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Lemons, List Prices and Other Problems With Measuring Economic Depreciation Rates for Agricultural Machinery

A new flexible functional form is used to estimate remaining value equations for combine harvesters. Results indicate that list prices are discounted and "market for lemons" problems exists for relatively new combines. Depreciation rates are shown to linear functions of age if asset prices are adjusted for salvage values.

Understanding the determinants and patterns of asset depreciation rates is essential in any analysis of investment and replacement decisions of the firm and the effects of governmental policies upon those decisions. Several studies have examined depreciation patterns and rates (see for example, Hulten and Wykoff; Lee; Jorgenson; Penson et al.; Perry and Glyer; Reid and Bradford). These studies have identified a number of econometric complications associated with the use of data for machinery equipment prices (Perry and Glyer, Reid and Bradford). These include problems with list prices for new machines, a "lemons" problem in early year sales of used assets, and the selection of appropriately flexible functional forms that permit tests of several important hypotheses. Examples of such hypotheses are whether depreciation rates are constant over the life of the asset, and whether government policies affect patterns of depreciation. For the most part, the lemons and list price problems either have been ignored or dealt with by omitting data on prices for new or nearly new assets. Perry and Glyer tackle the lemons problem by using auction price and quality data for used individual machines in a study of tractor depreciation patterns. However most of the available data on used asset prices are average prices received on sales of a specific model and vintage of asset (see, for example, Parks; Hulten and Wykoff).

In this paper we examine the abilities of a dynamic flexible exponential functional form to address the above concerns. Specifically we show that an exponential function form allows the depreciation schedule to be adjusted for potential biases in observed prices at various ages. Complications with respect to list prices and "lemons" are similar in that observed prices are not representative of the prices actually paid for new machines (the list price case) or the true economic value of newly acquired used assets (the lemons case). Typically actual acquisition prices for new machinery assets are not observed but are somewhat lower than list prices because of dealer discounts. Similarly, the actual average value of relatively new non-traded used assets is also likely to be higher than observed prices for traded assets of the same vintage if a disproportionate number of "lemons" are sold soon after purchase.

Results presented by Perry and Glyer indicate that the pattern of depreciation rates over the life of a machine may be quite complex. We demonstrate that accounting for the salvage or "scrap" value of the asset can greatly reduce apparent complexities in depreciation rates as well as in estimating depreciation patterns. Thus the results presented below have interesting ramifications for the development of simple rule of thumb formulas for estimating remaining values of the type presented in **The Agricultural Engineering Handbook**.

The remainder of the paper is organized as follows. The next section contains a discussion of the properties of the exponential polynomial functional form used here as the basis for econometric models of patterns of depreciation. Econometric models of remaining values are then estimated using data on new and used prices for 23 models of combine harvesters over the period 1979 to 1989. Subsequently, results of the econometric analysis are presented and implications for depreciation patterns discussed.

The Model

The value of an asset at time S is assumed to be determined by a general exponential function of the form:

$$P(S) = \delta + K \exp\left\{\alpha S + \beta_1 S^2 + \ldots + \beta_{n-1} S^n\right\} \tag{1}$$

where P(S) is the value of the asset of age S, δ is the asset's salvage value, and $\left\{\alpha S + \beta_1 S^2 + \ldots + \beta_{n-1} S^n\right\}$ is a polynomial of degree n in S. The initial depreciable base of a new asset is its price P(0) less its salvage value δ. Setting S equal to zero in (1), it follows that $K = P(0) - \delta$.

The asset's depreciation rate can be calculated in two ways using (1). When the depreciate rate is calculated with respect to the full remaining value of the asset, P(S), it is defined as:

$$\frac{\partial P(S)}{\partial S} \Big/ P(S) = \frac{\left(\alpha + 2\beta S + \ldots + n\beta_{n-1} S^{n-1}\right) K \exp\left\{\alpha S + \beta_1 S^2 + \ldots + \beta_{n-1} S^n\right\}}{\delta + K \exp\left\{\alpha S + \beta_1 S^2 + \ldots + \beta_{n-1} S^n\right\}} \tag{2}$$

