AN ECONOMETRIC ANALYSIS OF QUALITATIVE CHOICE AMONG PERFORMANCE CHARACTERISTICS OF AGRICULTURAL TRACTORS

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The mechanization of American agriculture has played a key role in the technological progress of U.S. agriculture in this century (Heady and Tweeten). In turn, the demand for farm tractors and other farm machinery has been highly dependent on the year-to-year strength of the agricultural economy. Unit sales of tractors have varied by as much as 50 percent from one year to the next (Royal Commission on Farm Machinery).

From the late 50s to the mid 60s, the estimation of aggregate demand functions for farm tractors was a research problem for a number of agricultural economists. The 70s and 80s have been marked by increasing real liquid fuels prices, substantive increases in the average size and prices for farm tractors, and increased efforts by tractor manufacturers to differentiate their products from those of their competitors. But agricultural economists made few attempts to reestimate demand functions for farm tractors to take into account these new conditions.

Conley and Lambert in two studies have recently estimated demand functions for farm tractor horsepower using time series data for the U.S. Their analysis did not take into account the comparative energy efficiency of competing makes. Fettig was concerned with adjusting farm tractor prices for quality changes over time, but his study was conducted in 1962, long before liquid fuels efficiency became of major concern. Other studies on farm tractors have dealt primarily with the tractor as an investment decision (Penson et al.), with the impacts of inflation (Bates, et al.; Leatham and Baker), and with the competitiveness and efficiency of the industry (Barber).

In this paper, determinants of farm tractor prices are identified, with emphasis on measuring the relative importance of liquid fuels efficiency as a characteristic of tractors. The perceptions by farmers of relative fuel efficiency and other characteristics of individual tractor models probably differ. Jones and Hunt each suggest that other factors such as durability, performance, and personal preference for design characteristics of a particular machine may also play a role.

A theoretical framework for describing qualitative choice in an agricultural input market characterized by product differentiation and interdependence among sellers was developed. Previous studies treated farm tractors as either a homogeneous input (Cromarty; Heady and Tweeten), or heterogeneous in only a single characteristic (Fox). Instead, our focus is on the qualitative choices of farmers when tractors are treated as heterogeneous inputs with unique characteristics.

MARKET EQUILIBRIUM AND THE INTERPRETATION OF IMPLICIT PRICES FOR TRACTOR CHARACTERISTICS

The agricultural tractor is a differentiated product. Both farmers and manufacturers must make decisions regarding the quality and characteristics of the tractors that they employ and produce, respectively. Tractor manufacturers maximize profits on the basis of the package of characteristics they produce, and farmers purchase tractors for their profit-maximizing characteristics. Equilibrium in the market for agricultural tractors can then be described in terms of input and output equilibrium in implicit characteristic markets. The choice between alternative levels of characteristics is assumed to be a continuous function.

Market equilibrium and the meaning of implicit prices for tractor characteristics depend on the parameters of production functions of agricultural producers and tractor manufacturers. This concept was first advanced in Rosen and later extended by Deaton and Muellbauer. If agricultural producers are identical (i.e., the same shift parameters) but agricultural tractor manufacturers differ (i.e., have different shift parameters), the marginal implicit prices for tractor characteristics under market equilibrium reflect the rates of product transformation between characteristics by tractor manufacturers. Differences in production costs among manufacturers will assure that a number of models will appear on the market. If agricultural producers differ but tractor manufacturers are identical, the marginal implicit prices for characteristics reflect the rates of technical substitution between characteristics by agricultural producers. Again, a number of

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models will appear on the market, but, in this instance, it is a result of variations in the production costs of agricultural producers. If agricultural producers are identical and tractor manufacturers are identical, only one model will appear on the market, and product differentiation will be nonexistent. If agricultural producers differ and tractor manufacturers differ, the marginal implicit prices for tractor characteristics will reflect both the rates of technical substitution of characteristics by agricultural producers and the rates of product transformation between characteristics by tractor manufacturers. A number of models will appear on the market owing to differences in cost structure among agricultural producers and tractor manufacturers.

