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Gregory M. Perry

Farm equipment is becoming an increasingly important financial asset for many farmers. Tractors probably represent the single largest component of equipment asset value. As such, changes in tractor values can have a dramatic effect on a farmer's financial situation. Changes in equipment value can be attributed to depreciation and the value of output produced. The general objective of this study was to identify a specific set of variables explaining changes in equipment value and to determine the relative importance of these variables.

The Box-Cox power transformation technique was employed in estimating the depreciation patterns. The method was applied to two different sources of used tractor prices--auction and advertised. Remaining value (RV), defined as the real market price in time t divided by real purchase price, was regressed against several independent variables. These independent variables were age, usage per year, condition, horsepower, manufacturer, regions of the U.S., auction types, and net farm income.

A number of these variables were found to have some important impact on RV. Depreciation patterns were found to differ between manufacturers. Significant differences in remaining values (RV) were found to exist for different regions of the U.S. and different auction types. For both auction and advertised data, an increase in usage produces a noticeable decrease in RV. For auction data, however, the level of usage tends to have greater influence on RV when the tractor is newer.

The results did not closely approximate any clear depreciation pattern. The depreciation patterns are accelerated relative to straight-line method and are a combination of the geometric and sum-of-the-year's digits functions.

The RV model was used to examine optimal replacement ages for farm tractors. Annual usage levels had the most influence on the age at which tractors were replaced. Expensing and some tax law changes had a less significant impact.

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DEDICATION

This thesis is dedicated to the memory of my father after whom I am named, Ahmet Bayaner (1909-1985).

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CHAPTER 1

INTRODUCTION

Farmers in the U.S. have witnessed a technological revolution over the last 80 years. One result has been a large reduction in the percentage of the U.S. labor force directly engaged in the production of food. Although many technological advances have contributed to this reduction, it could be argued that mechanization of many farming operations has been the single most important cause.

As one might expect, the shift from labor intensive to capital intensive production systems has resulted in equipment being an increasingly important financial asset for many farmers. The significance of farm equipment as a financial asset can be readily seen in Table 1.1. These figures consistently show that machinery is the second most important asset owned by farmers (next to land). In 1986, for example, machinery was worth 89 billion dollars, or 11.2 percent of total farm asset values.

Equipment is a more important financial asset than Table 1.1 indicates. Much of the land in production is rented by farmers. By contrast, virtually all equipment is owned or being purchased by farm operators. Tenant farmers, who represented 11.6 percent of all farmers in 1982, own no land at all. Thus, equipment is their major financial asset.

Table 1.1. Farm Asset Value in the United States.*

Asset	1984	1985	1986	1987
	Billion dollars			
Real estate**	793.9	686.2	597.2	549.8
Land	688.9	595.7	517.9	476.1
Building	105.0	90.5	79.3	73.7
Nonreal estate	178.4	177.0	162.0	161.0
Livestock and poultry	49.6	45.9	45.0	49.0
Machinery and motor vehicles	95.0	92.2	89.0	86.0
Crops stored on and off farms	33.8	37.1	29.0	27.0
Financial assets	38.0	36.7	35.0	34.0
Total	1010.3	899.9	794.2	744.8

Sources: * Agricultural Finance--Situation and Outlook Report, March 1987.

** Agricultural Resources--Agricultural Land Values and Markets Situation and Outlook Report, December 1987.

Other comparisons between land and equipment are worth noting. Equipment is considered a depreciable asset because it declines in value due to wear and tear. Equipment deterioration reduces its productivity value. Land also can decline in productive value (e.g., when severely eroded), but the process is much slower. Consequently, land is not considered a depreciable asset. Technological obsolescence is also not a factor in determining land values but can have a major influence on equipment values. The value of both assets is influenced by the health of the farm economy because it is derived in part from the value of output produced.

Tractors probably represent the single largest component of equipment asset value. Green indicated that the tractor is a major item of machinery both in terms of total dollars invested and numbers of machines purchased. In 1956, for example, tractors accounted for 30 percent of the total number of machines found on farms.

Depreciation is the cost that reflects a decline in value of an asset over time (Monks). It represents the implicit cost borne by an asset owner when choosing to keep and use the asset rather than to sell it. Several studies suggest that depreciation is the single most important cost associated with farm equipment. Depreciation is primarily a function of the age of the equipment, how much it has been used, and the care it has received.

Economic pressures are encouraging farmers to pay more attention to the management of their machinery resources. As already noted, the long-standing trend of substituting capital for labor in the form of more productive and higher capacity machinery has progressed to the point where today large amounts of capital are used annually by many farming operations. Thus, on today's commercial farm, a significant component of both capital investment and annual production costs is machinery related (Mohasci, Willett, and Kirpes).

Tax depreciation schedules are sometimes used to estimate depreciation costs of farm machinery. These methods are simple but do not reflect year to year changes in the "market value" of used farm machinery. They also do not account for the effects of usage and care on depreciation costs.

Because depreciation represents a major component of equipment expenses, accurate estimates of these expenses depend on accurate depreciation estimates. Cook et al. estimated per acre machinery cost, for example, for wheat in Oregon Columbia Plateau as $50.74 for the 1986-1987 season. Depreciation represented 31 percent of this machinery cost. Producers must know the costs incurred in depreciation if they are to make optimal machinery management decisions (Reid and Bradford). They must also be cognizant of the effect their management practices can have on depreciation costs. Leatham and Baker stressed that depreciation is particularly important when comparing ownership versus leasing. Finally, an understanding of the effect of the farm economy on equipment values could influence required downpayment, repayment period, and interest rate charged on equipment purchases financed by lenders.

