning technique and has widely been discussed and used (Anderson et al., 1977, Berbel, 1988, Hazel and Norton, 1986, Misra and Spurlock, 1991, Novak et al., 1990, Watts et al., 1984, and Zia, 1992). It considers net returns that fall below a critical target as the risk associated with a farm plan. In this analysis, a target MOTAD model is used to generate a risk-return frontier. It is generally argued that farmers do not consider fluctuations in higher mean income a problem, it is always fluctuations on the lower side that poses a threat to farm business. Thus, it is very difficult to view positive income deviations as source of risk. However, it seems logical to consider negative income deviations a source of risk.

The target MOTAD model is defined as a two-attribute risk and return model. The optimal farm plans depend on target level (T)* and level of expected short fall from T as defined by $\lambda$.

In vector notation, the target MOTAD model is specified as:

1) Max E (C) X = $\overline{C}$X
   subject to
2) $A X \leq B$
3) $C X + d \geq T$
4) $p d < \lambda$
5) $X.d \geq 0$

Where X is an nx1 vector of activity levels; C is an mxn matrix of returns for each activity; $\overline{C}$ is a 1xn vector of expected returns for each activity; A is a kxn vector of resource requirements; B is a kxl vector of resource constraints; d is a mxl vector of negative deviations from target; T is a mxl vector of the target income; P is a lxm vector of probabilities for each observation; n is the number of activities; m is the number of observations, and k is the number of constraints.

Equation (1) is the objective function of the model used in this analysis. Equations (9) through (5) represent the constraints in the model. Equations (3) and (4) are the heart of the target MOTAD model where deviations from a specified target and weighted sum of deviations are calculated respectively. The solution vector will be the expected-return-maximising mixture, whenever (4) is not an effective constraint. The target MOTAD risk-efficient set is traced by parameterizing $\lambda$ for a specified target income T.

## 4. ASSUMPTIONS OF TARGET MOTAD

Because target MOTAD has a linear objective function and linear constraints, the assumptions of linear programming model also hold in target MOTAD. Some simplifying assumptions associated with target MOTAD are: (a) the solution to (1) and (2) is a unique vector; (b) the target MOTAD model provides a unique solution for each combination of $\lambda$ and T whenever (4) is an effective constraint; and (c) each state of nature is assumed to be equally likely. The last assumption is made only because the data on probability distribution of states of nature are not required. However, the model can also accommodate unequal probabilities.

## 5. DATA COLLECTION

Applications of the target MOTAD model used for analysing risk-efficient resource allocation by Pakistani farms require enterprise budgets with additional information on the time series data in returns and cost of production for each enterprise in the model to develop a distribution of gross margins. The IFFS model is used for generating enterprise budgets. The deviations are computed by subtracting the expected gross margin from the gross margin for each enterprise for each year in the series. This deviation matrix is the heart of the target MOTAD and is used to compute risk.

Data on enterprise budgets are required to specify input-output coefficients ($a_{ij}$) for each enterprise ($X_j$). The resource availability and constraints ($b_i$) must be specified. The resource constraints specified in the model developed here include land, family labour, hired labour, fertiliser use, and institutional credit. The real activities include all major crops grown in the area.

A set of nine representative farms was selected for analysis. This selection was based upon existing budget information. An attempt was made to select farms that give a comprehensive picture of the dominant farming systems in Punjab, Pakistan. A survey form was designed for use in collecting data from each of these farms. This form was designed from the inputs known to be needed to use target MOTAD models, as well as from considerations given to the types of information farmers will readily have available and will be willing to provide. The survey form was then used as a basis for conducting personal interviews with managers of the selected representative farms. All interviewing was done personally. No surveyors, interviewers were used. All surveys were conducted by the author.

The data collected was first used to generate enterprise budgets. The generated enterprise budgets were then used to develop target MOTAD models. The cost of production series for each farm was not available for all the years in the study. However, prices of agricultural inputs and outputs are announced by the government. It is assumed that indices of prices paid by the farmer and prices received by the farmers are highly correlated with actual farm prices (Zia). Fertiliser cost is a major input cost in crop production. Moreover, it is the only input for which a complete price series is available. All other production costs except fertiliser cost and labour cost were aggregated into cost of production. The cost of production series was adjusted over time to the changes in the fertiliser price series and prices received by the farmer. The index of prices paid by the farmer was not available for this period. The computed cost of production series is then used to develop a series of gross margins.

