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THE DEMAND FOR FARM TRACTORS IN THE UNITED STATES

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ABSTRACT

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in the United States

Several shortcomings are noted in previous studies of the aggregate demand for farm tractors, including the measurement of the cost of capital and capacity depreciation. Empirical results presented in this study show that net investment regressions based upon the USDA's capital series are inferior to those based upon engineering data.

THE DEMAND FOR FARM TRACTORS IN THE UNITED STATES

The investment behavior of U.S. farm operators as it relates to purchases of farm tractors has been investigated in previous studies by Cromarty, Griliches and Heady and Tweeten. Recognizing a long neglected area of research, these studies sought to identify those factors which explain annual capital expenditures for this major production input.

Several questionable assumptions are revealed by a review of these studies, however, that have a direct bearing on the specification, measurement and estimation of their statistical models. For example, one or more assumptions as to the manner in which the productive capacity of farm tractors depreciates over their service life were made. The level of replacement investment and the size of the existing capital stock suggested by these assumed capacity depreciation patterns differ substantially from those suggested by engineering data considerations (Penson, Hughes and Nelson). Further, the measurement of the cost of capital in these studies ignores such seemingly important factors as the rate of investment tax credit and the income tax rate, thus departing from the frequently used definition of the implicit rental price of capital found in nonfarm investment studies. Finally, each study implicitly assumes that the desired stock of farm tractors is determined independently from the desired stocks of all other production inputs. Yet, the demand equation for farm tractors can be shown to be one of a system of simultaneous equations which describe the demand for fixed and variable production inputs deduced from the production function.

The purpose of this study is to conceptualize and test an aggregative behavioral model for investment in farm tractors by farm operators. This study initially incorporates a more universally accepted definition of the

implicit rental price of farm tractors which explicitly accounts for the affects of changes in selected tax laws. This study then compares the regression results found using the declining balance depreciation pattern examined by Griliches and Heady and Tweeten based upon time series data published by the U.S. Department of Agriculture with regression results found when using the capacity depreciation pattern based upon engineering data reported recently by Penson, Hughes and Nelson. Finally, the implications of these results for further research are discussed.

Investment Behavioral Model

The behavioral model investigated in this study is initially developed along the lines of the theory of the firm in continuous equilibrium in a certainty environment. As such, the model explicitly accounts for the simultaneity between the aggregate production function and fixed factor demand. Then, recognizing that conditions of uncertainty and lags in investment response do exist, the model is modified to include the partial adjustment and adaptive expectations hypotheses.

Desired stock of farm tractors

Under conditions of perfect competition, including perfect knowledge, Coen suggests that firms will continue to add to their fixed capital stock as long as the present value of the marginal value product exceeds its original acquisition cost, or

$$(1) \quad \sum_{t=1}^{\infty} [PR(\partial X/\partial K) - PP_K(\partial D_t/\partial K)](1+r)^{-t} > PP_K$$

where Penson, Hughes and Nelson define capacity depreciation, D_t , as

$$(2) \quad D_t = \sum_{j=0}^{\infty} h_j I_{t-j}$$

and where PR represents actual prices received for farm products, PP_K represents actual prices paid for fixed producer capital, X represent real farm output, K represents the existing capital stock, r represents the actual rate of interest, h_j represents the fraction of the original productive capacity of fixed capital lost due to physical deterioration in the jth year after its original acquisition, and I_t represents deflated capital expenditures for plant and equipment. Maximization of farm operator net worth under conditions of perfect knowledge therefore requires that

$$(3) \quad (\partial X / \partial K) = (PP_K r (1 + \sum_{t=1}^{\infty} (\partial D_t / \partial K) (1+r)^{-t})) / PR = C_K / PR$$

where C_K represents a preliminary measure of the actual implicit rental price of capital. While equation (3) encompasses the entire stock of fixed plant and equipment, the argument presented is equally applicable for each individual category of depreciable fixed capital used to produce farm output.

If we assume that farm tractors are used principally in crop production activities and that crop output is produced according to the Cobb-Douglas production function

$$(4) \quad X_C = AL^\alpha K_T^\beta K_O^\xi$$

where L represents the labor input, K_T represents farm tractors and K_O represents all other categories of farm capital items used to produce crop output, then the marginal product expression for farm tractors is given by

$$(5) \quad (\partial X_C / \partial K_T) = \beta (X_C / K_T)$$

where α , β and ξ are the partial production elasticities associated with L, K_T and K_O , respectively.^{1/} By substituting equation (5) into equation (3), we can solve for the optimal or desired stock of farm tractors in long run equilibrium. Doing this and expressing the result in functional form, the desired

year-end stock of tractors measured in efficiency units ($K_{\tau_{t+1}}^*$) is given by

$$(6) \quad K_{\tau_{t+1}}^* = a_0 + a_1 \beta [(PRC \ Xc)/C_{\tau}]_t^*$$

Thus, equation (6) suggests that the desired year-end stock of farm tractors will be positively affected by expected increases in prices received for crops (PRC_t^*) and/or expected crop output (Xc_t^*) while being negatively affected by expected increases in the implicit rental price of tractors ($C_{\tau_t}^*$).

