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A Stochastic Dominance Evaluation of Alternative Western Ranching Systems

Elizabeth R. Edens, University of Wyoming
Larry J. Held, University of Wyoming
Dillon M. Feuz, South Dakota State University

ABSTRACT

Riskiness of range livestock systems is analyzed with stochastic dominance. Although pure stocker systems appear too risky for even mildly risk averse producers, diversifying a few stockers with mixed short/long yearling sales is efficient over a wide range of risk aversion coefficients, while a cow-calf system is inefficient overall.

Evaluating the riskiness of alternative livestock systems with mean-variance analysis has been quite common. However, using criteria such as stochastic dominance which captures higher moments of a system's return distribution could have implications for evaluating the riskiness of purchase stocker or other mixed systems rendering extreme income variability, but yet high levels of returns. The purpose of this paper is to characterize a selected set of ranching systems in terms of their preferability for different classes of decision makers ranging from those who are risk neutral and mildly risk averse to those who are more highly risk averse. As described more fully below, this will be accomplished by using a mathematical programming model to develop alternative ranch plans, along with their corresponding income distributions, over a historic 28-year period (1963-90). These plans and income distributions are then tested within a stochastic dominance framework using the GSD program developed by Goh, et al.

Approach

A Target-MOTAD risk programming model (Tauer) was initially constructed for a large scale model mountain valley ranch, based on production data from a survey of mountain valley ranches (Feuz and Kearl). A detailed description of the ranch and Target-MOTAD model can be found in Edens. The general form of the Target-MOTAD model featured in Table 1 is:

Minimize vy^- (sum of negative deviations from target income) such that:

(1) $Ax \leq b$
(2) $Rx + Iy^- \geq t$
(3) $rx = e$
(4) $x, y^- \geq 0$

where:

v	=	1 X s vector in which each element is 1 and where s is the number of years;
y^-	=	s X 1 vector of annual income deviations below the fixed level of target income;
A	=	m X n matrix of technical coefficients, where m is the number of constraints and n is the number of production activities;
x	=	n X 1 vector of production and market activities;
b	=	m X 1 vector of resource constraints;
R	=	s X n matrix of annual costs and returns for designated activities;
I	=	s X s identity matrix;
t	=	s X 1 vector of target incomes;
r	=	1 X n vector of mean net income for the ranch; and
e	=	mean income for the total ranch plan.

With reference to Table 1, Matrix A (rows 1 - 32; col. 1 - 42) contains production coefficients for the case ranch. Row 61 (e = 28-year mean income) incorporates production costs associated with designated activities, as well as 28-year mean livestock values. Matrix R (rows 33 - 60; col. 1 - 42) shows annual production costs, 1963-90 (which are held constant across years), as well as annual livestock values (which vary each year in response to price risk). The income target (t) is considered to be a critical level of income necessary for meeting fixed obligations. With a designated income target ($40,000), a series of efficient solutions can be derived by parameterizing income (e) from the profit-maximizing amount (upper-limit) to successive lower values approaching a minimum risk solution (lower-limit).

Figure 1 summarizes the alternative livestock activities in the Target-MOTAD model (col. 14 - 40), which follow through the various stages of cow-calf, cow-short yearling, and cow-long yearling. Weaned calves can be sold in the fall, or wintered on improved hay (for a lower ADG) and/or alfalfa (for a higher ADG). Short yearlings can then be sold in May or summered for sale in October as long yearlings. Stocker steer calves (425#) can be purchased in November for wintering on improved hay, and similarly, spring stockers (547#) can be purchased in May for summer grass.