Income series were developed for all the crops grown over a six-year period (1986-91). Though a longer time period may be desirable, it is assumed that a six-year period adequately captures long-term price fluctuations. However, it is observed that using information from a limited number of historical periods is congruent with farmers' behaviour since farmers tend to discard information from more distant periods when forming price expectations.

A typical farm with 20.5 acres of land is selected for analysis. Out of 20.5 acres, 13 acres are cultivated by the landlord, and 7.5 acres are cultivated by a sharecropper. According to the sharecropping terms, the landlord provides the land and half of the inputs, and the tenant provides labour and half of the inputs. It is the landlord who decides the enterprise and its level. The sharecropper just provides labour and half of the inputs to get his share or we may say wage. Vegetables are labour-intensive crops and generally landlords rely on sharecroppers to raise vegetable crops because the casual labour needed for vegetable production is simply not available. The farm manager owns a tractor and has a private tube-well for supplemental irrigation water.

## 6. ENTERPRISES

The farm is growing almost all the traditional and non-traditional crops being grown in the study area. The traditional crop rotations include wheat, rice, sugarcane, sorghum, and berseem. The non-traditional crops include peas, bringle, gourds, and carrots. The non-traditional crops are labour-intensive and generally grown only on farms that have enough family labour or that can make some sharecropping arrangements. The weather and rotation system permit production of two crops from the same land every year.

Livestock enterprises are an integrated part of the crop rotations in the study area. Generally, livestock is raised to satisfy the milk consumption requirement of the family. Sometimes surplus milk is also sold to get supplemental income from livestock. The farm raised buffaloes to meet the milk consumption requirements of the family.

## 7. RESOURCE CONSTRAINTS

The farm had an area of 20.5 acres. The land is assumed to be homogeneous in fertility. Average crop yields are used for the computation of gross margins. Availability of surface irrigation water is a constraint in the area. However, because the farm owns a tubewell, irrigation water is not specified as a binding constraint. The binding constraints include institutional credit and hired labour. Hired labour is critical during peak use periods, such as planting and harvesting. Labour inputs were specified on a monthly basis. There are two crop production seasons in Pakistan, namely Rabi and Kharif. The availability of family labour, hired labour and institutional credits is specified for each season. The restrictions for the family consumption requirement are also specified. For instance, a family keeps sufficient quantity of wheat for home consumption and the rest enters the market. It is assumed that Rs. 10,000 will be available as institutional credit at the current interest rate.

## 8. OPTIMAL FARM ORGANISATION

Farmers, it is frequently argued, tend to maximise profits from their farming business. To look at the profit-maximising resource allocation of the farm, a basic linear programming (LP) model was developed. The results of the LP model are presented in Table 1. Risk theory indicates that risk-neutral decision-makers will seek the LP profit-maximising plan. The expected income (Rs. 96736) associated with this plan reflects the maximum attainable income given the existing resources of the farm. The profit-maximising plan is a high risk plan also as indicated by the associated mean absolute deviation (MAD) of Rs. 32946.

The profit-maximising farm plan suggests a crop rotation with 13.68 acres of wheat, 18.18 acres of rice, 2.31 acres of sorghum, 2.99 acres of peas, 1.81 acres of berseem, and 2.0 acres of carrots. The farm plan includes 3.25 buffaloes for meeting the consumption requirements of the family. Sugarcane and eggplants do not enter the optimal farm plan. However, sugarcane and eggplants are common in the present crop rotations of the study area. That implies that the profit-maximising plan does not truly represent farmers' current behaviour. The high risk attached to the profit-maximising farm plan may explain why farmers do not adopt this profit-maximising rotation.

Table 1
Profit Maximising Farm Plan

| | | |
|---|---|---|
| Expected Income (Rs) | | 96736 |
| Mean Absolute Deviation (MAD) | | 2946 |
| Activity | Unit | Level of Activity |
| Wheat | Acre | 13.68 |
| Rice | Acre | 18.18 |
| Sorghum | Acre | 2.31 |
| Peas | Acre | 2.99 |
| Berseem | Acre | 1.81 |
| Carrot | Acre | 2.00 |
| Buffaloes | Head | 3.25 |

Source: Survey data.