The specification of the implicit rental price of farm capital suggested by equation (3) can now be broadened to include the effects of the income tax and investment credit tax rates. In the case of farm tractors, this rental price is instead given by

$$(7) \quad C_{\tau_t} = \left[\frac{[(PP_{\tau} \ r)]}{1 - \sum_{j=1}^{\infty} h_j (1+r)^{-j}} \right] \left[\frac{(1-T_c - T_{\pi}(1-\delta T_c)B_{\tau})}{1-T_{\pi}} \right]_t$$

where T_c represents the investment credit tax rate, T_{π} represents the income tax rate, PP_{τ} represents the purchase price of farm tractors, δ represents the portion of investment credit which is deducted from the depreciable base of the farm tractor and B_{τ} represents the present value of the stream of tax depreciation stemming from one dollar of current investment in tractors.^{2/} Thus, the implicit rental price of farm tractors as given by equation (7) will increase if the purchase price of tractors, the cost of loan funds, the rate of capacity depreciation or the income tax rate increases. These effects, however, can be offset to a degree by a simultaneous increase in the investment credit tax rate.

Net investment in farm tractors

Annual capital expenditure flows can be partitioned into replacement and net investment. Replacement investment refers to those expenditures required to restore losses in the productive capacity of existing capital while net

investment refers to those expenditures which expand the existing productive capital stock. Stated another way, net investment in tractors is given by

$$(8) \quad N_{\tau_t} = K_{\tau_{t+1}} - K_{\tau_t} = I_{\tau_t} - D_{\tau_t}$$

which simply states that real net investment in farm tractors is equal to the net change in the stock of farm tractors measured in efficiency units between successive accounting dates. The relationship between the desired year-end stock of farm tractors and current net investment is then given by

$$(9) \quad N_{\tau_t} = \theta_{\tau}(K_{\tau_{t+1}}^* - K_{\tau_t}) \quad 0 < \theta_{\tau} \leq 1$$

where θ_{τ} represents the adjustment coefficient which describes the speed of adjustment of actual stocks to desired levels. Substituting equation (6) into equation (9), we see that

$$(10) \quad N_{\tau_t} = \theta_{\tau}a_0 + \theta_{\tau}a_1 \beta[(PRc Xc)/C_{\tau}]_t^* - \theta_{\tau}K_{\tau_t}$$

which suggests the following estimating equation

$$(11) \quad N_{\tau_t} = B_0 + B_1 [(PRc Xc)/C_{\tau}]_t^* + B_2 K_{\tau_t} + \mu_t .$$

With regards to the expectational variable in equation (11), little is known about how producers form their expectations for future prices and yields. Because of this, we must choose from several expectations hypotheses identified in the literature. For the immediate purposes of this study, the commonly-used adaptive expectations hypothesis, which assumes that the weights producers place upon past outcomes decline at a geometric rate, was selected. Thus,

$$(12) \quad [(PRc Xc)/C_{\tau}]_t^* = (1-\lambda)[[(PRc Xc)/C_{\tau}]_t + \lambda[(PRc Xc)/C_{\tau}]_{t-1} \\ + \lambda^2[(PRc Xc)/C_{\tau}]_{t-2} + \dots] \quad 0 \leq \lambda < 1 .$$

Substituting equation (12) into equation (11) and applying a koyck transfor-

mation, we see that

$$(13) \quad N_{\tau_t} - \lambda N_{\tau_{t-1}} = B_0(1-\lambda) + B_1(1-\lambda)[(PRc \ Xc)/C_{\tau}]_t + B_2 K_{\tau_t} - \lambda B_2 K_{\tau_{t-1}}$$

if we ignore the properties of the disturbance term for the moment. Solving for N_{τ_t} , however, we find that any attempt to estimate the above equation would suffer from perfect multicollinearity since $K_{\tau_{t-1}} \equiv K_{\tau_t} - N_{\tau_{t-1}}$. Yet, by substituting this identity into equation (13) after having initially solved for N_{τ_t} , we can show that

$$(14) \quad N_{\tau_t} = B_0(1-\lambda) + B_1(1-\lambda)[(PRc \ Xc)/C_{\tau}]_t + B_2(1-\lambda)K_{\tau_t} + \lambda(1+B_2)N_{\tau_{t-1}}$$

which suggests the following estimating equation

$$(15) \quad N_{\tau_t} = b_0 + b_1[(PRc \ Xc)/C_{\tau}]_t + b_2 K_{\tau_t} + b_3 N_{\tau_{t-1}} + v_t$$

where v_t represents the modified disturbance term. In summary, we hypothesize that the b_1 and b_3 coefficients will have a positive sign while the b_2 coefficient will have a negative sign based upon the above behavioral model.

