Utility-Efficient Programming: An Evaluation

by

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Utility-efficient programming (UEP) is a programming technique developed by Patten et al. (1988) for whole-farm planning under risk. UEP has several claimed advantages over previously used methods in risky farm planning. Two such advantages are that the degree of risk aversion can be limited to a plausible range and the form of the distribution for activity net revenues need not be normal. Stochastic dominance with respect to a function (SDRF, Meyer 1977; King and Robison 1981) is an efficiency criterion that also eliminates the need for restrictive assumptions about the functional form associated with the E-V approach. SDRF permits the ordering of risky decision options for DMs whose absolute risk aversion functions fall within the specified lower and upper bounds. However, SDRF cannot be used directly in a programming objective function. UEP and SDRF, both based on the SEU hypothesis, are evaluated for equivalence using a Monte-Carlo programming approach applying a negative exponential utility function.

Introduction

The many different motives of farming decision makers complicate the choice between existing feasible alternatives for agricultural producers and makes formalisation of decision making techniques that much more cumbrous. These motivational differences between farmers, coupled with the uncertainty associated with the production environment as well as the inherent difficulty in eliciting farmers utility functions, have made it difficult to put forward a wholly satisfactory approach to selecting the plan option that maximises farmer (farm-family) utility amongst a set of risky farm plans. Many of these models are designed to reproduce decision maker

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(DM) beliefs about possible outcomes encoded as their probabilities, as well as the DM's attitude to risk.

Methods of stochastic efficiency (SE) analysis can be used to partition a set of pre-specified risky prospects, such as alternative farm plans, into efficient and 'dominated' sub-sets. There should then be no farm plan outside the efficient set which would be preferred by the farmer(s) in question. However, most SE rules provide for the analysis of pre-specified alternatives and, with the exception of a few of the less satisfactory rules, there is no means by which the SE methods can be used to generate farm plans. By contrast, mathematical programming (MP) models used for farm planning generate an 'optimal' plan, for a specified objective function. Using parametric procedures, two or more goals can be incorporated into the model and the 'efficient' set of solutions, in terms of the possible trade-offs between these goals can be obtained.

Using such parametric methods of MP, a number of approaches to generate risk-efficient farm plans have been proposed, such as expected value-variance (E-V), minimisation of total absolute deviation (MOTAD), Target-MOTAD and mean-Gini programming (see Hardaker et al. 1991, Whitmore 1970; Hazell 1971; Anderson 1975; Anderson et al. 1977; Yizhaki 1982 and Tauer 1983 for a review of these models). Some of these methods produce plans that are members of the efficient sets in terms of particular SE rules. However, Patten, Hardaker and Pannell (1988) have argued that the 'utility-efficient programming' (UEP), effectively a reformulation of the Lambert and McCarl (1985) approach, has some important advantages over these methods.

Utility-Efficient Programming (UEP)

According to Patten et al. (1988), employing UEP allows identification of an efficient set of farm plans which includes all potentially farmer-selectable options. That is, plans in the identified efficient set dominate those not within the set and hence, no member of the target group of decision makers under consideration could possibly prefer any plan outside the efficient set.

An attraction of UEP is the elimination of the need to assume that the farm income (or other outcome of interest) is normally distributed or that decision makers of interest exhibit increasing absolute risk aversion as with quadratic risk programming (QRP).

Compared with QRP, utility-efficient solutions are superior as a basis of choice of farm plans (Patten et al. 1988).

Obtaining the efficient set of plans must necessarily involve the use of a utility function (or an approximation thereof) which is consistent with farmer preferences. Pratt (1964), has shown that the coefficient of absolute risk aversion, r_a, uniquely represents the preferences of a decision maker and consequently, a restriction on r_a should correspond to a restriction on DM preferences (Meyer 1977*a*,*b*). Such restriction of the DMs absolute aversion to risk forms the basis of both SDRF and UEP. Utility efficient programming utilises both a defined utility function and a restriction of the absolute risk aversion to represent DM preferences which effectively serves to further narrow the efficient set.

The more stringent choice criterion of UEP implies the least chance of excluding the most preferred plan. Where no utility function can be elicited or identified, a parametric programming model provides a feasible option for obtaining efficient farm plans that have the 'best probability' of including the farm plan (within the efficient set) that is most likely to be the most preferred by the individual DM. Within a defined range of risk aversion therefore, it is possible to obtain a limited set of optimum farm plans consistent with farmer preferences.