May-June and November-December are the peak labour requirement seasons. Labour shortage in these seasons will compel the farm manager to adopt a sub-optimal farm plan. The area under carrots was constrained at the margin by the availability of harvest labour. All the institutional credit available was used. Thus, the constraint on institutional credit is binding. Sorghum and berseem are forced in the solution for meeting the fodder requirements of livestock raised on the farm.

## 9. LOW RISK PROFIT MAXIMISING FARM ORGANISATION

Farmers do not intend to minimise risk, some researchers argue, rather farmers maximise farm profit. However, they are concerned about farm income falling below a specified target level. To generate farm plans consistent with this type of decision-making, the target MOTAD technique was applied. It is not very clear what income level should be specified as target income. The literature on behavioural studies is silent on that. Sometimes it is argued that the average income of the last three years should be taken as target. Others express the opinion that subsistence level income should be taken as target, as safety first is normal behaviour under risky environments. In order to avoid this controversy, different target income levels were specified for the farm and risk was measured as the expected short fall, $\lambda$, from the target. The parameter $\lambda$ was initially set at a large value, in this case the target MOTAD model was equivalent to the deterministic linear programming model. As $\lambda$ was reduced, solutions that varied from the deterministic LP were generated. At each change in $\lambda$, the corresponding expected income and optimal solutions were recorded for each target level of income considered.

The risk optimal cropping plan, expected net returns, and corresponding values of $\lambda$ for a target income of Rs.60,000 are shown in Table 2. Expected net returns ranged from Rs.96,736 when negative income deviations were ignored, to Rs.94998 when negative income deviations were not permitted.

Table 2
Optimal Net Returns and Enterprise Mix for Varying Levels of Risk for Target Income Rs. 60,000

| Characteristics | Units | Farm Plans | | | |
|---|---|---|---|---|---|
| | | Plan 1 | Plan 2 | Plan 3 | Plan 4 |
| Target Income Rs | Rs | 60000 | 60000 | 60000 | 60000 |
| $\lambda$ | Rs | 0 | 2000 | 6000 | 11000 |
| Obj. Function | Rs | 94998 | 95342 | 96028 | 96736* |
| Crop Mix: | | | | | |
| Wheat | Acre | 14.09 | 14.00 | 13.85 | 13.65 |
| Rice | Acre | 16.77 | 17.05 | 17.61 | 18.18 |
| Sorghum | Acre | 1.91 | 1.99 | 2.15 | 2.31 |
| Peas | Acre | 3.00 | 3.00 | 2.99 | 3.00 |
| Berseem | Acre | 1.41 | 1.49 | 1.65 | 1.81 |
| Carrot | Acre | 2.00 | 2.00 | 2.00 | 2.00 |

| | | | | | |
|---|---|---|---|---|---|
| Eggplant | Acre | 1.81 | 1.45 | 6.73 | 6.00 |
| Buffalo | Heads | 1.64 | 1.96 | 2.60 | 3.25 |

Source: Survey data.
*LP Solution.

For λ greater than 11.000, the target MOTAD model was equivalent to a deterministic linear programming model. At the other extreme, when λ equals zero, 1.81 acres of eggplants were brought into the solution The area under rice declined to 16.77 acres, and the area under wheat experienced a slight increase. Other crops in the solution remained the same. The number of buffaloes was also decreased. Thus, the areas under fodder crops, sorghum, and berseem, also declined. Surprisingly, sugarcane was not included in any farm plan

As λ was decreased keeping the target income at the same level, crop plans were altered. The area under wheat increased, while the area under rice, sorghum, and berseem declined. The area under sorghum and berseem declined because the fodder requirement was reduced due to the decrease in the number of buffaloes. These results imply that rice is the high risk crop included in the solution. Peas and carrots were included in each plan at their upper limit.

The optimal solutions for target income of Rs.70,000, Rs.80,000 and Rs.90 000 are reported in Tables 3, 4, and 5, respectively. The analysis shows that variations in λ have similar effects on crop mixes at all target income levels. At target income levels higher than Rs.60.000, the zero risk (λ = 0) option was not feasible. Higher minimum feasible values of λ were associated with higher levels of target income.

