Choice of Technology: The Case of Grass Fed Versus Grain Fed Cattle in Hawaii

Peter V. Garrod and Roland K. Roberts

A model describing the choice of technology is developed from theoretical considerations. It is shown that the model can be approximated using a logit function. Estimates of short-run elasticities are easily obtained. The model is then applied to the decision to place feeder cattle in confined feeding situations or on range. With one possible exception, the results are consistent with theoretical expectations and with previous studies.

The general topic of this paper is the relationship between economic and environmental parameters and the choice of technology by firms. The specific focus is on the choice of technology when the availability of one or more inputs is predetermined, i.e., in the short run. The empirical application concentrates on how ranchers in Hawaii choose between alternative methods of growing out their market animals. As on the mainland, market beef in Hawaii, other than breeding herd culls, is produced in two ways: steers and heifers are fattened either on the range or in confined feeding systems. Each method involves quite different uses of resources and produces a different product, and as such, can be considered a different technology.

The technology chosen by a firm which continuously faces a set of possible technologies has typically been approached in one of three general ways. The first, and perhaps most general, is activity analysis. This approach has been widely used by agricultural economists, often in a linear programming framework. The study by Brokken, O'Conner and Nordblom is a recent example of the use of activity analysis in the context of the beef industry. A second approach focuses on technological change or the adoption of new technology. Studies following this approach often use models incorporating learning curves, differential rates of growth, and have time as an explanatory variable (Surry and Meilke). The third approach is based on econometric simulation models. In this approach, the choice of activities is typically confined to those represented by historical data. The analysis focuses on the intensity of the activities. In the context of the beef industry, Arzac and Wilkinson, Freebairn and Rausser, Roberts, Vieth and Nolan, Yanagida and Conway, and many others have made contributions.

This paper proposes a method of analyzing the choice of technology based on a probabilistic behavioral model that differs from previous models in several important aspects. As in activity analysis, the choice of appropriate technology is based on relative profits or, in the case where the choice engenders a future revenue and cost stream, on expected profits. In activity analysis, changes in cost and revenue parameters usually result in the selection of different alternatives or combinations of alternatives. This implies the existence

Peter Garrod and Roland Roberts are Associate and Assistant Professors, respectively, Department of Agricultural and Resource Economics, University of Hawaii, Manoa.

This research contributes to Western Regional Project W-145. Hawaii Institute of Tropical Agriculture and Human Resources Journal Series Number 2809.

Western Journal of Agricultural Economics, 8(2): 112–123

of abrupt changes in behavior. In the proposed model, only the probability of a given technology being selected changes. As economic conditions vary, the proposed model permits a firm to adopt a new or previously unutilized technology, to maintain its current technology or to revert to a previously used technology. These options are typically not possible in models used to describe technological adoption, particularly if the model incorporates trend variables (Surry and Meilke). In large econometric models and other system analytical approaches, the choice of technology and other decisions, such as changes in inventory, interact, adding to the complexity of the model. The model we propose allows the decision on technology to be analyzed independently of other decisions, if certain criteria about the decision-making process are met. The proposed model can be used by itself or as part of a larger econometric simulation effort.

The next section of the paper outlines the theoretical development of the model we propose. This is followed by a brief description of the beef industry in Hawaii. The decision of ranchers in Hawaii to market their steers and heifers as grain fed or grass fed beef is then analyzed. The results we obtain are compared with the results of other studies and the validity of the proposed model is discussed.

Theoretical Framework

Define the set of alternative activities or technologies facing the firm each period as

$$A = (a_1, \ldots, a_n)$$

and let the associated profits be defined by

$$P = (p_1, \ldots, p_n)$$

where each p_i is conditional on the level of the activity (q_i), the output price vector (r_i), and the input price vector (c_i). That is

$$p_i = p_i(q_i, r_i, c_i) \text{ for } i = 1, \ldots, n.$$

The elements of A are production functions and the elements of P are conditional profit functions. If the production decision produces a future income and cost stream, P is then the set of expected conditional profits and r_i and c_i are the vectors of expected prices associated with each p_i. With no loss in generality, the elements of P can be defined as average profit functions where the average is taken over q.