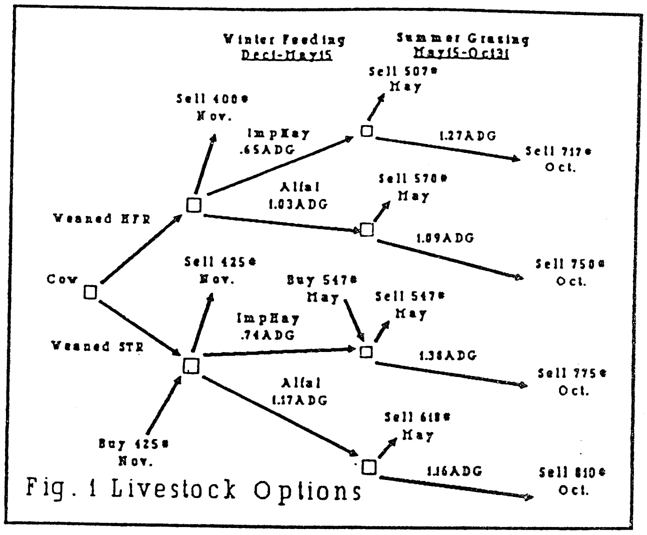

Fig. 1 Livestock Options

For purposes of estimating net income, costs of production as derived by Feuz and Kearl were updated using the prices paid index from the USDA. To derive livestock returns, the respective weights and prices (obtained from Kearl) were multiplied and adjusted to real 1990 dollars with the GNP deflator. Net income represents a return to deeded land; and machinery and equipment; and the $40,000 income target reflects a near breakeven (or zero return) to deeded land.

The Target-MOTAD model was used to generate three separate sets of solutions including: (1) a series of solutions along a Target-MOTAD frontier; (2) several non-optimal predetermined solutions without any purchased stockers; and (3) several MaxiMin solutions wherein the model could select the plan having the highest "worst-possible" return, for a given amount of 28-year average income. As described by Hazell and Norton (p. 94 - 96), this was accomplished by (a) deleting the negative deviation activities (col. 43 - 70) and substituting a "worst possible return" activity (W) in column 43; (b) inserting a vector of -1s within the income rows (33 - 60) and a value of 1 in a maximize (vs. minimize) objective function for activity (W); and (c) revising the RHS values for the income rows (33 - 60) to be ≥ zero (vs. t).

Results

Table 2 features income and risk measures for "eight selected ranching systems," comprised of: (1) three selected Target-MOTAD solutions (col. 1 - 3); (2) three forced solutions without stockers including cow-calf, cow-short-yearling and cow-long-yearling (col. 4 - 6); and (3) two selected MaxiMin solutions (col. 7 - 8). Considering the Target-MOTAD solutions, (col. 1 - 3) the profit-max plan is a pure stocker operation with no breeding herd. This system is by far the most risky in terms of standard deviation ($143,200) and total negative deviations (-$713,613). Reducing income from the profit-maximizing level ($112,232) to that associated with the minimum-risk solution ($73,628), results in rather substantial reductions in risk, i.e., negative deviations decrease by a total of $564,557 (from $713,613 to $149,056) in conjunction with reduced income of $38,604, as a result of purchasing fewer stockers and incorporating a larger breeding herd.

Eliminating the options of purchasing stocker steers in favor of pure cow-calf or cow-yearling systems (col. 4 - 6) greatly reduced 28-year average income (by a margin of over $50,000 for cow-yearling; and over $66,000 for the cow-calf). However, as a benefit, income variability was reduced by a large margin and downside target deviations were considerably lower for the cow-yearling systems (-$223,011 and -$233,927 vs. -$713,613). However, relative to cow-yearling systems, the cow-calf organization performed very poorly with respect to all measures, including: (1) a $15,000 plus shortfall in returns ($46,026 vs. $61,392 and $60,652); (2) higher income variability; and (3) a much greater degree of target risk ($473,750 vs. $223,011 for short-yearling and $233,927 for long-yearling). Moreover, cow-calf returns exceeded cow-yearling returns in only five of 28 years (1963, 1964, 1974, 1980, and 1981). The short-yearling system yielded slightly higher income ($61,392) compared to long-yearling ($60,652), and comparative risk measures were also very similar. However, the short-yearling system experienced two years of modest losses (1975, 1986), while the long-yearling system incurred none.

