Journal of Rural Development 10 (June 1987): 41~53

THE TRADEOFF BETWEEN EXPECTED RETURN AND RISK IN FARM PLANNING: MOTAD AND TARGET MOTAD APPROACH

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Introduction

Risk is widely recognized as a key factor in farm enterprise choice. Thus, the inclusion of risk in farm planning has been considered desirable in many theoretical discussions. The tradeoff between expected return and income variability is at the heart of the enterprise choice under risk. An efficient frontier provides information concerning the tradeoff between expected return and risk in the enterprise choice decision. The frontier is particularly useful when the risk among enterprises varies substantially.

Several approaches have been proposed in deriving out the efficient sets. Markowitz(1959) proposed the mean-variance(E-V) approach. Subsequently, Freund adapted the E-V model to farm enterprise choice decisions. This approach is the most familiar and most widely used. When decision makers are risk averse and the outcome distributions are normal or the decision maker's utility functions are quadratic, then E-V efficient set is identical to the second stochastic dominance(SSD) efficient set. This approach uses quadratic programming. Hazell(1971) suggested the mean-absolute deviation (MOTAD) approach that is an approximation to E-V efficiency approach. The MOTAD efficiency sets(E-A) holds for risk averse decision makers. It closely resembles the E-V efficient set when the outcome distributions are approximately normal. The MOTAD is modelled with linear programming. Tauer (1983) developed Target MOTAD whose solutions are a subset of SSD solutions. The model can be solved with a linear programming algorithm. Since the model contains a parameter to be varied, the solution procedure is similar to the algorithm for a regular MOTAD model. Kliebenstein (1984) presented target semi mean squared deviations(TSMSD) in place of, or as a supplement to, Target MOTAD for computing stochastically efficient mixtures of risky alternatives.

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The unique solutions of TSMSD belong to the set of third degree stochastic dominance(TSD) efficient sets. This approach uses quadratic programming. However, it is not widely recognized yet. Stochastic dominance criteria, which are consistent with expected utility theory, have largely replaced the E–V and E–A criteria for analysis involving discrete alternatives. However, stochastic dominance criteria are not widely used for portfolio problems as there is no widely known simple way to find all efficient mixtures of alternatives.

Each approach has its own strength and weakness in its practical usage. In this tradeoff analysis, the MOTAD and Target MOTAD approaches were used because they can be solved with a linear programming algorithm and offer computational and cost advantages over quadratic programming.

The objectives of this paper are 1) to derive efficient frontier that shows tradeoff between expected return and risk with the data for an assumed representative farm in southwestern Oklahoma and 2) to examine some questions in the use of the efficient frontiers in the enterprise choice decisions.

This paper first presents the two models, MOTAD and Target MOTAD. It then defines an assumed representative farm in Caddo County in Southern Oklahoma and describes data requirements. The data analysis and its results follow. Finally, summary and conclusions are provided.

The Models

MOTAD

This model assumes a utility function:

$$U(Z) = a + bZ + c[Z - E(Z)]$$

where

a, b, and c are positive constants and

Z is the random variable.

The general form of the model is

Minimize Ld^-

Subject to

$AX \leq B$

$DX + Zd^- \geq 0$

$C'X = \lambda$

and

$$X,\ d^-,\ \lambda \geq 0,$$

where

X, A, B, and C represent activity levels, technical coefficients, resource constraints and gross margin expectation, respectively. The gross margin expectation is the mean of gross margin series. D is the matrix of deviations, the differences between the observed gross margin and the gross margin expectation for each activity in a given year. The vector d^- represents yearly total negative deviations summed over all risky activities. Ld^- repersents the summed total negative deviations over all years. λ is a scalar used to represent the income constraint. Then, the efficient frontier is developed by parameterizing λ from zero to its maximum value. The tradeoff occurs between mean gross margin and risk(negative income deviation).

In the MOTAD model, risk measured as linear deviations from the mean. Implicitly, risk is undesirable, and hence is minimized (Watts 1984). The E–A frontier inherent in MOTAD is often used as a substitute for the E–V frontier since the linear programming codes required to solve MOTAD formulations are more widely available, better understood and more dependable than the quadratic programming codes required to implement the E–V frontier. Johnson and Boehlje(1981) have provided theoretical support for the MOTAD by arguing that it can be used to maximize expected utility when the outcome distributions are symmetric and the utility function is quadratic, negative exponential or logarithmic (Kliebenstein, 1984). However, it has been also criticized by Buccola who argues that MOTAD is inferior to the E–V criterion since it involves the use of inefficient estimators of population parameters.

