IMPACT OF RISK AVERSE BEHAVIOR ON FERTILIZER DEMAND FOR TAME FORAGES*

C. Richard Shumway and Tesfaye Gebremeskel

The importance of risk in affecting production decisions is amply attested in the economics literature [3, 12]. Recent investigation of the influence of risky alternatives on supply relations has included both econometric analyses [1, 2, 11, 19] and programming studies [10, 17]. Hazell and Scandizzo [9, p. 642] suggest that when risk aversion is present, the slope of the supply schedule (i.e., with price plotted on the vertical axis) is expected to be greater than that for a risk-neutral supply schedule.

In spite of considerable interest in the supply implications of risk aversion, little empirical attention has been given to its effects on factor demand. The authors attempt to do so, and examine the applicability of Hazell and Scandizzo's supply assertion to factor demand.

Long-term demand equations are derived for fertilizer on an intensively managed Texas Gulf Coast cow-calf farm. The functions are developed by fitting regression equations to the results of linear programming parametric analyses. The parameterizations are effected under two alternative behavioral assumptions: (1) profit maximization is the only management goal or (2) the producer's utility function is lexicographic, the first goal being an arbitrary limit on the total amount of acceptable risk and the second and subordinate goal being profit maximization.

METHOD OF ANALYSIS

The model farm consists of 500 acres of cleared land operated under good management. It is designed to be self-sufficient in production of required forages for pasture and hay in the mean year.

Hazell's risk-constrained linear programming model [8], with risk measured as mean annual absolute deviations from expected net returns, is adapted to accommodate both intermediate (forage) and final (beef) products. Expected net returns to land and management are maximized subject to bimonthly feed supply/animal consumption identities and restrictions on mean absolute deviations and available land.

Hay purchase and sale activities transfer forage yield variability to gross return variability and thus permit constant annual production of livestock. Both purchase and sale activities for hay are essential because the cost due to deficit forage production is greater than the return net of harvesting and transportation costs from an equal amount of excess production. Hazell's method of measuring only negative deviations is adequate for modeling annual crop production in the absence of storage. However, if that procedure were followed in this case, the asymmetry in prices would not be accounted for, and both expected net returns and mean absolute deviations would be overestimated.

To account for interaction between forage quality and voluntary intake, [22] forage supplies are divided into two quality categories. The highest quality forage required by any livestock activity in the model is 1.1 megacalories of digestible energy and .06 pound of digestible protein per pound of dry matter. Therefore, these are the minimum quality standards met by each forage placed in the high quality classification. Low quality forages are supplemented as required to meet the needs of the consuming unit.

C. Richard Shumway is Associate Professor of agricultural economics, Texas A&M University, and Tesfaye Gebremeskel, formerly Research Assistant at Texas A&M, is now Assistant Professor of Economics, Texas Southern University.

The authors express sincere appreciation to Marvin Riewe and Gerald Evers for permission to use unpublished data from their forage experiments. Neal Pratt, Robert Whitson, Charles Long, and Tom Cartwright were most helpful in providing additional data and technical advice pertinent to modeling the beef-forage economic system. Thanks also go to Enrique Ospina and the anonymous *Journal* reviewers for constructive suggestions.

*Texas Agricultural Experiment Station Technical Article No. 14032.

MODEL PARAMETERS

Forage and Fertilizer Options

Bimonthly forage yields for three years are taken from experimental plot clipping data on the Texas Gulf Coast [4, 5, 12]. Missing observations are estimated. These data, representing yield levels achieved under good management, are available for three warm season perennial grasses (coastal bermudagrass, common bermudagrass, and dallisgrass), for three perennial mixtures (each of the grasses with clover), and for five cool season annual forages (gulf ryegrass, new nortex oats, Florida oats, milam wheat, and wintergrazer rye).