Two MiniMax solutions are shown in Table 2: a high income version (col. 7) and a low income (col. 8) version. The high income version was developed by setting 28-year average income equal to that realized with the min-risk Target-MOTAD solution ($73,628). Compared to the min-risk solution (col. 3), the $73,628 MiniMax showed higher income variability and target deviations with a greater mix of long yearling sales. However, its worst income year (1986) is slightly better ($875 vs. -$708). To derive the low income MaxiMin solution (col. 8), 28-year average income was left unconstrained. As a result the worst income level is more favorable ($4412), however, 28-year average income is also considerably lower ($55,830). In both MiniMax cases, stocker steers were not eliminated, but instead were held to modest levels.

Annual incomes from solutions in Table 2 were next incorporated into a stochastic dominance program for analysis, and the cumulative probability distributions (CPDs) of annual incomes were analyzed for several selected ranching systems. Figure 2 features CPDs for the "least risky" min-risk (#3) vs. the "most risky" stocker system. Since the distributions "cross" at approximately $40,000, it follows that no preference exists in terms of first degree dominance. Essentially the probability of falling below the "higher" levels of income is much lower for the stocker vs. the min-risk solution, e.g., with the min-risk solution, there is nearly a 90 percent chance of falling below $119,000 compared to only a 60 percent chance for the stocker option. However, the lower tail of the min-risk CPD crosses the horizontal axis at an income level of -$708, reflecting a zero probability of expecting annual income below -$708. Conversely, the probability of incurring income below -$708 is higher with the stocker option (15 percent).

The CPD for the cow-calf organization (Figure 3) shows the probability of realizing below zero income is quite high (25 percent) compared to min-risk (4 percent). Moreover, the cow-calf system is clearly inefficient by first degree stochastic dominance, since its CPD lies above and to the left of min-risk (#3). Finally, the min-risk CPD (#3) is plotted with the short-yearling system (Figure 4) and long-yearling system (Figure 5). In both cases, the min-risk CPD generally lies below and to the right of the other two CPDs (#5 and #6), but with a few points of crossing. Hence, neither the short-yearling or long-yearling systems are eliminated by first degree stochastic dominance.

Table 3 summarizes the efficiency status of the eight systems described above with selected stochastic dominance criteria. First-degree stochastic dominance (FSD) is applicable for all types of decision-makers (risk-averse, -neutral and -seeking) and assume risk aversion coefficients (RACs) ranging from $-\infty$ to $+\infty$ where the RAC reflects the percentage change in marginal utility per unit of income. The cow-calf organization is eliminated from the FSD efficient set, in being dominated by Target-MOTAD solutions #2 (Med. Inc.) and #3 (Min-Risk) as well as MaxiMin High (#7). Second-degree stochastic dominance (SSD), which is applicable for risk-averse decisionmakers (with RACs ranging from 0 to $+\infty$), eliminates the short-yearling system (#5), as well as cow-calf (#4) from the efficient set. As expected, all of the Target-MOTAD solutions are SSD efficient.

With generalized stochastic dominance (GSD), selected subranges of RACs are specified to identify solutions acceptable for those who are only mildly risk averse (i.e., having smaller RACs closer to zero), vs. those who are more highly risk averse (i.e., having RACs increasingly greater than zero). The medium income Target-MOTAD solution #2 (which purchased 215 fall and 529 spring stockers) is acceptable within the mildly risk averse RAC ranges (.000005 to .00015). In contrast, the min-risk Target-MOTAD solution (#3) which included a small number of stockers is shown to be acceptable over a much wider range of RACs (.000005 to .0006), being unacceptable within only the most risk averse RAC range (.0003 and above). The long-yearling system (#6) is efficient within a very narrow risk averse range of RACs. As expected, the MaxiMin solutions are associated with the more risk averse ranges (.0001 and up). The extreme level of risk aversion associated with the low income MaxiMin solution (#8) vs. the min-risk Target-MOTAD (#3), is quite evident in observing that nearly \$18,000 of average annual income would be willingly sacrificed (\$55,830 vs. \$73,628) in exchange for incurring a \$4412 (vs. -\$708) worst possible outcome.