The UEP technique, as originally proposed, depends on the definition of a separable utility function of the form

$$U = F(z) + \beta G(z) \qquad (1)$$

such that the variation of the β parameter may be interpreted as risk preference variation. The model is defined as:

$$\max \; E(U) = p'F(z) + \beta[p'G(z)] \qquad (2)$$

subject to

$$Ax \le b$$
$$Cx - Iz = uf$$
$$\text{and } x \ge 0$$

where

F and G = appropriate functions of total net revenue (z);
β = risk preference variation;
p = vector of state probabilities;
A = matrix of technical coefficients;
x = vector of decision variables;
b = vector of RHS coefficients;
C = matrix of activity expected revenues;

I = identity matrix;
z = state-wise vector of criterion function;
u = vector of ones;
f = fixed costs.

Although the sumex function (Schlaifer 1971) was emphasised by Patten et al., they also provide an appendix of other suitable forms of utility functions that may be used for UEP. The use of a non-restrictive function such as the recently proposed Expo-Power (Saha 1993) is also a possibility.

Stochastic Dominance with Respect to a Function (SDRF)

The method of generalised stochastic dominance or stochastic dominance with respect to a function (SDRF) combines the use of a measure of decision maker preference interval (absolute risk aversion) with a stochastic dominance criterion and has been suggested (King and Robison 1981, Robison and Barry 1987) to be superior to single-valued utility functions or first-order stochastic dominance (FSD) and second-order stochastic dominance (SSD) for assessing risky prospects. The decision maker's risk preference is defined by upper and lower bounds on the absolute risk aversion coefficient (Pratt 1964). In formal terms, SDRF is a criterion that defines the necessary and sufficient conditions for the distribution of outcomes defined by a cumulative distribution function, A(y), to be preferred to that defined by another cumulative distribution function, B(y), by decision makers with absolute risk-aversion functions that lie between explicitly defined lower (r_2) and upper (r_1) bounds (Meyer 1977*b*; King and Robison 1981). SDRF can be used effectively to eliminate a large number of choices from consideration in comparison to the fundamental SE approaches of FSD and SSD (Hanoch and Levy 1969). SDRF achieves a higher discriminatory power than other SE criteria through the introduction of bounds on the absolute risk aversion coefficient. In so doing, of course, it is implicit that the results are valid only for DMs whose risk aversion falls within the set bounds.

For SDRF, upper and lower (r_1 and r_2) bounds are defined for r_a, the coefficient of absolute risk aversion, such that ,

$$r_1 < r_a < r_2$$

The absolute risk aversion, $r_a(y)$, may be represented by the Pratt/Arrow relationship;

$$r_a(y) = -u''(y)/u'(y) \qquad (3)$$

where,

$u'(y)$ = first derivative of the Neumann-Morgenstein utility function, $u(y)$; and
$u''(y)$ = second derivative of the same function.

Risk preference is indicated by the degree of convexity or concavity of $u(y)$. However, it follows from the axioms of utility theory that this latter function is defined only up to a positive linear transformation. The absolute risk aversion function is the simplest measure of curvature that remains constant for such a transformation. It therefore provides a unique and consistent indication of the risk attitude of the decision maker - whether risk-preferring or risk-averse.

The solution procedure for SDRF, according to Meyer (1977*a*), involves the identification of some utility function $u_0(y)$ which minimises

$$\int_{-\infty}^{\infty} [B(y) - A(y)]u'(y)dy \qquad (4)$$

subject to

$$r_1(y) \le -u''(y)/u'(y) \le r_2(y) \qquad \text{(for all individuals)}$$

Equation 4 may be interpreted as the difference between the expected utilities of outcome cumulative distributions A(y) and B(y). For a defined group of DMs for whom the minimum value of this difference is positive, A(y) would always be preferred to B(y) since the expected utility of A(y) is always greater than that of B(y). A minimum difference of zero implies indifference between A(y) and B(y). A negative minimum difference indicates A(y) cannot always be preferred to B(y). Thus,

$$\int_{-\infty}^{\infty} [A(y) - B(y)]u'(y)dy \qquad (5)$$

is alternatively minimised to determine whether B(y) would always be preferred to A(y). Another negative minimum difference for this formulation would suggest that neither A(y) nor B(y) is always a preferred choice of the DMs under consideration. Meyer (1977*a*) demonstrates how to find the necessary and sufficient conditions for some distribution B(y) to be preferred or indifferent to another distribution, A(y) for given group of DMs.