The problem facing the profit maximizing firm is then to choose the activity or combination of activities in A that will maximize (expected) profits. If the supply of one input is constrained to be less than or equal to a fixed quantity (QT), the problem can be stated as

$$\text{Max } \Sigma q_i p_i \quad \text{s.t. } \Sigma q_i \leq QT, \quad q_i \geq 0,\ i = 1, \ldots, n \tag{1}$$

where the level of the activity (q_i) is measured in terms of the limited resource. An equivalent expression for (1) can be obtained by defining one of the activities contained in A as a disposal activity for any excess q. That is

$$\text{Max } \Sigma k_i p_i \quad \text{s.t. } 0 \leq k_i \leq 1,\ i = 1, \ldots, n, \quad \Sigma k_i = 1 \tag{2}$$

where $k_i = q_i/QT$ could be interpreted as the share of the i-th technology or the probability that the i-th technology will be utilized.

Given the usual neo-classical assumptions about profit and production functions[1] the solution to (2) will satisfy the Kuhn-Tucker conditions of non-linear programming. Obviously, each k_i, and thus each q_i, will (potentially) depend on the conditional profit of each member of A.

Define $q_i = f_i(p_1, \ldots, p_n, QT)$, $\quad i = 1, \ldots, n$

then $k_i = f_i/\Sigma f_j$. $\quad i = 1, \ldots, n$

Further, if $f_i = e^{g_i(p_1, \ldots, p_n, QT)}$ $\quad i = 1, \ldots, n$

then k_i is defined by a universal logit func-

[1] Production functions concave in inputs or equivalently, the profit function quasi-convex in prices. If there are constraints, the constraint set is convex.

tion (Amemiya). If each g_i is a function only of p_i, then k_i is defined by an independent logit function (Amemiya, McFadden). An alternative expression for the logit function is obtained by taking one activity as the numeraire, in this case the n-th technology

$$k_i = e^{h_i}/(1 + \Sigma e^{h_j}), \quad i = 1, \ldots, n-1$$
$$k_n = 1/(1 + \Sigma e^{h_j}) \tag{3}$$

where $h_i = g_i - g_n$ and the sum is over j from 1 to n − 1. Note that

$$\log(k_i/k_j) = g_i - g_j, \text{ or equivalently}$$
$$\log(q_i/q_j) = g_i - g_j. \tag{3'}$$

When equation (3) defines an independent logit model, an alternative derivation exists. Assume that each firm selects an activity each period and the conditional profit expression contains an additive stochastic term, s, distributed according to a Type I extreme value distribution, or the log Weibull distribution. That is

$$p_i = g_i(r_i, c_i, QT) + s$$

Then the probability of technology a_i ($\text{Prob}(a_i)$) being selected by a given firm is

$$\text{Prob}(a_i) = e^{g_i}/\Sigma e^{g_j}$$

which is the same as (3) when each g_i is assumed to be a function of only p_i. The steps of this derivation can be found in McFadden and a summary of McFadden's proof is given by Amemiya. While McFadden's proof is based on stochastic utility functions rather than stochastic profit functions, the algebra is identical and will not be presented here.

If it can be assumed that $\log(k_i/k_j)$ is stochastic, estimates of k can be obtained by standard econometric techniques as long as the form of g (or h) and the distribution of the error term are amenable to estimation. For sufficiently large samples and g linear in (transformed) variables, the logit equation can be estimated using regression techniques.

Elasticities (E) of q_i given QT are readily available. Define x as any exogenous variable affecting P, then the elasticity of q_i with respect to x given QT is

$$E(q_i, x \mid QT) = x(g_i' - \Sigma k_j g_j') \tag{4}$$

where $g_i' = dg_i/dx$.[2] These elasticities are consistent with the conditional formulation of the model and have several theoretically and intuitively satisfying properties: (1) the conditional elasticity of q_i approaches zero as k_i goes to unity, implying that when there is only one activity, it cannot be increased in the short run; (2) the conditional elasticity of q_i approaches $x(g_i' - g_j')$ as k_j goes to unity or when there is a predominant activity, activity j in this case, the sign and magnitude of the proportional change in an alternative activity (activity i) depends on the relative marginal profitability of the activities; and (3) the weighted sum of the elasticities with respect to x, where the weights are the share of each technology, is zero. That is, in the short run, the level of a given technology cannot be increased(decreased) unless at least one other activity is decreased(increased).

The principal advantage of conditional elasticities defined by (4) is their well defined short-run nature. Economists are typically very conscientious in labeling estimated relationships as either short-run or long-run, but rarely is a precise definition made available. In the proposed estimates, short-run is clearly defined—it is the time frame where QT is fixed in the decision-making framework. There are many situations in agriculture where such elasticities are applicable. One example would be the allocation of land between crops during a given growing season.

