THE DEMAND FOR GASOLINE AND DIESEL FUEL IN AGRICULTURAL USE IN VIRGINIA

Oral Capps, Jr. and Joseph Havlicek, Jr.

A useful guide for the direction of future agricultural policy on energy requires, in part, detailed knowledge of the demand for different types of energy in different types of agriculture. Two approaches have been used in examining these demand relationships: (1) projecting total agricultural energy requirements, allocating these requirements among different agricultural subsectors, and estimating energy use in different agricultural enterprises [3-5, 7]; and (2) linear programming (LP) or constrained input-output (I/O) analyses to assess impacts of high energy prices and quantity restrictions on agricultural activities [2, 6, 12, 16]. However, these approaches usually require some stringent assumptions which limit the applicability of the results, and they provide little information about the economic factors that influence the demand for various types of energy. In short, the two approaches may be too restrictive to portray adequately the range of opportunity and response open to the agricultural sector. Emphasis needs to be given to those approaches which can provide information about the economic structure of energy use in the agricultural sector.

The purpose of this article is to present the results of a study designed to estimate the demand for gasoline and diesel fuel in agricultural use in Virginia. A description of the statistical models used is followed by a discussion of the results. Finally, concluding remarks are made as well as suggestions for further study.

THE STATISTICAL MODELS

Some experimentation was involved in the choice of mathematical form and the selection of the empirical variables. The criteria for the selection of a functional form involved a subjective weighing of consistency of signs and magnitudes of the estimated parameters in comparison with *a priori* reasoning and previous studies, statistical significance of the estimates, and explanatory power of the estimated relationships [8]. The mathematical form chosen for the gasoline and diesel fuel demand relationships was linear in double logarithms although linear actual variate and semilogarithmic functional forms also were considered. The following statistical models were formulated and estimated.

Gasoline

$$\begin{aligned}(1)\quad LnQ^D_{G_{it}} = {} & LnA_o + \beta_1 LnACRE_{it} + \beta_2 LnRPCR_{it} + \beta_3 LnRPGS_{it} + \\ & \beta_4 LnRPGS_{i,(t-5)} + \beta_5 LnRPDFL_{i,(t-5)} + \beta_6 LnRWPFR_{it} + \beta_7 LnINTER_{it} + \\ & \beta_8 LnRPLABO_{it} + \beta_9 LnRPLND_{it} + \beta_{10} LnPRECIP_{it} + \beta_{11} LnTE_{it} + \varepsilon_{it}\end{aligned}$$

Diesel Fuel

$$\begin{aligned}(2)\quad LnQ^D_{D_{it}} = {} & LnA_1 + \beta_{12} LnACRE_{it} + \beta_{13} LnRPCR_{it} + \beta_{14} LnRPGS_{i,(t-3)} + \\ & \beta_{15} LnRPDFL_{it} + \beta_{16} LnRPDFL_{i,(t-3)} + \beta_{17} LnRWPFR_{it} + \beta_{18} LnINTER_{it} + \\ & \beta_{19} LnRPLABO_{it} + \beta_{20} LnRPLND_{it} + \beta_{21} LnPRECIP_{it} + \beta_{22} LnTE_{it} + u_{it}\end{aligned}$$

where:

$Q^D_{G_{it}}$ = the quantity of gasoline purchased from SSC (gallons)[1]

$Q^D_{DF_{it}}$ = the quantity of diesel fuel purchased from SSC (gallons)

Oral Capps, Jr. is Research Assistant, Department of Agricultural Economics, and Joseph Havlicek, Jr. is Professor, Department of Agricultural Economics and Department of Statistics, Virginia Polytechnic Institute and State University. The authors appreciate the helpful comments received from two anonymous reviewers; however, the authors are responsible for any remaining errors or ommissions.

[1]SSC refers to Southern States Cooperative, Inc. Private service agencies, local cooperatives, and retail branches of SSC make gasoline, diesel fuel, and other fuels available to farmers.

