A MONTE CARLO APPROACH TO GENERATING DISTRIBUTIONS OF CATTLE RETURNS[a]

by

Odell L. Walker, Daniel J. Bernardo and Paul H. Gutierrez[b]

Time series data for building a distribution of cattle returns are difficult to obtain. Average market price series are available for general categories of inputs and for broad cattle classes. Central market series may not reflect local price conditions and short term price shocks affecting costs and returns. Data series are seldom kept for non-price variables such as range forage yield, feed requirements, cattle weights, death loss and calving percentages. Ideally, detailed farm or ranch records would provide estimates of inputs and resulting production relationships, but most records emphasize economic data only. As a result of the data problem, returns series used to analyze cattle returns may reflect only price variability (Ikerd; Watt). Even if complete time series were available, the analyst would probably want to modify them to better reflect the future.

In addition to demonstrating an approach to estimating returns distributions for cattle using Monte Carlo methods, this study has two other objectives:

1. to provide a comparison of activity and firm level return variability, and
2. to evaluate the importance of the time dimension in determining the returns distribution for the activity and the firm levels.

A synthetic approach to building a trended, cyclic, stochastic series of beef activity returns using Monte Carlo modeling is feasible. The first step is to identify variables which most affect returns and build data series and correlations among variables. Unlike the time series approach, the synthetic technique allows use of bits of information from a wide range of experimental, farm and expert-subjective sources. Several possibilities exist for doing the calculations. We used REPFARM, an early generation of the Texas FLIPSIM whole farm simulator (Baum, et al; Richardson and Nixon). For activity analyses alone, a simpler spread sheet template and a microcomputer would do well.

Activity and Firm Level Returns Variability

Business uncertainty (price and production variability within the activity) and financial uncertainty are sometimes cited as definitive sources of farm and ranch risks (Boehlje and Eidman). As implied by Miller, activity and firm level uncertainty might be more useful categories. Firm uncertainty reflects interaction of activity variability within a given firm situation (e.g. resource endowment, debt levels, family living

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[b]Authors are Professor and Assistant Professor, Dept. of Agri. Econ. Oklahoma State University and Ranch Management Specialist, Colorado Cooperative Extension, Colorado State University, respectively.

requirement, family labor, etc). It includes financial effects but has a broader source than interest rates, loan terms, and leverage.

We present returns distributions for both levels. Activity uncertainty is represented by returns above cash costs for cow-calf, cow-yearling and yearling stocker activities on a Southern Plains Ranch. Net ranch income for the cow-calf and stocker activities is estimated assuming a 65% equity. Net ranch income is also estimated for the cow-calf activity with 100% equity..

Firm level returns distributions were estimated by net ranch returns from the annual income statement prepared by the whole-firm simulator. All interest costs are deducted and returns are adjusted for inventory changes, except land. Breeding cattle values and machinery and equipment depreciation are the major changes from year to year. The level of net ranch income through time is very dependent on the firms' beginning equity situation as well as income across the years. Borrowing to cover operating losses adds to interest costs and the effects from deficit years may accumulate across time. Thus, we hypothesize that the range (or variance) of net farm income should be greater than for gross activity returns because of those effects across time.

The Time Dimension.

Current problems in farm and farm related businesses encourage study of how firms do or can operate through time to attain goals. An earlier S-180 study (Patrick, et al) indicated that "agricultural producers view their business environment in a multi-period fashion where 'safety first' considerations are emphasized." Many risk analyses blur the time dimension. For example, what is assumed about the path of firm returns across time in a traditional diversification analysis? Also, trends and cycles may have an important role which is ignored. Thus, it is very difficult to conduct a very useful normative or positive analysis without considering the order that events affecting the firm occur in time. Analysts need to integrate income, balance sheet and cash flow considerations across time.

Our Monte Carlo simulation approach tracks the income and balance sheet items and annual cash flow across 6 years time for 25 iterations. The distribution of returns can be analyzed for each year across iterations or globally across years and iterations. Returns above cash costs for each activity trend and cycle across the six years simulated, so a year by year analysis is probably preferable.