Target MOTAD

This model assumes a utility function:

$$U(Z) = a + bZ + c(Z - h) \quad \text{if } Z < h, \text{ and}$$
$$U(Z) = a + bZ \quad \text{if } Z > h$$

where

a, b and c are positive constants,
h is the fixed reference points of target and
Z is the random variable.

The general form of the model is

$$\text{Maximize } \overline{C}'X$$
$$\text{Subject to}$$
$$AX \leq B$$
$$-CX - Y \leq -UT$$
$$P'Y = \lambda$$

and

$$X,\ Y \geq 0$$

where

$\overline{C}$, X, A, and B represent expected return, activity levels, technical coefficients, and resource constraints, respectively,

C is returns associated with the activities for various states of nature,

Y is deviation from target income,

U is an identity matrix,

T is target income,

P is probabilities associated with the various states of nature,

and

λ represents the absolute value of expected negative deviations from target income. The efficiency frontier may be traced out by parameterizing λ for each target income level.

In this model, mean return is maximized subject to a limit on the total negative deviations measured from a fixed target rather than from the mean. Since deviations are not measured from the mean, total negative deviation is not equal to the total positive deviation. This model allows for comparison between solutions using a common risk reference point (Watts 1984). Tauer (1983) has shown that all unique Target MOTAD solutions are members of the SSD efficient set. However, McCamley and Kliebenstein(1984) argue that there are no assumptions that it will find all SSD efficient solutions.

The Farm Situation and Data Requirement

A representative family farm situation for Caddo County in southwestern Oklahoma was assumed for the analysis (See location map). The farm contains 1,200 acres of dry cropland and $100,000 of own operating capital. It also has 3,000 man hours of family labor available per year which are equally distributed over four quarters in a year. Crop activities include wheat, cotton, sorghum, oats, barley, and alfalfa. Both models require data on yield, product price and production cost. Historical data for 1975–84 were obtained from Oklahoma Agricultural Statistics and Oklanoma State University Farm Budget Generator for each activity in the models. Current product prices were used in calculating gross revenue. Agricultural technologies were assumed constant over the period. The index of prices paid by farmers was used to obtain the production cost series at current value from 1984 back to 1975 for each activity. Then nominal gross margins for each activity were calculated by subtracting the variable cost of production during each year from the appropriate gross revenue in that year. To find the different effects between the nominal gross margin and the deflated gross margin on the enterprise choice decision analysis, nominal gross margin was deflated by index of prices received by farmers that gave deflated gross margin expressed in 1977 value. Estimated nominal gross margins and deflated gross margins for selected crops are presented in Tables 1 and 2. The nominal gross margin correlation was positive between most of the crops, with the exception between alfalfa, wheat, oats and cotton(Table 3). The deflated gross margin correlation was the same with the nominal gross margin in sign except that sorghum now has negative correlation with alfalfa(Table 4).

Location Map (Caddo County)

