USE OF PRODUCTION ISOQUANTS IN EVALUATING THE RESPONSE OF WHEAT PASTURE STOCKER CATTLE TO INCREASING LEVELS OF ENERGY SUPPLEMENTATION[1]

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Story in Brief

A cattle response function relating weight gain of wheat pasture stocker cattle to levels of energy supplementation and forage availability was estimated using time series and cross-sectional data from a three-year wheat pasture grazing study. Ordinary least squares and maximum likelihood procedures were used to estimate quadratic and logarithmic cattle response functions. A multiple-input quadratic form was selected as the appropriate functional form based upon non-nested specification tests. Both forage availability and the quantity of supplement fed, as well as steer weight and two annual dummy variables were identified as statistically significant in explaining variability in average daily weight gain. The response function reaches a maximum at a forage availability level of approximately 26 lb/steer day, which indicated forage availability becomes a limiting factor at this point. Also, the response function did not reach a maximum within the range of supplementation levels (0 to 5.0 lb/day) used in the study. Production isoquants were derived indicating combinations of forage availability and supplementation levels that yield the same level of average daily gain. The quantity of energy supplement required to maintain weight gain at a constant level is shown to increase as forage availability is decreased. Also, the isoquants indicated larger increases in energy supplement are required to offset a reduction in forage availability as forage availability is decreased.

(Key Words: Wheat Pasture, Energy Supplementation, Response Functions.)

Introduction

Provision of energy supplements to stocker cattle grazing wheat pasture has particular significance because of large potential fluctuations in amounts of available forage. The response of cattle grazing wheat pasture to energy

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supplements has been variable (Elder, 1967; Lowrey et al., 1976; Utley and McCormick, 1976). Energy supplements may have different effects on forage intake, utilization, and animal performance depending upon composition of the supplement, climatic conditions, and the quantity and nutritive value of available forage. Additional studies have been conducted to achieve a better understanding of factors influencing the response of wheat pasture stocker cattle to energy supplements (Horn et al., 1991; Horn et al., 1993).

Response functions are a useful tool for analyzing the response of livestock to the various factors influencing livestock performance. Using data from grazing studies, response functions can be estimated which quantify relationships between cattle gain and various environmental and management variables. Those factors which significantly influence weight gain can then be identified. In addition, important interrelationships between these variables can be analyzed using mathematical and graphical techniques. Quantifying the relationships between livestock performance and production inputs is an important first step in evaluating economically efficient management practices.

The objective of this paper is to estimate a response function and thus quantify the relationship between performance of stocker cattle on wheat pasture and energy supplementation levels and forage availability, and to use the response function to evaluate interactions between forage availability and supplemental feed inputs. These findings should prove useful in understanding the complex management decisions facing producers of wheat pasture stocker cattle in the Southern Great Plains.

Materials and Methods

A study assessing the effects of energy supplementation on wheat pasture stocker cattle performance was conducted over a three-year period. Crossbred, fall-weaned steer calves grazed clean-tilled wheat pasture and either received no supplement, a corn-based energy supplement, or a high-fiber energy supplement containing soybean hulls and wheat middlings. Steers grazed wheat pasture for 115, 107 and 84 days during the 1989-90, 1990-91 and 1991-92 grazing seasons, respectively. Treatment steers received supplemental feed for 96, 100, and 69 days during the three grazing seasons. In the first and third years of the study, stocking densities were 2 ac/head for the control and 1.5 ac/head for the supplementation treatments. In the second year, stocking densities were 2, 1.64, and 1.38 ac/head for both control and supplementation treatments. For a more detailed description of these grazing experiments, see Horn et al. (1991) and Horn et al. (1993).

Time series and cross-sectional data from the grazing study were used to estimate a cattle response function relating weight gain of wheat pasture stockers to supplementation level and forage availability. Data used were forage availability per steer day, quantity of supplement fed, calf weights, and final weights. Total forage production was estimated from clipping data and converted to forage availability (pounds of forage per steer day) based upon the number of grazing days and stocking density. To account for differences in feedstuff composition of the two energy supplements, the quantity of each supplement fed was multiplied by its net energy for gain content (Mcal/kg). Thus, supplementation levels were expressed in net energy terms (Mcal/day).

Data and characteristics of stocker cattle production on wheat pasture fundamentally determine the choice of the functional form of the cattle response function. Marginal products (first derivatives of the function) should be positive over some range of the sample data. Also, second derivatives of the response function should be negative. Each additional unit of feed should result in less additional weight gain than the previous one, since, in general, energy requirements per pound of weight gain increase at heavier weights (Epplin et al., 1983). Two functional forms which conform with these hypotheses are the quadratic and logarithmic forms.

Ordinary least squares procedures were used to estimate the two production functions. The Glejser statistic was used to test for heteroskedasticity and the Durbin-Watson statistic for autocorrelation. If either autocorrelation or heteroskedasticity existed, maximum likelihood procedures were used for the final estimation in order to obtain efficient parameter estimates.