Surprisingly research in the area of farm equipment depreciation has been quite limited, given the importance of this cost for many farming operations. A better understanding of the factors influencing equipment costs would aid farmers in making better management decisions. It would also help statisticians and others interested in measuring the stock of farm equipment capital currently in place, and how that capital will depreciate over time.

Objectives

The focus in this research is on evaluating the current market relationships for used tractors. The general objective of this thesis is to identify a set of variables that will explain changes in the equipment value and to determine how important these variables are. The accuracy of using advertised prices for estimates of depreciation will also be examined. The estimated model will then be employed in an equipment replacement model to illustrate its use in making this type of decision.

Thesis Organization

The remainder of this thesis is presented as follows: Chapter Two presents the theoretical underpinnings of the research. After reviewing previous work in the subject area, a tractor depreciation model is hypothesized. The importance of functional form is also discussed. The final section in the chapter is devoted to a discussion of data issues. Chapter Three contains a statistical analysis of the data used in the econometric analyses. In Chapter Four the empirical results of econometric analyses are presented, as is an interpretation of these results. Some comparisons are made between the results and previous research. Chapter Five presents an application of the model reported in this study. Results are applied to optimal replacement of farm tractors. Chapter Six contains a summary of the thesis and suggestions for further economic research.

CHAPTER 2

THEORETICAL DEVELOPMENT

In this chapter, discussion focuses on the hypothesized model used to estimate tractor value. Previous studies are initially reviewed to provide some ideas as to what variables might be included in the current study. A hypothesized model is then formulated, and the question of functional form is considered. Data issues are discussed at the end of the chapter, and the proposed models are presented.

MODEL SPECIFICATION

Previous Studies

Peacock and Brake were among the first to estimate remaining value equations for tractors and other large farm machines. They demonstrated that tax depreciation "write-offs" do not adequately reflect economic depreciation of farm machines. Using simple econometric models, they also examined the effects of a number of potentially important factors influencing depreciation, including age, realized net farm income, index of prices received by farmers, farm labor cost, inflation, make, new models, horsepower, gasoline versus diesel, and acreage. They found that age, make, and inflation were consistently significant in explaining Remaining Value (RV). RV is the current market price (times 100) divided by the original sales (or list) price when the tractor was new, with the original price generally in current dollars. Only RV equations with age as the independent variable were reported. Despite their recognition of inflation as an important variable, no attempt was made to adjust the list price to current dollars. The data used were obtained from <u>Official Tractor and Farm Equipment Guide</u> (National Farm and Power Equipment Dealer Association), for the period 1954-1963. The estimated equation for tractors is

$$RV = 64.3 - 3.1 \text{ Age}$$

Peacock and Brake also estimated a semilog model of the form

$$RV = 66.6 \, (0.935)^{Age}$$

The American Society of Agricultural Engineers (ASAE) also used the NFPEDA data to estimate depreciation functions. Their function for tractor is

$$RV = 68 \, (0.92)^{Age}$$

The ASAE estimates are in real dollars and are based on prices from the late 1960s.

Leatham and Baker estimated a more elaborate RV equation. They hypothesized that the RV of a machine is a function of age and the increase in the price of new machines, a hypothesis supported by Hall. They also explicitly included a number of variables suggested by Peacock and Brake including horsepower and dummy variables for different companies. Their estimated function is

$$RV = I^{1.4358}\ H^{-0.0543}\ (-1.059)^{D1}\ [1.0867(-0.9942)^{Age}]^{D2}$$

$$[-0.993(-0.9933)^{Age}]^{D3}\ [-0.7282(-0.8948)^{Age}]^{D5}$$

$$[-0.7582(-0.8963)^{Age}]^{D6}\ [-0.7534(-0.9171)^{Age}]^{D7}$$

$$[-0.7417(-0.9001)^{Age}]^{D8}$$

where

I is the ratio of the price index for new machines in year t divided by the price index for new machines in the year the now-used machine was manufactured

H is Drawbar horsepower,

D1 is 1 if t = 1974 or 1975, 0 otherwise,

D2 is 1 if diesel, 0 otherwise,

D3 is 1 if 4-wheel drive, 0 otherwise,

D5 is 1 if Allis-Chalmers, 0 otherwise,

D6 is 1 if International, 0 otherwise,

D7 is 1 if John Deere, 0 otherwise,

D8 is 1 if Massey-Ferguson, 0 otherwise,

McNeill developed a remaining value equation from cross-sectional data on prices, age and condition for utility type Canadian tractors. His model is

$$RV = e^{-.4299\ -.6436Age\ +.0691Condition}$$

where condition is a 0 to 4 interval index where excellent equals 4 and poor equals 0.

Reid and Bradford (1983) estimated a remaining value equation that was somewhat similar to the Leatham-Baker model but accounted for changes in tractor supply and demand and technological obsolescence. Their estimated model is

$$RV = 368.7\ Age^{-.273}\ HP^{-.242}\ NF^{-.305}\ MX^{-.121}$$

$$MY^{-.263}\ T1^{-.621}\ T2^{-.205}$$

where HP is PTO horsepower; NF is three year average net farm income per farm; MX and MY are dummy variables for different tractor makes; T1 and T2 are technological change time-index dummy variables. Their data were from the 1953-1977 period.