King and Robison (1981) provide a feasible procedure for eliciting the upper and lower bounds of the risk aversion function which is seemingly easier than attempting elicitation of a utility function. For the purposes of this paper however, the upper and lower bounds of the risk aversion function are set at 1 x 10^{-4} and 1 x 10^{-6} respectively, following Patten et al.

As noted by Lin and Chang (1978), the properties of absolute risk aversion functions derived from estimated utility functions are determined by the functional form. The attraction of the SDRF approach is that risky alternatives can be ranked without the necessity for a detailed knowledge of DM preferences. As an efficiency criterion however, SDRF is yet to be incorporated into standard MP models.

Empirical Evaluation

Whilst Patten et al. opted to use a separable, sumex-type utility function, here in contrast a non-separable negative exponential utility function is used, given by:

$$U(y) = 1 - \exp\text{-}(r_1 + \lambda d)z_k \qquad \text{for } 0 \leq \lambda \leq 1 \qquad (6)$$

where

z_k = total net revenue for state k;
r_1 = upper bound of risk-aversion function;
d = difference between lower and upper bound (r_2 - r_1) of risk-aversion function;
λ = non-negative measure of risk-aversion.

This functional form exhibits constant absolute risk aversion as income, z, increases and allows variation of r_a between r_1 and r_2 as the parameter, λ is varied. Instead of using linear approximation of the function (Duloy and Norton 1975; Patten et al. 1988), the solution procedure adopted is the use of non-linear programming with stepwise variation of λ.

For the UEP approach, the problem is formulated as a mathematical programming problem of the form:

$$\max \quad E[U] = \Sigma_k p_k [\, 1 - \exp\text{-}(r_1 + \lambda d)z_k \,] \qquad (7)$$

subject to

$$z_k = c_k{}'x \qquad \text{for } k = 1, 2, \ldots, K$$
$$Ax \leq b$$

and

$$x \geq 0$$

where

A = vector of input-output coefficients;
z_k = total net revenue for state k;
λ = non-negative parameter;
b = vector of RHS values (resource stocks);
p_k = probability of state k (subjectively assessed);
x = vector of activity levels;
c_k = activity net revenue vector for state k.

The example problem in Hardaker (1979) is adapted for the purposes of this paper. The indicated problem is one of choice between five activities (wheat, barley, seed grass, potatoes and pigs) subject to eight constraints (land, cereal, wheat, potatoes and pig limits and labour availability over three periods). Details of these activities and constraints are given in Table 1. The vector of activity net revenues over four states of nature (each considered to be equally likely) are provided in Table 2. The formulation was solved using MINOS-5 (Murtagh and Saunders 1988), a non-linear, non-parametric algorithm, with stepwise variation of the measure of risk aversion, λ.

UEP Results

With the assumption that the vector of activity net revenues representing the five activities given in Table 2 are equally likely to occur (probability of 0.25) and the further assumption that the negative exponential utility function described by equation 6 closely approximates DM preferences, the utility-efficient set of farm plans for selected values of the parameter, λ are provided in Table 3. For parameter values above 0.7, there was no significant change in the farm plans obtained. This result occurs because, in this case with a simplistic model, the utility maximising solution for a range of lower values of r_a is the same as for the maximisation of total expected net revenue, i.e., the risk-indifferent solution.