The Simulation Model

REPFARM is a recursive, simulation model that simulates the production, marketing, financial management, and growth aspects of a representative farm or ranch over a finite planning horizon. The model was modified to include a number of additional stochastic variables, livestock enterprise alternatives, and economic relationships to more accurately represent livestock production in a stochastic and dynamic environment.

REPFARM is designed to evaluate the profitability, solvency, liquidity, and probability of firm survival for production scenarios characterized by alternative management plans, economic conditions, and production settings. The model simulates a representative farm over a finite planning horizon recursively, using the ending financial position for one year as the beginning financial position for the next. At the beginning of each iteration the model is initialized using an exogenously determined farm situation; production in each successive year of the planning horizon is then simulated following a specified management plan. Annual product prices, factor costs, and yields employed in the analysis are drawn at random from probability distributions specified by the researcher. An income statement, cash flow, and balance sheet are produced for each year.

Stochastic Processes for the Ranch Analysis

The whole-firm simulation model utilizes a series of triangularly distributed random variables to represent the uncertaintities inherent in livestock production on native range. Annual steer calf prices, steer calf weights, weaning percent, supplemental feed prices, and range forage yields are represented using multivariate probability distributions estimated from historical data series. A procedure presented by Clements et. al. was employed to factor historical correlation matrices into unique upper-right triangular matrices for the purpose of generating correlated random variables. Independent normal deviates are generated for each year, multiplied by the factored correlation matrix, and then transformed into a unit scale (0.0 to 1.0). These correlated values are employed in an inverse transformation formula to calculate random values from each empirical cumulative probability distribution.

Modal steer prices for the planning horizon were estimated from a harmonic regression price prediction model to account for seasonal variation, cyclical variation, and long-term linear trend of livestock prices (Franzmann and Walker). The stochastic component of steer prices is represented as a random deviate drawn from a probability distribution around the modal value. Annual prices for cull cows, replacement heifers, bulls, heifer calves, and stocker cattle are calculated from the stochastic steer calf price using specified price adjustment factors.

Annual supplemental feed prices are derived from probability distributions around time-trended modal values. Parameters defining the triangular distributions for the variables were estimated from a time series of annual factor prices detrended to real terms using the appropriate price deflation index. For reasons cited in Young, 5 and 95 percentiles are substituted for exact endpoints (0 and 100 percentiles) in deriving triangular distribution parameters from the data series. Modal factor and steer calf prices for each year of the analysis, as well as parameters defining the minimum and maximum values of the triangular probability distributions, are given in Table 1.

The major difficulty in incorporating production risk in an analysis of livestock production lies in specifying relationships among environmental influences, forage production, and livestock response. The interaction of these processes is represented in the simulation model to estimate stochastic range forage yields, supplemental feed requirements and steer weights.

The quantity of supplemental roughage fed annually is conditional upon a number of factors, including the availability of range forage over the year. To represent this phenomenon, it is assumed that supplemental roughage feeding rates in a given year, $FEDRATE_t$, are a function of the level of stochastic range forage yield in that year, SYR_t, as determined by equation 1.

$$(1)\ FEDRATE_t = (((LBSDM_t - SRY_t).5)*TAUM_t/PCTDM_t)*FRATIO_t*NOLYSTK_t$$

where $LBSDM_t$ represents the modal pounds of dry matter per acre for year t, $TAUM_t$ is the total acres required per animal unit, $PCTDM_t$ is the percent dry matter of supplemental roughage, $FRATIO_t$ is the rate at which range forage dry matter is replaced by hay dry matter, and $NOLVSTK_t$ is the number of livestock. Supplemental feed calculations are made for each class of livestock in the analysis and are