Conclusion

Pure stocker systems are shown to be too risky for even mildly risk averse producers since the magnitude of added risk is extremely high relative to the added income. However, the choice does not need to be limited to either all or no stockers. Ranchers may wish to diversify a modest number of stockers with their breeding herd to capture some of their income potential without adding unnecessarily high amounts of risk. Stochastic dominance indicates these mixed strategies can be attractive for a wide range of producers who are only mildly to more highly risk averse, depending upon the number of stockers. In addition, as opposed to confining sales to either all short-yearlings or all long-yearlings, producers may wish to consider a combination of the two, in conjunction with purchasing a modest number of stockers. Finally, unless ranchers are able to wean heavier calves than generally observed in the study area, the cow-calf organization appears to be the poorest with respect to both income and risk.

Table 1. Target-MOTAD Matrix

	(1) Grow Alf Hay ac	(2) Grow Alf f Hay ac	(3) Grow Imp Hay ac	(4) Grow Imp f Hay ac	(5) Graz Irrg Past ac	(6) Graz Deed Rnge ac	(7) Graz Prvt Leas ac	(8) Graz Ste Leas AUM	(9) Graz BLM AUM	(10) Graz FS AUM	(11) Leas Fall Past AUM	(12) Feed Alf Hay ton	(13) Feed Imp Hay ton	(14) Cow-Calf hd	(15) Wean Hfr hd	(16) Wean Str hd	(17) Bull hd	(18) Yrlg Repl Hfrs hd	(19) Sell 400# Hfrs hd	(20) Sell 425# Strs hd	(21) Sell Cull Cows hd	(22) Sell Cull Repl hd	RHS
MIN.NEG.DEV.$																							
1. alf:field	1	1																					= 100 ac
2. impr:mead			1	1																			= 565 ac
3. irrg:past					1																		< 235 ac
4. deed:rnge						1																	< 5600 ac
5. prvt:leas							1																< 900 ac
6. stat:leas								1															< 190 AUM
7. BLM:permt									1														< 1572 AUM
8. FS:permt										1													< 1126 AUM
9. alf:hay	-3	-4										1											< 0 ton
10. impr.hay			-1.5	-2.5									1										< 0 ton
11. cowHAY:eq												-1.1	-1	1.8			2.25						< 0 ton
12. sumGRAZNG					-4	-.25	-.25	-1	-1	-1				5.5	1.9	2.0	7.3	3.8					< 0 AUM
13. falGRAZNG	-1	-1	-1.5	-1.5	-1.5						-1			1.5	.5	.5	2.0	1.2					< 0 AUM
14. hfrCALF														-.45	1								< 0 hd
15. strCALF														-.45		1							< 0 hd
16. cullCOW														-.13							1		< 0 hd
17. bull														.05			-1	.05					< 0 hd
18. weaned:HFR															-.98				1				< 0 hd
19. weaned:STR																-.98				1			< 0 hd
20. rep:HFR														.17				-.90					< 0 hd
21. repHFRcul																		-.10				1	< 0 hd
22. wntrdHF:1																		1					< 0 hd
23. wntrdHF:2																							< 0 hd
24. wntrdST:1																							< 0 hd
25. wntrdST:2																							< 0 hd
26. yrlgHF:1																							< 0 hd
27. yrlgHF:2																							< 0 hd
28. yrlgST:1																							< 0 hd
29. yrlgST:2																							< 0 hd
30. spgLABOR	.45	.53	.60	.69	.12									2.12									< 0 hr
31. sumLABOR	4.61	4.79	3.42	3.57	.75									1.66				1.06					< 0 hr
32. winLABOR												1.12	1.12	1.31									< 0 hr
33. INC:63	-153	-168	-80	-112	-19	-.69	-3.00	-2.50	-1.97	-1.97	-8.25	-4.95	-4.95	-57	-6	-7	-35	-32	440	524	524	629	> t $
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60. INC:90	-153	-168	-80	-112	-19	-.69	-3.00	-2.50	-1.97	-1.97	-8.25	-4.95	-4.95	-57	-6	-7	-35	-32	361	418	495	582	> t $
61. 28yrAVG	-153	-168	-80	-112	-19	-.69	-3.00	-2.50	-1.97	-1.97	-8.25	-4.95	-4.95	-57	-6	-7	-35	-32	363	441	546	581	= e $