Two fertilization treatments, differing only in the amount of nitrogen applied annually (100 vs. 200 pounds per acre), were applied to the perennial grasses. Phosphorus (P_2O_5) was applied uniformly at the rate of 80 pounds per acre each year. No potassium (K_2O) was applied. The perennial mixtures were divided into three fertilizer treatment groups differing both in nitrogen and potassium used but not in phosphorus. All treatment groups received an annual average application, including establishment requirements, of 100 pounds of phosphorus. The first treatment group received no nitrogen or potassium, the second 100 pounds of nitrogen, and the third 100 pounds of nitrogen and 80 pounds of potassium annually. Consequently, a wide array of forage options, many with alternative fertilization rates, provides the hypothetical producer with considerable flexibility in the amount of fertilizer he may demand.

The clipping yields are adjusted downward 20 percent to account for likely losses due to trampling and refusal when forages are grazed. An additional 5 percent is deducted for forage harvested and fed as hay in the same year and another 5 percent for hay stored for a year or more. Montly quality estimates in digestible energy and digestible protein per unit dry matter were provided by Texas A&M crop scientists.

Production costs per acre are adapted from Texas Agricultural Extension Service budgets for 1975 [18] and are reported in Table 1. Production data in terms of expected annual energy yields and mean absolute deviations also are reported in the table. Expected yields are separated into high and low quality categories, and deviations are reported as the mean annual sum of seasonal absolute deviations. The latter are listed only to indicate the general degree of variability evident in the production of each forage. Seasonal means and deviations, necessary to determine yield correlation between forages, are reported in [7]. Some forage pairs demonstrate a negative correlation, but most are positive.

TABLE 1. FORAGE PRODUCTION, COSTS, AND FERTILIZATION LEVELS[a]

Forage Options	Fertilization Levels, Annual Average[b]	Expected Annual Digestible Energy Yields[c] High Quality	Low Quality	Total	Mean Annual Absolute Deviations in Seasonal Digestible Energy Yields[c]	Annual Production Costs Exclusive of Land and Management 1975
	lbs/acre	megacalories/acre				$/acre
Perennial Forages						
Coastal bermudagrass	100, 80, 0	4713	4402	9115	3586	69
	200, 80, 0	6043	6848	12891	4057	100
Coastal bermudagrass-clover	0,100, 0	5757	3808	9565	2556	50
	100,100, 0	5786	4636	10422	3207	81
	100,100, 80	6269	5206	11475	3532	87
Common bermudagrass	100, 80, 0	3271	3064	6335	2169	64
	200, 80, 0	3933	5442	9375	3027	95
Common bermudagrass-clover	0,100, 0	4823	2308	7131	2143	44
	100,100, 0	5153	3493	8646	2671	76
	100,100, 80	4724	3254	7978	2557	82
Dallisgrass	100, 80, 0	3589	3131	6720	2781	70
	200, 80, 0	4352	3901	8253	3081	101
Dallisgrass-clover	0,100, 0	4073	2382	6455	1831	51
	100,100, 0	4225	2745	6970	2585	82
	100,100, 80	5553	1585	7138	2624	88
Annual Forages						
Gulf ryegrass	180, 60, 0	6503	0	6503	465	97
New Nortex oats	180, 60, 0	4875	0	4875	694	107
Florida oats	180, 60, 0	4681	0	4681	708	107
Milam Wheat	180, 60, 0	3157	0	3157	200	106
Wintergrazer rye	180, 60, 0	3264	0	3264	103	115

[a]Sources: Fertilization levels and yield data are based on [15] for perennial forages and [4, 5] for annual forages.

[b]Pounds of nitrogen, phosphorus and potassium, respectively.

[c]Clipping data were adjusted downward 20 percent to account for trampling and refusal losses when grazed.