The choice between the two production functions was based on two statistical tests. It has been shown that when competing models are not nested, it is appropriate to base model specification on non-nested hypothesis tests, such as the J-test or the JA-test (Davidson and MacKinon, 1981). Indeed, while R^2 always indicates a "better" specification and the F statistic indicates the statistical significance of the model as a whole, the J-test or the JA-test indicates a "true" specification (Doran, 1993).

The estimated response function was used to evaluate the response of wheat pasture stocker cattle weight gains to changes in forage availability and supplementation level. The effect of each of these variables on weight gain was isolated by holding one variable constant and graphing projected changes in weight gain as the remaining variable was incremented. Production isoquants, representing different combinations of forage availability and supplemental feed that yield the same level of gain, were also derived. The production isoquants were then used to evaluate the substitutability of forage and energy supplement under various forage supply conditions.

Results and Discussion

The alternative production functions were estimated using ordinary least squares (OLS). The Glejser statistic indicated the presence of heteroskedasticity in the quadratic form, and the Durbin-Watson statistic indicated the absence of autocorrelation at the 5% level in either estimated function. The quadratic form was reestimated using maximum likelihood procedures. The non-nested specification test results indicated that the JA-test accepted both models, but the J-test rejected the logarithmic form. Therefore, based on the J-test, the quadratic form was accepted as the "true" specification. The estimated cattle response function (with t-values in parenthesis) is:

$$\underset{}{G_{it}} = \underset{(-9.37)}{-6.29} + \underset{(13.46)}{.016\ CFWT_{it}} + \underset{(2.24)}{.688\ EN_{it}} + \underset{(3.76)}{.104\ FA_{it}} - \underset{(-3.12)}{.4456\ EN_{it}^2} \underset{(-2.05)}{-.0019\ FA_{it}^2}$$

$$- \underset{(-1.15)}{.0017 EN_{it} FA_{it}} + \underset{(-5.66)}{-.377 D_1} + \underset{(-7.24)}{-.472 D_2} + \epsilon_{it}$$

G_{it}, $CFWT_{it}$, EN_{it}, and FA_{it} are the daily rate of weight gain (lb/grazing day), calf weight (lb), the daily quantity of energy supplement fed (Mcal/grazing day), and pound of forage available per steer day, respectively, on the i^{th} cross-sectional unit, in year t and ϵ_{it} is the error term. D_1 and D_2 are year dummy variables corresponding to the first and second grazing seasons. FA is a measure of forage availability over the grazing season and is the principal physical source of production risk facing wheat pasture stocker cattle producers. All the signs of the coefficients comply with the underlying assumptions of stocker cattle weight gain response to the independent variables. The estimated coefficients are significant at the 5% level, with the exception of the interaction term. The coefficient of the interaction term is negative, indicating a trade-off between forage availability and energy supplement.

Figure 1 illustrates the relationship between average daily gain (ADG) and the quantity of energy supplement fed at three levels of forage availability (15, 22, and 29 lb/steer day). The energy supplement variable in equation 1 has been converted to pounds of energy supplement to ease interpretation of the graphs. The average forage availability observed in the study was 22 lb/steer day, and forage availability of 15 and 29 lb/day were representative of low and high forage levels, respectively. Although statistical results indicated gain response to energy supplement to be non-linear, response curves were characterized by a relatively small curvature. The response functions did not reach a maximum within the range of supplementation levels (0 - 5.0 lb/day) used in the study. When interpreting the graphs, one must keep in mind the weight gain response shown reflects the environmental conditions which prevailed during the three grazing seasons the data was collected. Two of these seasons would be considered below average years in terms of wheat pasture stocker cattle performance. Therefore, although an ADG in excess of 2.3 lb/day can often be achieved without supplementation, the expected ADG of non-supplemented cattle over the three-year period was not projected to exceed 2.3 lb/day.

The relationship between forage availability and ADG, holding the quantity of supplement fed constant, is presented in Figure 2. Response curves are presented for situations when no supplement is fed and for daily

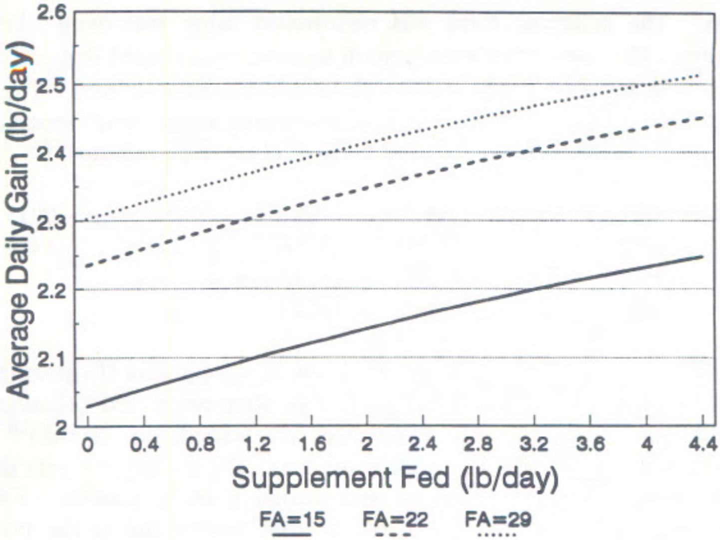

Figure 1. Relationship between the quantity of supplement fed and average daily gain at three levels of forage availability.