[2] The formula for the conditional elasticity is derived directly from the definition of the logit. By definition $k_i = q_i/QT = e^{g_i}/\Sigma e^{g_j}$ where g is assumed to be a function of x. Solving the above equation for q_i and then taking the derivative with respect to x yields $dq_i/dx = x(g_i' - \Sigma k_j g_j')$.

Another example, which we discuss in detail later, is the decision to market cattle as grass or grain fed animals. In this case, the number of animals subject to the decision will be determined by past calf crops, which in turn is a function of the cow inventory.

In general, whenever availability of an input is determined from an inventory relationship and current and expected conditions determine which technology will best use the input, such conditional estimates are valid. In fact, in a comprehensive analysis, the proposed relationship will define the relationship between inventory equations, which by definition are long-run in nature, and output equations which are contingent on short-run production decisions.

One of the properties of a logit function is that there is a non-zero probability associated with every alternative. In the production possibility situation being discussed here, this implies that every alternative will be used. This obviously makes no sense for an individual firm. Generally, we would expect an individual firm to exhibit more of a "bang-bang" type behavior, switching between alternatives as (expected) conditions change. However, as the (expected) profitability of alternatives will vary across firms, implying that the choice of technology will also vary, the association of a non-zero probability with each alternative may actually be very realistic for an industry.

The Beef Industry in Hawaii

The beef industry in Hawaii differs from its mainland counterpart in two important ways.[3] The price of beef is determined exogenously and there is no feeder market. Only 33 percent of the beef consumed in Hawaii is produced in Hawaii. Imports from the mainland accounted for 49 percent of consumption in 1978–80, and imports from Australia and New Zealand the remaining 18 percent. The price of beef in Honolulu, the principal consumption point, is the mainland price (Los Angeles) c.i.f. Honolulu.

Steers and heifers are marketed as either grass fed or pen fed animals. Typically, the rancher maintains ownership until the animal is slaughtered. Feeding and slaughtering are predominantly carried out on a custom basis, or in the case of feeding, by the ranch that owns the cattle.[4] As a result, there is no established market for feeders in the State.

On the mainland, feedlot and slaughter/packing facilities are typically located near the source of production. In the State of Hawaii, 70 percent of feedlot capacity is concentrated in one feedlot on Oahu and 56 percent of all the cattle slaughtered are slaughtered in one of two plants on Oahu. However, 70 percent of the cattle are produced on the islands of Maui and Hawaii and only 2 percent are produced on the island of Oahu.

During the past five years, 70 percent of the steers and heifers marketed came out of feedlots and the remaining 30 percent were grass fed. Some ranches market their entire output of steers and heifers as fed beef, some entirely as grass fed animals, and the remainder as a combination of grass and pen fed beef. In the remaining portions of this paper we investigate the parameters of this beef production decision process.

[3] A complete and current description of the market organization of the Hawaii beef industry is given in Schermerhorn *et al.*

[4] There are exceptions to this. On Oahu, the two large slaughterhouses will occasionally purchase feeder stock. Sometimes the feedlots on Maui and Hawaii, which are considerably smaller than the one on Oahu, will purchase feeder stock. However, the quantity of animals on feed owned by the slaughterhouses typically amounts to less than 15 percent of the total number of animals on feed on Oahu and the numbers purchased by the feedlots on Maui and Hawaii are relatively small.

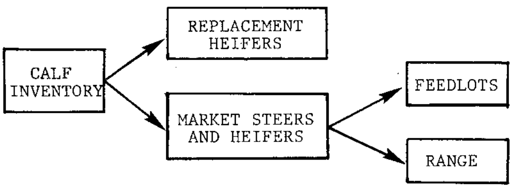

Figure 1. Beef Herd Decision Tree.

Application

The particular point in the decision-making process on which we are focusing is the decision whether to send the steers and heifers destined for market to a feedlot, or to keep them on grass. In the case of heifers, we assume that ranchers first decide how many to keep for replacement. Then they decide whether to send the remainder to a feedlot or keep them on grass, or some combination of both. This is the simplest possible decision tree and is illustrated in Figure 1.