Livestock System

The breeding herd consists of Brahman-Hereford crosses with mature cows weighing about 1,050 pounds. Calving season centers on February 1. Calves weigh an average of 70 pounds at birth and 550 pounds when weaned at 7 months of age. Calves in excess of replacement requirements may be sold (1) when weaned, (2) after a 4½ month stocker phase, or (3) after an additional 6½ months divided between 4½ months on forage and 2 months of on-farm finishing. Calves gain an average of 2.3 pounds per day before weaning, 1.5 pounds per day during the next 9 months, and 2.5 pounds per day in the feedlot. They weigh 750 pounds if sold as yearlings and 1,100 pounds if sold as good grade slaughter animals.

On the basis of underlying assumptions about conception rate, death loss, and replacement practices [7], the cow herd produces a 75 percent calf crop and requires annual retention for replacement of 23 weaned heifers per 100 cows. Animal nutrient requirements are based on NRC standards [14] for growth and maintenance and on [13] for milk production and pregnancy.

Livestock prices are from the San Antonio market [21]. Monthly prices for relevant livestock categories for the years 1955 to 1974 are inflated to 1975 levels by the index of prices paid for factors of production [20]. As there is no significant trend, the averages of these inflated series are used as estimates of 1975 "normal" prices (see Table 2). Deviations in prices are computed for the same years in which the forage data were collected to account for forage yield/beef price interactions in the risk measure; their absolute averages are included in Table 2. Production costs exclusive of forage costs are estimated to be $69 per pregnant cow, $20 per stocker, and $98 per slaughter animal [6].

Estimation of Fertilizer Demand Equations

Typical 1975 Texas fertilizer prices were $.30 per pound for nitrogen, $.24 for phosphorus, and $.075 for potassium. These prices were close to the all-time highs and have since declined somewhat. Two pairs of price parameterizations are made with the linear programming model to investigate the impact of fertilizer price on quantity demanded by the farm. The first pair consists of varying the price of nitrogen from $.15 to $.45 per pound in arbitrary steps of $.03 when (1) profit maximization is the only goal and (2) profit maximization is a secondary goal to having an arbitrarily low level of risk (viz., mean absolute deviation in net returns no greater than $5,000 per year, a goal that does not have large adverse effects on expected net returns). The second pair consists of varying all fertilizer prices proportionately given the same two utility functions. The lower and upper limits on nitrogen price in this case are $.09 and $.54 per pound, respectively.

TABLE 2. 1975 "NORMAL" CATTLE PRICES, SAN ANTONIO

Livestock Class	Expected Normal Price	Mean Absolute Deviation in Normal Price
	$/cwt	
Weaned calves, August	49.32	3.48
Stockers, January	46.37	5.21
Slaughter Animals, July	50.85	5.48
Open Heifers	44.08	5.35
Open Cows	32.95	4.62
Old Cows	29.46	3.96

Source: [21]. Price data from the San Antonio livestock market for the most similar classes were used (e.g., 500-800 lb. good grade feeder steer and heifer prices adjusted for sex proportions represent the stocker class, 500-800 lb. good grade heifer prices represent the open heifer class, and cutter grade beef prices represent the old cow class). Data were inflated to a 1975 basis by use of the index of prices paid for factors of production [20].

RESULTS

In all four cases examined, the quantity of nitrogen demanded decreases as the price of nitrogen increases up to $.30-.36 per pound. At higher prices demand becomes perfectly inelastic (at a zero level with the profit maximizing utility function). This observation persists whether nitrogen price is changed alone or proportionately with other fertilizer prices. It is also true for both utility functions.

The quantity of phosphorus demanded increases when the price of nitrogen is increased up to $.24-.30 per pound. At higher prices, demand for phosphorus is perfectly inelastic, having reached its technical maximum given the model activity options. The quantity of phosphorus demanded increases similarly as the prices of all fertilizers are increased proportionately. Though the latter finding is not what one would expect in practice, a cursory review of Table 1 provides an explanation. All forage options require phosphorus in amounts ranging from 60 to 100 pounds per acre. The perennial grasses mixed with clover can be produced with no nitrogen, but they require the largest amount of phosphorus. Given the model activity options, decreased demand for nitrogen is accompanied by an increased demand for phosphorus. No potassium is demanded at any of the fertilizer prices considered. Consequently, attention is limited to nitrogen demand.