However, if the depreciation rate is calculated with respect to the remaining depreciable base, $P(S)-\delta$, a simpler polynomial of degree $n-1$ results; that is

$$\frac{\partial P(S)}{\partial S} \Big/ \left[P(S) - \delta\right] = \left(\alpha + 2\beta_1 S + \ldots + n\beta_{n-1} S^{n-1}\right) \tag{3}$$

From (2) it follows that if depreciation rates are computed on the basis of the remaining value of an asset, P(S), then depreciation rates are constant with respect to age if delta and $\beta_1, \beta_2, \ldots, \beta_{n-1}$ are all equal to zero. If depreciation rates are computed on the basis of the remaining depreciable base of the asset, $P(S) - \delta$, from (3) it follows that depreciation rates are constant with respect to age if only all of the β's are zero. This is a much less restrictive requirement because in this case the asset's salvage value can be non-zero and depreciation rates still remain constant.

Note that equation (1) is in fact a relatively flexible functional form, effectively incorporating the translog as a subset of possible functional forms. The inclusion of higher order polynomials creates a potential degrees of freedom problem. However, data sets on asset prices are often quite large (see, for example, Perry and Glyer and Hulten and Wykoff). In this application, over 2000 observations on combine harvester prices were available.

Equation (1) involves a polynomial of degree n in the exponential and is unattractive for estimation purposes. Lagging (1) to obtain an expression for P(S − 1), subtracting the expression for P(S − 1) from P(S) and rearranging terms results in the following expression:

$$P(S) = \delta + [P(S-1) - \delta] \exp (a + b_1 S + \ldots + b_{n-1} S^{n-1}) \tag{4}$$

Equation (4) is clearly a dynamic representation of the behavior of P(S) and can be estimated readily using nonlinear econometric methods.

The Econometric Model

The above model is applied to a data set for combine harvesters, a detailed description of which is available in Gorowski et al. The data were collected on a cross section/time series basis over the period 1979-89 for the spring and fall of each year. Thus the data are semiannual. During the period 1979-89 three major changes (in 1981, 1984, and 1986) were made to the tax code that altered the value of depreciation tax allowances and investment tax credits. In addition, substantial shocks occurred to the demand for farm machinery because of changes in expected farm incomes. To account for possible effects of these events on machinery prices three tax dummy variables (T1, T2 and T3 which are set equal to 1 respectively for the periods 1982-84, 1985-86 and 1987-89 and 0 otherwise) and real gross cash income from crops (GCI) are included in the estimation model. The possibility of seasonal effects is accounted for by including a spring fall dummy variable (F) set equal to 0 if prices were observed in the fall and 1 if they were observed in the spring.

New price data were included in the information set. To account for the list price effect a dummy variable d_0 is included which is set equal to 1 if the machine of interest is half a year old (that is, sold in the spring having been purchased as a new machine in the previous fall). All new machinery prices are observed in the fall. The value of the coefficient for the list price effect is allowed to adjust under alternative tax regimes by including tax-list price interaction dummies of the form $T_j d_0$. To account for the existence of a lemons effect, we also include a second dummy variable, d_1, set equal to 0 if the used asset is older than one year and zero otherwise.

Thus the general form of the econometric estimation model for combine harvesters is as follows:

$$P(S)_i = \delta + \left[P(S-1)_i - \delta + DD0 \cdot d_0 + DD1 \cdot d_1 + \sum_{j=1}^{3} DTJ \cdot (T_j d_0) \right] \tag{5}$$
$$\exp \left\{ A0 + AG \cdot GC1 + A_S \cdot F + \sum_{j=1}^{3} ATJ \cdot T_j + B0 \cdot S + \sum_{j=1}^{3} BTJ \cdot (T_j S) + v_i \right\}$$

where δ, DD0, DD1, DT1, DT2, DT3, A0, AG, AS, AT1 AT2 AT3 B0 BT1 BT2 and BT3 are parameters and v_i is the error term associated with the i'th observation.