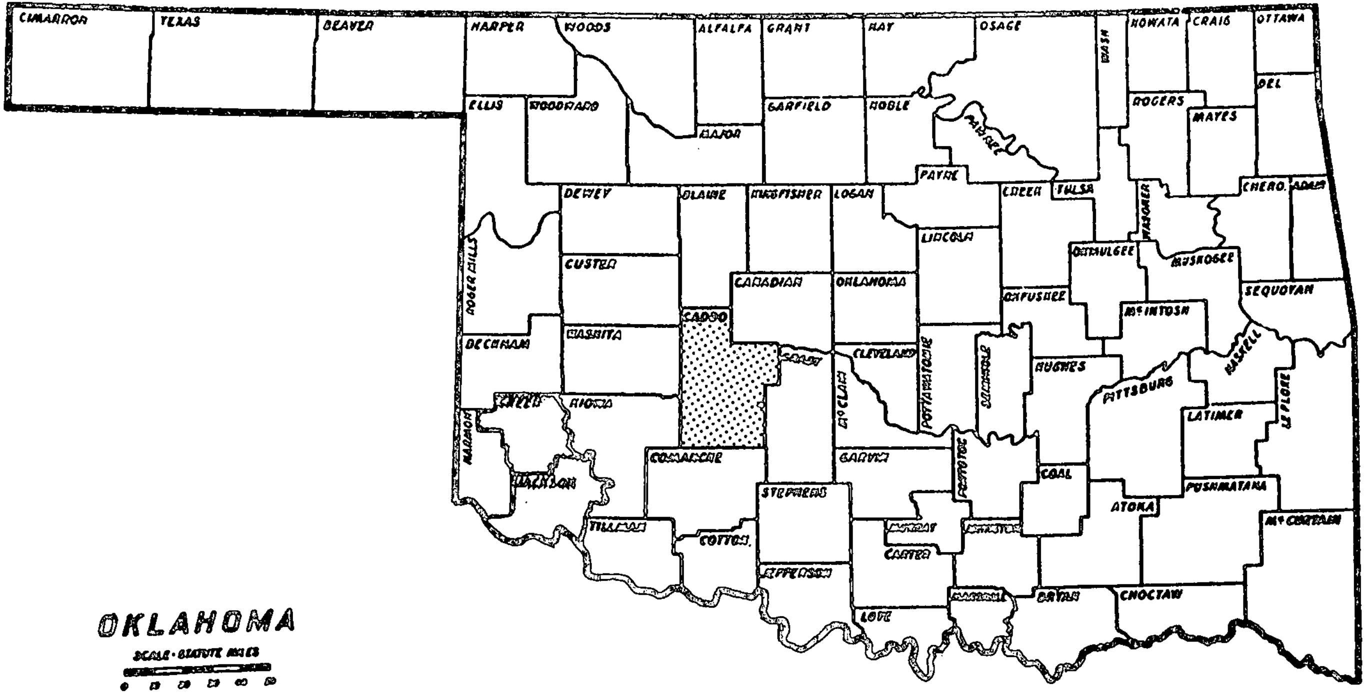


TABLE 1 **Estimated Nominal Gross Mangins for Selected Crops in Southwestern Oklahoma**

$/ACRE

Year	WHEAT	BARLEY	SORGHUM	OATS	COTTON	ALFALFA
1975	61.36	38.71	86.36	16.36	43.87	87.54
1976	35.23	69.91	26.00	26.86	97.36	145.31
1977	40.43	18.54	34.04	25.25	117.03	68.62
1978	50.09	5.08	57.96	10.01	88.68	62.20
1979	121.88	46.26	76.89	29.47	160.71	87.56
1980	50.91	11.62	18.07	7.80	63.60	87.19
1981	70.71	17.82	65.21	26.40	94.53	107.18
1982	62.57	9.34	59.57	1.74	21.42	96.91
1983	77.94	47.81	80.88	38.83	66.21	101.71
1984	58.99	25.26	69.41	-4.32	30.23	167.89
MEAN	63.11	29.04	57.44	17.84	78.36	101.21
STANDARD DEVIATION	23.10	19.82	22.49	13.04	40.15	30.98
C.V.	0.37	0.68	0.39	0.73	0.51	0.31

TABLE 2 **Estimated Deflated Gross Margins for Selected Crops in Southwestern Oklahoma(1977 = 100)**

$/ACRE

Year	WHEAT	BARLEY	SORGHUM	OATS	COTTON	ALFALFA
1975	48.32	30.48	68.00	12.88	34.54	68.93
1976	29.36	59.26	21.67	22.38	81.14	121.09
1977	40.43	18.54	34.04	25.25	117.03	68.62
1978	49.59	5.03	57.38	9.91	88.68	61.58
1979	118.33	44.91	74.65	28.61	156.03	85.01
1980	39.33	8.80	13.69	5.91	48.18	66.05
1981	50.15	12.63	46.25	18.73	67.05	76.01
1982	52.14	7.79	49.64	1.45	17.85	80.76
1983	54.12	33.20	56.17	26.57	45.98	70.63
1984	38.31	16.40	45.07	-2.61	19.13	109.02
MEAN	52.01	23.61	46.66	14.93	67.52	90.77
STANDARD DEVIATION	23.28	16.75	18.24	10.56	41.92	18.55
C.V.	0.45	0.71	0.39	0.71	0.62	0.23