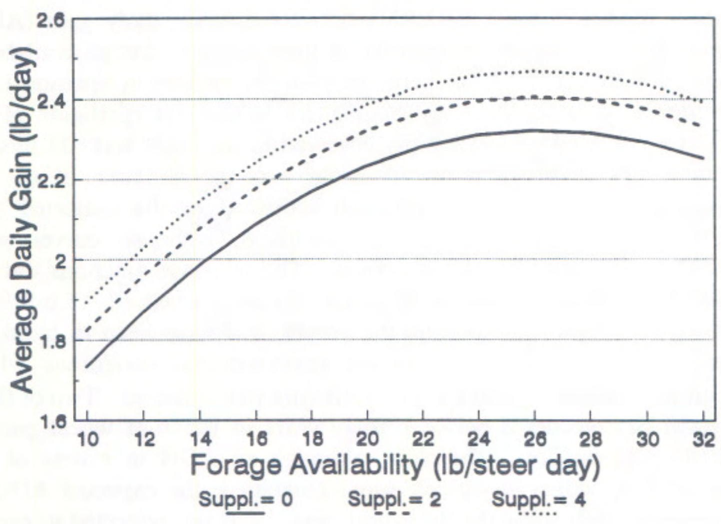

Figure 2. Relationship between forage availability and average daily gain at three levels of supplementation.

supplementation levels of 2.0 and 4.0 lb/day. The response functions reached a maximum at a forage availability between 24 and 28 lb/steer day, which indicated forage availability becomes a limiting factor at these levels. Diminishing marginal returns of energy supplement is illustrated by the smaller distance between curves representing gain response under supplementation levels of 2 and 4 lb/day, relative to the curves corresponding to 0 and 2.0 lb/day supplementation levels. This result simply implied the first 2 lb of supplement will have a greater marginal effect on gain than the second 2 lb fed.

Figure 3 illustrates three energy-forage isoquants, showing possible energy supplement-forage availability combinations for obtaining a targeted ADG. For example, 2.2 lb of daily gain can be obtained by feeding either no energy supplement with 20 lb of forage available per steer day or 4.2 lb/day of energy supplement when 15 lb of forage per steer day are available. An ADG of 2.2 lb/day can also be achieved from all combinations of forage availability and supplement level lying between these two points on the isoquant.

The isoquants also provide interesting insights into the substitutability between energy supplement and forage availability. Using the isoquant corresponding to an ADG of 2.2 lb/day to illustrate, a reduction in forage availability from 20 to 19 lb/steer day must be accompanied by a .4 lb increase in supplemental feed to maintain ADG at 2.2 lb/day. As forage availability is

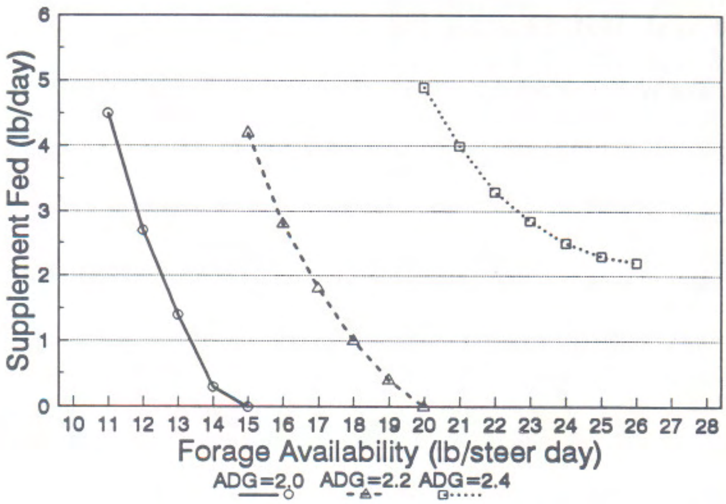

Figure 3. Production isoquants illustrating alternative combinations of forage availability and supplemental feed that yield three levels of average daily gain.

reduced, larger increases in supplemental feed are required to maintain weight gain at 2.2 lb/day. For example, when forage availability is decreased from 16 to 15 lb/steer day, an additional 1.4 lb/day of supplement must be fed to maintain ADG at 2.2 lb/day. Smaller increases in supplementation requirements are needed to offset reductions in forage availability along the isoquant corresponding to an ADG of 2.4 lb/day.

The isoquant map can also be used to illustrate the marginal contribution of supplementation. For example, holding forage availability constant at 15 lb/day, daily gain is increased by .2 lb/day as a result of increasing supplementation rates from .0 to 4.2 lb/day. Since the isoquants which correspond to ADG of 2.0 and 2.2 lb/day intersect the horizontal axis, these levels of gain can be achieved without energy supplementation. However, supplementation is required to achieve weight gains of 2.4 lb/day, given the environmental conditions prevailing over the three years of the grazing study. Even at high levels of forage availability (26 lb/steer day), 2.2 lb/day of supplemental feed was required for stocker cattle to gain 2.4 lb/day.

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