If agricultural tractors possess two objectively measurable characteristics, z_1 and z_2, and both buyers and sellers differ, the conditions for market equilibrium in the agricultural tractor market can be written as (Johnson):

$$(1) \qquad \frac{\frac{\partial r_1}{\partial z_2}}{\frac{\partial r_1}{\partial z_1}} = \frac{p\frac{\partial q}{\partial z_2}}{p\frac{\partial q}{\partial z_1}} = \frac{\frac{\partial c}{\partial z_2}}{\frac{\partial c}{\partial z_1}} = RTS_{z_1 z_2} = RPT_{z_1 z_2}$$

where:

r_1 = the price of the tractor,
p = the price of agricultural output produced by the farm firm,
q = the output of the farm firm,
c = the average unit cost of the tractor producing firm.

When the market is in equilibrium, the rate of technical substitution of z_1 for z_2 among agricultural producers equals the rate of product transformation of z_1 and z_2 by tractor manufacturers, and both equal the inverse ratio of the marginal implicit prices of z_1 and z_2. Because of variations in the cost structures of agricultural producers and tractor manufacturers, a number of models of tractors will appear on the market.

Expanding the number of characteristics to n, the market equilibrium price of tractors can be defined as a function of their characteristic content. The implicit price function for i tractor characteristics can then be represented by

$$(2) \qquad r_1 = g(z_1, z_2, \ldots, z_n) \; i = 1, 2, \ldots, n.$$

From equation (2) the marginal implicit price functions for characteristics can be derived:

$$(3) \qquad \frac{\partial r_1}{\partial z_i} = h_i(z_i, z_2, \ldots, z_n) \; i = 1, 2, \ldots, n.$$

In addition, the rate of technical substitution between characteristics among agricultural producers and the rate of product transformation of characteristics by tractor manufacturers can be derived from equations (3) and (1) and written as

$$(4) \qquad RTS_{z_i z_j} = RPT_{z_i z_j} = \frac{h_j(z_1, z_2, \ldots, z_n)}{h_i(z_1, z_2, \ldots, z_n)} = m_{ij}(z_1, z_2, \ldots, z_n) \quad i, j = 1, 2, \ldots, n; \; i \neq j.$$

Determining the relevant characteristics of agricultural tractors is an important aspect of specifying the implicit price function for tractor characteristics [equation (2)]. As was noted by Griliches, the choice of characteristics for an implicit price function is largely an empirical matter. Dhrymes states that a characteristic of a good is relevant only so far as it captures a share of the market and is of significance to the buyer. We will assume that buyers are sovereign in the market for agricultural tractors, and that manufacturers assemble tractors with those characteristics relevant to the agricultural producer.

Farmers are concerned with the durability, performance, and personal preference characteristics of agricultural tractors. Personal preference characteristics such as the color of the machine that may generate utility for the farmer were not dealt with here. Little information exists regarding durability characteristics of individual tractor models, and, therefore, lack of data precludes their use in the study (Kudrle). Performance characteristics of agricultural tractors, to the extent that they are perceived as relevant to the profit-maximizing agricultural producer, were included in this analysis.

MODEL SPECIFICATION

The rapid increases in liquid fuels prices that have taken place in the last decade provided the underlying motivation for the specification of the model to be estimated. The basic assumption of the model is that a farmer is interested in minimizing the cost of a tractor, subject to constraints imposed by horsepower (drawbar and power takeoff) and fuel efficiency requirements. Uncertainty or multiple-goal objective functions were assumed away. Although the authors feel that the durability and service aspects of tractor ownership are important to farmers as well, reliable data on durability for the various tractor makes are simply not available. The service aspect might be quantified, in part, by surveying farmers with respect to their attitudes toward various dealers within their areas, but this would require a totally different, disaggregated, market-research-oriented approach than that used in this study. And measuring the importance of fuel efficiency and horsepower in determining tractor prices could not have been readily addressed if a survey approach had been used. Instead, the authors chose to use secondary data, focus on the fuel efficiency and horsepower issues, but use dummy variables to capture preferences for particular brands not measurable with fuel efficiency and horsepower variables.

Persson has stated that farmers frequently make fuel consumption comparisons between different models and sizes of tractors. The fuel efficiency of tractors is generally measured in terms of horsepower hours per gallon, and as a result, tractors of varying sizes can be compared with respect to fuel efficiency (Hunt).

If Persson's argument is correct, then farmers do become quite aware of the relative fuel efficiencies of competing models while making the purchase decision. Moreover, if fuel efficiency does affect demand for a particular manufacturers product, then manufacturers over the past decade should have devoted additional engineering resources aimed specifically at improving the fuel efficiency of farm tractors. It might also be expected that one manufacturer of farm tractors would attempt to distinguish his products from those of a rival firm by advertising the fuel efficiency advances made in the engineering department, in much the same way that EPA mileage numbers have been used as a sales gimmick for automobiles.