TABLE 3 **Correlation Coefficients of Crop Enterprise Nominal Gross Margins**

$/ACRE

	WHEAT	BARLEY	SORGHUM	OATS	COTTON	ALFALFA
WHEAT	1.00000	0.17916	0.07794	0.31776	0.39842	-0.11501
BARLEY		1.00000	0.83283	0.59322	0.29645	0.44473
SORGHUM			1.00000	0.35179	0.06536	0.52149
OATS				1.00000	0.64965	-0.21654
COTTON					1.00000	-0.33319
ALFALFA						1.00000

TABLE 4 **Correlation Coefficients of Crop Enterprise Deflated Gross Margins**

	WHEAT	BARLEY	SORGHUM	OATS	COTTON	ALFALFA
WHEAT	1.00000	0.2644	0.6887	0.4118	0.6057	-0.1422
BARLEY		1.0000	0.0950	0.6358	0.3871	0.5771
SORGHUM			1.0000	0.1907	0.1814	-0.2507
OATS				1.0000	0.7276	-0.0790
COTTON					1.0000	-0.0673
ALFALFA						1.0000

Results

MOTAD Results

Risk–return sets and associated enterprise combinations are presented in Tables 5 and 6. Nominal gross margin was varied in $5,000 intervals with a few $ 500 intervals at the high risk–return level(Table5). Deflated gross margin was varied in $4,000 intervals with a few $ 500 intervals at the high risk–return level(Table 6). The resulting E–A frontiers are illustrated in Figure 1(nominal gross margin)and Figure 2(deflated gross margin). There is a specific farm plan associated with each point on the frontiers. However, only selected farm plans for the frontiers are shown in the two tables. The enterprise combinations appear to be consistent with those expected, based on the level and variability of individual crop enterprise gross margin. Crop combinations changed along the frontiers. There appeared differences in enterprise combinations between the analysis with nominal gross margin and with deflated gross margin.

TABLE 5 **Tradeoff between Risk and Expected Return(MOTAD)**

(Nominal Gross Margin)

Mean Gross Margin	Negative Deviation from Mean Income	CROP COMBINATION						
		WHEAT	BARLEY	SORGHUM	OATS	COTTON	ALFALFA	C.V.
$	$	ACRE						
82740	93122	879	0	0	0	298	66	0.3
82240	86681	965	0	0	0	107	128	0.28
81740	85637	958	13	0	0	96	131	0.28
78740	82562	905	70	0	0	96	129	0.27
77740	79480	851	126	0	0	94	128	0.27
62740	58853	555	183	0	0	118	130	0.25
52740	46178	403	58	0	0	150	137	0.23
47740	39865	322	0	8	0	166	138	0.22
42740	33897	169	0	117	0	174	115	0.21
37740	27926	16	0	226	0	183	93	0.2
32740	24015	0	0	209	0	161	79	0.19
27740	20347	0	0	177	0	137	67	0.19
17740	13017	0	0	113	0	88	43	0.19

TABLE 6 **Tradeoff between Risk and Expected Return(MOTAD)**
(Deflated Gross Margin)

Mean Gross Margin	Negative Deviation from Mean Income	CROP COMBINATION						
		WHEAT	BARLEY	SORGHUM	OATS	COTTON	ALFALFA	C.V.
$	$				ACRE			
68882	88557	839	0	0	0	295	66	0.34
68382	78651	897	0	0	0	212	93	0.3
67882	74871	951	0	0	0	129	121	0.29
64882	66876	988	0	0	0	3	165	0.27
60882	61070	904	0	0	0	2	169	0.26
59882	59631	884	0	0	0	2	170	0.26
58882	58192	863	0	0	0	2	170	0.25
56882	55327	821	5	0	0	1	174	0.25
52882	49615	727	9	16	0	0	175	0.25
45882	43902	632	12	34	0	0	175	0.24
46882	38190	538	14	53	0	0	175	0.22
36882	32476	443	17	71	0	0	175	0.21
32882	26766	348	20	69	0	0	175	0.19
28882	21408	213	0	160	9	23	157	0.17
24882	16673	95	0	181	1	53	147	0.15
20882	14152	0	0	187	68	53	143	0.15
16882	11877	0	0	157	57	45	120	0.15
	9602	0	0	127	46	36	97	0.15