Table 1. Price and Production Parameters and Modal Values

Name	Parameters		Unit	Year					
	Minimum % of Mode	Minimum % of Mode		1986	1987	1988	1989	1990	1991
				Modal Prices					
Steer Calf Price	-07.35	10.30	$/lb	.7348	.7586	.7730	.8255	.8625	.8662
Steer Calf Weights	-01.78	01.56	lb/hd	450	450	450	450	450	450
Weaning Percent	-09.09	02.27	pct	.88	.88	.88	.88	.88	.88
Range Forage Yield	-30.20	36.25	lbs/acre	700	700	700	700	700	700
Supplemental Feed:									
Prairie Hay	-20.00	13.30	$/lb	.0306	.0312	.0320	.0325	.0325	.0331
Cttn Seed Meal	-09.20	10.00	$/lb	.1071	.1092	.1114	.1136	.1159	.1182
Cubes, 20% Protein	-14.34	14.00	$/lb	.2642	.0655	.0668	.0682	.0695	.0709
Soybean Meal	- 7.40	7.00	$/lb	.1326	.1352	.1379	.1380	.140	.1435

premised on the assumption that 50 percent of dry matter yield is harvested by range livestock.

Variability in annual livestock performance (weight gain) is represented through specification of a probability distribution of season-ending steer calf weights. Annual livestock weights are further adjusted using a relationship to reflect the influence of stochastic range forage production on livestock weight gain. Thus, variability in season-ending livestock weights may be conceptualized as having two components: (1) differences in weight gain that would result in a controlled feeding environment, (2) dispersion due to alternative levels of forage availability. Adjustment factors are applied to the stochastically derived steer weight to obtain annual weights for each livestock class in the analysis.

Triangular probability distributions for each of the stochastic production variables were specified using data from range research studies conducted in the vicinity of the 13 county study area. Annual estimates of dry matter forage production from three multiple-year range studies were used to estimate parameters defining the distribution of range forage yields. Weaning percent estimates were derived from cow reproductive performance data from several Southern Plains research sites. Although these estimates were derived from experiments occuring outside the study area, they represent the most current data avilable of cow reproductive performance on mixed-grass range sites.

Steer weights employed in the analysis represent random values drawn from the specified probability distribution of annual weights adjusted to reflect the effect of range forage yield on cattle performance. Thus, the distribution of steer weights must be specified so as to generate a joint probability distribution having the same statistical properties as the distribution of observed steer weights. A distribution of stochastically estimated steer weights was compared to a hypothesized population distribution derived form available range research data to assure that this condition was met.

Variability of Returns Above Cash Costs

Table 2 presents selected parameters of the returns above cash cost distributions for cow-calf, cow-yearling and steer activities. The cow-calf operation represented consists of a 254 head spring calving cow herd. A herd of 224 cows and 99 yearlings comprise the cow-yearling plan. Steer calves were retained as stockers and heifer calves were sold in the fall. The stocker operation involve the purchase of 1188 summer stocker steers on May 1 and marketed September 30. Both ranch and per unit values are provided. The ranch returns are most comparable because the same set of land, building, family labor and overhead costs was used. Dollar per unit comparisons would involve different amounts of "fixed" inputs per unit of activity and fall into the area of concern expressed by Helmers, et. al.

Average ranch returns above cash costs per ranch across the six years and 25 replications, cow-calf ($40,126), cow-yearling ($39,173) and steers ($38,224), are very similar despite the low returns in year six for the steer enterprise caused by cyclic adjustments. Uncertainty comparisons for the activities can be based in part on the minimum and maximum returns experienced. In general, steer minimums were lower and the maximums were higher, suggesting that steer returns are more variable year to year. The mean plus and minus one standard deviation provides another measure of uncertainty. By this measure, the steer enterprise is characterized by the highest degree of uncertainty, while the cow-calf activity has the least variability.

Table 2. Distribution Parameters of Activity Returns above Cash Costs for a 6800 Acre Southern Plains Ranch.