Perry, Glyer, and Musser also used the NFPEDA data to estimate an RV model for large (over 90 horsepower) tractors manufactured between 1974-1986. The independent variables hypothesized were age, net national farm income, horsepower, dummy variables representing different manufacturers, first year depreciation, technological change, and changes in tax policy. A flexible (Box-Cox) functional form was used. The estimated model is

$$\frac{RV^{-0.14} - 1}{-0.14} = 2.9647 + [2.9647 + (-0.058728$$

$$+ 0.023101\ D + 0.004669\ F + 0.001496\ MF)]\ \frac{Age^{1.01} - 1}{1.01}$$

$$+ 0.19867\ \frac{NFI^{-0.74} - 1}{-0.74} + 0.062724\ D + 0.006556\ F$$

$$+ 0.036198\ MF - 0.025588\ DISCON + 0.016193\ TAX$$

where

D = 1 if manufacturer is John Deere, 0 otherwise,

F = 1 if manufacturer is Ford, 0 otherwise,

MF = 1 if manufacturer is Massey Ferguson, 0 otherwise,

NFI = National Farm Income (in billions),

DISCON = Discontinuation of an equipment series, and

TAX = 1981 tax law.

Age was the greatest factor in determining current value, but national farm income and obsolescence also were significant. Moreover, a noticeable difference in depreciation rates between companies was observed. A geometric depreciation pattern could not be statistically rejected.

Hypothesized Model

Consistent in previous tractor depreciation studies was use of RV as a dependent variable. The principal advantages of using RV are related to sample size and the time period over which given tractor models are manufactured. Most previous studies relied on NFPEDA' Official Guide as a data source. These data give an average resale price for each year a particular tractor model was manufactured (usually 3-8 years). Combining resale prices for different tractor models is not desirable because price may be heavily influenced by the specific model type. A used John Deere 4650, for example, would almost always sell for more than a John Deere 4050 of the same age, simply because the 4650 is a much larger tractor.

Dividing resale price by the original price when new (thus creating the RV variable) puts all tractor models on an equivalent basis and allows for pooling of data across different models. Use of RV also imposes a number of implicit assumptions. First, all RV values are assumed the same, unless specific independent variables are used to explain any differences. In addition, most researcher desire to estimate real economic depreciation, thereby requiring the original resale price be converted to the same price level as the current price level. Use of any price index in this conversion presumes it accurately represents the price level changes that actually occurred for all models manufactured by all companies included in the data set. The RV approach also may not result in the best model for forecasting prices of used equipment (Perry, Glyer, and Musser). Despite these potential problems, however, RV was used as the dependent variable in the study.

As has already been stated, depreciation is the change in asset value over time. Thus, it is not surprising to find asset age as the principal (and sometimes only) explanatory variable used in previous depreciation studies. Beidleman pointed out that asset age is the most significant explanatory variable of "second-hand" asset values (p.35). Age represents the decline in asset price because of technological obsolescence and the natural deterioration that occurs over time.

Depreciation is also greatly influenced by the intensity of use. Usage accelerates the depreciation process by increasing the rate of deterioration. Previous studies have generally ignored usage, presumably because information on usage was unavailable. A lower rate of usage might be expected to reduce the rate of asset depreciation over time.

High levels of equipment care can slow the effects of deterioration but can also increase total production costs above the optimal level. One might expect a firm to provide care for an asset only so long as the marginal care cost does not exceed the reduction in depreciation costs plus the value of additional output produced. Some deterioration will occur each year unless the cost of care is zero (Parks). In this case, the machinery owner would invest enough care to maintain the machine's value.

Depreciation patterns may differ between tractor manufacturers because of differences in repair cost, reliability, and expected life. Parks suggests that the price of a durable asset is influenced by its perceived reliability. Assets with high expected reliability will have a higher initial price. Parks identified significant differences between prices of automobiles manufactured by different companies.

Factory list price will differ from sale price because of 1) transportation cost between factory and the point of sale and 2) dealer markups or discounts. Perry and Glyer (1987) suggest that significant regional differences in tractor price received in a particular year can also result from inadequate information about regional supply and demand conditions.

Tractor price may also depend on the type of market in which it is sold. A tractor sold in a bankruptcy auction may sell for a much different price than the same tractor taken as a trade-in by a dealer. The difference between the dealer trade-in price and resale price may be larger percentage-wise for older tractors because a) there are some fixed costs associated with buying and reselling equipment, and b) there is greater risk that a dealer will not be able to sell the tractor or, if he does sell it, that the buyer will be dissatisfied. Alternative marketing outlets (e.g., consignment sale at an auction) may be a more profitable alternative for the farmer.

Horsepower was used or considered as a variable in several previous estimates of economic depreciation for tractors. Peacock and Brake suggested that models with certain horsepower ratings may be in greater demand than others. The existence of different demand levels for each tractor size would depend on an associated range of tractor sizes suited to the greatest number of farming operations. Perry, Glyer, and Musser hypothesized that larger tractors would depreciate at a slower rate than smaller tractors, since larger tractors presumably do not become functionally obsolete as rapidly as smaller ones.