Farmers might make fuel consumption comparisons, but other factors may be overriding in the purchase decision. For example, it is widely believed that, for many farmers, loyalty to a particular brand is a key factor. This is often combined with the relative availability of local service, the reputation of the dealer, past experiences with respect to the durability of other equipment of the same brand, and the availability of parts. None of these items is readily quantifiable in a study using aggregate data for all tractors of a particular make and model. Even though fuel prices have risen dramatically over the past decade, they still represent only a fraction of the total cost of owning and operating a contemporary farm tractor.

Another possibility is that increased fuel efficiency in tractors may be more difficult to achieve than was possible in automobiles. Recent improvements in the fuel efficiency of automobiles have occurred primarily through reductions in weight and horsepower. Horsepower reductions that reduce fuel consumption for farm tractors would be self-defeating. Even weight reduction that results in reduced fuel consumption might lead to reduced traction and lessened operating efficiency under marginal field conditions. Engineering improvements such as new carburetion and ignition systems have been responsible for but a small fraction of the improvements in mileage in domestic automobiles. The same might be true for tractors.

A final possibility is that farmers might not be aware of fuel efficiency differences among competing products. Advertisements for farm tractors seldom stress the fuel efficiency of the model, particularly in a manner that lends itself to comparisons with rival brands. This may be by design. The University of Nebraska tractor tests regularly check an array of tractors with respect to horsepower and fuel efficiency. The fuel efficiency numbers are seldom quoted in advertising. Tractor manufacturers seem reluctant to post fuel efficiency numbers on tractors in a manner similar to that now used for automobiles. While most farmers are probably now aware of Nebraska tractor test data, these data have not been as widely distributed as they could be.

Compared with fuel efficiency data, drawbar and power takeoff horsepower data are readily available. Many farmers could quote drawbar horsepower for the tractor they own (perhaps even to two decimal places!). Horsepower numbers are generated by the Nebraska tests, and supplemented by the manufacturer's own data. Manufacturers have often relied on the Nebraska data as the true horsepower of the tractor, and regularly quote that figure in advertising copy. Both the power takeoff horsepower and drawbar horsepower are quoted, and these figures are positively correlated, though not perfectly. Power takeoff horsepower is of primary concern to farmers who own large equipment, such as combines, balers, and windrowers, that are not powered. Drawbar horsepower is probably a better indication of the relative ability of the tractor to pull large plows and other large tillage equipment. Jones notes that it is the ratio of maximum drawbar horsepower to maximum takeoff horsepower that is indicative of the efficiency that technology embodied in the tractor's drive system. A higher ratio corresponds to a more effective transfer of power from the engine to the drawbar.

Thus, a model was specified with the price of the tractor as the dependent variable, and the three variables—fuel efficiency, power takeoff horsepower and the ratio of drawbar to power takeoff horsepower—as explanatory variables. A series of dummy variables was used to control for variation in prices attributable to a brand preference. To a degree, these dummies also capture differences in the quality of service and durability as perceived through farmer preferences based on the above arguments. One would expect the signs on power takeoff and drawbar horsepower to be positive, and the fuel efficiency variable to be positive, or at least non-negative.

STATISTICAL ESTIMATION AND RESULTS

Cross-sectional data in an ordinary least squares framework were used to estimate the implicit price function for tractor characteristics for each of the years 1968 to 1980.[1] Only two-wheel-drive diesel tractors marketed by the seven leading U.S. tractor manufacturers—Allis-Chalmers, J. I. Case, John Deere, Ford, International Harvester, Massey-Ferguson, and White companies—were included in the cross-section used in this study. These firms accounted for 98 percent of the value of domestic wheeled tractor shipments in 1972. Kudrle estimated that their combined share of total domestic sales was 94 percent in 1966. Models were limited to those for which a list price for the year and a Nebraska tractor test report for the model was available. Variations in basic models not affecting basic performance were excluded, as were models with hydrostatic or power shift transmissions.

Nebraska tests a particular model of a tractor only periodically. If a manufacturer continues to produce the same model for several years, the test data for the model when production was begun applies for all years until significant changes in the engine or drive train are made, and the revised model is retested. Since models are retested when significant engineering changes that might affect tractor performance are made, results should not be biased.