Statistical and Measurement Procedures

Net investment in farm tractors was hypothesized in the previous section to be positively influenced by an increase in the value of crop output and negatively influenced by the implicit rental price of tractors and the size of the existing capital stock. Because of the current nature of the endogenous variable $[(PRc \ Xc)/C_{\tau}]_t$, a simultaneous equations estimator must be used to estimate the b_i coefficients in equation (15). In addition, the time series values for N_{τ_t} , $N_{\tau_{t-1}}$, K_{τ_t} and C_{τ_t} will differ according to the alternative capacity depreciation pattern under investigation. The remainder of this section discusses our choice of estimator, presents the statistical model to be estimated and identifies the sources of data used in this study.

Equation (15) can be viewed as a part of a relatively large system of simultaneous equations which includes not only the production input demand equations and production function but the demand for financial assets and loan funds as well (Penson). Because of this, the endogenous variable $[(PRc Xc)/C\tau]_t$ must be expressed as a function of all the current exogenous and lagged endogenous variables in the larger model. Yet, since the sample period is limited to the post-WW II period, we encounter the statistical problem of having more predetermined variables than observations in the first stage of the frequently used two stage-least squares estimator. Because of this, we choose instead to use the two stage-principal components estimator originally proposed by Kloeck and Mennes. This estimator allows the researcher to instead include a selected number of principal components in the first stage where the minimum number selected is that which satisfies identification requirements. The first four principal components, which both satisfy identification requirements and account for 95 percent of the variation in the exogenous variables, were selected.

Two alternative capacity depreciation patterns are examined in this study: (1) the geometric decay (GD) pattern used by the U.S. Department of Agriculture in their calculations of that "estimated outlay which would be required if farmers were to replace the plant and equipment used up during the year" (USDA 1969, p.10), and (2) the engineering data (ED) pattern reported by Penson, Hughes and Nelson. The GD pattern implies that the largest loss in the productive capacity of a farm tractor is realized in its first full year of use, declining geometrically thereafter. The ED pattern, on the other hand, is concave rather than convex to the origin and suggests that the largest losses in productive capacity due to physical

deterioration in the latter stages of the tractor's service life. To account for the effects of these alternative capacity depreciation patterns, the estimating equations must instead take the form

$$(16) \quad N_{\tau kt} = b_{k0} + b_{k1}[(\hat{P}Rc \hat{X}c)/\hat{C}_{\tau k}]_t + b_{k2}K_{\tau kt} + b_{k3}N_{\tau kt-1} + \omega_{kt}$$

where

$$(17) \quad [(\hat{P}Rc \hat{X}c)/\hat{C}_{\tau k}]_t = b_{k0} + \sum_{j=1}^4 b_{kj}PC_{jt} + \eta_{kt}$$

and where $k = GD, ED$ and PC_j represents the j th principal component. Thus, the statistical model advanced in this study requires a recursive estimation of two sets of equations.^{3/}

Empirical Results

Equations (18) through (22) below provide the empirical results found when estimating both stages of the statistical model suggested above.

$$(18) \quad [(\hat{P}Rc \hat{X}c)/\hat{C}_{\tau GD}]_t = \begin{matrix} 265.63 & + & 69.16 & PC_{1t} & + & 71.13 & PC_{2t} & - & 2.75 & PC_{3t} \\ (11.68) & & (10.89) & & & (12.88) & & & (13.15) \end{matrix} \\ - \begin{matrix} 35.77 & PC_{4t} \\ (13.22) \end{matrix} \quad R^2 = .82$$

$$(19) \quad [(\hat{P}Rc \hat{X}c)/\hat{C}_{\tau ED}]_t = \begin{matrix} 743.53 & + & 280.40 & PC_{1t} & + & 307.27 & PC_{2t} & - & 60.06 & PC_{3t} \\ (57.39) & & (53.53) & & & (63.28) & & & (64.59) \end{matrix} \\ - \begin{matrix} 206.11 & PC_{4t} \\ (64.94) \end{matrix} \quad R^2 = .79$$

$$(20) \quad N_{\tau GDt} = \begin{matrix} 0.018 & + & 0.0005 & [(\hat{P}Rc \hat{X}c)/\hat{C}_{\tau GD}]_t & + & 0.0032 & K_{\tau GDt} \\ (0.353) & & (0.0005) & & & (0.0611) \end{matrix} \\ + \begin{matrix} 0.565 & N_{\tau GDt-1} \\ (0.174) \end{matrix} \quad SSE = 0.47 \quad R^2 = .71$$

