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DEMAND FOR FARM TRACTOR HORSEPOWER IN THE U.S.

by

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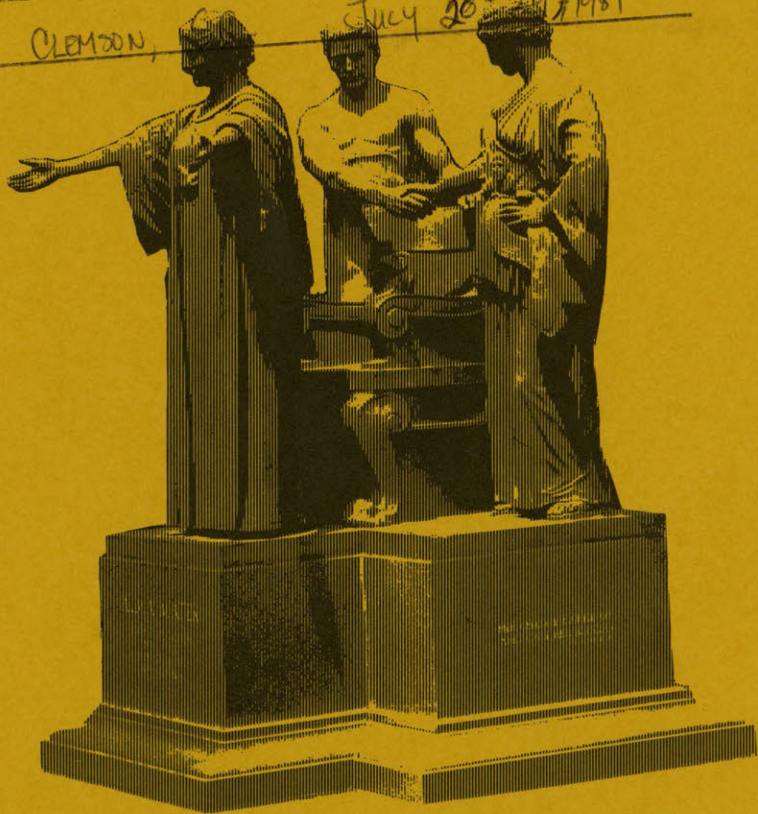

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DEMAND FOR FARM TRACTOR HORSEPOWER IN THE U.S.

The substantial growth of U.S. agricultural output in the past 75 years can be partly attributed to the development and use of farm tractors. This labor saving technology expanded farmers horsepower resources which led to more extensive production and added timeliness to planting and harvesting operations. The long-term uptrend in tractor horsepower on farms has been sustained, but its composition has undergone considerable change. The pivotal years were the mid-1960's. Prior to then, tractor numbers were increasing and horsepower per tractor was only modestly moving up. In 1920, the average size of tractors sold developed about 20 horsepower; by 1950 it was only 30 horsepower. Since the mid-1960's tractors on farms have declined but were offset by substantial increases in the power of individual units. In 1980, the average size of tractor sold will develop close to 110 horsepower.

Previous studies (Cromarty, Griliches, Heady and Tweeten, Fox, Rayner and Cowling) estimated the aggregate demand for farm tractors, but the most recent time series ended in the early 1960's, the pivotal years when horsepower composition started changing. In addition, U.S. agriculture itself underwent significant changes in the 1970's, primarily led by increased exports. Most of the studies measured demand in units (Cromarty) or dollars (Griliches, Rayner and Cowling, Heady and Tweeten). The exceptions were Fox and versions of Rayner and Cowling who used horsepower. A more recent study (Hughes and Penson) goes to 1976 with demand measured in dollars. The purpose of this study was to develop and estimate demand models for U.S. tractor horsepower purchases which occurred during the 1950-78 time period.

The Model

Briefly summarized, input demand is derived from the demand for the output produced, the production function, the price of the input, and the availability of other inputs in the production process. A profit maximiztion function is formed as the difference between gross revenue and production costs. Solution of the first order conditions gives the demand for the input as a function of the price of the input, the price of other inputs, price of products, and other variables affecting use of the input in the production process. Griliches and Fox point out that the input of tractor services into the production process comes from the stock of tractors on farms rather than the flow of annual tractor purchases. Griliches, Rayner and Cowling, and Hughes and Penson go one step further and distinguish between the "desired" and "actual" stock of tractors. They add an adjustment process which hypothesizes the temporal changes between desired and actual stock. The flow demand for tractors, that is tractor purchases, are important since they affect the stock of tractors on farms.

While the flow and stock demand models have similar independent variables, the dependent variable Y is measured differently. This study estimates a flow demand model with units measured in farm tractor horsepower purchases. All models were linear regressions estimated with ordinary least squares. Variables were measured in natural and logrithmic numbers with various combinations used in developing the models.