More complex decision trees are possible. One possibility is that decisions may not be irrevocable, as economic conditions change, managers could reverse previous decisions. For example, a second tree could be defined by assuming that the decision to place animals on grass is continuously revised. As relative profitability conditions change, ranchers may divert some of the (presumably younger) market stock on range to feedlots, and possibly some of the heifers on range that were destined to market into the replacement herd. Some of the heifers in the replacement herd could also be sent to market under certain profitability conditions.

It is also possible that Hawaii ranchers use more than two technologies. For example, some ranchers might send their animals to the feedlots at relatively light weights, while others might hold their animals destined for the grain fed market on grass and send them to the feedlots at heavier weights for finishing. In this application we assume that there is only one feedlot technology. Observed behavior tends to support this assumption. Data on the age and weight of animals, when the decision to use confined feeding or range feeding is made, are not available.

To be consistent with an hypothesis of multiple technologies (say short times and long times on grass with feedlot finishing) the animals arriving at the feedlot from a given ranch in a given lot should be relatively uniform in size and age. However, the converse is true in Hawaii. Typically, animal sizes and ages within a given lot from a given ranch vary widely. This variation, however, is consistent with ranchers making the decision on grass fed versus grain fed at a specific time (probably during round-up or when the cattle have to be moved).

The decision between range and pen feeding is based on the relative expected profitability of the two alternatives. Expected profitability is based on the expected prices and costs. Expected price depends on expected grade and yield, which in turn are a function of the age and breed of the animal and the feeding regime. Currently, between 15 and 40 percent of the pen fed beef in Hawaii grades choice or better, while the range fed beef rarely grades better than good. Feedlot costs are a function of the price of imported grains, primarily corn and barley, and of imported roughages, primarily alfalfa.

The profitability of keeping cattle on grass depends on the quality and quantity of grass available, which is basically a function of weather, range management practices, the price of grass fat beef, and the number of animals being grazed. The profitability of grass fattening animals also depends on the cost of grass. This cost has at least two components: the time cost of money and the opportunity cost of forgone calf production. The decision to keep an animal on grass, given current management practices, implies that the receipt of revenue from that animal is postponed from 6 to 18 months relative to the time of sale of pen fed beef. Also, the grass the market animal consumes cannot be used to maintain the cow-calf herd.

Based on these considerations, the following relationship was postulated

$$\log(k_1/k_2) = \log(q_1/q_2) = h(\text{PFED, PGRASS, FEED, RAIN, QT, INV})$$

where PFED is the average monthly price of fed cattle for the month in which the decision is made; PGRASS the average monthly price of grass fed steers and heifers lagged one month; FEED a monthly index of feed costs in feedlots based on the Honolulu price of rolled barley, rolled corn, and alfalfa; RAIN the cumulative rainfall during the previous three months; QT the number of animals for which the decision on whether to feed grain or grass is made; and INV the estimated number of steers and heifers, excluding replacement heifers, greater than 500 pounds currently on grass lagged one month.[5]

Data on the age, weight, and breed of the animals are not available and are therefore not included. The subscripts 1 and 2 refer to animals destined to be fed in feedlots and animals to be fed grass, respectively, and q to the number of animals.

Both INV and PGRASS are lagged one month because this best represents the information available to the ranchers. The price of grass fed beef is based on weight and grade of animals slaughtered, and the current information reflects animals previously sent to the slaughterhouse.

The variable RAIN is used as a proxy for range conditions. As range conditions are a function of intensity of use and climatic conditions, levels of rainfall combined with numbers of animals on grass should be a good proxy for grazing conditions. However, to be applied correctly, the climatic and range use variables should be matched with cattle numbers from each climatic zone. Such data are typically not available, particularly in Hawaii, where cattle are grazed in conditions ranging from tropical rain forest, to desert, to high mountain slopes. In such a situation, the use of aggregate weather data, such as state or regional rainfall can be quite misleading. Consider the problem of trying to assign weights to rainfall data collected at different points to arrive at a useful composite index. However, while the amount of rain varies drastically between various points in Hawaii, because of the island nature of the State, the relative levels tend to be correlated. For example, based on annual data, the correlation between rainfall at Hilo, Hawaii where it typically rains more than 100 inches a year and Kahului, Maui where it typically rains less than 20 inches a year is .81. Thus a measure of the relative fluctuation in rain could be used as an index of weather conditions affecting range conditions.

The actual values used in RAIN come from one collection point in the center of the beef production region on the island of Hawaii. This region produces more beef than any other region in Hawaii and the selection of rainfall from this region as the climatic index for statewide range conditions will typically produce the highest correlation with actual range conditions.