	(23) Buy 425# Strs hd	(24) Buy 547# Strs hd	(25) Wtr Hfr 1 hd	(26) Wtr Hfr 2 hd	(27) Wtr Str 1 hd	(28) Wtr Str 2 hd	(29) Sell 507# Hfr 1 hd	(30) Sell 570# Hfr 2 hd	(31) Sell 547# Str 1 hd	(32) Sell 618# Str 2 hd	(33) Sum Hfr 1 hd	(34) Sum Hfr 2 hd	(35) Sum Str 1 hd	(36) Sum Str 2 hd	(37) Sell 717# Hfrs hd	(38) Sell 750# Hfrs hd	(39) Sell 775# Strs hd	(40) Sell 810# Strs hd	(41) Full Time Labr FTE	(42) Part Time Labr hr	(43) Neg Dev 63 $	..	(70) Neg Dev 90 $	RHS
MIN.NEG.DEV.$																					1		1	
1. alf:field																								= 100 ac
2. impr:mead																								= 565 ac
3. irrg:past																								< 235 ac
4. deed:rnge																								< 5600 ac
5. prvt:leas																								< 900 ac
6. stat:leas																								< 190 AUM
7. BLM:permt																								< 1572 AUM
8. FS:permt																								< 1126 AUM
9. alf:hay				1.32		1.42																		< 0 ton
10. impr.hay			1.15		1.23																			< 0 ton
11. cowHAY:eg																								< 0 ton
12. sumGRAZNG											3.8	4.0	4.0	4.3										< 0 AUM
13. falGRAZNG																								< 0 AUM
14. hfrCALF																								< 0 hd
15. strCALF	-1																							< 0 hd
16. cullCOW																								< 0 hd
17. bull																								< 0 hd
18. weaned:HFR			1	1																				< 0 hd
19. weaned:STR					1	1																		< 0 hd
20. rep:HFR																								< 0 hd
21. repHFRcul																								< 0 hd
22. wntrdHF:1			-.99				1				1													< 0 hd
23. wntrdHF:2				-.99				1				1												< 0 hd
24. wntrdST:1		-1			-.99				1				1											< 0 hd
25. wntrdST:2						-.99				1				1										< 0 hd
26. yrlgHF:1											-.99				1									< 0 hd
27. yrlgHF:2												-.99				1								< 0 hd
28. yrlgST:1													-.99				1							< 0 hd
29. yrlgST:2														-.99				1						< 0 hd
30. spgLABOR																			-600					< 0 hr
31. sumLABOR											1.06	1.05	1.06	1.06					-1200	-1				< 0 hr
32. winLABOR			1.18	1.34	1.25	1.44													-900					< 0 hr
33. INC:63	-534	-597	-21	-22	-24	-25	518	569	587	650	-16	-17	-18	-19	625	640	722	747	-18000	-5.50	1			> t $
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60. INC:90	-428	-496	-21	-22	-24	-25	459	495	486	549	-16	-17	-18	-19	578	594	626	648	-18000	-5.50			1	> t $
61. 28yrAVG	-455	-565	-21	-22	-24	-25	463	505	555	597	-16	-17	-18	-19	577	595	687	709	-18000	-5.50	---		---	= e $