Data

Estimating tractor demand from long time series data, as done in previous studies, encounters special problems. Two major ones are the occurrence the Great Depression in the 1930's and World War II in the 1940's. Both were periods of curtailed tractor production followed by several years of artificially high demand. During recent decades substantial quality changes have occurred and tractors have become more heterogeneous. A 1980 model of a large two-wheel drive tractor can provide the same amount of services as four or five new tractors in 1950. The changes in quality and the more heterogenous tractors cause problems when specifying the dependent variable over the 1950-78 time period. By using tractor numbers as a dependent variable, some of the quality changes are lost. In an earlier study, Fettig had made tractor price adjustments to account for quality changes over time. Fox used tractor horsepower for the dependent variable to capture quality changes, and this study follows his approach.

The dependent variable for the flow models was new farm tractor horsepower purchases (Implement and Tractor) where monthly retail tractor sales, by horsepower categories, were reported by all dealers to the Farm and Industrial Equipment Institute. Data for the independent variables were from USDA, Agricultural Statistics.

Results

The variables tested in the initial models were based on those used in previous studies. However, many of the significant variables in previous studies offered little explanatory power when using data for the 1950-78 time period. The initial model started with a large number of independent variables but when not significant, were eliminated or transformed in further models. New variables were added or experimented with to improve the model.

The first model estimated (Table 1) was:

1) HPP = f(PT, PR, FE, FIL1, HPFL1, NF, AHP, IR)

where HPP are annual horsepower purchases for new farm tractors (100,000 horsepower); PT is an index of tractor prices (1967 = 100); PR is an index of prices received for crops (1967 = 100); FE is farm employment (1,000's); FIL1 is cash receipts from crops and livestock lagged one year (deflated in 1967 dollars); HPFL1 is horsepower on farms lagged one year (million horsepower); NF is number of farms (10,000's); AHP is average size of new tractor purchases (horsepower); and IR is interest rate (percent). The intercept is measured in 100,000 horsepower. The high R^2 of 0.92 partly reflects the large number of variables with

Table 1. Demand Models for Farm Tractor Horsepower Purchases in the U.S., 1950-78.

Model	Inter-cept	HPFL1	FE	PR	PT	AC	SPC	IR	FIL1	NF	AHP	D-W	R^2	$\bar{R}^2$
1	439.39*	-1.70**	-0.02**	0.87**	-0.29			-4.07	-8.39	-0.18	1.45	3.02	0.92	0.89
	(1.75)	(-2.11)	(-2.40)	(4.17)	(-1.25)			(-0.97)	(-0.11)	(-0.33)	(1.19)			
2	236.80*	-0.83**	-0.25**	0.79**	-0.26*	0.31						2.37	0.91	0.89
	(1.84)	(-2.01)	(-3.67)	(6.61)	(1.97)	(1.55)								
3	145.82	-0.74**	-0.02**	0.79**	-0.29**	0.42**	0.07**					2.97	0.95	0.94
	(1.38)	(-2.25)	(-3.66)	(8.28)	(-2.69)	(2.58)	(3.67)							
4	24.36	-0.69**	-0.01**	0.35	-0.01	0.47**	0.09**		0.12*			2.88	0.96	0.94
	(0.21)	(-2.22)	(-2.34)	(1.42)	(-0.07)	(3.00)	(4.34)		(1.92)					
5	221.56**	-0.90**	-0.03**	0.92**	-0.33**	0.39**	0.07**	-2.36*				3.13	0.95	0.94
	(2.00)	(-2.74)	(-4.14)	(7.85)	(-3.12)	(2.42)	(3.57)	(-1.69)						
6	13.01**	-1.06**	-1.20**	0.87**	-0.42**	0.86	0.06**					2.01	0.92	0.90
	(2.61)	(-2.45)	(-5.29)	(5.98)	(-2.16)	(1.65)	(4.19)							
ln	ln	ln	ln	ln	ln	ln	ln							

Note: t values are in parenthesis; * indicates significance at the 90% level, and ** at the 95% level.

only three being significant.

The number of farms NF was not significant in contrast to the Fox study, who also estimated horsepower demand, and was dropped from subsequent models. Average horsepower purchases AHP was included to reflect the trend toward larger, more efficient machines, also done in the Fox study. Since it was not significant, it was dropped from further models.

Interest rates IR were Production Credit Association (PCA) non-real estate loan rates. They were not significant and this was attributed to lack of variation in the data. The PCA rates ranged from 6.1 percent in 1950 to 9.3 percent in 1974. They have been historically stable and apparently do not reflect the true fluctuation in the cost of capital. Interest rates were eliminated from the model, but reintroduced in later models in the form of commercial paper rates.