Data on the number of animals placed on feed each month were available[6] but the number of steers and heifers placed on grass had to be estimated. The method used was to assume that the number of range fattened animals slaughtered each month were placed on grass 11 months earlier. This assumption is not as valid as we would like it to be. The modal length of time on grass after the decision is made is probably between 11 and 12 months. However, for some animals the decision could have been made as much as 24 months earlier.

[5] The monthly inventory estimates were obtained using monthly slaughter data and annual inventory data.

[6] Unpublished data, Hawaii Crop and Livestock Reporting Services.

TABLE 1. Choice Between Range or Confined Feeding: Estimated Coefficients.

Variable	Coefficient	t-Statistic
PFED	2.49	2.48
QT	3.48E-4	6.13
RAIN	−7.02E-3	−1.29
PGRASS	−3.45	−2.16
INV	2.14E-6	0.25
Constant	−0.355	

$R^2 = .64$ n = 53, DW = 2.01.

TABLE 2. Choice Between Range or Confined Feeding Technologies: Estimates of Conditional Elasticities Evaluated at the Means.

	Number Placed on Feed With Respect to	Number Placed on Grass With Respect to
PFED	.428	−.924
PGRASS	−.493	1.065
QT	1.407	.121
RAIN	−.019	.041
INV	.024	−.051
FEED	.065	−.141

No variables specifically representing the cost of grass are included for two reasons. Ongoing budget studies of beef production in Hawaii by the authors indicate that the important variables in determining the relative profitability of pen fed versus grass fed operations are the price of pen fed beef, the price of grass fed beef, the cost of feed, and the rate of gain of range fed cattle. All these variables or their proxies are included in the equation. Relative to the impact of the above variables, comparable changes in the discount rate were observed to have a very minor effect on the relative profitability.

The second reason was that interviews with ranchers during the fall of 1982 indicated that the ranchers treated marginal increases in range conditions as free. That is, when grass was available it was a free substitute for expensive imported feed.

Monthly data starting in August 1976 were collected. As no price index appropriate to the livestock industry in Hawaii could be found and national indices were felt to be inappropriate because of the large transportation cost component in all prices in Hawaii, cattle prices were divided by feed costs. Thus the price variables used represented cattle-price feed-cost ratios. The estimated coefficients are given in Table 1 and the estimated conditional supply elasticities evaluated at the means are given in Table 2. The estimates of the elasticities with respect to QT are obtained by adding one to the estimates computed according to (4) and are also reported in Table 2.[7]

All the coefficients have expected signs and, with the exception of RAIN and INV, are significant at the 5 percent level. RAIN is significant at the 10 percent level. The Durbin-Watson (DW) d statistic indicates that a null hypothesis of no autocorrelation should not be rejected. The insignificance of INV is probably due to two factors. One, it was the change in range conditions, as measured by RAIN, which was influencing the decision and two, the decision maker possibly gave little weight to the opportunity cost of feeding grass in making his decisions.

The signs on the derived estimates of the elasticity of supply with respect to feed costs are negative, contrary to expectations (Table 2). As feed costs (FEED) are used as a price deflator in the estimated equation, the elasticity of supply with respect to feed costs can be obtained as the negative of the sum of the price elasticities. There is no readily available statistical method for testing whether these es-

[7] As $QT = q_1 + q_2$, it appears as if one of the explanatory variables is a function of the dependent variable (q_1/q_2). However, as increases in QT are not necessarily associated with either an increase or decrease in the dependent variable nor with changes in the residuals, there is no reason to believe that the inclusion of QT on the right-hand-side will be statistically invalid.

timates are significantly different from zero as the elasticities contain products of variables. A weak test of the significance is obtained by testing whether the weighted sum of the coefficients of PFED and PGRASS (Table 1) is significantly different from zero, where the weights are the means of PFED and PGRASS, respectively. This test, while by no means conclusive, does not indicate a significant difference.

The estimates of the conditional elasticities have to be interpreted carefully. They represent the impact a change in the variable would have on the number of animals placed on feed, or on the number placed on grass, given the number of animals available for placement. They are not elasticities of supply of either grass or grain fed beef. However, as compared to the elasticities of supply estimated using the usual econometric techniques, the estimates reported in Table 2 should agree in sign and be less elastic due to their short run nature.