Table 3
Optimal Net Returns and Enterprise Mix for Varying Levels of Risk for Target Income Rs 70,000

| Characteristics | Units | Farm Plans | | |
|---|---|---|---|---|
| | | Plan 1 | Plan 2 | Plan 3 |
| Target Income Rs | Rs | 70,000 | 70,000 | 70,000 |
| λ | Rs | 11,000 | 15,000 | 20,500 |
| Obj. Function | Rs | 94786 | 95895 | 96736* |
| Enterprise Mix: | | | | |
| Wheat | Acre | 14.13 | 13.89 | 13.68 |

| | | | | |
|---|---|---|---|---|
| Rice | Acre | 16.60 | 14.47 | 18.18 |
| Sorghum | Acre | 1.86 | 2.11 | 2.31 |
| Peas | Acre | 3.00 | 2.99 | 2.99 |
| Berseem | Acre | 1.36 | 1.61 | 1.81 |
| Carrot | Acre | 2.00 | 2.00 | 2.00 |
| Eggplant | Acre | 2.04 | .92 | 0.00 |
| Buffalo | Heads | 1.45 | 2.44 | 3.25 |

Source: Survey data.
*LP Solution.

The target MOTAD frontiers associated with the results in Tables 2 through 5 were traced for each level of target income and are reported in Figure 1. The target MOTAD frontiers were quite flat as the expected income from all solutions vary only slightly. In almost all cases, the expected income from farm plans over the range of λ tested were quite close to the expected income from the deterministic LP plan.

Table 4
Optimal Net Returns and Enterprise Mix for Varying Levels of Risk for Target Income Rs 80,000

| Characteristics | Units | Farm Plans | | | |
|---|---|---|---|---|---|
| | | Plan 1 | Plan 2 | Plan 3 | Plan 4 |
| Target Income Rs | Rs | 80000 | 80000 | 80000 | 80000 |
| λ | Rs | 32000 | 35000 | 40,000 | 43,000 |
| Obj. Function | Rs | 93287 | 95019 | 96152 | 96736 |
| Crop Mix: | | | | | |
| Wheat | Acre | 16.80 | 14.09 | 13.82 | 13.68 |
| Rice | Acre | 16.02 | 16.72 | 17.71 | 18.18 |
| Sorghum | Acre | 1.83 | 1.89 | 2.17 | 2.31 |
| Peas | Acre | 0.36 | 3.00 | 2.99 | 3.00 |
| Berseem | Acre | 1.33 | 1.39 | 1.68 | 1.81 |
| Carrot | Acre | 2.00 | 2.00 | 2.00 | 2.00 |
| Eggplant | Acre | 2.65 | 1.91 | 0.61 | 6.00 |
| Buffalo | Heads | 1.33 | 1.58 | 2.71 | 3.25 |

Source: Survey data.

Table 5
Optimal Net Returns and Enterprise Mix for Varying Levels of Risk for Target Income Rs 90,000

| Characteristics | Units | Farm Plans | | |
|---|---|---|---|---|
| | | Plan 1 | Plan 2 | Plan 3 |

| | | | | |
|---|---|---|---|---|
| Target Income Rs | Rs | 90000 | 90000 | 90000 |
| λ | Rs | 65000 | 70000 | 72,500 |
| Obj. Function | Rs | 94928 | 96152 | 96736 |
| Enterprise Mix: | | | | |
| Wheat | Acre | 14.10 | 13.82 | 13.68 |
| Rice | Acre | 16.72 | 17.71 | 18.18 |
| Sorghum | Acre | 1.90 | 2.17 | 2.31 |
| Peas | Acre | 3 00 | 3.00 | 3.00 |
| Berseem | Acre | 1.40 | 1.68 | 1.81 |
| Carrot | Acre | 2.00 | 2.00 | 2.00 |
| Eggplant | Acre | 1.88 | 0.61 | 0.00 |
| Buffalo | Heads | 1.58 | 2.71 | 3.25 |

Source: Survey data.