The model was estimated with a separate regression equation for cross-sectional (model) data for each year. The statistical model was

$$\ln r_1 = \ln\hat{\gamma}_0 + \hat{\gamma}_1 \ln z_1 + \hat{\gamma}_2 \ln z_2 + \hat{\gamma}_3 \ln z_3 + \sum_{j=2}^{7} \hat{\alpha}_j D_j + \hat{\epsilon}$$

where:

r_1 = the real price of a particular model of agricultural tractor adjusted for variations in standard equipment. It represents the f.o.b. tractor manufacturer's suggested list price reported in the Official Guide to Tractors and Farm Equipment published by the National Farm and Power Equipment Dealers Association.[2]

z_1 = power takeoff performance, defined as maximum power takeoff horsepower (Nebraska Tractor Test Reports),

z_2 = drawbar performance, defined as the ratio of maximum drawbar horsepower to maximum power take-off horsepower (Nebraska Tractor Test Reports),

z_3 = fuel efficiency defined in terms of average horsepower hours per gallon of fuel used (Nebraska Tractor Test Reports),

D_2 = 1 if model is a Case, 0 otherwise,

D_3 = 1 if model is a John Deere, 0 otherwise,

D_4 = 1 if model is a Ford, 0 otherwise,

D_5 = 1 if model is an IH, 0 otherwise,

D_6 = 1 if model is a Massey-Ferguson, 0 otherwise,

D_7 = 1 if model is a White, 0 otherwise,

$\hat{\gamma}_0$ = base intercept associated with the omitted brand (Allis-Chalmers).

Since standard equipment offered on individual tractor models varied across manufacturers, as well as among horsepower groups, list prices were adjusted for variations in standard equipment within horsepower groups (Johnson). A basic model was defined for each of four horsepower classes—under 50 h.p., 50 h.p. to under 100 h.p. to under 150 h.p., and 150 h.p. and over (Johnson).

Basic equipment for tractors under 50 horsepower consisted of lights, single speed power takeoff, 8-speed transmission, power steering, 3-point hitch, and either a differential lock or power-adjusted rear wheels. In the 50–100 h.p. class, tractors were equipped with lights, single-speed power takeoff, power steering, 12-speed transmission, differential lock, power adjusted rear wheels and 3-point hitch. Basic equipment for tractors of 100 to 150 horsepower included lights, dual speed power takeoff, power steering, power brakes, 3-point hitch, 16-speed transmission, differential lock and power adjusted rear wheels. Tractors over 150 horsepower were equipped with lights, dual speed power takeoff, cab, power steering, power brakes, 16-speed transmission, 3-point hitch, differential lock, and power adjusted rear wheels. The list price of a tractor model in a particular year was adjusted if the model was not equipped as described. If a piece of basic equipment was not standard to a model, but was offered as an option by the manufacturer, the price of the option in that year was added to the list price. If a standard model was equipped beyond that of the basic model, the average price charged by other manufacturers for added equipment on a similar size tractor was deducted from the list price.

While this procedure makes it easier to compare prices across competing makes, it does not necessarily ensure that equipment offered by competing makes is equal in engineering design

[1] Over time, some tractor models were discontinued and other models appeared. As a result, it was not possible to combine both model and time series data into an interrelated system of equations. If most or all of the tractor models had existed throughout the time span, a generalized least squares approach, which would take into account the correlation of errors within models over time, might have been appropriate.

[2] Retail list prices may not completely reflect actual transaction prices to farmers. Discounts vary somewhat from one dealer to another, even within the same manufacturer and from year to year, depending on the state of the agricultural economy. However, we do not feel that it would be in one manufacturer's best interest persistently to inflate retail list prices in order to make it appear to farmers that the tractor was getting a larger discount. Farmers would quickly discover such a tactic. To the extent that all retail list prices are at levels slightly above actual transaction prices, the only impact on our model should be a slight increase in the magnitude of the coefficients. Conclusions with respect to the relative importance of explanatory variables should not be altered. An assessment of the extent to which farmers receive discounts when making tractor purchases would have to be conducted from survey data probably gathered for several years. This was outside the focus and scope of this study.