The elasticity with respect to QT indicates how the number of animals placed on feed or on grass will vary with changes in the number of animals available for placement. The weighted sum of the elasticities for grass and pen fed beef must sum to one where the weights are the relative proportions of grass and pen fed beef. The estimates for both technologies meet a priori expectations in terms of sign and the estimates indicate that as more animals become available for placement, the proportion of animals going to the feedlot increases.

In his quarterly U.S. livestock model, Martin obtained an estimated elasticity of 0.3 for placements on feed with respect to feeder price, which is close to the estimate of 0.428 given in Table 2. We could find no study that included both fed and nonfed beef prices. However, Bain hypothesized that placements on feed were positively related to fed and negatively related to nonfed cattle prices. The price of fed cattle had a positive coefficient in his final U.S. placements on feed equation, but the price of nonfed beef was dropped due to multicollinearity problems. Studies of the U.S. cattle industry reported by Arzac and Wilkinson, Freebairn and Rausser, and Yanagida and Conway also included only the price of fed beef. In each case, the estimated coefficient was positive. Ospina and Shumway, in their analysis of U.S. beef slaughter supply using annual data, estimated own price elasticities for choice and good steers, and for choice and good heifers. As expected, their estimates agree with the elasticities in Table 2 in sign and are of greater magnitude.

In their quarterly model of the Hawaii beef industry, Roberts, Vieth, and Nolan estimated equations for fed and nonfed steer and heifer beef production. Each equation included both fed and nonfed beef prices. Elasticities calculated from their results were respectively 0.924 and −0.672 for fed beef supply with respect to fed and nonfed beef prices, and −0.566 and 0.283 for nonfed beef supply with respect to fed and nonfed beef prices lagged three quarters. These estimates are not strictly comparable in that they refer to the quantity of beef rather than to the number of head placed on feed or grass. However, the elasticity estimates obtained from Roberts *et al.* agree with the estimates in Table 2 on sign; and given that their estimates are based on quarterly rather than monthly data, the larger order of magnitude of the elasticities of fed beef conforms with theoretical expectations. Because of differences in specification, the magnitude of the estimates of the nonfed beef price elasticities are not comparable to those obtained by Roberts *et al.*

The short-run supply elasticities of grass fed beef, in terms of the number supplied for slaughter, can be estimated using the same data and technique. These are the elasticities that reflect the decisions made by the rancher after he has decided to

TABLE 3. Short Run Supply of Grass Fed Beef: Estimated Coefficients.

Variable	Coefficient	t-Statistic
INV	−3.12E-5	−8.60
PGRASS	−0.95	−2.01
RAIN	−5.80E-3	−2.54
RAIN (1)	−1.37E-3	−1.06
RAIN (2)	3.06E-3	2.12
RAIN (3)	7.49E-3	2.97
Constant	−1.851	

$R^2 = .64$, $n = 61$, $DW = 1.71$.
Numbers in parentheses refer to the number of months lagged.

place the feeders on grass. The short-run supply of grass fed beef is a function of (1) the age and weight distribution of the animals currently on grass, (2) the expected price of grass fed beef, and (3) range conditions. Redefining k to be the proportion of the number of animals on grass marketed, the elasticities can be obtained from the following equation:

$$\log(k/(1 - k)) = \log(\text{GRFED}/(\text{INV-GRFED})) = h(\text{PGRASS, INV, RAIN})$$

where GRFED is the number of grass fed animals slaughtered each month, and the other variables have the same definitions used previously. No data on the specific ages and weights of animals on grass were available and thus no variable for either weight or age was included. The lagged inventory variable represents the estimated number of animals in place during the previous month, or the potential number of animals available for slaughter during the month.

This equation was estimated assuming h was linear in its arguments using Almon lags on RAIN.[8] The estimated coefficients are given in Table 3 and the associated elasticities in Table 4. The numbers in parentheses after RAIN indicate the length of the lag.

TABLE 4. Estimated Conditional Short Run Supply Elasticities of Grass Fed Animals Evaluated at the Means.