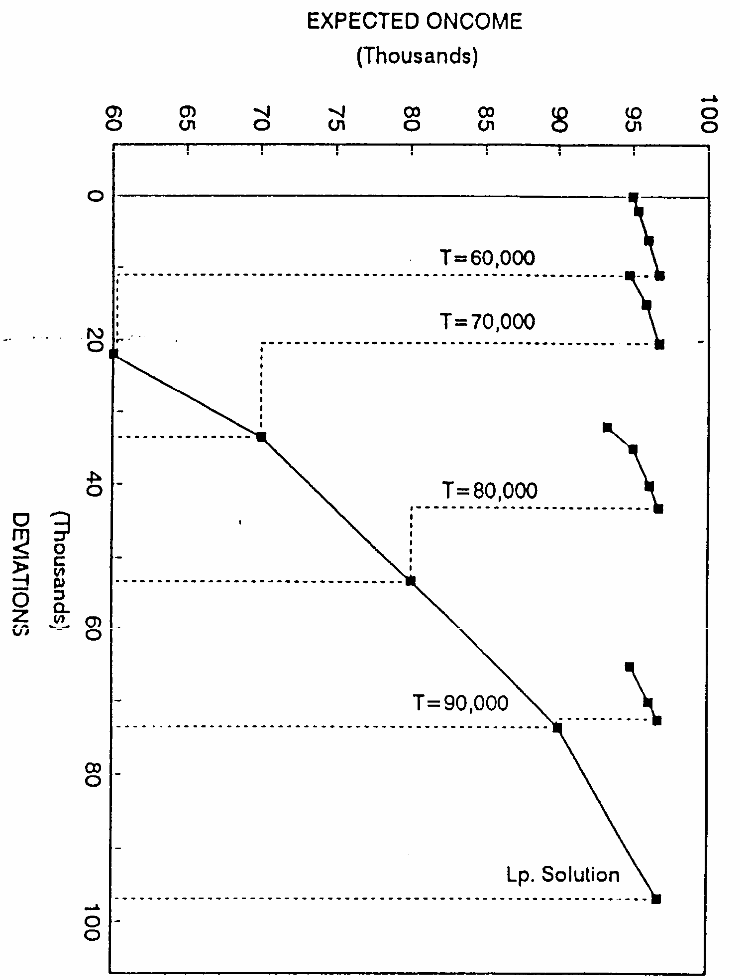


Figure 1 A Comparison of MOTAD & Target MOTAD

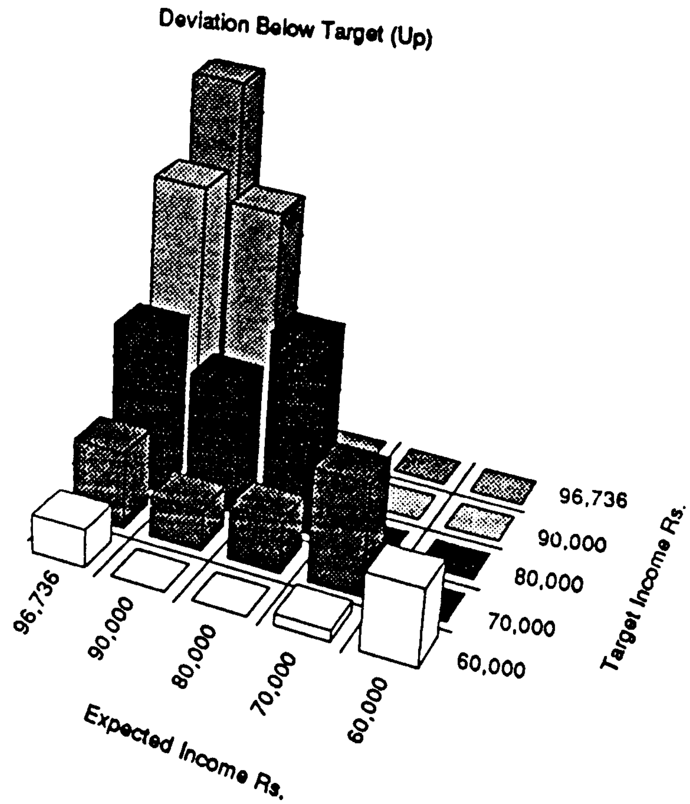


Figure 2. Target MOTAD Surface for
Resource Allocation Analysis

## 10. MOTAD AND TARGET MOTAD: A COMPARISON

For comparison, the target MOTAD solutions were generated by using the MOTAD expected income, discussed elsewhere (Zia, 1993) as a target. Expected shortfall l was parameterized to trace an efficiency frontier. When it was set at the same level as the negative deviations of the corresponding MOTAD solution, it always generated the deterministic LP solution. The comparison of MOTAD and target MOTAD solutions is depicted in Figure I.