TABLE 1. Estimated Determinants of Farm Tractor Prices, 1968–1980

Year	1968	1969	1970	1971	1972	1973	1974	1975	1976	1977	1978	1979	1980
	(Regression Coefficients[a])												
$\hat{\gamma}_0$	5.858	5.911	5.485	5.531	5.592	5.778	5.877	5.626	5.122	5.531	4.905	4.833	5.635
	(0.332)	(0.231)	(0.283)	(0.212)	(0.232)	(0.311)	(0.365)	(0.405)	(0.413)	(0.445)	(0.342)	(0.321)	(0.399)
$\hat{\gamma}_1$	0.758	0.773	0.836	0.852	0.823	0.786	0.786	0.827	0.851	0.854	0.875	0.880	0.896
	(0.031)	(0.027)	(0.028)	(0.019)	(0.019)	(0.016)	(0.018)	(0.020)	(0.018)	(0.019)	(0.013)	(0.012)	(0.016)
$\hat{\gamma}_2$	0.505	0.697	-0.022	0.029	0.329	0.311	0.306	0.075	0.160	-0.011	0.030	-0.289	0.067
	(0.353)	(0.292)	(0.428)	(0.318)	(0.347)	(0.360)	(0.381)	(0.407)	(0.359)	(0.380)	(0.267)	(0.268)	(0.375)
$\hat{\gamma}_3$	-0.036	-0.074	-0.051	-0.062	-0.075	-0.106	-0.202	-0.122	0.038	-0.135	0.084	-0.087	-0.257
	(0.139)	(0.105)	(0.123)	(0.087)	(0.095)	(0.112)	(0.131)	(0.150)	(0.157)	(0.170)	(0.132)	(0.120)	(0.152)
$\hat{\alpha}_2$	-0.039	-0.008	-0.013	0.013	0.030	0.009	-0.035	-0.049	-0.045	-0.005	-0.001	-0.124	-0.035
	(0.050)	(0.037)	(0.038)	(0.029)	(0.030)	(0.027)	(0.035)	(0.037)	(0.036)	(0.038)	(0.028)	(0.028)	(0.037)
$\hat{\alpha}_3$	-0.086	-0.062	-0.072	-0.068	-0.029	-0.064	-0.054	-0.094	-0.021	-0.009	-0.031	-0.076	-0.009
	(0.050)	(0.037)	(0.036)	(0.025)	(0.029)	(0.028)	(0.034)	(0.032)	(0.034)	(0.036)	(0.024)	(0.024)	(0.032)
$\hat{\alpha}_4$	-0.081	-0.133	-0.083	-0.055	-0.029	-0.063	-0.052	-0.042	-0.011	-0.047	0.010	-0.051	-0.014
	(0.055)	(0.043)	(0.042)	(0.032)	(0.034)	(0.029)	(0.036)	(0.037)	(0.035)	(0.036)	(0.023)	(0.024)	(0.031)
$\hat{\alpha}_5$	-0.083	-0.049	-0.040	-0.030	-0.027	-0.010	-0.026	-0.035	0.036	0.079	0.052	0.042	-0.006
	(0.064)	(0.046)	(0.044)	(0.033)	(0.032)	(0.026)	(0.034)	(0.036)	(0.034)	(0.036)	(0.025)	(0.026)	(0.033)
$\hat{\alpha}_6$	-0.110	-0.097	-0.059	-0.034	0.004	-0.019	-0.048	-0.106	-0.056	-0.010	-0.015	-0.052	0.031
	(0.043)	(0.038)	(0.036)	(0.027)	(0.030)	(0.027)	(0.034)	(0.033)	(0.034)	(0.035)	(0.025)	(0.025)	(0.034)
$\hat{\alpha}_7$	-0.065	-0.068	-0.050	-0.019	0.004	0.035	0.036	-0.072	0.028	0.026	0.028	-0.021	0.053
	(0.047)	(0.037)	(0.056)	(0.027)	(0.034)	(0.030)	(0.034)	(0.033)	(0.037)	(0.037)	(0.026)	(0.027)	(0.035)
R^2	0.965	0.972	0.972	0.982	0.980	0.982	0.981	0.981	0.979	0.976	0.987	0.988	0.982
N	38	44	44	52	57	55	55	56	61	62	70	72	74
F-Statistics	87.08	135.23	135.45	264.61	255.27	284.15	265.57	264.37	267.71	241.61	509.21	592.19	391.97

[a] Figures in parentheses are standard errors.

and performance. Ideally, durability and other data for each equipment item would be needed to make a truly accurate comparison of makes.