With nominal gross margin, most acreage was committed to wheat, cotton and alfalfa at higher risk–return levels. As the levels decrease, the crop mixes changed to wheat–barley–cotton–alfalfa, then to wheat–sorghum–cotton–alfalfa, finally to sorghum–cotton–alfalfa at the lower risk–return levels. Oats never entered the farm plans at any risk–return level. This may be due to its highest gross margin variation with the lowest gross margin among the corps under consideration. Crop diversification was not evident at the lowest range of risk return levels although more crop combinations were observed at the medium range of the risk–return level. Cotton and alfalfa stayed in the crop mixes at every risk–return level.

With deflated gross margin, five different crop combinations were observed at different risk–return levels. As the risk–return levels decreased, crop diversification was evident. Cotton was not selected at the medium range of risk–return level, while oats entered the farm plan at the lower levels. This may be due to the fact that, from deflation, variation of oats decreased while that of cotton increased.

The tradeoff between risk and return is obtained by the coefficient of variation. In both of the nominal and deflated gross margin uses, as gross margin decreased, the coefficient of variation was reduced which shows that risk per dollar of expected return was reduced.

The E–A frontier with nominal gross margin are presented in Figure 1 and the E–A frontier with deflated gross margin in Figure 2. Both of the frontiers show the identical shape of curve. Three ranges of risk–return tradeoff are eminent. In risk range C, small increase of expected return accompanied considerable risk increase. The tradeoff in range A was opposite to that in range C. Range B showed moderate tradeoff and was the widest in the choice range.

Target MOTAD Results

Target MOTAD results were generated by using the MOTAD mean income as

FIGURE 1 **Tradeoff between Risk and Return(Nominal Gross Margin)**

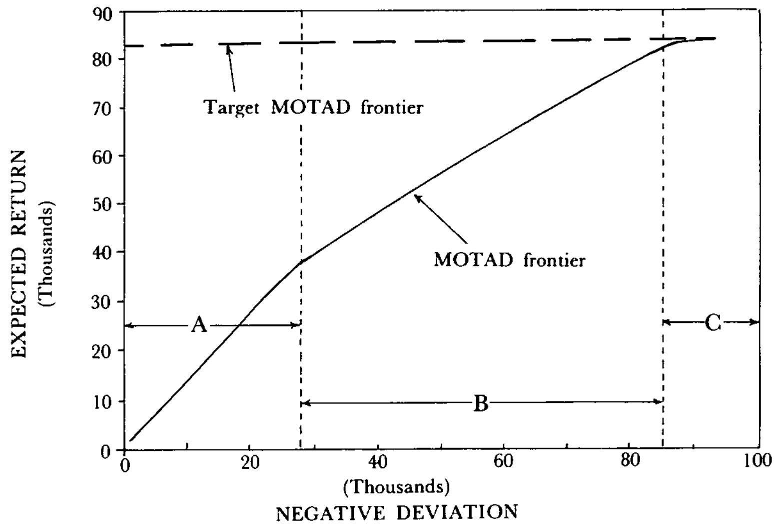
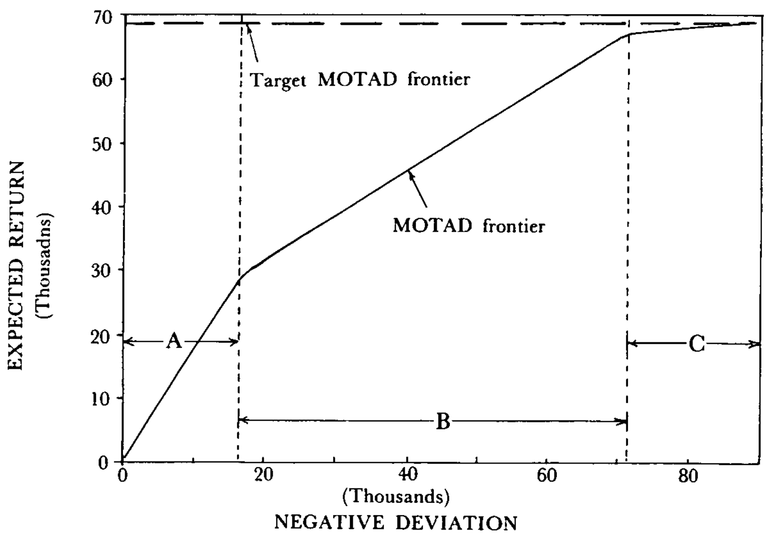