Variable	Elasticity
INV	−.020
PGRASS	−.415
RAIN	−.048
RAIN (1)	−.011
RAIN (2)	.025
RAIN (3)	.062

Again, the fit is good; all the variables—with the exception of RAIN(1)—are significant at the 95 percent level. The Durbin-Watson statistic indicates that a null hypothesis of no autocorrelation should not be rejected. The signs and magnitudes of the coefficients and associated elasticities indicate that the short-run supply curve is downward sloping. This conforms with observed ranch behavior and with a priori expectations. As the price of grass fed beef increases, the rancher tends to hold his beef longer on the range. The coefficients on the rain variable indicate that as range conditions improve, cattle are held longer on grass. The positive signs on RAIN(2) and RAIN(3) illustrate the impact on current sales of past decisions to delay the sale of range steers and heifers due to improved range conditions. The sum of all the rain elasticities is a measure of the impact of an overall improvement in range conditions.

Several other studies of the beef industry found similar short-run nonfed beef supply response to changes in beef prices. Aggregate U.S. studies by Langemeier and Thompson, and Shuib and Menkhaus reported short-run price elasticities of supply for non-fed beef of −0.55 and −0.97 respectively. The estimate of −0.415 reported in Table 4 is consistent in sign. The lower magnitude is expected since the elasticity was estimated from monthly

[8] The initial article is the reference to Almon. Discussions of the technique can be found in most modern econometric texts. For example, see Johnston. The equations were estimated using SHAZAM [White]. The lag was specified as three periods and a first order polynomial with no end point constraints was used.

rather than annual data. In Freebairn and Rausser's equation for the production of other beef (nonfed), the variable representing the price of good and choice feeder steers has a negative coefficient. Other studies which disaggregated on the basis of sex rather than on a fed/nonfed basis also obtained downward sloping supply curves. Reutlinger obtained negative estimates for the expected beef-corn price ratio in his U.S. heifer and cow slaughter equations and a positive coefficient for steers. Meyers, Havlicek and Henderson, in estimating a monthly aggregate cattle supply equation for the U.S., obtained a negative current beef price coefficient. Jarvis theorized that beef price and optimal slaughter age were positively correlated, which would imply negative short-run supply responses to changes in price. Jarvis' empirical work in Argentina generally supported his hypothesis. Guiterrez, De Boer and Ospina compared their estimated short-run elasticities for the Columbian beef industry with studies by Reutlinger, Lattimore and Schuh (Brazil), Yver (Argentina), Nores (Argentina), and Barros (Chile). Short-run supply elasticities for male animals ranged between −0.668 and 0.162 with four of the six studies reporting negative elasticities. The elasticities for female animals ranged between −1.20 and 0.049 with five of the six studies reporting negative estimates.

Conclusions

The use of a logit function to describe the choice of technology appears to be promising. The implied relationship between choice of technology and economic variables such as prices, costs, and profits can be derived from theoretical considerations. The empirical application to the decision on how to fatten beef animals destined for the market in Hawaii yielded expected results.

The application illustrating the proposed method focused on just two technologies. However, it is a simple and straightforward process to apply the same methodology to situations involving more than two technologies. One technology is chosen as numeraire and the estimating equations are given by (3′) and the associated elasticities by (4). Also, when more than two technologies are being used, it will often be desirable to estimate the (n − 1) equations simultaneously and impose restrictions across equations. The linear structure of (3) would facilitate such a procedure.

Like all economic models, the applicability of this model of technological choice is dependent on a certain set of behavioral assumptions. The model described in this paper is based on the assumption that the decision on the choice and intensity of technologies is based on conditional profits and once made, the decision is not reversible. It is also implicitly assumed that the technologies are separable, i.e., there exists a set of technologies, not a single technology with a continuum of different outputs. These assumptions may be appropriate for many situations occurring in agriculture, such as the allocation of land between crops in a multicropping environment or when technological choice is limited by inventory conditions as in livestock industries.

One of the points of the proposed model is that the interpretation of the estimates is well defined. The estimates are functions of the relative profitability of the alternative technologies conditioned on the availability of a specified input. Thus, the estimates are definitely short-run estimates, where short-run is precisely defined as the time period for which the availability of the specified input is predetermined.

The choice equations defined by the proposed technique could form an appropriate part of larger econometric models. The equations would provide the link between inventory equations and output equations.

References

Almon, S. "The Distributed Lag between Capital Appropriations and Expenditures." *Econometrica,* 30(1965): 178–96.

Amemiya, T. "Qualitative Response Models: A Survey." *Journal of Economic Literature,* XIX(Dec. 1981): 1483–1536.

Arzac, E. and M. Wilkinson. "A Quarterly Econometric Model of the United States Livestock and Feed Grain Markets and Some of its Policy Implications." *American Journal of Agricultural Economics,* 61(1979): 297–308.