Given the set of variables just mentioned, the hypothesized RV model for a single year of data could be written as

RV = f(Age, Care, Usage, Manufacturer, Sales Outlet,
Tractor Size, Region)

This model presumes all macroeconomic factors influencing tractor prices are held constant during the year. The macroeconomy can influence equipment prices in a number of ways. Commodity prices influence the profitability of investment in newer equipment and may increase equipment demand if total crop acreage increases. Lower interest cost or more favorable tax laws may reduce the costs of acquiring tractors, thereby increasing demand. Income from nonfarm sources (such as government payments) may also influence tractor demand. Dramatic changes in demand may cause sharp shifts in tractor prices because tractor supplies are more or less fixed in the short run. That is, the total stock of tractor is much larger than the quantity of tractors that can be added to the stock within a given year.

A multiyear RV model would be formulated as

RV = f(Age, Care, Usage, Reliability, Sales Outlet, Equipment Size, Company, Region, Macroeconomic variables)

Functional Form

Previous studies have used a number of functional forms to estimate RV. Peacock and Brake, for example, used a simple linear form, while Leatham and Baker and McNeill used an exponential functional form, and Reid and Bradford (1983) used a Cobb-Douglas transformation.

Selecting a functional form is a primary consideration when estimating a depreciation pattern for durable assets (Hulten and Wykoff, 1981). The functional form can influence the depreciation pattern. The exponential form, for example, imposes a constant depreciation rate for changes in age.

Given that one purpose of this study is to identify the depreciation patterns for tractors, it is desirable that a flexible functional form be chosen so the data can more freely exhibit the correct depreciation pattern. One flexible form commonly used is the so-called Box-Cox power transformation. The Box-Cox transformation function was originally intended to remove suspected heteroskadesticity but in econometrics has been mainly used for detecting nonlinear functional form (Kmenta). The Box-Cox power transformation is a more flexible functional form that has been recommended for use in estimating depreciation patterns (Hulten and Wykoff, 1980).

Judge et al. indicate that Box-Cox is a logarithmic data transformation. For some statistical models the dependent variable may not be normally distributed, but there may exist a transformation such that the transformed observations are normally distributed.

Considering the nonlinear model

$$(1) \qquad y_t = \exp(X_t b) \cdot \exp(e_t), \qquad t = 1,2,\ldots T$$

where y_t is the t^{th} observation on a dependent variable, X_t is a (Kx1) vector containing the t^{th} observation on the same explanatory variable, b is a (Kx1) vector of parameters to be estimated, and the e_t are the error terms normally distributed $\{N(0,\sigma^2)\}$. In this model the y_t are log, normally distributed and heteroskadestic.

However, taking the log of equation (1) yields

$$(2) \qquad \ln y_t = X_t b + e_t$$

where $\ln y_t$ is normally distributed, homoskedastic, and a linear function of b, and so application of least squares to equation (2) gives a minimum variance unbiased estimator for b.

For this class, the Box-Cox presumes there exists a value λ such that

$$(3) \qquad \frac{y^\lambda - 1}{\lambda} = X_t b + e_t$$

where the e_t are the normally distributed error terms, $N(0,\sigma^2)$. Thus Box and Cox assume that there exists a transformation of the dependent variable, of the form given in equation (3), such that the transformed dependent variable 1) is normally distributed, 2) is homoskadestic, and 3) has an expectation that is linear in b.

If $\lambda = 0$, equation (2) is regarded as a special case of (3), and if $\lambda = 1$, it yields the familiar linear model $y_t = X_t b + e_t$. If λ were known, the application of least squares to equation (3) would yield a minimum variance unbiased estimator for b. However, it is usually assumed that λ is unknown and is simultaneously estimated with b. The values for independent variables are also transformed in the same manner. If it is assumed that λ is the same for dependent and independent variables, the model is

$$(4) \qquad \frac{y^\lambda - 1}{\lambda} = a + \frac{b\ X^\lambda - 1}{\lambda} + e$$

If λ is different for each variable, the model becomes

(5) $$\frac{y^{\lambda} - 1}{\lambda} = a + \frac{b\ X^{\theta} - 1}{\theta} + e$$

where θ is a (K x 1) vector of transformations to be estimated.

The Box-Cox power transformation estimates the parameters determining a specific functional form within the Box-Cox class. It also involves estimating the parameters that determine the slope(s) and the intercept of the equations using maximum likelihood method. The Box-Cox model assigns two parameters to each transformed variable, unlike the standard regression model.

The Box-Cox power transformation parameters determine the functional form within the Box-Cox power family. As the power transformations take on different values, the form of equations (4) and (5) changes. The transformations for some of the more common or relevant different functional forms are given in Table 2.1.

Perry and Glyer (1988) suggest what transformations must exist for depreciation rates to be increasing, constant, or decreasing over time. Depreciation rate is the change in price during a particular time period, divided by the price at the beginning of the time period. Expressed mathematically,

(6) $$\frac{\partial RV\ /\ \partial AGE}{RV} = b\ Age^{\theta-1}\ RV^{-\lambda} = R^{*}$$

with $R^{*} < 0$ when $b < 0$.

