A STOCHASTIC FINANCIAL MODEL FOR STOCKING RATE DECISIONS ON A BRAZILIAN BEEF CATTLE FARM

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Summary Pastoral farmers in the Tropics need to make the key decision of the number of animals that should be farmed each year in the absence of reliable data on pasture production and quality, and animal requirements. This study describes a decision support model used to make stocking rate decisions for a case study steer finishing farm in Brazil. The model is based on a stochastic cashflow model, and data on the carcass weight of animals sold to the local abattoir , monthly rainfall and the stock selling policy used on the farm.

The distribution of animal carcass weight on the farm for each month is fitted to a beta distribution by assuming that the sample of animals sold to the abattoir has been based on decisions whereby only animals above a minimum weight are sold. Mean monthly animal growth rates are then estimated and fitted to rainfall data by linear regression. A Monte Carlo simulation of the farm's cashflow which incorporates variable prices and animal growth rates indicated that a stocking rate of 1.0 animal per hectare was the best option. The cumulative distribution of the December cashflow for 1.0 animal per hectare has first degree dominance over other stocking rate options.

1. INTRODUCTION

A cashflow budget summarises the relationship between income and expenditure for a business over a given period of time. The budget gives the manager an opportunity to reschedule seasonal cash inflows and outflows to ensure that the business remains viable and the end of year cash balance is maximised. The monthly cashflow budget for a grazing system can be used in conjunction with the farm feed budget to evaluate decisions on stocking rate (stock carried per unit area), calving and lambing date, time of weaning, stock purchase and selling policies. The feed plan matches seasonal feed supply with livestock demand and the cashflow budget indicates whether the seasonal cashflow is sufficient for the farmers needs. Simulation models such as Stockpol can be used to determine polices that yield feasible feed plans (Marshall, McCall and Johns 1991). The effects of farm management policies on the farm cashflow or gross margin are also provided.

These models have a number of weaknesses. Detailed input data on variables, such as pasture growth and feed requirement, are required but these are either not available or difficult to estimate in many farming situations. The models are also deterministic and do not account fully for the variability in pasture and animal production, or in product prices. The variability of farm returns and the farmer's attitude to risk can determine policies adopted by the farmer.

The purpose of this study was to show how a cashflow model can be used with stochastic production and price variables to assist the farm manager in formulating a stocking rate policy. The case study was based on a prime beef production farm in the Amazon region of Brazil where historical data on the amount of feed present on the farm and livestock consumption were not available.

2. DESCRIPTION OF THE CASE STUDY FARM

The farm is 8,700 hectares of which 4360 hectares is in improved pasture, which mainly comprises three different grasses: Brachiaria Brizanta, Panicum Maximum, and Andropogon Guanines (Cunha,1995). Replacement steers are purchased as rising 1 years olds and finished before reaching 4 years of age. Steers are sold on a per kilogram of carcass weight payment basis that is the same across weights and grades, but the level of payment varies with seasonal market conditions. The decision to sell is taken when the average price per animal is equal to or greater than US$ 300. However, if the farm has a negative cashflow steers are sold even if the average price per animal is less than US$ 300 until a positive cashflow is retained. Animals not sold under these two criteria are disposed of before they reach four years of age.

3. THE STOCKING RATE DECISION

As part of the managerial process for grazing systems, the farmer must decide on the numbers and mix of animals to farm. The choice of stocking rate can significantly impact on the productivity and profitability of the grazing system since it affects the feed supply to individual animals (Campbell, 1969; White, 1987; Conniffe, Browne and Walsh, 1970).

Selecting the optimum stocking rate is complex when production and economic variables, and hence farm returns, are stochastic. The farmer's degree of risk aversion will also dictate the optimum stocking rate (McArthur and Dillon, 1971). A risk averse farmer may adopt a stocking rate which is lower than that selected by a risk taker. In a situation where the farmer's attitude to risk is unknown then the cumulative distribution of enterprise returns will need to be considered when choosing the most appropriate stocking rate (Anderson, Dillon and Hardaker, 1977).