With the usual caveats about nonindependence of observations and the implied assumption of a uniform price distribution [16, p. 347], simple regressions are fit to the observed quantity and price data from the linear programming parameterizations. Observations are deleted at either extreme in prices for which the quantity demanded is the same as for the preceding parametric change. This step is used to avoid biasing the regression estimate over the most relevant part of the price range by a series of perfectly inelastic observations in the extremes. Linear regressions are fit to the parameterization results based on the profit maximizing objective function. Regressions are fit to data in linear and logarithmic form based on the latter (i.e., lexicographic) utility function.

The estimated nitrogen demand equations are:

(1) $$N = 138{,}080 - 470{,}952P, \; R^2 = .93, \; SE$$
$$(14{,}765) \quad (63{,}986)$$
$$\text{with } 5DF = 8{,}030$$

(2) $$N = 90{,}324 - 247{,}937P, \; R^2 = .79, \; SE$$
$$(13{,}844) \quad (52{,}419)$$
$$\text{with } 7DF - 10{,}191$$

(3) $$\ln N = 6{,}874 - 2.216 \ln P, \; R^2 = .96, \; SE$$
$$(.267) \quad (.187)$$
$$\text{with } 7DF = .150$$

(4) $$N = 131{,}857 - 446{,}667P, \; R^2 = .96, \; SE$$
$$(8{,}824) \quad (40{,}404)$$
$$\text{with } 6DF = 6{,}414$$

(5) $$N = 101{,}865 - 288{,}424P, \; R^2 = .89, \; SE$$
$$(8{,}418) \quad (34{,}938)$$
$$\text{with } 9DF = 9{,}520$$

(6) $$\ln N = 7.555 - 1.702 \ln P, \; R^2 = .93, \; SE$$
$$(.276) \quad (.169)$$
$$\text{with } 9DF = .231$$

where N is nitrogen quantity demanded, P is nitrogen price, SE is standard error of the estimate, and DF is degrees of freedom. Standard errors of the estimated parameters are in parentheses.[1] Only nitrogen price is variable in equations (1), (2), and (3) whereas all fertilizer prices vary in proportion to nitrogen price in equations (4), (5), and (6). Equations (1) and (4) are based on the profit maximizing utility function and equations (2), (3), (5), and (6) are based on the lexicographic utility function. For the latter utility function, the logarithmic equations (3) and (6) provide the better fits. Their R^2 values are higher and they predict the data with lower average percent error than do the linear equations (2) and (4). Consequently, discussion of the lexicographic utility function is restricted to inferences from these logarithmic equations.

Data and demand equations (1) and (3) are plotted in Figure 1 and equations (4) and (6) in Figure 2. The demand curves in each figure intersect at a price of about $.25 per pound. Decreases in price from this level stimulate approximately similar increases in quantity demanded with both utility functions. Increases in price, however, stimulate substantially smaller decreases in quantity demanded by the risk averter than by the profit maximizer.