The change in the depreciation rate with respect to a change in age is

(7) $$\frac{\partial R^{*}}{\partial AGE} = \epsilon\ [(\theta-1) - \lambda\ (R^{*}\ \frac{AGE}{RV}\ )]$$

Table 2.1. Box-Cox Power Transformations Associated with Different Functional Forms

	Power Transformation for Variables	
Functional form	Dependent	All independent
Linear	1.0	1.0
Cobb-Douglas	0.0	0.0
Geometric	0.0	1.0
Logarithmic	1.0	0.0
Square Root	1.0	0.5
Sum of Year Digits	0.5	1.0

where ϵ is the elasticity of price with respect to AGE (negative). The rate of depreciation is constant (or follows a geometric pattern) if θ=1 and λ=0. If λ>0 and θ>1, the rate becomes more negative or accelerates with time. If λ<0 and θ<1, the rate becomes positive with time (or decelerates). A set of λ and θ values not reflecting any of these conditions probably represent a situation in which depreciation alternately accelerates and decelerates at different stages of equipment life.

DATA

Markets for used tractors can be divided into three major categories: 1) sales by equipment dealers, 2) auction sales, and 3) person-to-person transactions (e.g., classified ads, sales to neighbors, etc). Virtually all previous studies of tractor depreciation have relied on equipment dealers average resale prices as reported semiannually by the National Farm and Power Equipment Dealers Association (NFPEDA). There are a number of reasons why these data are inadequate in estimating depreciation patterns for equipment at the farm level. First, the prices are averages instead of actual transaction prices. Second, they probably do not represent "arms length" transactions. Transactions between dealer and farmer usually involve warranties, a trade-in of older equipment, availability and quality of repair services, and so forth. For example, farmers are more willing to buy used farm machinery with more acceptable guarantees, rather than a lower price (Singh). These factors can also influence the transaction price. Finally, a casual comparison of resale prices reported by NFPEDA suggests a constant depreciation rate is assumed when calculating prices for the same model of tractor manufactured in different years. Although depreciation may actually occur at a constant rate, it would be pointless to identify depreciation patterns in data that have a pattern already imposed on them.

An alternative to resale prices reported by NFPEDA is to use prices advertised by equipment dealers. Advertised prices for tractors sold by dealers allow one to sidestep a number of the biases mentioned for the NFPEDA data but are probably above actual transaction prices (to provide some negotiating room). Nevertheless, one might expect advertised prices to exhibit roughly the same depreciation pattern as the dealer's resale prices.

Most used tractors are probably sold by equipment dealers, but significant numbers are also sold in the other markets. The disadvantage of using transactions by equipment dealers is that many are not "arms length" transactions, but involve warranties, financing options, and trade-in considerations as mentioned previously. Similar factors may be present in person-to-person transactions. Prices from auction data, however, represent actual productive values of the equipment "as is".

Although advertised prices might be higher than auction prices (because of dealer markup), the depreciation patterns exhibited in auction data could be the same as exhibited by advertised data. Important factors that might cause the patterns to differ include 1) a change in the cost of dealer services with age, 2) different usage and care patterns, and 3) a difference between depreciation patterns perceived by equipment dealers versus those reflected in actual tractor sales.

Hot Line, Inc. has since 1984 published monthly reports of auction and advertised prices for farm equipment throughout the U.S. Very few of the 1984 publications were available, but a nearly complete set of publications was obtained for 1985-1987. Each publication contains information on numerous individual tractor transactions or advertisements, including model, manufacturer, year manufactured, where and when sold (if auction data), price, condition, and general descriptive information. These transactions formed the basis for the data used in this study. Only tractors manufactured during the 1971-1987 period were included in the data set since technological change was perceived as being relatively constant during this period.

Age was calculated for all observations and was transformed using the Box-Cox technique. Although most observations did not contain usage information, some data on usage (total chronometer hours) were available. One might expect total hours to be highly correlated with age, a situation that would result in undesirable estimation properties. To reduce correlation between hours and age, the hours variable was divided by age to create an hours per year (or average usage) variable. A Box-Cox transformation was performed on this usage variable.

The data set was also limited to large (over 80 horsepower) tractors since these are used in the bulk of field work and are not in demand by smaller, hobby farmers. Power-takeoff (PTO) horsepower was used as a proxy for tractor size.

Only observations for the seven major domestic tractor manufacturers (John Deere, International Harvester, Case, Allis Chalmers, Ford, Massey Ferguson, and White) for this segment of the tractor market were included in the data. A set of dummy variables was created to account for the influence of companies on the RV model. Only one dummy was used to represent Ford, Massey-Ferguson, and White tractors because there were so few observations for all these companies. This multiple company dummy variable was omitted prior to the estimation process in order to avoid matrix singularity. An age-manufacturer interaction term was also included, presuming depreciation rates differed between companies.

Although factory list prices were used in calculating RV, an attempt was made to account for regional prices differences by including dummy variables for nine regions. These regions are shown in figure 2.1. Subsequent analysis revealed that some regions were poorly represented in the overall data set. These nine regions were combined to form the five regions used in the analysis. These five regions are West and Northern High Plains, consisting of Regions 1, 2, and 9 (R1); Southern Plains (Region 3) (R2); Western Corn Belt (Region 4) (R3); Eastern Corn Belt and Northeast, (Regions 5 and 6) (R4), and the South, (Region 7 and 8) (R5). R3 was set as default.