Table 2. Income and Risk Measures for Selected Ranching Systems

Head of Livestock	Alternative Ranching Systems: Target-MOTAD Solutions (1) Prof. Max.	(2) Med. Inc.	(3) Min. Risk	Forced Solutions (4) Cow-Calf	(5) Short Yrlg.	(6) Long Yrlg.	MaxiMin Sol. (7) High Inc.	(8) Low Inc.
Cows	--	325	562	646	584	485	518	379
Sell 400# Hfr	--	--	--	162	--	--	--	--
Sell 425# Str	--	--	--	285	--	--	--	--
Buy 425# Str	1396	215	68	--	--	--	149	58
Buy 547# Str	259	529	19	--	--	--	--	70
Sell 507# Hfr	--	--	--	--	--	--	--	--
Sell 570# Hfr	--	81	139	--	144	--	128	--
Sell 547# Str	--	--	--	--	110	--	--	--
Sell 618# Str	279	204	149	--	145	--	98	45
Sell 717# Hfr	--	--	--	--	--	--	--	--
Sell 750# Hfr	--	--	--	--	--	119	--	--
Sell 775# Str	1349	673	180	--	--	44	272	93
Sell 810# Str	--	--	--	--	--	166	--	246
	- - - - - - - - - -	Annual Income ($)	- - - - - - - - - -					
Year								
1963	55,689	84,967	89,655	79,215	80,610	72,903	83,767	63,389
1964	-33,824	33,279	23,673	44,987	16,705	19,586	18,797	17,426
1965	259,780	116,922	76,502	6,538	52,311	60,492	85,580	62,742
1966	192,468	99,975	90,896	37,435	75,275	71,183	94,503	66,838
1967	131,453	89,142	79,003	46,756	65,192	63,092	79,369	58,622
1968	114,036	81,191	77,274	47,577	65,700	60,758	76,425	56,155
1969	210,438	113,549	113,755	51,919	99,006	83,984	115,760	78,353
1970	108,513	95,637	95,942	74,443	83,808	80,315	94,020	71,263
1971	176,962	124,848	103,075	68,224	82,863	91,652	105,714	84,199
1972	260,516	175,579	147,928	98,528	121,372	130,645	151,972	120,075
1973	324,283	206,838	214,156	144,010	191,033	184,566	216,673	162,582
1974	-334,479	6,574	31,785	129,239	41,655	14,927	875	4,412
1975	273,328	100,825	28,806	-34,058	-1,483	35,345	44,653	42,777
1976	48,693	-8,127	33,276	-12,030	39,228	4,912	30,319	6,209
1977	123,013	57,231	28,560	-3,562	13,249	27,438	33,521	30,643
1978	423,591	182,627	144,098	34,174	111,403	128,750	160,363	122,505
1979	256,753	153,621	206,050	136,176	196,879	161,910	205,128	138,637
1980	-31,356	107,697	110,703	160,248	99,346	117,162	101,280	94,954
1981	-79,855	35,767	48,839	81,148	46,851	45,137	39,074	34,799
1982	108,889	55,576	48,351	14,250	38,034	37,955	49,854	37,064
1983	1,752	-8,111	26,315	5,759	30,950	8,423	22,558	6,669
1984	102,192	48,518	25,769	-4,747	12,859	20,773	29,157	23,999
1985	22,986	-2,205	13,468	-9,245	13,434	2,953	12,530	4,412
1986	21,169	12,498	-708	-10,302	-8,164	1,246	875	4,412
1987	156,206	70,946	40,159	-3,867	22,644	32,515	46,669	37,228
1988	120,365	85,065	62,529	33,405	47,140	49,090	62,795	49,467
1989	56,765	50,089	48,269	39,290	39,533	45,982	48,157	40,919
1990	72,176	68,488	53,454	33,210	41,533	44,568	51,579	42,477
28-yr Avg Inc. ($)	112,232	79,965	73,628	46,026	61,392	60,652	73,628	55,830
Std. Dev. ($)	143,200	55,820	53,406	50,864	49,520	47,229	55,451	41,329
Total Amt. Inc. (63-90) <$40,000	-713,613	-210,325	-149,056	-473,750	-223,011	-233,927	-172,294	-232,727

Fig. 2 Cumulative Distribution
Stocker (#1) vs Min-Risk (#3)

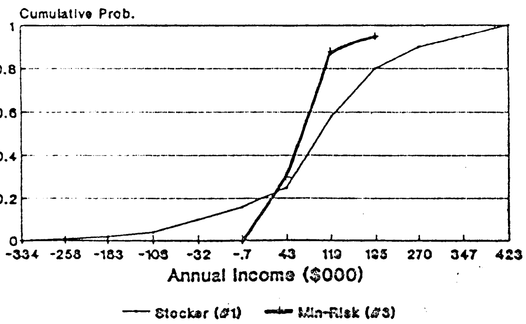

Fig. 4 Cumulative Distribution
Shrt-Yrlg (#5) vs Min-Risk (#3)