Equation 5 implies that in equation 1 only quadratic terms in S are relevant to the pattern of depreciation. This is not necessarily the case. Initially, higher order polynomial functions were estimated. However, the coefficients associated with third and higher order terms in S were not statistically significant. Thus the estimated models reported below assume equation 1 is a second order polynomial. Finally, the model was estimated with both additive and then multiplicative error structures.

Results

Table 1 presents the parameter estimates and asymptotic t-ratios for the above system under a multiplicative error specification. With an additive error structure there was an apparent heteroskedasticity problem with respect to the age and value of the machines. Estimating (5) under the assumption of a multiplicative error removed any evidence of this problem. As reported by Gorowski et al., changes in tax regimes and demand shocks both affect depreciation patterns. While these effects are interesting in their own right, a detailed discussion of these effects is beyond the scope of this paper.

The results presented in table 1 are consistent with the hypothesis of a list price problem. The list price coefficients DD0, DT1, DT2, and DT3 are all negative and statistically significant. These results are consistent with the hypothesis that dealers do discount from list prices for combine harvesters. Thus Perry and Glyer are correct in pointing out that this problem must be taken into account in econometric work. However, list prices do contain useful information which is lost if such observations are ignored. The results also suggest that changes in tax policy alter the size of list price discounts.

The econometric results also support the hypothesis that a "lemons" problem exists. The coefficient associated with the dummy variable d_1 is positive and significant. This implies that prices for combines that are resold within one year are lower than those predicted by the estimated remaining value equation. Again, however, the solution is not necessarily to ignore the information contained in observations on average prices for relatively new used machinery. A viable alternative is to allow the estimation procedure to account for lemon effects.

Finally, the results indicate that both δ and B0 are significantly different than zero. Thus the asset's depreciation rate changes with age whether depreciation rates are measured in relation to the asset's remaining value, P(S), or its depreciable base, P(S) - δ. However, the pattern of depreciation rates with respect to age is much more complicated if depreciation is calculated using remaining values.

Representative depreciation patterns were estimated by setting GCI equal to its mean value and assuming that tax laws are those that existed between 1987 and 1989. (Similar results are obtained under other tax codes.) The resulting patterns of depreciation rates based on the remaining value and depreciation base formulas are illustrated in Figure 1. The pattern obtained using the remaining value formula is more complex. As the asset's age increases, depreciation rates first rise and then fall. The pattern obtained using the asset's depreciation base is very simple; the depreciation rate increases linearly with age. Given estimates of salvage values, the latter formula thus provides an easier "rule of thumb" method for computing economic depreciation.

One important implication of the analysis is of particular interest. Equations 2 and 3 indicate that if the salvage value for an asset is positive and the depreciation rate based on the depreciable base of an asset is constant over the asset's life, depreciation rates estimated on the basis of remaining values (market prices) will not be constant. Ignoring salvage values in econometric models thus represents an important potential source of bias.

Conclusions

This study has applied a new dynamic flexible functional form to the estimation of asset remaining value functions. The functional form can be modified to account for a variety of effects on the pattern of depreciation over the asset's life and permits the direct estimation of salvage values. The results support the hypothesis that list price and lemons effects are significant in the case of combine harvesters but do not preclude the use of data on average prices of new and relatively new assets in studies of depreciation rates. The findings of the study also show that patterns of depreciation rates estimated using remaining values are more complex than those estimated using the asset's depreciable base.

References

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Table 1
Estimated Results for the Multiplicative Error Combine Depreciation Model[a]

Parameter	Parameter Estimates
δ	6860 (10.99)
DD0	-13876 (-16.58)
DT_1	-8831 (-7.36)
DT_2	-18718 (-15.90)
DT_3	-17417 (-15.11)
DD_1	2024 (4.95)
A_0	-.3688 (-11.45)
A_g	.003519 (8.36)
A_s	.1082 (21.23)
AT_1	.04656 (3.99)
AT_2	.005077 (.36)
AT_3	.1162 (6.74)
B_0	-.003590 (-1.95)
BT_1	-.003515 (-1.66)
BT_2	.003403 (1.53)
BT_3	-.001098 (-.52)
Adjusted R^2	.9831

[a]Asymptotic t statistics are presented in parentheses.

FIGURE 1

ALTERNATIVE DEPRECIATION RATES