4. THE CASHFLOW MODEL

To establish the relationship between the stocking rate and the distribution of farm returns for the case study farm, a financial model was developed to simulate the management of seasonal cash transactions on the farm when both production and prices received are stochastic. The equations in the cashflow model are essentially accounting identities and time dependencies are achieved by ensuring the cash opening balance in a particular month equals the closing balance of the previous month. It was assumed that decisions are made from January, and the distribution of the cash balance in December was used to evaluate the stocking rate options.

Cash required to purchase replacement animals, is directly related to the stocking rate. The total cost of maintaining animals, such as animal health (vaccination, minerals), also increases with stocking rate. Cash inflows were only affected by stocking rate through the number and carcass weight of steers sold each month.

4.1 Deriving Mean Growth Rate of Steers

The distribution of carcass weights of rising 3 year old steers was obtained from farm records of the number and carcass weight of monthly sales. A beta distribution was used to describe the probability density function of carcass weight, because it has a flexible form which can be described by two parameters.

The probability density function for the beta distribution was assumed to be defined as:

$$f(x, a, b, L, U) \qquad (1)$$

where

x is the carcass weight (kg);
a,b are the shape parameters of the Beta distribution;
L and U are minimum and maximum carcass weights (kg).

The mean carcass weight of animals sold above a minimum weight can be derived from (1) as:

$$\text{MeanS} = \int_{\text{MinS}}^{U} (x.f(x, a, b, L, U)\, \partial x)/\text{PropS} \qquad (2)$$

where

MeanS is the mean (kg) weight of carcasses sold to the abattoir;
MinS is the minimum carcass weight sold;
PropS is the proportion of rising 3 year old steers sold.

If the proportion of rising 3 year old steers sold, PropS, is known then

$$1 - \text{PropS} = \int_{L}^{\text{MinS}} f(x, a, b, L, U)\, \partial x \qquad (3)$$

Beta shape parameters (a, b) and L can be found by solving (2) and (3). The variables MeanS, MinS and U and can be calculated from farm records of livestock sales to the abattoir.

It is convenient to restate (2) and (3) as:

$$\text{DivMean} = ((\text{MeanS} - (\int_{\text{MinS}}^{U} x.f(x, a, b, L, U)\, \partial x/\text{PropS}) / \text{MeanS})^2 \qquad (4)$$

$$\text{DivProp} = ((1 - \text{PropS} - \int_{L}^{\text{MinS}} f(x, a, b, L, U)\, \partial x))/(1-\text{PropS}))^2 \qquad (5)$$

The problem can be solved as a non-linear minimisation problem which can be stated as:

Find a, b, L (6)

in order to

Minimise

DivMean + DivProp

Subject to

$L \leq \text{MinS}$

$a > 0, b > 0, L > 0.$

The mean carcass weight of rising 3 year old steers in each month can therefore be calculated form the parameters of the distribution.

(In estimating the above non-linear model using data from the case study farm it was found that the estimated L did not always yield 'plausible' estimates. Using farmer experience, L was therefore fixed at 85% of MinS (Cunha, 1995)).

5. DATA ANALYSIS

The primary source of data were the carcass weight of 2696 rising 3 year old steers sold over four years (1989-1993) and the associated prices received for each kilogram of carcass weight. Monthly rainfall records were also available for the farm during this period.

5.1 Distribution of carcass weight of animals

Using (6) the beta shape parameters of the monthly distribution of carcass weight were derived (Table 1). The parameters indicate that the distribution of carcass weights in each month was not normal, but was rather skewed to the right.

Table 1 Estimated Beta distribution of monthly carcass weights of rising 3 year old steers.