FIGURE 2 **Tradeoff between Risk and Return(Deflated Gross Margin)**



the target (initially with LP solution) and setting the maximum total negative deviations at the same level as in the corresponding MOTAD solution. Risk-retrurn sets and associated enterprise combinations at different target income levels are presented in Table 7 (with nominal gross margin) and Table 8 (with deflated gross margin). The efficient frontiers at different target income levels are again illustrated in Figures 1 and 2. The maximum mean income levels remained constant at $82,740 for nominal gross margin analysis in every negative income deviation for different target income levels. With deflated gross margin analysis, it remained at $68,882. In both cases, the crop combination includes three crops; wheat, cotton and alfalfa at every level of risk–return level. That is, the increase or decrease of risk did not cause change of the expected returns and crop combinations. Thus, the Target MOTAD frontier was horizontal at the certain level of expected return in both (nominal and deflated) cases. This may be due to the fact that the three crops selected are dominating over the other crops in terms of mean gross margin and coefficient of gross margin variations. In this farm situation the Target MOTAD solution was identical to LP solution that is the riskest.

Watts(1984) provides detailed comparisons between MOTAD and Target MOTAD approaches in risk analysis. However, it may be still worth to note some problems in the use of MOTAD and Target MOTAD approaches in tradeoff analysis on this specific farm situation where some crops are dominating. The principle purpose of risk–return analysis lies in ranking alternative farm plans on the basis of risk and examining tradeoffs between risk and mean income (Watts 1984). MOTAD offered some tradeoff between risk and return at various levels, which gave different crop combinations. However, Target MOTAD gave only one choice of crop combination with expected return that was identical to initial LP solution which is the riskest. Although wheat, cotton and alfalfa are dominating crops in Caddo County, the farmers are growing sorghum, oats and barley substantially. With the exception of the highest initial risk level, Target MOTAD gave higher expected returns than the MOTAD approach at every risk level. It was not clear which approach might be more useful for crop mix selection in reality with this farm situation. One way to make comparison between the two may be the sensitivity analysis of the frontiers for each approach (Schurle and Erven 1979), which is beyond the scope of this study.

In the use of the frontiers, some cautions need to be mentioned. With MOTAD, risk reduction is obtained from decreasing expected return. However, farmers have many other risk management strategies which can reduce risk without decreasing expected return. With Target MOTAD, it presented only one crop combination. In reality, farmers have more diversification of crops. They may need information on the risk–return tradeoff for other crops included. In this analysis, profit maximization was assumed the goal of the farm. But, it is generally accepted that farmers have many other goals. These goals may have to be considered in the use of the frontiers.

TABLE 7 **Tradeoff between Risk and Expected Return(Target MOTAD) (Nominal Gross Margin)**