These regressions are summarized in Table 1. In all, 186 different tractor models were represented in the various cross sections. The regression coefficients can be interpreted as estimates of the partial flexibility of price with respect to the characteristic content of z_1, z_2, and z_3. They directly indicate the estimated percentage change in price that results from a 1-percent change in the content of a particular characteristic, holding all other characteristics constant.

As is evident in Table 1, the explanatory power of the set of independent variables is quite high. The three performance characteristics account for 96 to 98 percent of the variation in the real adjusted list prices of new agricultural tractors.

The power takeoff performance coefficient ($\hat{\gamma}_1$) was positive in all of the regressions.[3] Between 1968 and 1980, the partial elasticity of price with respect to maximum power takeoff horsepower rose steadily—from 0.253 in 1968 to 0.829 in 1980. Not surprisingly, the power takeoff horsepower of the tractor was found to be the most important determinant of its price in all years.

The coefficient of the ratio of maximum drawbar horsepower to maximum power takeoff horsepower ($\hat{\gamma}_2$) was positive and significantly different from zero in some but not all individual year regressions. If the technology for improving the transmission of power between the engine and the drawbar is costly, it is not being reflected very well in retail prices. Again, farmers may be largely unaware that improvements in the ratio of power takeoff to drawbar horsepower reflect better design in the components of the tractor responsible for the transfer of power from the engine to the drawbar. Manufacturers no douht face a choice when attempting to improve the drawbar horsepower of a tractor in that they can either spend money to upgrade the transmission of power from the existing engine, or to increase the horsepower of the engine, but leave the drive train alone. This may not always be an easy choice. While the first choice might be preferred from the standpoint of improving fuel efficiency, combines, balers and other equipment that is PTO driven has in recent years proven increasingly popular, and for such applications a high PTO horsepower would be designed. Moreover, greater fuel efficiency may be achieved through the application of new materials and technology to the engine as well as the drive train. These arguments provide a clue as to why farmers may not be particularly concerned with the ratio of drawbar to PTO horsepower and why this variable was not always significantly related to tractor prices.

The relative insignificance of the ratio of drawbar horsepower to power takeoff horsepower could also be explained by the lack of variation in this variable within the individual cross-sections. The standard deviation of this drawbar performance variable was only 2 to 3 percent in any given year (Johnson). Farmers may have been largely unaware of the small differences in this variable among the tractors they consider purchasing in a particular year.

The fuel efficiency variable did not have a

[3] The true value of the coefficient on the power takeoff performance is given by $\gamma_1 - \gamma_2$ because the variable Z_1 is also included in Z_2, the drawbar performance variable, which is defined as the ratio of the maximum drawbar horsepower to maximum power takeoff horsepower.

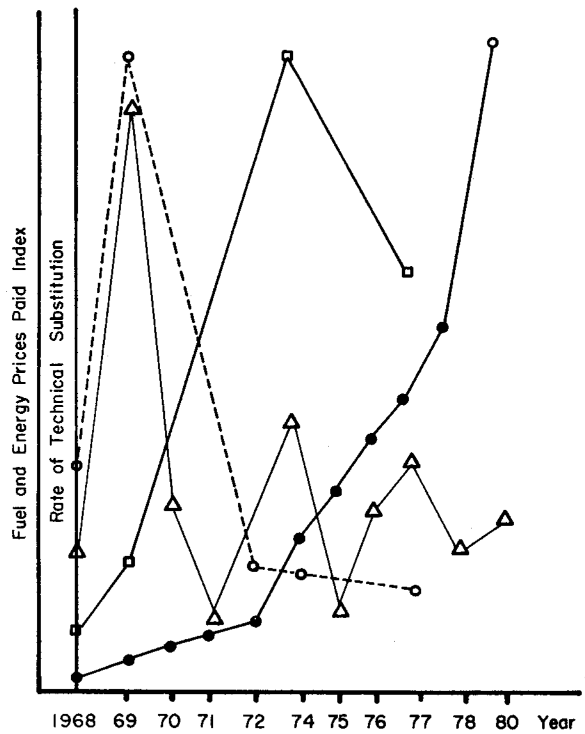
coefficient twice its standard error for any year, and for several years the coefficient was negative, not positive. This suggests that fuel efficiency is not currently being reflected in the retail prices for farm tractors. This would provide empirical support for earlier arguments that proposed that farmers either are not aware of differences in fuel efficiency among competing makes of tractors, or these differences are not important to farmers relative to their total costs of tractor ownership. Tractor manufacturers have clearly not felt a competitive need to promote the fuel consumption figures for their fuel efficient models. Johnson estimated equations similar to those presented here that included the weight of the tractor as an additional explanatory variable, but, even for these equations, it was not possible to obtain an estimated coefficient on the fuel efficiency variable that was both positive and significant. Clearly the relationship between prices, performance, and fuel efficiency is much more complicated for tractors than for automobiles. The maximum correlation coefficient between z_1 and z_2 was 0.20 in 1975, the maximum correlation coefficient between z_2 and z_3 was 0.38 in 1970, and the maximum correlation coefficient between z_1 and z_3 was 0.32 in 1970 (Johnson). The estimates of the partial flexibilities of price with respect to z_2 and z_3 were erratic, and no discernible trend in either of these coefficients was evident over the period of this study.