$$(21) \quad N_{\tau EDt} = \begin{matrix} 1.256 & + & 0.00016 & [(\hat{P}Rc \hat{X}c)/\hat{C}_{\tau ED}]_t & - & 0.1029 & K_{\tau EDt} \\ (0.972) & & (0.00015) & & & (0.0808) \end{matrix} \\ + \begin{matrix} 0.626 & N_{\tau EDt-1} \\ (0.182) \end{matrix} \quad SSE = 0.68 \quad R^2 = .81$$

where the numbers in parentheses represent the standard errors associated with the coefficient estimates.

The relative performance of equations (20) and (21) can be evaluated on either positive or normative grounds. If we employ a positivistic approach in this study, however, we are confronted with several difficulties. For example, while the descriptions of the dependent variables are similar, they represent two entirely different time series. In addition, most, if not all, of the frequently used statistical inference tests are not valid when evaluating estimates provided by a two stage estimator. Friedman provides a solution to our dilemma, however, when he asserts that the "best" model is the one that forecasts most accurately. This suggests that we can assess the relative performance of the net investment models based upon the GD and ED capacity depreciation patterns by taking the following steps: (1) remove the most recent observation from the sample and re-estimate the statistical model, and (2) use these re-estimated equations to forecast annual net investment in farm tractors for the following year. Since 1974 represents the latest year for which complete data were available, the re-estimated GD and ED net investment models were used to forecast 1974 outcomes. Doing this, we found that the GD model forecast net investment in farm tractors of \$0.57 billion while actual net investment according to the GD capacity depreciation pattern was only \$0.22 billion. Thus, the GD model incurred a 159 percent forecast error one year beyond the sample period used to estimate the statistical model. The ED net investment model, on the other hand, forecast net investment in farm tractors of \$0.62 billion as compared to actual net investment given by the ED capacity depreciation pattern of \$0.46 billion, a 35 percent forecast error. Thus,

while both models over-estimated actual net investment measured by these alternative capacity depreciation patterns, the error associated with the ED net investment model was substantially less in both absolute and percentage terms. A normative comparison of equations (20) and (21) can also be made by seeing whether or not the signs hypothesized earlier for the b_i coefficients were confirmed by our empirical results. Again the ED net investment model shows its superiority. While equation (21) reports the signs hypothesized in our behavioral model, equation (20) reports a positive sign on the coefficient corresponding to the lagged capital stock which is in direct conflict with the partial adjustment hypothesis. A positive value for this coefficient would suggest that the adjustment coefficient is negative, thereby implying an unstable model.^{4/}

Implications for Further Research

While the geometric decay capacity depreciation pattern was assumed in previous demand for tractor studies by Griliches and Heady and Tweeten, Griliches clearly questioned its relevancy, suggesting that "we need to know the 'right' measure in practice and how much difference it actually makes" (p.205). The results presented in this study lend support to Coen's conclusion for the manufacturing sector that this wearout pattern does not appear to underlie actual capital spending decisions. Further research is also needed for other types of producer capital such as farm buildings. Coen concluded that "structures in the majority of the industries suffer no loss in productive capacity over their service lives (they resemble one-hoss shays)" (p.73). Yet, the uninitiated may be unaware that the building depreciation series estimated by the U.S. Department of Agriculture is also based upon the geometric decay capacity depreciation pattern.

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FOOTNOTES

1. Productive capital inputs have been partitioned into two groups for the purposes of this study: farm tractors (K_T) and all other fixed and variable production inputs (K_0). This distinction carries over to the implicit rental price of capital (C_T) and the purchase price (PP_T) as well.
2. This stream of tax depreciation assumes that the straight line method was used by producers prior to 1954 while the declining balance method was used thereafter to reflect the change in the tax laws.
3. A complete listing of the time series data used to measure the implicit rental price of farm tractors given by equation (7) and the exogenous variables used to compute the principal components used in equation (17) is available from the authors upon request.
4. While it is difficult to determine the exact value of the adjustment coefficient because of the inclusion of both the partial adjustment and adaptive expectations hypotheses, we do know that it would be negative in this instance. A negative adjustment coefficient would suggest that producers would decrease their actual capital stock even though it may be less than the desired level, thus implying a movement away from rather than toward equilibrium for any given exogenous shock. In addition, the small value observed for the ratio of b_{GD2} in equation (20) to its estimated standard error also suggests a coefficient of zero. Yet, this would suggest that no adjustment towards desired stocks occurs which, in itself, is not acceptable.