Table 1: Problem Matrix

Constraint	*Unit*	*RHS*	*Sign*	*Activity*				
				Wheat	*Barley*	*Grass Seed*	*Potatoes*	*Pigs*
				ha	ha	ha	ha	head
Land Area	ha	150	≥	1	1	1	1	0
Limit Cereals	ha	130	≥	1	1	0	0	0
Limit Wheat	ha	100	≥	1	0	0	0	0
Limit Potatoes	ha	20	≥	0	0	0	1	0
Limit Pigs	head	30	≥	0	0	0	0	1
Labour Period I	h	500	≥	1	3	1	10	2
Labour Period II	h	550	≥	3	3	4	0	2
Labour Period III	h	450	≥	3	1	0	25	2

Table 2: Vector of Activity Net Revenues, $/unit

State	*Activity*				
	Wheat	*Barley*	*Grass Seed*	*Potatoes*	*Pigs*
	ha	ha	ha	ha	head
1	200	170	300	600	120
2	250	230	500	350	190
3	270	200	100	1050	140
4	300	260	250	800	160

Between risk aversion values of 0.3 and 0.65, there was significant variation in the activity levels included in the utility-efficient production strategies. Surprisingly, despite a much lower standard deviation of its expected net revenue than either potatoes or pigs, which were consistently included in the utility-efficient solutions and the strong positive covariance between wheat and pig expected net revenues. The inclusion of barley and pigs tended to decline with increasing risk aversion values. The converse was true for grass seed, and also for potatoes which has the highest net revenue variance. Not surprising was the inclusion of high levels of barley and pigs at low values because of the lower net revenue standard deviations of both these activities. Such a strategy would be one favoured by the more risk averse farmer with consequent lower expected total net revenue. Decreasing aversion to risk as measured by increasing λ levels, resulted in the inclusion of the relatively more 'risky' activities, potatoes and grass seed. Expected net revenue increased with increasing risk aversion up to a maximum (optimum) of $51682 at a level of risk aversion equal to 0.7.

Table 3: UEP solution for selected risk aversion values

	Activity levels					
Lamda value	Wheat (ha)	Barley (ha)	Grass Seed (ha)	Potatoes (ha)	Pigs (head)	Expected Total Net Revenue ($)
0.00	0.00	75.02	62.93	12.07	37	48256.75
0.05	0.00	73.35	64.47	12.18	36	48327.48
0.10	0.00	71.12	66.65	12.35	35	48465.68
0.15	0.00	68.87	68.64	12.50	34	48540.10
0.20	0.00	66.09	71.25	12.68	33	48664.75
0.35	0.00	55.37	81.21	13.42	30	49151.28
0.45	0.00	44.74	91.11	14.16	26	49641.43
0.55	0.00	29.14	105.63	15.23	20	50349.30
0.65	0.00	4.58	128.57	16.93	11	51498.43
0.70	0.00	0.00	132.76	17.24	10	51682.00
1.00	0.00	0.00	132.76	17.24	10	51682.00

Monte Carlo Programming

In order to evaluate the UE programming results in a risk-efficiency context, another method of generating an unconstrained set of feasible plans was needed. A Monte Carlo programming (MCP) approach (Anderson 1975, 1976) was used. An Excel spreadsheet was developed to determine at random both the order of selection and the levels of activities in the same planning matrix as shown in Table 1.

In order to attain proper comparability with the MP results, some of the potential advantages of MCP, such as the ready facility to allow for integer constraints, were not made use of.

A total of 100 farm plans were generated and evaluated in terms of the returns under each of the four states of nature, as indicated in Table 4.

SDRF Results

The SDRF criterion was applied to the farm plans generated from 100 Monte Carlo (MC) simulations ($0 \leq \lambda \leq 1$, Table 4) and the utility-efficient strategies of UEP using generalised stochastic dominance algorithm, MAIN, described by Raskin and Cochran (1986). The range for the coefficient of absolute risk aversion was set as the same as for the UE programming. None of the utility-efficient solutions within the defined bounds of risk aversion was dominated by the MC plans, although several of the latter were included within the efficient set of strategies. This result is as expected and is evidence in support of the proposition that UEP generates a set of plans that are indeed SDRF.

Table 4: Monte Carlo generated farming strategies[1]