The stock variable, tractor horsepower on farms lagged one year HPFL1, was significant suggesting farmers adjust the size of stock to provide the necessary services. The coefficient was negative indicating horsepower purchases will increase if previous year's horsepower on farms is lower than desired. As the stock increases, farmers will respond by purchasing less horsepower. In comparing this study with previous ones, the coefficient can be positive or negative depending on how the variable is measured and on the influence of other independent variables.

Farm employment FE was significant and had a negative coefficient. This was consistent with economic theory with tractor horsepower being substituted for farm labor during a period when both the farm population and labor force were decreasing.

The tractor price index was not significant and this may have resulted from the influence of other nonsignificant variables. When it was reintroduced in later models, it became significant. In considering the dependent variable, a better price measure would have been an index of tractor horsepower prices. However, such a series could not be found, and constructing such a variable causes problems when adjusting for quality and size changes, as well as optional equipment.

Farm income FIL1 was not significant. Several measures of the variable were tested including gross and net farm income, income from farm and non-farm sources, income with and without government payments, and income in the current or previous year. Both actual and deflated (1967) dollars were tried. Since total cash receipts from crops and livestock implicitly include crop prices, the income variable was excluded from subsequent models, and the prices received index PR used was highly significant in all models where included.

One variable which none of the previous studies included was total acres planted AC (million acres). It reflects the year-to-year changes in tractor work requirements.

Government programs have had a considerable impact on acres planted, particularly during the period of study when land diversion programs were used to limit crop production. Acres planted was added to Model 2 and was not significant, but the tractor price index became significant.

Another variable expected to affect tractor sales was self-propelled combines SPC (100's of units), which came into widespread use in the early 1950's. It was hypothesized that a harvesting machine with its own power source would cause a decline in the demand for tractor horsepower. When SPC was added in Model 3, the coefficient was significant and had a small positive sign. This was opposite of what was expected. One possible explanation is related to the introduction of larger tractors. Due to engineering limitations most pull-type combines are small, and designed to be pulled by small horsepower tractors. It is not economical to use the large horsepower tractors prevalent today to pull combines. Also, tractors and combines have become compliments due to changing farming methods. Fall plowing has become more frequent, and trash is plowed under immediately after harvest. It is common to see a combine and tractor working in the same field. Another factor influencing concurrent tractor and combine sales, though probably minor, is dealer discounts. A farmer purchasing a tractor may be offered a considerable cash discount as an incentive to also purchase a combine.

After adding self-propelled combines SPC in Model 3 all coefficients became significant at the 95 percent level, including acres planted AC and the index of tractor prices PT. All signs were consistent with economic theory; the $\bar{R}^2$ of 0.94 was the highest for all five models estimated; the coefficient of variation was 5.76 percent: and the Durbin-Watson statistic showed no autocorrelation.

Variations of Model 3

Model 3 was considered to have good explanatory power and be sound when applying both economic and statistical criteria. Variations of Model 3 were tried to improve the fit and three relevant ones are documented here.

Model 4 added a farm income variable measured as cash receipts from crops and livestock lagged one time period in constant 1967 dollars FIL1. The coefficient was significant at the 90 percent level but indexes of prices received PR and tractor prices PT became nonsignificant.

Model 5 introduced interest rates IR in the form of commercial paper rates. The coefficient was significant at the 90 percent confidence level; all other coefficients were at the 95 percent level; and $\bar{R}^2$ was 0.94. While R^2 measures goodness of fit, it does not necessarily indicate if the model will track changes in direction or extreme movements of horsepower purchases HPP. Figure 1 shows the computed values closely track the observed values, and they exhibit the appropriate changes in direction for 26 out of the 28 years. The extreme movements in observed values were also closely tracked, especially in 1973. Model 5 is