Information on tractor condition (excellent=1, good=2, fair=3, or poor=4) was reported for each tractor in both the auction and advertised data. As noted earlier, care might have some effect on

Figure 2.1. Regions of the U.S. used in the econometric analyses.

RV. Appropriate information on care is almost impossible to obtain. Condition, however, would probably reflect the type of care given the tractor. McNeill found that a similar condition variable had a statistically significant effect on RV. The impact of condition was small in comparison to age, however. The condition variable was included in the model as a proxy for care.

Four types of auction situation are included in the data. The predominant situation is that of an estate sale or when a farmer is voluntarily retiring from agriculture. A second situation is a bankruptcy sale or involuntary retirement caused by financial constraints. The third situation is sale of equipment on consignment. The fourth is an auction held by dealer to liquidate excess used equipment. Auction dummies were included in the equation to account for the effect of auction types on RV. The farmer retirement dummy was dropped from the equation prior to estimation.

As noted earlier, the macroeconomy can influence equipment prices. Farm income has often been used in previous models because it reflects both the farmers' current purchasing power and the expected returns from the tractor purchase. Crop acreage might be expected to also be a good indicator of tractor demand. As crop acreage is removed from production, less farm machinery is needed by the sector, and thus demand is reduced. Demand for farm machinery in 1987 is believed to have been adversely affected as farmers idled 14.9 million additional acres under the Conventional Reserve Program (CRP). The acreage reduction program, however, helped support farm income. The result is an inverse correlation between Net Farm Income

(NFI) and acreage. NFI is also highly correlated with the current prices received by farmers. Therefore, only NFI was added to the model to account for the effect of the macroeconomy on RV. Data for NFI were obtained from U.S.D.A. Agricultural Outlook (Economic Research Service, January-February 1988). An index of average prices paid for 110-129 Horsepower tractors was developed (based on USDA data) to inflate list prices and to deflate 1985-87 sale prices to 1982 levels.

The proposed cross-sectional model for each year is of the form:

$$RV^* = \beta_1 + (\beta_2 + \sum_{i=1}^{4} \beta_3 C_i)\ AGE^* + \sum_{i=1}^{4} \beta_4 C_i + \sum_{j=1}^{4} \beta_5 R_j$$

$$+ \beta_6 USE^* + \beta_7 Condition + \sum_{k=1}^{3} \beta_8 A_k + \beta_9 HWP$$

where

$$RV^* = \frac{RV^\lambda - 1}{\lambda}, \quad AGE^* = \frac{AGE^\gamma - 1}{\gamma}, \quad \text{and} \quad USE^* = \frac{USE^\theta - 1}{\theta}$$

in which

λ, γ, and θ are power transformation parameters estimated by the Box-Cox technique and which determine the functional form within the Box-Cox power family,

C_i = dummy variables representing companies where

i=1 Allis-Chalmers

i=2 Case

i=3 John Deere

i=4 International Harvester

R_j = region dummies where

j=1 Northern High Plains and West

j=2 Southern Plains

j=3 Eastern Corn Belt

j=4 South

A_k = Auction types where

k=1 Consignment

k=2 Bankruptcy

k=3 Dealer Closeout, and

HWP = PTO Horsepower.

The model for cross-sectional time-series analysis is

$$RV^* = \beta_1 + (\beta_2 + \sum_{i=1}^{4} \beta_3 C_i)\ AGE^* + \sum_{i=1}^{4} \beta_4 C_i + \sum_{j=1}^{4} \beta_5 R_j$$

$$+ \beta_6 USE^* + \sum_{k=1}^{3} \beta_7 A_k + \beta_8 Condition + \beta_9 HWP + \beta_{10} NFI$$

where

NFI = Net farm income in 1982 dollars, and all other variables are defined as before.

The SHAZAM econometric statistical package was used to estimate these two RV models. The Box-Cox technique in SHAZAM is not capable of estimating separate transformation values for dependent and each independent variable. To overcome this limitation, a manual grid search technique was used to estimate the γ and θ values for AGE^* and USE^*.

CHAPTER 3

STATISTICAL ANALYSIS OF DATA

This chapter presents a statistical analysis of the data set used in the econometric analyses. The data set contains 7153 observations of advertised and auction prices for used farm tractors from 1985 to 1987. The data were obtained from Hot Line Inc., which has been publishing monthly reports of auction and advertised prices since 1984 for farm equipment throughout the United States. No analysis was made of 1984 data because most monthly reports for that year were unavailable at the time of this study.

The characteristics of the data set are an important aid in understanding the reasons why certain results are exhibited in the econometric models. Such an analysis can also identify any potential biases that may be embodied in the econometric results. Some of these biases were removed in the process of formulating the final models reported in the thesis. Other possible biases will merely be identified as such in the course of the presentation.

Another important reason for reporting the statistical results is the nature of the data itself. A great deal of information about farmers' equipment purchase and usage patterns is extremely dated, available only through private sources, or is completely unavailable. Some of this information could be quite useful in future economic studies involving tractors.

was an annual usage level of 800 hours per year for tractors. No supporting evidence was given to justify this assumption, although 800 hours had been used in previous studies (e.g., Kay and Rister). The statistical analysis in this chapter provides information on this and a number of related subjects.