	Activity Levels									
Plan	Wheat	Barley	Grass Seed	Potatoes	Pigs[2]	NR_1	NR_2	NR_3	NR_4	E[TNR]
1	7.82	34.94	83.79	12.20	43	45155.95	64380.59	36349.27	49064.22	48737.51
2	11.60	6.92	108.18	13.86	31	47970.55	69296.22	34210.03	48351.59	49957.09
3	83.74	4.07	55.47	5.20	32	41082.61	57571.97	38959.69	49383.25	46749.38
4	22.95	10.63	104.99	11.43	15	46510.26	67461.37	32874.51	47384.68	48557.70
5	3.97	125.16	20.71	0.16	40	33166.26	47768.79	33925.54	45418.91	40069.88
6	0.47	3.88	134.14	11.51	0	47923.37	72144.10	26427.55	43922.29	47604.33
7	37.18	47.26	61.99	3.57	24	39131.84	57037.30	32847.62	45692.03	43677.20
8	3.46	106.42	26.94	12.19	14	35886.09	45779.76	39703.16	47469.94	42209.74
9	3.18	2.79	112.39	14.21	41	48303.05	70444.63	33348.59	47744.05	49960.08
10	44.54	39.37	55.19	10.90	2	38969.58	52030.90	37180.29	46477.87	43664.66
11	82.03	19.22	38.08	3.63	47	38911.64	54162.24	40187.18	49545.06	45701.53
12	1.40	9.04	121.59	16.18	16	49939.10	71956.36	33593.78	48695.27	51046.13
13	16.03	8.20	115.20	10.57	8	46494.02	68761.91	29745.86	45520.29	47630.52
14	16.03	8.20	115.20	10.57	8	46494.02	68761.91	29745.86	45520.29	47630.52
15	1.48	110.22	26.80	4.11	50	35537.63	50058.22	36435.79	47086.68	42279.58
16	5.75	36.20	89.36	13.19	33	46030.05	65397.98	36251.46	49368.35	49261.96
17	14.51	14.76	105.03	13.99	21	47835.51	68428.92	35002.18	49001.80	50067.10
18	7.60	31.56	95.23	15.61	3	45142.29	62746.71	34654.18	47210.97	47438.54
19	25.60	6.32	105.95	12.13	15	47085.54	67966.83	33641.77	47952.44	49161.65
20	96.12	16.57	36.05	1.25	34	37669.60	52737.99	38923.64	48574.48	44476.43
21	6.45	103.66	36.72	3.17	36	36199.07	51839.45	34572.70	46428.21	42259.86
22	5.03	2.29	131.91	10.78	0	47457.70	71548.86	26349.71	43734.38	47272.66
23	12.06	75.21	47.05	9.54	50	41038.59	56677.54	40024.63	50570.06	47077.71
24	7.92	104.06	0.18	7.97	50	30110.97	38292.90	38339.16	43853.78	37649.20
25	83.68	5.02	55.87	5.44	29	41093.41	57424.59	38954.87	49367.91	46710.20
26	4.73	95.30	48.80	1.17	27	35773.48	53109.10	30279.88	43713.04	40718.87
27	6.33	13.91	113.30	16.46	3	47832.16	67723.79	33496.04	47456.25	49127.06
28	18.50	33.96	88.82	8.71	19	43588.07	63443.07	32431.99	46542.86	46501.50
29	34.90	3.39	101.84	9.87	14	45694.41	66516.55	32587.36	46925.50	47930.96