Target MOTAD solutions always generated higher expected incomes with negative deviations less than those in the corresponding MOTAD solutions. If risk is conceived as deviations below target income, target MOTAD solutions resulted [in] lower negative deviations and, thus, less risk. Moreover, the target MOTAD efficiency frontiers are above the MOTAD efficiency frontier everywhere. This implies that target MOTAD solutions have higher expected income than MOTAD solutions in all situations. Therefore, target MOTAD solutions were found to be clearly superior to MOTAD solutions. Similar corroborative results were also found by Watts et al., (1984) and Helmers et al., (1986).

Figure 2 depicts a three-dimensional surface for target MOTAD analysis. The horizontal axis represents the expected income that decreases from left to right. Deviations from target incomes are shown by the vertical axis as heights. The “side” axis reflects target incomes. The diagonal set of columns (from the front corner to the back corner), where the expected income equals the target income, represents the MOTAD frontier. The LP solutions are shown in the far left column for the cases where l is not a binding constraint in the target MOTAD solution.

As the expected income is increased for specified targets, negative deviations decline and then increase. This positively sloped part of the surface represents the decision area. It can clearly be seen from the surface that the decision area is substantially away from the MOTAD frontier, indicating that target MOTAD solutions are superior to MOTAD solutions.

## 11. CONCLUSION

The profit-maximising plan does not truly represent farmers' current decision- making and resource allocation behaviour. This implies that there are some other factors that influence farmers resource allocation. Essentially, price and production risk is one of them. It looks imperative that research efforts need to be directed towards generating risk-efficient farm plans for all agro-ecological zones of the country to help decision-makers in allocating available agricultural resources more efficiently in a risky environment.

This research effort has developed some crop rotations for various levels of target income and risk associated with each crop rotation for farmers in the rice-wheat zone of the Punjab. The result, however, needs to be used with care as the plans are generated for a typical farm that owns a tractor and has a tube-well for supplementary irrigation. These farm plans will have little applications for the farms with irrigation water as a binding constraint.

Though the target MOTAD model has generated farm plans that include a variety of crops and livestock activities, it suggests more specialisation. As with almost all target income levels and with whatever risk permitted, wheat and rice are the dominant crops in all the strategies. As the climatic conditions are ideal for this rotation in the area, these two crops are the dominant crops in the existing farming systems. The model results are, thus, congruent with the prevailing conditions.

Work needs to be extended to small and medium farms to develop risk-efficient farm plans for them and help assess the risk involved at different levels of resource base and provide them with information that can help allocate available farm resources more efficiently and enable small farmers in developing their own risk management strategies.

The model results can usefully be utilised to transform our traditional agriculture through allocating available agricultural resources more efficiently and scientifically. To do so, risk programming models can be developed for all classes of farmers and for all agro-ecozones and resource allocation plans can be conveyed to the farm community through existing extension network. However, extension workers will require substantial training in using these computer-based models. Extensionists, by using the model results, can assist the farmers in selecting farm plans that can best suit the farmers' production environment and risk attitude. For instance, a farmer who has information available on farm returns and associated risk and is willing to take risk, can realise substantially higher income from the same resources by selecting high- income, high-risk farm plans. On the contrary, the risk-averse farmers will have the opportunity to avoid risk by selecting low-risk farm plans but they will have to sacrifice some income as a trade-off.

These models can also be utilised effectively in tailoring credit policies and in their implementations. The model will provide information on the credit needs of the farm, if any. Thus, the financial institutions can assess the total credit requirements in each crop season and can allocate funds for farm credit as required. On the other hand, farmers can make necessary credit arrangements well in advance. The farm manager can avoid delays in credit availability. With each farm plan, the model provides estimates of the resources required. This information can indeed be very useful for farm managers resource use planning.

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