$ACRE_{it}$ = the number of acres of cropland times the market share estimates of SSC (acres)[2]

$RPCR_{it}$ = the real weighted average price of farm output (cents per pound)[3]

$RPGS_{it}$ = the real average price of gasoline paid by farmers in the current time period (bulk delivery, cents per gallon)

$RPGS_{i,(t-3)}$ = the real average price of gasoline paid by farmers in time period t-3 (bulk delivery, cents per gallon)

$RPGS_{i,(t-5)}$ = the real average price of gasoline paid by farmers in time period t-5 (bulk delivery, cents per gallon)

$RPDFL_{it}$ = the real average price of diesel fuel paid by farmers in the current time period (cents per gallon)

$RPDFL_{i,(t-3)}$ = the real average price of diesel fuel paid by farmers in time period t-3 (cents per gallon)

$RPDFL_{i,(t-5)}$ = the real average price of diesel fuel paid by farmers in time period t-5 (cents per gallon)

$RWPFR_{it}$ = the real weighted average price of fertilizer (dollars per ton)[4]

$INTER_{it}$ = the real average interest rate charged farmers by Production Credit Associations (percent)

$RPLABO_{it}$ = the real average price of farm labor (field workers, dollars per hour)

$RPLND_{it}$ = the real average price of farm land and buildings (dollars per acre)

$PRECIP_{it}$ = the average number of inches of rainfall

TE_{it} = the ratio of diesel fuel tractors to gasoline tractors in the U.S. (no units)[5]

i = a subscript denoting crop reporting district in the state (i = 2, 4, 5, 6, 7, 8, 9)

t = a subscript denoting time period (quarter)

Ln = a prefix denoting transformation to natural logarithms

β_j = the coefficient of the jth empirical variable (j = 1, . . . , 22).

All data used were pooled quarterly time-series, cross-sectional observations taken from the period 1971 through 1976. Real prices were obtained by deflating actual prices by the wholesale price index (1967=100). The disturbance terms, ε_{it} in (1) and u_{it} in (2), were assumed to follow a different first-order autoregressive scheme for each cross-section and were specified as cross-sectionally heteroscedastic and mutually correlated. A generalized least squares (GLS) procedure was used to obtain asymptotically efficient, asymptotically normal, and consistent estimators of the parameters. Under the assumption that the supply relationships of gasoline and diesel fuel were perfectly elastic, a single equation approach rather than a simultaneous equation approach was warranted.

ANALYSIS AND RESULTS

The estimated coefficients and standard errors of the gasoline and diesel fuel demand relationships are shown in Tables 1 and 2. The coefficients of determination, R^2, were .973 and .841 respectively in the gasoline and diesel fuel demand relationships. The adjusted coefficients of determination, $\bar{R}^2$, were respectively .971 and .829.

The .10 level of significance was chosen for the F-tests and the t-tests. Because the F-tests were statistically significant, the amount of variation in the quantities of gasoline and diesel fuel purchased accounted for by the set of exogenous variables was judged to be significantly different from zero. In the gasoline demand relationship, the estimated coefficient

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[2]A one-to-one correspondence between the number of cropland acres and farmers' purchases of gasoline and diesel fuel were assumed. It was also assumed that farmers' sources of fossil energy did not influence the quantities purchased.

[3]A weighted average price of farm output was developed from the quantities produced and season average prices received by farmers for corn, winter wheat, soybeans, peanuts, flue-cured, fire-cured, sun-cured, and burley tobacco, and hay. The selection of these crops was based on their importance to Virginia agriculture. In addition, farmers who raise these crops were the key users of gasoline and diesel fuel in agricultural production.

[4]A weighted average price of fertilizer was developed from the quantities consumed and prices paid by farmers for ammonium nitrate (33.3% N), superphosphate (20% P_2O_5), and muriate of potash (60% K_2O).