	Beta Shape Parameters		Carcass Weight (kg)		
Month	a	b	Min	Max	Mean
January	0.10	1.59	183	321	191
February	0.10	1.52	165	291	173
March	0.10	1.11	183	343	196
April	0.31	2.91	219	352	231
May	0.10	1.35	186	278	192
June	0.10	0.71	185	312	201
July	0.16	1.43	181	343	197
August	0.14	1.86	185	400	200
September	0.76	3.79	185	292	203
October	0.52	5.44	171	366	188
November	0.70	1.51	195	297	228

The effect of rainfall on steer growth rate was estimated from a linear regression between monthly growth rate, and the previous month's mean carcass weight and rainfall as:

$$G_t = 8.36 - 0.042\, W_{t-1} + 0.001\, R_{t-1}$$
$$(3.4) \quad (-3.5) \quad (0.7)$$

(The t-statistics of the regression parameters are shown in brackets).

where

G_t is the growth rate in current month;
W_{t-1} is the mean carcass weight in the previous month;
R_{t-1} is the rainfall in the previous month.

On the basis of the t-statistic, rainfall did not appear to significantly affect monthly liveweight change for this formulation of the regression model.

Random growth rates can be simulated by sampling from the distribution of the regression coefficients which are assumed to be normally distributed with a mean and standard deviation equal to the estimated coefficient and standard error, respectively. The standard error of the constant term and the coefficients of the meant carcass weight and rainfall were 2.367, 0.012 and 0.002, respectively.

5.2 Price Variability

Prime steers from the case study are sold to the local abattoir on the basis of carcass weight irrespective of grade. Historically, prices have ranged from about US$ 0.9 to 1.60 per kg. Insufficient data was available to estimate the correlation between price and carcass weight. The price data for each month was fitted to a truncated normal distribution. No correlation between price and carcass weight was assumed. Instead the effect of price on carcass weight was modelled as part of the selling decision.

6. RUNNING THE SIMULATION MODEL

The model used in this study is similar in concept to the lamb drafting model developed by Garrick, Purchas and Morris (1986). Their model simulates a flock of lambs of specified weight and sex using relationships between liveweight, carcass weight and carcass grade.

Based on historic data, the individual carcass weight of animals at the start of the farm year (January), is generated randomly from a beta distribution with shape parameters of 0.1 and 1.59, and with minimum and maximum values of 183 kg and 321 kg, respectively. Using a price sampled at random from the distribution of prices, the model sells animals if their average return is equal to or greater than $US300. Alternatively, if the monthly cash balance was negative, the selling process continued until a positive balance was achieved. Animals not sold were grown to the next period using the estimated stochastic growth function. The process was repeated until December when all remaining animals were sold. The whole process was repeated twenty times to yield a cumulative distribution for the closing December cash balance.

The simulation model was programmed on a Microsoft Excel Spreadsheet using the Visual Basic programming language (Microsoft, 1994), and the @Risk (Palisade, 1994) Monte Carlo simulation package.

The model was used to simulate the effect of two different beginning of season (July) stocking rates on the annual cashflow. July is a critical month as pasture growth rates and pasture quality are low, as a consequence of the dry period. Based on previous experience, the optimum stocking rate that can be carried in July is 1 animal per hectare. At this rate over-grazing is usually avoided but carcass weights are relatively low. The effect of two stocking rates on cashflow were therefore simulated:

Plan1: Sell 1416 animals per year which corresponds to 0.80 animals per hectare in July.

Plan2: Sell 1800 animals per year which corresponds to 1.00 animal per hectare in July.

An increase in stocking rate may result in reduced animal growth rates although the interaction between pasture utilisation and production can ameliorate this effect. The model was therefore re-run for the stocking rate of 1.0 animal per hectare with a 10% and 25% reduction in animal growth rate.

7. RESULTS AND DISCUSSION

The mean cash balance in December for Plans 1 and 2 were US$ 84,811, and US$ 124,149 respectively. The mean cash balance therefore increased with stocking rate. The cumulative distribution of the December balance values for the two stocking rates simulated are shown in Figure 1.