Bain, R. *An Econometric Model of the United States Beef Market.* Bureau of Agricultural Economics, Beef Research Report No. 20, Canberra, Australia, 1977.

Barros, M. C. "Respuesta de la Produccion Boviana Ante Cambios de Precios: Un Enfoque Econometrico." Trabajos de Investigacion No. 8, Departmento de Economia Agraria, Universidad Catolica de Chile, 1973.

Brokken, R. F., C. W. O'Conner, and T. L. Nordblom. *Costs of Reducing Grain Feeding of Beef Cattle.* U.S. Department of Agriculture, Economics, Statistics, and Cooperatives Service, Agricultural Economics Report No. 459, 1980.

Freebairn, J. W. and G. Rausser. "Effects of Changes in the Level of U.S. Beef Imports." *American Journal of Agricultural Economics,* 57(1975): 676–88.

Gutierrez, N. F., J. De Boer, and E. Ospina. "An Econometric Model of the Colombian Beef Sector: 1950–1970." *Canadian Journal of Agricultural Economics,* 30(1982): 61–70.

Hawaii Department of Agriculture, USDA Statistical Reporting Service, *Statistics of Hawaiian Agriculture,* various issues.

Jarvis, L. S. "Cattle as Capital Goods and Ranchers as Portfolio Managers: An Application to the Argentina Cattle Sector." *Journal of Political Economy,* 48(1974): 489–520.

Johnston, J. *Econometric Methods.* 2nd Edition. McGraw Hill Book Company, New York, 1963.

Langemeier, L. and R. G. Thompson. "Demand and Supply, and Price Relationships for the Beef Sector, Post-World War II Period." *Journal of Farm Economics,* 49(1967): 169–83.

Lattimore, R. G. and G. E. Schuh. "Endogenous Policy Determinations: The Case of the Brazilian Beef Sector." *Canadian Journal of Agricultural Economics,* 27(1979): 1–16.

Martin, W. J. "U.S. Agricultural Policy and the Demand for Imported Beef." Unpublished Ph.D. Dissertation, Department of Economics, Iowa State University, 1982.

McFadden, D. "Conditional Logit Analysis of Qualitative Choice Behavior." *Frontiers in Econometrics.* Edited by P. Zarembka. Academic Press, New York, 1975: 105–42.

Meyer, L. H., J. Havlicek, and P. L. Henderson. "Short Term Price Structure of the Hog-Pork Sector of the United States." Purdue University Research Bulletin 855, 1970.

Nores, G. "Quarterly Structure of the Argentina Beef Cattle Economy: A Short Run Model, 1960–1970." Unpublished Ph.D. Dissertation, Purdue University, 1972.

Ospina, E. and R. Schumway. *Disaggregated Econometric Analysis of U.S. Slaughter Beef Supply.* Texas Agricultural Experiment Station, Technical Monograph 9, 1980.

Reutlinger, S. "Short Run Beef Supply Responses." *Journal of Farm Economics,* 48(1966): 909–19.

Roberts, R. K., G. R. Vieth, and J. C. Nolan, Jr. "An Analysis of the Impact of Energy Price Escalations during the 1970's on Hawaii Beef Production and Prices." Paper presented at the meeting of the American Agricultural Economics Association, Logan, Utah, August 1–3, 1982.

Schermerhorn, R. W., P. V. Garrod, and C. T. K. Ching. *A Description of the Market Organization of the Hawaii Beef Cattle Industry.* Hawaii Institute of Tropical Agriculture and Human Resources, University of Hawaii, Information Text Series 011, August 1982.

Shuib, A. B. and D. J. Menkhaus. "An Econometric Analysis of the Beef-Fed Grain Economy." *Western Journal of Economics,* 1(1977): 152–56.

Surry, Y. and K. D. Meilke. "Incorporating Technological Change in the Demand for Formula Feed in France." *American Journal of Agricultural Economics,* 64(1982):2 254–59.

White, K. J. "A General Computer Program for Econometric Methods—SHAZAM." *Econometrica*, 46(1978): 236–40.

Yanagida, J. F. and R. K. Conway. *Annual Livestock Model of the United States*, National Economics Division, Economics, Statistics, and Cooperatives Services, USDA, Staff Report, 1980.

Yver, R. "The Investment Behavior and Supply Response of the Cattle Industry in Argentina." Paper presented at the Workshop on Price and Trade Policy in Agricultural Development, Purdue University, August 1971.