[5]Gasoline and diesel fuel tractor numbers were not available for Virginia, and the diesel fuel/gasoline tractor ratios for the U.S. and Virginia were assumed to be identical.

[6]The estimated variances and standard errors of the estimated coefficients were estimates of asymptotic variances and standard errors. The generalized least squares algorithm used to obtain parameter estimates of the statistical models did not calculate R^2, $\bar{R}^2$, and F−values. These values were calculated from the information provided by the algorithm. However, not enough information was available to calculate the exact R^2 $\bar{R}^2$, and F−values.

TABLE 1. THE ESTIMATED COEFFICIENTS AND STANDARD ERRORS OF THE GASOLINE DEMAND RELATIONSHIP

Variable	Estimated Coefficient	Estimated[a] Standard Error
Intercept	0.987060	1.0800
Acres (cropland)	0.954426[b]	0.021757
Real Price of Output	0.516849[b]	0.048623
Real Price of Gasoline	-0.168451	0.26039
Real Price of Gasoline in Period t-5	-1.05951[b]	0.40088
Real Price of Diesel Fuel in Period t-5	0.785196[b]	0.25920
Real Price of Fertilizer	-0.443836[b]	0.14411
Interest Rate	-0.198895	0.19888
Real Price of Labor	0.990572[b]	0.29288
Ratio of Diesel Fuel Tractors to Gasoline Tractors	0.282943[b]	0.094320
Real Price of Land and Buildings	0.573520[b]	0.022086
Precipitation	0.118197[b]	0.037200

[a]The estimated variances and standard errors of the estimated coefficients were estimates of asymptotic variances and standard errors. The generalized least square algorithm used to obtain parameter estimates of the statistical models did not calculate R^2, $\bar{R}^2$, DW, and F— values. These values were calculated using the information provided by the algorithm. However, not enough information was available to calculate the exact R^2, $\bar{R}^2$, and F— values. The computed R^2, $\bar{R}^2$, DW, and F— values were .973, .971, 2.213, and 488.138 respectively.

[b]Significant at .10 level.

TABLE 2. THE ESTIMATED COEFFICIENTS AND STANDARD ERRORS OF THE DIESEL FUEL DEMAND RELATIONSHIP

Variable	Estimated Coefficient	Estimated[a] Standard Error
Intercept	-10.7893[b]	2.3719
Acres (cropland)	1.51204[b]	0.10021
Real Price of Output	1.81707[b]	0.20630
Real Price of Diesel Fuel	0.288363	0.52946
Real Price of Diesel Fuel in Period t-3	-1.09013[b]	0.52289
Real Price of Gasoline in Period t-3	1.92170[b]	0.73696
Real Price of Fertilizer	-0.461010	0.50214
Interest Rate	-1.51714[b]	0.36776
Real Price of Labor	1.50450[b]	0.50726
Ratio of Diesel Fuel Tractors to Gasoline Tractors	0.889023[b]	0.19369
Real Price of Land and Buildings	0.910776[b]	0.15255
Precipitation	-0.0888608[b]	0.065843

[a]The estimated variances and standard errors of the estimated coefficients were estimates of asymptotic variances and standard errors. The generalized least square algorithm used to obtain parameter estimates of the statistical models did not calculate R^2, $\bar{R}^2$, DW, and F— values. These values were calculated using the information provided by the algorithm. However, not enough information was available to calculate the exact R^2, $\bar{R}^2$, and F— values. The computed R^2, $\bar{R}^2$, DW, and F— values were .841, .829, 2.099, and 71.646 respectively.