A general statistical breakdown of all data is presented in Table 3.1 for each year. Likewise, Table 3.2 presents a year by year statistical analysis of data with usage information. The tables contain data from both auction and advertised sources.

Average age increases from 7.6 for 1985 data to 8.9 for 1987 data. The average age for all observations is 8.2. There are fewer observations in 1986 than in 1985 and 1987, a result (according to Hot Line, Inc.) of poor management of Hot Line in 1986. Only 2573 (or 36%) of all observations contained information on total hours of use. Tractors that had usage reported tended to be a bit younger than all tractors in the total data base. Total average annual usage was 318.1. The highest average annual usage of all was observed in 1986 (335.1). A comparison of mean and standard deviation results suggests the vast majority of tractors in the data set have less than 5500 hours. Average condition for those observations with usage was slightly lower. The total average condition is approximately 2 (good). This is not surprising because 62.1% of the tractors reporting usage were rated "good". Table 3.1 and 3.2 also include average RV values.

Tables 3.3, 3.4, and 3.5 contain a statistical summary of the data when subdivided into auction and advertised data sets. Over 50%

Table 3.1. General Statistical Parameters by Year of All Data Used in the Study

Type	N	Mean	Standard Deviation	Maximum Value	Minimum Value
1985	2974				
Age		7.6	3.32	14	0
Condition		2.05	0.78	4	1
Remaining Value		0.36	0.19	1.27	0.04
1986	1196				
Age		7.71	3.35	15	1
Condition		2.0	0.25	4	1
Remaining Value		0.39	0.2	1.35	0.04
1987	2983				
Age		8.9	3.28	16	1
Condition		1.87	0.52	4	1
Remaining Value		0.37	0.18	1.4	0.05
Pooled	7153				
Age		8.2	3.36	16	0
Condition		1.97	0.65	4	1
Remaining Value		0.37	0.19	1.4	0.04

Table 3.2. General Statistical Parameters by Year of all Data Reporting Usage Information

Type	N	Mean	Standard Deviation	Maximum Value	Minimum Value
1985	818				
Age		6.9	2.92	14	0
Usage		2134.9	1351.5	8500	50
Condition		1.94	0.74	3	1
Usage Per Year		312.1	164.3	1600	0
Remaining Value		0.38	0.18	1.09	0.06
1986	365				
Age		7.2	3.11	15	1
Usage		2414.5	1355.2	9177	20
Condition		1.99	0.58	4	1
Usage Per Year		335.1	148.61	1666.7	10
Remaining Value		0.37	0.19	0.96	0.04
1987	1390				
Age		7.9	3	16	2
Usage		2450.2	1415	9200	7
Condition		1.77	0.53	4	1
Usage Per Year		317.1	164.6	1516.6	2.3
Remaining Value		0.42	0.18	1.4	0.06
Pooled	2573				
Age		7.5	3	16	0
Usage		2344.9	1393.6	9200	7
Condition		1.86	0.62	4	1
Usage Per Year		318.1	162.4	1600	0
Remaining Value		0.4	0.18	1.4	0.04

Table 3.3. Statistical Analysis for 1985 Advertised Versus Auction Data.*

	AGE	N	USAGE	CONDITION	REMAINING VALUE	HORSE POWER
			Advertised			
	1	15	481.0	1.07	0.806	156.6
	2	34	232.5	1.29	0.706	257.2
	3	28	270.5	1.54	0.635	148.5
	4	52	329.7	1.75	0.553	142.5
	5	69	333.7	1.93	0.468	150.2
	6	63	227.7	2.10	0.437	154.5
	7	63	300.3	2.29	0.411	148.2
	8	45	298.4	2.11	0.380	140.8
	9	54	237.5	1.96	0.320	143.3
	10	45	261.9	2.27	0.264	148.8
	11	26	261.9	2.69	0.213	133.4
	12	17	227.2	2.06	0.238	132.6
	13	0	NA	NA	NA	NA
	14	4	265.7	2.50	0.196	115.5
Average	6.5	516	288.8	1.98	0.437	147.3
			Auction			
	1	2	650.0	1.00	0.460	175.0
	2	5	261.2	1.20	0.674	135.0
	3	18	251.4	1.80	0.436	143.1
	4	27	347.5	1.52	0.429	132.4
	5	32	407.3	1.75	0.339	149.8
	6	37	332.5	1.76	0.306	146.3
	7	28	373.0	1.93	0.290	149.0
	8	30	353.8	1.97	0.278	145.6
	9	38	360.2	1.87	0.233	130.8
	10	37	363.8	2.05	0.215	129.7
	11	21	359.4	2.29	0.159	131.2
	12	19	312.9	2.32	0.173	123.8
	13	0	NA	NA	NA	NA
	14	8	343.2	2.50	0.122	118.6
Average	7.5	302	352.0	1.87	0.286	138.2

*All observations not reporting usage were excluded.