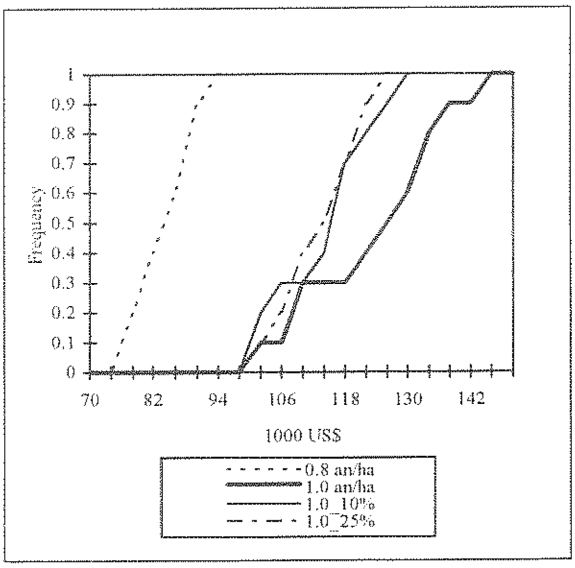

Figure 1: Cumulative distribution of the December cash balance for 0.8, 1.0 steers/ha, and a 10% and 25% reduction in growth rate, at 1.0 steers/ha.

The stocking rate of 1.0 animal per hectare is preferred to 0.8 animal per hectare since its distribution of December balances has first-degree stochastic dominance. In graphed terms, a first-degree stochastic dominant cumulative distribution function must lie nowhere to the left of a dominated curve (Anderson, Dillon and Hardaker, 1977).

The stocking rate of 1.00 animal per hectare is preferred even when animal growth rates were reduced by 10% and 25%, respectively (Figure 1). As expected, however, the reduction in steer growth rate reduced the profitability and risk efficiency of Plan 2.

The mean cash balance for January was US$ 71,226, followed by a slight reduction in February and a marked drop in March (coinciding with the purchase of replacement animals) (Figure 2). The cash balance remains at a low level until September when steer sales commence.

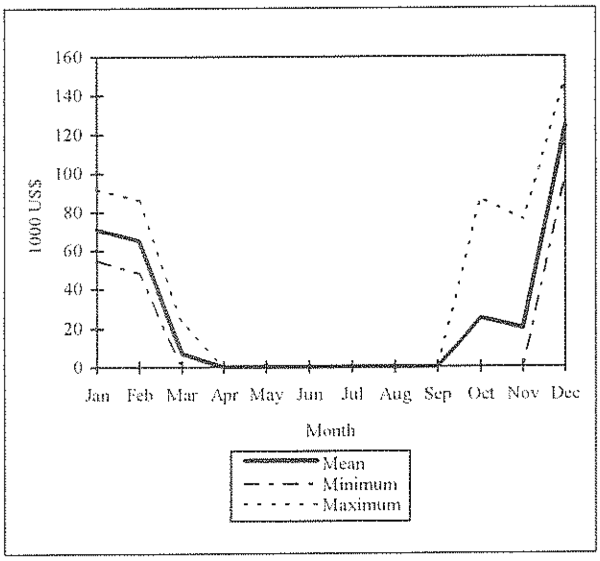

Figure 2: Monthly cash balances for a stocking rate of one animal per hectare in July.

8. CONCLUSION

A decision support model using a stochastic cashflow model was developed to assist a farm manager with stocking rate decisions. The model was developed for a situation where data on pasture supply and its growth rate were not available and therefore conventional forms of feed budgeting were not suitable. However animal growth rates could be estimated from historical data on the distribution of carcass weights of livestock sold. The cumulative distribution of end of year cash balances were used to discriminate between stocking rate options. This approach is useful if the preference of the farmer for the stocking rate options is unknown. Other policies, such as the purchase date of replacement stock, could also be evaluated with the model.

It is assumed that a farmer can accurately estimate carcass weight from animal liveweight but unless animals are routinely weighed, in which case actual liveweights would be available, this may be unrealistic. The biological feasibility of the model output should now be tested by collecting farm pasture data in relation to pasture supply and availability for alternative stocking rates.

9. REFERENCES

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