[b]Significant at .10 level.

of the real price of gasoline in the current period and the estimated coefficient of the interest rate were judged to be not significantly different from zero. All other factors were statistically significant in accounting for the variation in the quantity of gasoline purchased. The signs of the estimated coefficients conformed to *a priori* assumptions and hypotheses with the exception of the estimated coefficient of the ratio of diesel fuel tractors to gasoline tractors. In the diesel fuel demand relationship, the estimated coefficient of the real price of diesel fuel in the current period and the estimated coefficient of the real price of fertilizer were judged to be not significantly different from zero. All other factors were statistically significant in accounting for the variation in the quantity of diesel fuel purchased. Except for the estimated coefficient of precipitation and the estimated coefficient of the real price of diesel fuel in the current period, the signs of the estimated coefficients were consistent with previous assumptions and hypotheses.

Because the double logarithmic mathematical form was used in estimating the gasoline and diesel fuel demand relationships, the estimated parameters of the empirical variables represent elasticities.[7] The estimates of the elasticities should be interpreted with some degree of caution. The interpretation of any coefficient involves the assumption that *ceteris paribus* conditions hold with respect to all other empirical variables in the statistical model. In addition, the parameter estimates are applicable only within the range of data used in this study. Any projections outside the range of these data must be made with extreme circumspection. Nevertheless, the estimates of the elasticities are very useful in providing insights as to the relative responsiveness of farmers to relative price changes and changes in certain other measurable variables.

Gasoline and diesel fuel purchases were not influenced by changes in the current real prices of gasoline and diesel fuel. However, though farmers were somewhat passive in reaction to

[7]The double logarithmic transformation corresponds to the assumption of a constant elasticity.

increases in the real prices of these fuels in the current period, they were responsive to such increases when given time to adjust their use patterns. The lagged response to changes in the real prices of gasoline and diesel fuel may be due to capital costs and production costs involved in changes in management practices, lags in the production process, imperfect knowledge, uncertainty, rigidities and stickiness in the economy, technical factors, psychological factors, and other factors. It has been argued that the weights associated with various lagged variables are an empirical issue [1].

The lagged variables for the real prices of gasoline and diesel fuel were different in the two demand equations. The finding that a given percentage increase in the real price of gasoline resulted in a greater percentage decrease in the quantity of gasoline purchased indicated an elastic response of farmers to changes in the real price of gasoline. Similarly, farmers showed an elastic response to changes in the real price of diesel fuel.

The cross-price elasticity of the quantity of gasoline purchased with respect to the real price of diesel fuel was 0.79, and the cross-price elasticity of the quantity of diesel fuel purchased with respect to the real price of gasoline was 1.92. Gasoline and diesel fuel were substitutes for each other in agricultural use. The adjustment periods required for farmers to generate responses to changes in the real price of gasoline and diesel fuel were 9 months and 15 months, respectively. Finally, the magnitude of the responses of farmers to such price increases suggested that net farm income would rise, all other factors being nonvariant.

A given percentage increase in the real price of farm output generated a larger percentage increase in the quantity of diesel fuel purchased and a smaller percentage increase in the quantity of gasoline purchased. The positive influence of the real price of farm output on the quantities of gasoline and diesel fuel purchased indicated that these fuels, as expected, were not inferior inputs. An increase in the agricultural use of gasoline and diesel fuel would be associated with an increase in farm output.

The positive influence of the real price of labor and the positive influence of the real price of land and buildings on the quantities of gasoline and diesel fuel demanded indicated that land and labor were substitutes for these fuels in agricultural use. Agricultural producers had recognized the relatively low real prices of gasoline and diesel fuel and, behaving rationally, they substituted these fossil fuels for land and labor. In contrast, the negative relationship between the real price of fertilizer and the quantity of gasoline purchased indicated that fertilizer was a complementary factor to gasoline in agricultural use. However, fertilizer and diesel fuel were unaccountably independent factors because the quantity of diesel fuel purchased was not influenced significantly by a change in the real price of fertilizer. Further, the quantities of gasoline and diesel fuel purchased for agricultural use were affected positively by a change in cropland acreage. An increase (decrease) in scale of operation or farm size is likely to result in increased (decreased) purchases of gasoline and diesel fuel.