30	13.21	114.34	11.59	4.86	42	33488.36	45038.83	38546.96	47163.70	41059.46
31	5.95	84.38	47.43	12.24	21	39619.60	52874.20	39005.42	48722.07	45055.32
32	59.44	9.21	78.56	2.79	15	40483.60	60066.09	30762.30	44482.78	43948.69
33	9.04	24.97	101.25	14.20	22	47524.31	67678.86	35475.37	49312.39	49997.73
34	1.87	128.13	16.18	2.29	37	32863.48	45922.72	35378.60	45724.39	39972.30
35	51.83	46.50	43.91	7.76	27	39335.04	53442.80	39610.14	49138.62	45381.65
36	42.75	35.41	54.66	7.58	49	41326.95	58017.12	38829.52	49509.55	46920.79
37	8.66	60.89	75.62	4.83	19	40001.26	59363.57	29874.57	44310.85	43387.56
38	93.80	3.25	49.54	3.40	30	39857.42	55924.08	38749.85	48946.76	45869.53
39	0.35	0.36	122.11	15.57	30	49669.42	72318.91	32882.37	47933.50	50701.05
40	36.26	28.12	75.15	10.47	26	43939.36	61648.16	37516.59	49459.53	48140.91
41	0.53	3.27	128.48	17.72	1	49968.63	71534.78	32402.22	47478.98	50346.15
42	25.86	9.29	86.14	10.53	50	44908.04	64855.00	35505.03	48127.76	48348.96
43	100.00	2.39	43.76	3.84	26	38931.93	53669.21	39496.27	48758.05	45213.86
44	7.21	103.91	28.25	9.76	28	36749.79	48487.12	39666.65	48466.94	43342.63
45	23.99	15.50	96.02	14.49	0	44952.74	62676.80	34415.63	46850.23	47223.85
46	48.04	75.04	19.56	7.36	23	35458.05	46072.58	40940.73	48446.10	42729.36
47	23.37	36.16	77.84	12.63	14	43431.10	60160.16	36546.76	48216.36	47088.59
48	1.37	103.37	23.29	10.39	31	34747.18	45223.96	38575.62	46327.68	41218.61
49	27.73	102.27	15.00	5.00	50	36432.04	49204.69	41691.43	50659.39	44496.89
50	48.86	13.08	77.84	10.22	18	43575.11	61040.88	36765.40	48488.18	47467.39
51	12.33	70.33	50.58	9.72	50	41409.16	57420.89	39637.53	50381.19	47212.19
52	22.31	31.52	72.13	10.06	50	43495.82	61912.58	37105.47	48969.58	47870.86
53	89.05	28.59	28.92	3.44	34	37508.32	50991.87	41044.77	49593.57	44784.63
54	21.83	27.34	91.36	9.47	19	44328.00	64260.86	33036.96	47038.77	47166.15
55	9.98	2.78	124.03	13.21	8	48537.92	71254.22	30612.20	46537.54	49235.47
56	37.71	92.29	17.43	2.57	45	35420.32	48845.80	39403.57	48946.28	43153.99
57	100.00	4.21	35.49	2.02	48	38296.55	53482.91	40185.44	49211.92	45294.21
58	1.80	0.21	130.83	17.16	8	50861.70	73376.29	32704.80	48258.51	51300.33
59	19.16	16.90	99.43	14.52	6	46006.57	64681.17	34628.24	47629.68	48236.42
60	84.58	37.41	24.88	3.13	40	37457.59	50949.98	41737.60	50277.20	45105.59