Mean Gross Margin	Target Income	Negative Deviation from Mean Income	CROP COMBINATION					
			WHEAT	BARLEY	SORGHUM	OATS	COTTON	ALFALFA
$	$	$	ACRE					
82740	82740	93122	839	0	0	0	295	66
82740	82240	86681	839	0	0	0	295	66
82740	81740	88677	839	0	0	0	295	66
82740	79740	82562	839	0	0	0	295	66
82740	77740	79480	839	0	0	0	295	66
82740	62740	58853	839	0	0	0	295	66
82740	52740	46178	839	0	0	0	295	66
82740			839	0	0	0	295	66
82740			839	0	0	0	295	66
82740			839	0	0	0	295	66
82740	2740	2009	839	0	0	0	295	66
82740	82740	93122	839	0	0	0	295	66
82740	82240	90681	839	0	0	0	295	66
82740	82240	88681	839	0	0	0	295	66
82740	82240	86681	839	0	0	0	295	66
82740	82240	84681	839	0	0	0	295	66
82740	77740	81481	839	0	0	0	295	66
82740	77740	80480	839	0	0	0	295	66
82740	77740	79450	839	0	0	0	295	66
82740	77740	78450	839	0	0	0	295	66
82740			839	0	0	0	295	66
82740			839	0	0	0	295	66
82740	2740	2605	839	0	0	0	295	66
82740	2740	2309	839	0	0	0	295	66
82740	2740	2009	839	0	0	0	295	66
82740	2740	1709	839	0	0	0	295	66
68882	68882	88557	839	0	0	0	295	66
68882	68382	78650	839	0	0	0	295	66
68882	67882	74831	839	0	0	0	295	66
68882	64882	66826	839	0	0	0	295	66
68882	59882	59631	839	0	0	0	295	66
68882	52882	49615	839	0	0	0	295	66
68882	44882	38190	839	0	0	0	295	66
68882			839	0	0	0	295	66
68882			839	0	0	0	295	66
68882			839	0	0	0	295	66
68882	882	502	839	0	0	0	295	66
68882	68882	88557	839	0	0	0	295	66
68882	68382	84650	839	0	0	0	295	66
68882	68382	81650	839	0	0	0	295	66
68882	68382	78650	839	0	0	0	295	66
68882	68382	75650	839	0	0	0	295	66
68882	52882	53615	839	0	0	0	295	66
68882	52882	52615	839	0	0	0	295	66
68882	52882	49615	839	0	0	0	295	66
68882	52882	47615	839	0	0	0	295	66
68882			839	0	0	0	295	66
68882			839	0	0	0	295	66
68882	882	1501	839	0	0	0	295	66
68882	882	1001	839	0	0	0	295	66
68882	882	501	839	0	0	0	295	66
68882	882	101	839	0	0	0	295	66

Summary and Conclusions

The tradeoff between risk and return in efficient farm planning under uncertainty was examined with MOTAD and Target MOTAD approaches for assumed representative farm in southwestern Oklahoma. Efficient frontiers were driven out from each approach. Nominal gross margin as well as deflated gross margin were used to observe any difference in optimum combinations of enterprise, if any. In MOTAD, crop mixes from the use of nominal gross margin were different from that of deflated gross margin, In Target MOTAD, they were in the same. The MOTAD frontier showed the tradeoff at different risk–return levels.

On the other hand, Target MOTAD showed constant expected return at different risk levels. The return and enterprise combination with Target MOTAD was the same with the solutions of initial LP that did not incorporate risk into the farm plan at every risk level. MOTAD, with nominal gross margin, offered four different enterprise combinations with changing acreage allocated to each crop at different risk–return levels. MOTAD, with deflated gross margin, offered five different enterprise combinations. The Target MOTAD gave only one enterprise combination. Watts (1984) questions the usefulness of MOTAD in that risk is not expressed in a "pure" sense, and argues that Target MOTAD is a more plausible approach for examining risk–return tradeoffs. In the meantime, Kliebenstein(1984) claims that Target MOTAD has two limitations. First, there are no assurances that it will find all SSD efficient solutions. Second, for most applied problems, both the SSD efficient set and the complete set of Target MOTAD solutions are very large and include rather diverse mixtures. With the data used in this paper, the Target MOTAD did not show clearly the tradeoff between risk and return. It was hard to determine which model solutions be presented to the farmer with current farm situation when all the assumptions with the analysis are fulfilled. This paper cannot be conclusive about this question. Some additional work needs to be done investigating the two models in analyzing the farm situation like in this analysis.

Some limitations in this analysis may need to be mentioned. Farmer's goal was assumed to be only one: profit maximization. They may have many other goals in the selection of crop mixes. Government commodity programs were not considered. They influence the gross margin of the commodities under consideration. Peanuts, one of the major crops in Caddo County, was eliminated from the analysis due to data deficiency. The cost data of alfalfa obtained from the Oklahoma State University Farm Budget Generator was said to be underestimated a little bit when it was collected from the field. The correction of the cost data may result in the change of crop mix and the tradeoff relationship.

Despite many assumptions and limitations in this analysis, the MOTAD approach, by and large, offers some ideas about the possible efficient crop combinations at different risk–return levels. Target MOTAD turned out inflexible in the demonstration of the tradeoff at this farm situation (some crops are dominating). Final crop mix selections, of course, depend on the farmers utility function.

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