	Year 1	2	3	4	5	6
Cow-Calf Return Above Cash Costs			$ Per Ranch			
Mean	36157	34732	38692	46169	43770	41234
S.D.	6302	5849	6181	4826	7037	6062
Minimum	17649	17944	22515	32645	25402	25693
Maximum	44800	46383	47638	50865	53790	50440
			$ Per Unit of Activity			
Mean	142	137	152	182	172	162
S.D.	25	23	24	19	28	24
Coef. Var.	17	17	16	10	16	15
Minimum	69	71	89	129	100	101
Maximum	176	183	188	200	212	199
Stocker Return Above Cash Costs			$ Per Ranch			
Mean	46627	47330	33264	42009	40925	19189
S.D.	13959	12360	10778	13418	13353	13908
Minimum	14182	14581	8988	13601	8705	-6946
Maximum	76599	68917	44943	65774	68405	39228
			$ Per Unit of Activity			
Mean	39	40	28	35	34	16
S.D.	12	10	9	11	11	12
Coef. Var.	30	26	32	32	33	72
Minimum	12	12	8	11	7	-6
Maximum	64	58	38	55	58	33
Cow-Yearling Return Above Cash Costs			$ Per Ranch			
Mean	36102	34304	37220	45389	42543	39485
S.D.	5829	6936	6047	5437	6751	6287
Minimum	17991	10648	23144	31673	24360	23607
Maximum	42731	44714	46661	51172	53548	49206
			$ Per Unit of Activity			
Mean	161	153	166	203	190	176
S.D.	26	31	27	24	30	28
Coef. Var.	16	20	16	12	16	16
Minimum	80	48	103	141	109	105
Maximum	191	200	208	228	239	220

The offsetting influences of price trend and cyclic effects across time and stochastic variation make it difficult to analyze year to year changes in returns above cash costs. However, mean returns for both cow activities appear to increase and steer returns decrease over the analysis' six-year horizon. The influence of time on the variability of net returns is less apparent. No significant increase in the standard deviation is observed over time. However, the minimum and maximum for both cow-calf activities increase. Extending the time horizon of the analysis would probably more clearly isolate the cyclic effects and indicate the effect of time on the magnitude and variability of returns.

Variability of Net Ranch Income

Net ranch incomes in Table 3 follow a conventional income statement definition of residual to owned resources after inventory adjustments except for land. Family living, off-farm income and principal payments are not considered. The majority of the residuals are negative for the 65% equity scenarios. Despite the poor profitability situation under each of the enterprise alternatives, the results may still be used to analyze the uncertainty at the firm level.

Interest on initial debts (a deterministic component) plus interest on borrowing to cover operating loans or minus interest on cash reserves earned from positive net ranch incomes (stochastic components) have been deducted. Inventory adjustments have trend and stochastic components (e.g. the inventory change in value of breeding livestock is partly stochastic). Thus, we expect the net ranch income calculation to have an effect different than that expected from adding a constant to return above cash cost for each enterprise. That is, we expect the standard error to increase.

Mean cow-calf net ranch incomes exceed mean net income derived from steers by $2,541, compared to $1,902 for returns above cash costs. Thus, net ranch income is even more favorable for the cow-calf activity.

We are looking for evidence that the firm situation adds to activity uncertainty which results from production and price variability. The standard deviation increased drastically for the 65% equity, cow-calf activity. However, the steer standard deviation changed very little. The difference is probably due to the effect of inventory value changes of breeding cattle. We expected that steer variation would also increase due to increases in borrowing and interest payments in unfavorable years, but only a small increase occurred in 3 of 6 years and a decrease in standard deviation occured one year. The ranch is running cash deficits nearly every year. Perhaps the difference in interest paid after a "bad" year and a "normal" year is not great enough to significantly affect income variability. Most maximums were again higher and minimums lower for stockers than cows but not to the extent observed for returns above cash costs. Firm effects made the cow-calf activity more variable relative to stockers, primarily because of inventory changes.

The cow-calf with 100% equity section of Table 3 isolates the effect of inventory changes from interest charges. Depreciation of machinery and equipment (change in inventory) was about $11,000 in year 1 and $10,000 in years 4, 5 and 6. The remainder of the difference between return above cash costs and net ranch income is due to cattle inventory change. The average effect across replications for a given year was negative as cows and bulls aged and values declined. However, some of the maximums are nearly as great as for return above costs. Thus, under some sets of events, gains in cow herd values offset most of machinery and equipment depreciation.

Table 3. Distribution Parameters of Net Ranch Income for a 6800 Acre Southern Plains Ranch Using Alternatives Ranch Production Activities.