Because diesel engines have been substituted for gasoline engines in agricultural machinery, the ratio of diesel fuel to gasoline tractors represented a very particular type of technological change. A given percentage increase in this ratio generated a smaller percentage increase in the quantities of gasoline and diesel fuel purchased for agricultural use. Although diesel engines had been substituted for gasoline engines, farmers nevertheless used gasoline in their trucks and automobiles. Further, a shift from gasoline to diesel powered equipment involves a major capital expenditure on the part of farmers. Farmers were more willing to make the substitution to diesel powered machinery when interest rates were relatively low than when interest rates were relatively high. The quantity of gasoline purchased, however, was not influenced significantly by a change in the interest rate charged farmers. Finally, from common knowledge, when farmers use their machinery and equipment in field operations in wet weather, the quantities of gasoline and diesel fuel used increase. The quantity of gasoline demanded was influenced positively by a change in precipitation, but the quantity of diesel fuel demanded was influenced negatively by a change in precipitation. Evidently, in dry weather, farmers used a proportionally larger quantity of diesel fuel in crop irrigation systems.

CONCLUSIONS AND SUGGESTIONS FOR FURTHER RESEARCH

The quantity of diesel fuel purchased was more sensitive, in terms of magnitude of response, to changes in economic factors and other variables than was the quantity of gasoline purchased. Farmers were responsive to increases in the real prices of gasoline and diesel fuel when given time, specifically 9 to 15 months, to adjust their usage patterns. Hence, the allocation of gasoline and diesel fuel for agricultural use may be accomplished through market forces only after a period of 9 to 15 months, an important implication for public policy. However, changes in factors other than real energy prices, namely the real prices of labor, land and buildings, farm output, fertilizer, the number of cropland acres, the ratio of diesel fuel tractors to gasoline tractors, the interest rate charged farmers, and precipitation also affected the quantities of gasoline and diesel fuel purchased.

A potential increase in the nominal price of gasoline by as much as 50 cents per gallon over a period of 10 years was suggested by President Carter. If one assumes that the President's proposal might result in a 2 to 4 percent increase in the real price of gasoline and diesel fuel per year for the next 10 years, the quantity of gasoline purchased for agricultural use may decrease by 5 to 10 percent and the quantity of diesel fuel purchased for agricultural use may increase by 15 to 30 percent by 1987, all other factors being invariant.

Doubling the real prices of these fuels, *ceteris paribus*, may generate a 27 percent decrease in the quantity of gasoline purchased in 15 months and an 83 percent increase in the quantity of diesel fuel purchased in 9 months. In short, producers and distributors of fossil energy may change future production and distribution levels of gasoline and diesel fuel for the agricultural sector when changes in the real prices of these fuels occur.

Supporting the price for farm output above the market clearing price augments the quantities of gasoline and diesel fuel demanded for agricultural use. Price support programs for farm products thus appear to be in conflict with energy conservation programs.

Perhaps the most important contribution of this research is the indication that the agricultural sector in Virginia adjusts to changes in economic factors and other variables influencing the demand for gasoline and diesel fuel. Nevertheless, problem areas persist about which information and understanding are lacking. Because real price changes affect the quantity of gasoline and diesel fuel demanded for agricultural use, the effects in different types of agriculture merit investigation. For example, there is no reason to believe that dairy producers, tobacco producers, or wheat producers will respond to energy price changes in the same fashion. Thus, to really understand the impacts of increased energy prices, one needs to know how different types of farmers in Virginia respond to changes in the prices of gasoline, diesel fuel, and other sources of energy. Further, estimation of the demand relationships for fossil energy in food processing and distribution in Virginia and for fossil energy in the agricultural sector in other regions of the U.S. is worthwhile. In addition, it may be of interest to incorporate the behavioral characteristics of the management factor in the gasoline and diesel fuel demand relationships. Finally, the forecasting of gasoline and diesel fuel consumption in the agricultural sector in Virginia warrants attention.

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