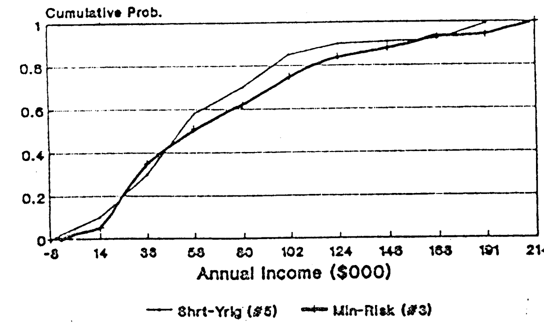

Fig. 3 Cumulative Distribution
Cow-Calf (#4) vs Min-Risk (#3)

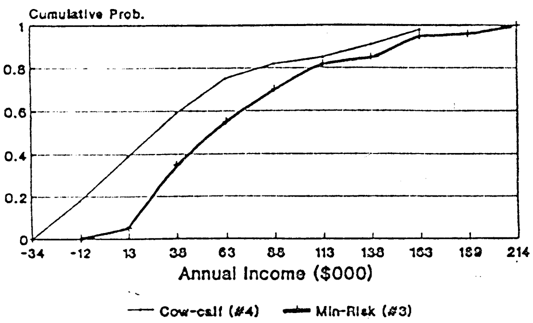

Fig. 5 Cumulative Distribution
Long-Yrlg (#6) vs Min-Risk (#3)

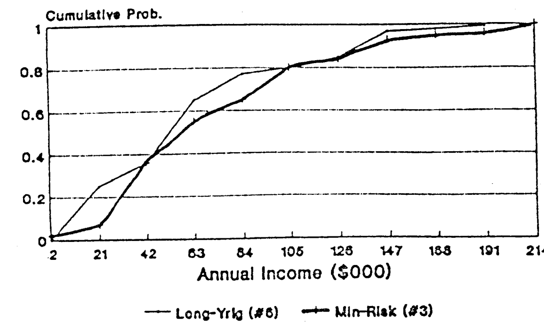

Table 3. Stochastic Dominance of Ranching Systems Associated with Various Degrees of Risk Aversion

	Alternative Ranching Systems							
	Target-MOTAD Frontier			Forced Solutions			MaxiMin Sol.	
Stoc Dom. Meth. & RAC Ranges	(1) Prof. Max.	(2) Med. Inc.	(3) Min. Risk	(4) Cow-Calf	(5) Short-Yrlg.	(6) Long Yrlg.	(7) High Inc.	(8) Low Inc.
FSD								
-∞ to ∞	F	F	F	--	F	F	F	F
SSD								
0 to ∞	S	S	S	--	--	S	S	S
GSD								
.000005 to .00008	--	G	G	--	--	--	--	--
.00001 to .00015	--	G	G	--	--	--	--	--
.0001 to .00045	--	--	G	--	--	G	G	G
.00015 to .0005	--	--	G	--	--	--	G	G
.0002 to .00055	--	--	G	--	--	--	G	G
.00025 to .0006	--	--	G	--	--	--	--	G
.0003 to ∞	--	--	--	--	--	--	--	G
Summary Stat.								
28-yr Avg ($)	112,232	79,965	73,628	46,026	61,392	60,652	73,628	55,830
Low Inc. ($)	-334,479	-8,127	-708	-34,058	-8,164	1,246	875	4,412
High Inc. ($)	423,596	206,838	214,156	160,248	196,879	184,566	216,673	162,582

F/ Systems within the efficient set, given first degree stochastic dominance (FSD)
S/ Systems within the efficient set, given second-degree stochastic dominance (SSD)
G/ Systems within the efficient set, given generalized stochastic dominance (GSD) and assoc. RAC Ranges.

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