	Year 1	2	3	4	5	6
Cow-Calf Net Ranch Income			$ Per Ranch - 65% equity			
Mean	-18215	-32890	-24652	-21298	-22295	-36162
S.D.	7436	8238	9793	8381	11670	9370
Minimum	-37835	-51702	-45806	-39133	-47800	-62519
Maximum	-7224	-13013	-6024	-6314	-4337	-17150
			$ Per Unit of Activity			
Mean	-72	-129	-97	-84	-88	-142
S.D.	29	32	39	33	46	37
Coef. Var.	41	25	40	39	52	26
Minimum	-149	-204	-180	-154	-188	-246
Maximum	-28	-51	-24	-25	-17	-68
Stocker Net Ranch Income			$ Per Ranch - 65% Equity			
Mean	-26015	-2546	-33428	-23287	-26463	-59023
S.D.	14244	12976	11019	14209	12422	16785
Minimum	-37533	-46279	-50095	-47840	-56630	-76471
Maximum	28185	13087	-7484	3120	5319	-21713
			$ Per Unit of Activity			
Mean	-22	-2	-28	-20	-22	-50
S.D.	12	11	9	12	10	14
Coef. Var.	55	510	33	61	47	28
Minimum	-32	-39	-42	-40	-48	-64
Maximum	24	11	-6	3	4	-18
Cow-Calf Net Ranch Income			$ Per Ranch - 100% Equity			
Mean	22640	10659	22888	30946	31880	21625
S.D.	7754	8432	10891	7927	11304	10975
Minimum	2693	-6697	1685	12030	8951	1718
Maximum	33424	35178	39877	45630	50737	38325
			$ Per Unit of Activity			
Mean	89	42	90	122	126	85
S.D.	30	33	43	31	44	43
Coef. Var.	33	79	48	26	35	51
Minimum	11	-26	7	47	35	7
Maximum	132	138	157	180	200	151

Standard deviation of net ranch incomes with 100% equity are higher than for 65% equity in four of 6 years and lower in two of 6 years. This result is similar to the result of subtracting interest form steer returns. It suggests that interest costs are nearly a constant.

As was the case with the net returns above cash costs presented in Table 2, cyclic and stochastic effects tend to mask any temporal trends in the magnitude or variability of net ranch income. No strong trends in either the mean or variance measures of net ranch income may be inferred from the results. Apparently, increased variability resulting from the inclusion of inventory changes and other firm effects tends to further coverup the temporal influences.

Summary and Conclusions

Our objectives were to demonstrate use of Monte Carlo Modeling to estimate distributions of cattle returns, compare activity and firm level variability and evaluate changes in variability across time. REPFARM, a recursive, stochastic whole-firm simulator, was modified to include important random variables affecting cattle returns. Random variables include selling weights, weaning percent, supplemental feed prices, range forage production and cattle prices.

Activity returns distributions were estimated using returns above cash costs. The model generates data for building an empirical distribution of returns, but we only present selected parameters. Mean returns for the ranch are comparable for the cow-calf, cow-yearling and stocker organizations evaluated. However, returns from yearlings are more variable than for cows. Changes in variability across time are not strongly apparent.

Firm returns distributions were estimating using net ranch income, an income statement definition which includes adjustments for inventory changes/depreciation. Returns from cows vary more drastically when firm effects are included. Changes in value of cows is the major source. Variability of steers is not affected, but the mean income is reduced. Our hypothesis that variability would increase across years is not supported. Perhaps, more years need to be simulated.

The modeling approach offers several advantages to the time series technique for estimating distributions of returns. It is forward looking rather than historical. Projections for technology and production price conditions can be incorporated as deemed appropriate. Production relationships which are not available in an appropriate time series form can be built from various data sources.

The S-180 Livestock Sub-Committee discussed the concepts of raw or full, v.s. ameliorated variability and they probably deserve some attention. For example, a good set of records for a successful ranch would yield estimates of cattle returns distributions which are ameliorated by strategies used on the ranch to manage risk. We can estimate more or less raw variability by controlling the risk management strategies employed in the simulation. These ideas may be useful for planning additional research to evalute risk strategies in a firm environment across time.

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