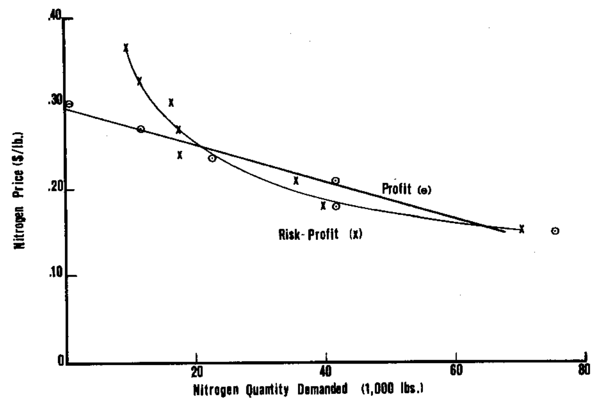

FIGURE 1. DEMAND FOR NITROGEN, OWN PRICE VARIABLE

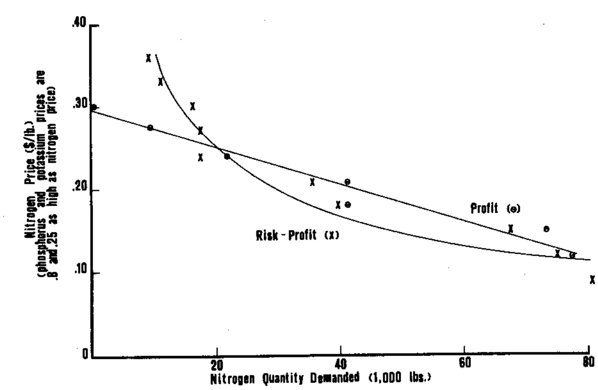

FIGURE 2. DEMAND FOR NITROGEN, ALL FERTILIZER PRICES VARIABLE

Demand elasticities for these equations are reported at four alternative nitrogen prices in

[1]Standard errors are reported only to provide information on goodness of fit. They do not have the conventional statistical meaning because data are generated from a deterministic model rather than being random observations from a real world population.

TABLE 3. ESTIMATED ELASTICITY OF DEMAND FOR NITROGEN FERTILIZER AT SELECTED PRICES

Variable Fertilizer Prices	Utility Function[a]	Nitrogen Price ($/lb.) .15	.20	.25	.29
Nitrogen	Profit	-1.0	-2.1	-5.8	-90.8
	Risk-Profit	-2.2	-2.2	-2.2	-2.2
All[b]	Profit	-1.0	-2.1	-5.5	-55.7
	Risk-Profit	-1.7	-1.7	-1.7	-1.7

[a]Profit means the profit maximization utility function; risk-profit means the lexicographic utility function in which expected net returns are maximized subject to mean annual absolute deviations in net returns being no greater than $5,000.

[b]Phosphorus and potassium prices are 80 and 25 percent, respectively, of nitrogen price.

Table 3. They are constant and elastic for the risk averter. They are smaller (beginning with unitary elasticity) at low prices for the profit maximizer and become extremely large at high prices. The results document substantial differences in the implications of these two utility functions on conditionally predictive model conclusions over a portion of the price range. Though reasonably similar response is suggested at low prices, the slopes and elasticities of the curves diverge markedly at high prices. At the higher prices, these results strongly support the notion that Hazell and Scandizzo's assertion about risk-averse product supply schedules also applies to factor demand. At the lower prices, no such conclusion is apparent.[2]

Major features of the beef-forage systems are reported for different nitrogen prices in Table 4. Results of the parameterization on all fertilizer prices are similar. Coastal bermudagrass and coastal bermudagrass mixed with clover dominate all forage systems. Some gulf ryegrass enters the system at the lowest nitrogen price considered. Heavily fertilized coastal bermudagrass is important at low nitrogen prices. Moderately fertilized coastal bermudagrass with clover becomes more important in the middle price range and then gives way at higher prices to its lightly fertilized counterpart (entirely so with profit maximization as the only goal).