Table 4 (cont'd)

61	96.22	30.56	22.94	0.28	39	36162.45	50051.45	40131.95	49002.14	43837.00
62	90.06	1.48	56.81	1.65	24	39185.89	56411.59	35397.44	46777.91	44443.21
63	14.98	7.06	109.51	14.09	23	48251.81	69409.06	34407.31	48643.76	50177.99
64	3.89	2.84	125.00	16.23	15	50286.11	72637.43	33243.73	48522.28	51172.39
65	58.51	8.49	74.16	8.84	23	43396.62	61028.14	37341.84	48970.61	47684.36
66	48.27	52.30	42.82	6.61	39	39980.06	55137.90	40109.59	50235.50	46365.76
67	4.24	118.65	18.97	8.14	20	33959.80	44430.68	38079.27	46530.70	40750.11
68	7.21	5.14	121.41	16.24	9	49517.28	71012.08	33374.26	48223.12	50531.69
69	42.08	14.41	83.06	10.44	24	44945.90	63605.79	36894.66	49352.65	48699.75
70	87.54	4.42	53.63	4.41	30	40571.02	56922.62	38686.17	49115.34	46323.79
71	8.29	65.39	62.48	13.84	7	40642.75	54493.07	37055.38	47274.75	44866.49
72	41.18	86.92	13.86	8.05	19	34298.13	43673.34	41021.61	47921.90	41728.74
73	0.34	6.47	110.37	14.18	44	48070.51	70088.80	33474.59	47765.27	49849.79
74	23.54	1.83	113.01	11.62	11	47203.11	68952.26	31750.08	46831.86	48684.32
75	8.57	69.32	71.17	0.94	16	37313.35	57006.97	26500.18	41672.63	40623.28
76	82.76	1.70	49.16	4.00	50	39988.27	56559.36	38801.24	48759.25	46027.03
77	55.26	6.21	84.48	4.05	14	41540.18	61528.53	30796.14	44763.70	44657.14
78	72.23	57.77	15.00	3.02	50	36579.90	49402.18	42728.81	50856.54	44891.86
79	94.90	2.95	47.76	4.40	26	39593.02	54803.02	39275.04	48888.01	45639.77
80	0.01	55.76	72.16	12.01	47	43976.49	62044.64	37561.06	49670.04	48313.06
81	89.59	10.35	46.58	3.48	32	39570.10	55351.96	39040.02	49104.64	45766.68
82	49.68	68.11	24.16	5.31	50	37950.95	51525.03	42030.57	50903.01	45602.39
83	76.73	25.89	43.48	3.90	34	39227.56	54725.43	39118.10	49201.49	45568.15
84	22.42	76.98	41.32	9.27	37	39969.04	54244.49	40495.54	50407.34	46279.10
85	43.64	53.88	46.47	6.01	36	39728.22	55439.76	38524.09	49250.23	45735.58
86	9.23	37.53	96.16	7.08	13	42829.57	63881.31	28809.32	44241.25	44940.36
87	52.39	35.04	53.70	7.40	37	41356.52	57521.62	39391.79	50001.21	47067.79
88	48.49	11.12	76.09	9.06	33	43862.35	62244.69	37118.87	49056.38	48070.57
89	9.62	2.07	122.34	15.96	10	49759.01	71544.67	33408.95	48383.84	50774.12
90	21.74	4.96	115.79	7.51	3	44839.02	67739.62	26799.46	43307.21	45671.33
91	20.13	41.11	72.13	10.83	39	43817.31	61730.60	37684.41	49644.73	48219.27
92	14.17	34.33	83.30	12.07	36	45183.08	64088.81	36690.47	49364.98	48831.83
93	0.13	55.44	90.92	3.52	10	40012.62	61336.86	25279.86	41564.91	42048.56
94	11.24	73.39	62.26	3.11	24	38091.72	56379.21	30498.14	44271.17	42310.06
95	96.20	4.27	44.83	4.70	20	38613.61	52858.68	39020.08	48108.56	44650.23
96	0.59	52.75	74.68	12.17	46	44266.19	62548.83	37342.47	49597.51	48438.75
97	36.66	12.56	75.59	9.10	50	43601.71	62530.74	36521.99	48438.52	47773.24
98	71.52	54.94	17.66	3.22	50	36872.36	49970.75	42444.92	50730.20	45004.56
99	56.49	12.71	72.08	8.73	25	43295.41	60852.56	37638.99	49221.87	47752.21
100	0.67	129.33	18.37	1.63	38	33210.02	46954.93	34961.96	45857.55	40246.12

[1] Net Revenue (NR, $) subscripts denote states 1 to 4 as described in Table 2.

[2] Rounded to integer values.

Conclusion

Risky decision analysis in agricultural production has, to a large extent, suffered from analytical techniques inconsistent with actual DM preference structures and cumbersome computational processes. As observed by Patten et al., the objective of any programming approach in risky farm planning, should be the identification of the smallest set of farm plans which includes the utility maximising plan.

Young et al. (1979) have inferred that changes in objectives, information and attitudes could make a DMs risk aversion coefficient an elusive moving target. Love and Robison (1984) demonstrated however, that for incomes close to those typically experienced by individuals, risk preferences are rather stable. Wilson and Eidman (1983) also concluded after studying Minnesota swine farmers, that majority of DMs fall within a relatively narrow band of risk aversion space. By implication, risky decision approaches, such as UEP and SDRF, using measures of individual risk preferences to derive efficient plans, are plausible.

The implicit 'hypothesis' that governed this evaluation was that if the SDRF criterion performed as proposed by Meyer (1977*a,b*), then the algebraic form of the utility function should be of no consequence in UEP formulations over a specified range of absolute risk aversion. This would appear to have been proven to be the case for the specific example considered.

Finally, the simple evaluation pursued here would appear to suggest that both approaches of SDRF and UEP may be regarded as equivalent in the results obtained. UEP has the advantage however, of producing utility efficient strategies that are SDRF rather than just stochastically dominant plans that may not necessarily be efficient. Such a conclusion however, still remains tentative until more rigorous comparisons can be made using more comprehensive examples and a variety of algebraic formulations of the utility function. Scope for further work includes 1) theoretical proof of the relationship between UEP and SDRF; 2) broader comparison between the results of UEP and those from such other approaches as MOTAD, Target-MOTAD, QRP and mean-Gini programming.

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