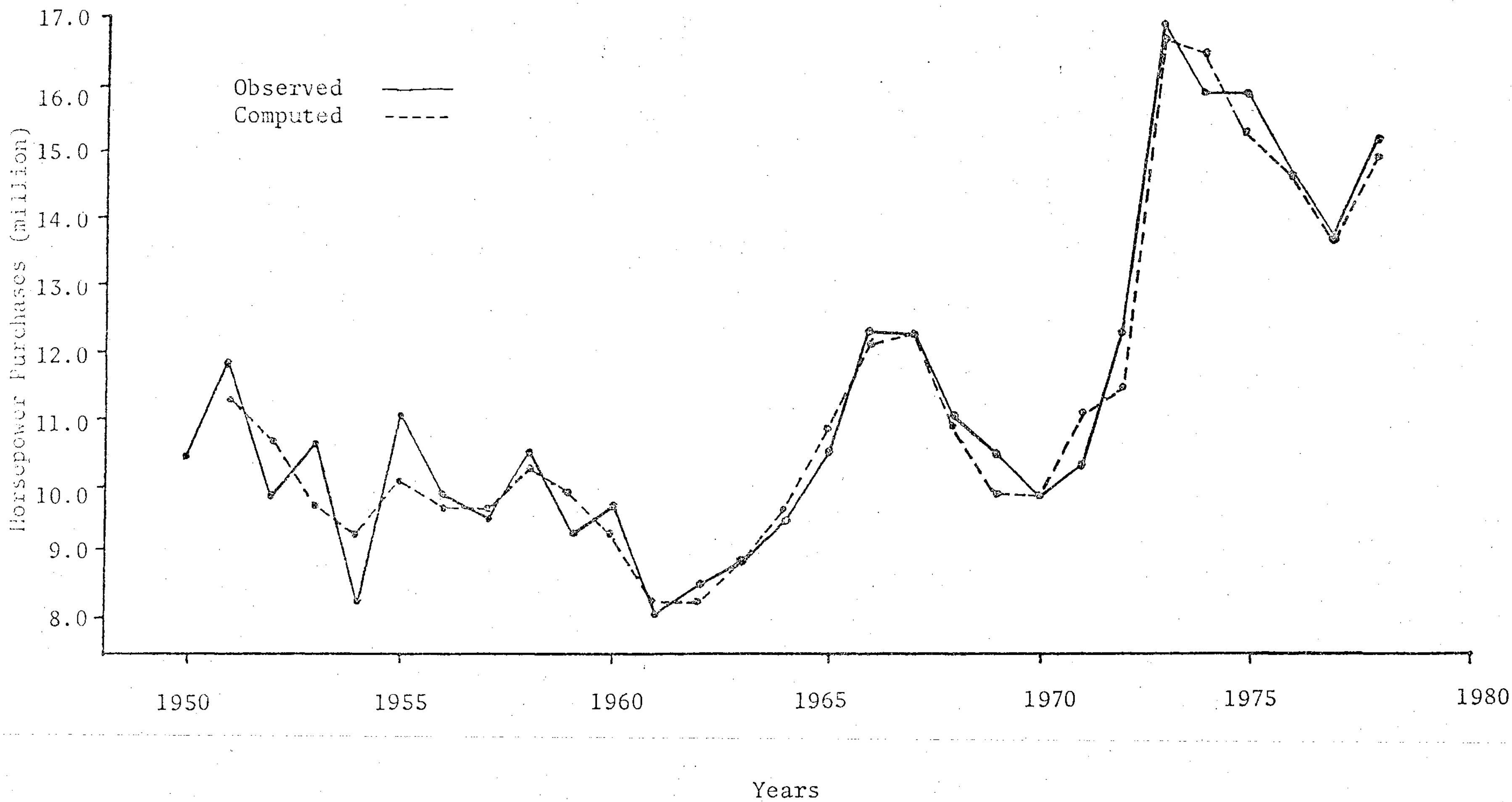

Figure 1. Observed and Computed Values of Farm Tractor Horsepower Purchases in the U.S., 1950-78.

considered to be the best model for explaining and predicting horsepower purchases, and it is consistent with economic and statistical criteria.

Measurement of the variables in natural logarithms was tried since the specification of the production function could result in a model linear in logarithms. All variables in Model 6 were measured in natural logs. All coefficients, except acres, were significant at the 95 percent level. $\bar{R}^2$ drops to 0.90. The coefficients are direct measures of elasticity. For example, the elasticity of horsepower purchases HPP with respect to the tractor price index PT is -0.42, and for prices received PR it is 0.87.

Summary and Conclusions

Over the past 75 years the increase in U.S. agricultural output can be partly attributed to the increasing horsepower on farms provided by tractors. Since the mid-1960's there has been a shift in the composition of tractor horsepower purchases. There are fewer numbers and more horsepower per tractor which has sustained the long term uptrend of horsepower on farms. Most of the previous studies preceeded these pivotal years and measured tractor purchases, or stock on farms, in either numbers or dollars. While they were an adequate measure during their periods of study, horsepower purchases provided a better measure of the services being bought, and captured some of the quality changes that occurred during the 1950-78 period.

This study found a number of signficant variables that explained horsepower purchases. Some were similar to those found in previous studies, particularly the indexes of tractor prices, prices received, the stock of tractor horsepower on farms in the previous year, and interest rates. One significant variable in this study was farm employment, which indicated the substitution of tractor horsepower for labor during a period of substantial decline in farm labor. Another variable was self-propelled combines which were introduced in the late 1950's, and were found to be complimentary implements to horsepower purchases. A third variable was acres planted whose fluctuation was influenced by government programs during the period of study.

Two models for tractor horsepower purchases, one in natural numbers and one in logs, were consistent with economic theory, met statistical criteria for goodness of fit, and closely tracked observed values over the 1951-78 time period.

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