TABLE 4. EFFECT OF NITROGEN PRICE ON OPTIMAL BEEF-FORAGE SYSTEM FOR ALTERNATIVE UTILITY FUNCTIONS

Utility Function[a]	Nitrogen Price	Forage System[b]: Coastal Bermudagrass-Clover, Lightly Fertilized	Coastal Bermudagrass-Clover, Moderately Fertilized	Coastal Bermudagrass, Heavily Fertilized	Gulf Rye-Grass	Beef System: Cows	Weaned Calves Sold	Slaughter Animals Sold	Fertilizer Purchased: Nitrogen	Phosphorus	Potassium	Expected Net Returns	Mean Absolute Deviation
	$/lb.	acres				number			lbs.			$	
Profit	.15	0	216	211	73	489	336	0	76,900	42,900	0	41,800	9,200
	.18	176	234	90	0	473	325	0	41,400	48,200	0	39,600	8,100
	.21	176	234	90	0	473	325	0	41,400	48,200	0	38,400	8,100
	.24	283	217	0	0	410	215	66	21,700	50,000	0	37,400	7,200
	.27	387	113	0	0	391	181	86	11,300	50,000	0	36,900	7,400
	.30[c]	500	0	0	0	370	144	108	0	50,000	0	36,500	14,000
Risk-Profit	.15	59	168	206	67	481	321	9	70,100	43,200	0	41,300	5,000
	.18	205	194	101	0	474	326	0	39,600	48,000	0	39,400	5,000
	.21	221	204	75	0	458	298	16	35,400	48,500	0	38,300	5,000
	.24	329	168	3	0	403	203	73	17,400	49,900	0	37,300	5,000
	.27	329	168	3	0	403	203	73	17,400	49,900	0	36,800	5,000
	.30	336	164	0	0	405	211	67	16,400	50,000	0	36,300	5,000
	.33	387	113	0	0	428	277	17	11,300	50,000	0	35,900	5,000
	.36[c]	408	92	0	0	436	299	0	9,200	50,000	0	35,700	5,000

[a]See footnote a, Table 3.

[b]Annual average fertilization levels, including establishment of perennials, in pounds of nitrogen, phosphorus, and potassium per acre: lightly fertilized coastal bermudagrass-clover, 0-100-0, moderately fertilized coastal bermudagrass-clover, 100-100-0, heavily fertilized coastal bermudagrass, 200-80-0, and gulf ryegrass, 180-60-0.

[c]Solutions were unchanged at higher nitrogen prices.

The cow herd size generally decreases with increased nitrogen price and declines more rapidly with the first utility function. The cow-calf system dominates at all prices. When calves are retained past weaning, they are always carried to slaughter. None are sold as yearlings. In all cases considered, more than half the calves are sold when weaned. Some integration is closely competitive with the straight cow-calf operation at all nitrogen prices. However, partly because of the seasonal distribution of the optimal forage systems, a substantial number of calves are raised to slaughter weight only in the range of 1975-1976 nitrogen prices. With the lexicographic utility function, the attractiveness of a cow-

[2]Calculation of arc elasticities between actual data points yields somewhat similar conclusions. Derived elasticities of demand for the two utility functions are nearly the same in the price range of $.15-$.24 per pound. At higher prices, the profit maximizer's elasticity of demand is at least six times higher than the risk averter's.

calf operation is also partly due to a negative correlation between weaned calf price deviations and certain forage yield deviations.

The mean absolute deviation in net returns is constant at the maximum permissible of $5,000 for the second utility function and ranges from $7,200 to $14,000 for the first. The change in risk for the first utility function is not monotonic with nitrogen price changes. Risk varies with the forage system and degree of integration because offsetting deviations can reduce total risk. Risk is highest when nitrogen price is $.30 per pound, at which a specialized forage system and partially integrated livestock system are optimal. It is lowest when nitrogen price is $.24 per pound, at which diversification is practiced in forage fertilization and fewer calves are carried to slaughter weights.

CONCLUSIONS

It is apparent from this linear programming analysis of a cow-calf farm on the Texas Gulf Coast that a producer's degree of risk aversion can substantially affect his demand schedule for a major input. In this case, the risk-averse producer's response to fertilizer price changes was less than the risk-neutral producer's response at high prices. This finding is consistent with Hazell and Scandizzo's assertion. But at low prices, not much difference in response was evident. With nitrogen priced at $.25 per pound, the quantity demanded by both was about the same, but the slope of the risk averter's demand curve was much steeper and his demand elasticity lower. Forage and livestock systems differed between utility functions and so did the optimal response in these systems to fertilizer price changes.

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