Estimates of the rates of technical substitution and the rates of product transformation among characteristics were derived for those estimates that were significant at the .10 level or greater. Figure 1 illustrates calculated rates of technical substitution and/or product transformation, plotted against the price of fuel and energy inputs over time. No discernible trend is evident in the rates of substitution over time, and, furthermore, no relationship exists between increasing fuel and energy prices and the substitution of tractor performance characteristics and tractor fuel efficiency.

As indicated earlier, fuel consumption efficiency information is not readily available to farmers. Nebraska law prohibits manufacturers from using Nebraska Tractor Test excerpts for advertising or promotional purposes without publishing the entire report (Johnson). According to Hunt, fuel costs represent 13 percent of total tractor costs, and in 1980 diesel tractors varying from 50 h.p. to 160 h.p. had differences in fuel consumption costs that affected total tractor operating costs by only 2 to 3 percent (Johnson). Between 1968 to 1978, the overall increase in fuel costs was slightly less than that of all productive inputs. Only in 1979 and 1980 did the price paid by the farmer for energy jump sharply relative to other production expenses (Johnson).

Coefficients on dummy variables representing various makes of tractors appeared to be different from zero in some, but not all, years and for some, but not all, competing models. Most of the dummy coefficients had negative signs, suggesting that prices for tractors associated with the omitted category (Allis-Chalmers) were highest for a given level of horsepower and fuel efficiency. There appeared to be no consistent pattern among the coefficients to suggest that any of the remaining makes were able to price their models consistently above the general price level for tractors in that size and horsepower range. This would support the argument that the reputation that a given model has with respect to durability or service is either not generally recognized or tends to be localized with respect to a particular dealer's service area, and is not measurable based on the data used for deriving the regression estimates. Another possibility is that the service and durability of a particular model is not reflected in retail prices, and that successful makes merely sell more tractors. Yet another possibility is that there are no real differences in service and durability across competing makes and, as a result, retail prices tend to be very similar.

FIGURE 1. Trends in the Substitution of Performance Characteristics



○ Power takeoff for drawbar performance
Δ Drawbar performance for fuel efficiency
□ Power takeoff for fuel efficiency
● Index of Prices Paid for Fuel and Energy (1967 = 100).

CONCLUSIONS

The empirical results suggest that, of the performance variables examined in this study, only power takeoff horsepower is reflected in the adjusted list prices of new agricultural tractors between 1968 and 1980. This variable alone accounted for 95 to 98 percent of the variation in the adjusted list prices of tractors. In addition, there was little evidence to suggest that prices were related to either the ratio of drawbar horsepower to power takeoff horsepower fuel efficiency.

The findings of this study are consistent with those of Fettig and of Rayner. Both authors found that maximum belt horsepower explained a large proportion of the variation in new tractor prices and used this in constructing quality-converted price indices. However, the results of our study are contingent upon the assumption that manufacturer's list prices accurately reflect the transaction prices of new tractors and the lack of cross-sectional variance in the drawbar performance variable. Furthermore, the lack of readily available fuel consumption information on tractors, the relatively small variance in total tractor cost owing to fuel prices, and the fuel allocation policies of the federal government have resulted in an apparent lack of awareness among farmers regarding the fuel consumption characteristics of the tractors that they purchase.

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