Table 3.4. Statistical Analysis for 1986 Advertised Versus Auction Data.*

	AGE	N	USAGE	CONDITION	REMAINING VALUE	HORSE POWER
Advertised						
	1	1	100.0	2.00	0.950	166.0
	2	4	282.9	2.00	0.790	153.0
	3	30	338.5	2.00	0.683	156.9
	4	23	345.6	2.00	0.555	162.7
	5	20	319.6	1.85	0.493	162.3
	6	33	367.1	2.09	0.423	150.4
	7	22	285.1	2.00	0.440	151.7
	8	23	307.8	2.13	0.403	156.0
	9	13	353.3	2.08	0.327	164.0
	10	13	285.3	2.00	0.326	146.3
	11	14	306.2	2.07	0.291	160.6
	12	5	333.3	2.00	0.165	158.0
	13	3	294.8	2.00	0.213	134.7
	14	1	285.7	2.00	0.207	117.0
	15	2	250.6	2.00	0.219	136.0
Average	6.6	207	324.2	2.09	0.458	155.7
Auction						
	1	0	NA	NA	NA	NA
	2	4	383.4	1.25	0.548	166.5
	3	5	406.3	1.20	0.457	161.8
	4	16	257.9	1.50	0.422	136.8
	5	11	372.8	1.55	0.367	141.6
	6	22	382.5	1.64	0.270	133.5
	7	14	365.1	1.86	0.320	147.3
	8	11	412.2	2.55	0.213	138.0
	9	15	366.0	2.07	0.216	122.8
	10	18	359.3	2.22	0.214	148.0
	11	18	284.2	2.22	0.165	138.8
	12	12	338.5	2.00	0.156	129.9
	13	5	403.1	3.00	0.155	121.6
	14	2	325.7	2.00	0.192	96.0
	15	4	326.4	2.00	0.148	116.5
Average	8	158	349.3	1.95	0.264	137.6
FARMER RETIRING	7.9	121	340.6	1.92	0.276	139.1
CONSIGNMENT	8.4	23	320.6	1.96	0.211	134.3
BANKRUPTCY	9.3	11	474.0	2.18	0.216	125.2
DEALER CLOSEOUT	4.3	3	465.0	2.33	0.386	149.3

*All observations not reporting usage were excluded.

Table 3.5. Statistical Analysis for 1987 Advertised Versus Auction Data.*

	AGE	N	USAGE	CONDITION	REMAINING VALUE	HORSE POWER
				Advertised		
	1	0	NA	NA	NA	NA
	2	0	NA	NA	NA	NA
	3	37	322.1	1.22	0.759	164.8
	4	144	316.1	1.56	0.667	161.2
	5	96	351.2	1.71	0.510	163.4
	6	130	354.9	1.75	0.481	159.1
	7	138	327.2	1.77	0.456	165.8
	8	145	326.4	1.80	0.426	154.7
	9	109	295.6	1.83	0.399	150.6
	10	57	312.2	1.95	0.314	157.5
	11	75	297.0	1.97	0.283	146.6
	12	40	233.0	1.96	0.288	143.4
	13	27	271.3	2.04	0.232	128.6
	14	25	250.3	2.08	0.262	135.1
	15	0	NA	NA	NA	NA
	16	7	162.6	2.89	0.215	121.9
Average	7.5	1040	315.4	1.77	0.457	150.1
				Auction		
	1	0	NA	NA	NA	NA
	2	0	NA	NA	NA	NA
	3	11	293.4	1.18	0.522	151.9
	4	10	498.0	1.30	0.518	140.7
	5	18	392.4	1.67	0.429	151.6
	6	41	316.4	1.34	0.392	142.4
	7	27	345.2	1.63	0.370	142.0
	8	40	329.7	1.85	0.309	136.7
	9	43	309.7	1.77	0.320	137.0
	10	28	342.0	1.93	0.257	130.8
	11	37	294.8	1.76	0.216	132.2
	12	40	308.0	2.00	0.221	125.7
	13	22	270.1	1.95	0.172	134.1
	14	21	347.6	2.14	0.202	120.4
	15	0	NA	NA	NA	NA
	16	12	216.2	2.16	0.155	112.3
Average	9.3	350	322.1	1.77	0.299	135.0
FARMER RETIRING	9.3	233	301.1	1.67	0.308	132.0
CONSIGNMENT	9.1	55	352.5	1.93	0.279	143.6
BANKRUPTCY	9.9	42	406.1	2.12	0.245	128.0
DEALER CLOSEOUT	7.6	20	318.7	1.70	0.369	149.8

*All observations not reporting usage were excluded.

of all tractors reported were 5-10 years of age. In 1985 advertised data, for instance, 53.5% of the observations were for 5-10 year old tractors, with 64.9% of 1987 advertised data in this range. Tractors manufactured in 1980, 1979, and 1983 were most common in the advertised data, and those manufactured in 1976, 1975 and 1979 were predominant in the auction data. The dominance of pre-1981 tractors is not surprising, given production of larger tractors has been in continual decline since 1978 (and particularly since 1982). Observations for 1-2 year old tractors were nearly nonexistent, particularly in the auction data. The distribution of the number of observations by year for 1987 advertised and auction data can be seen in figure 3.1.

Average age for advertised tractors is somewhat lower than that of auction tractors. This result can probably be attributed to a reluctance by farmers to use older tractors as a trade-in[1].

The average usage for tractors in the advertised data in all years examined is less than that for auction data. This difference can probably be traced to a bias in the advertised data. Auctioneers have no reason not to report hours of use for tractors with higher versus low usage. Equipment dealers, on the other hand. would probably not advertise hours of use if it were above average, since the information may limit the number of potential buyers.

Average usage is about 350 hours per year for auction data and 300 hours per year for advertised data. Average use tends to trend

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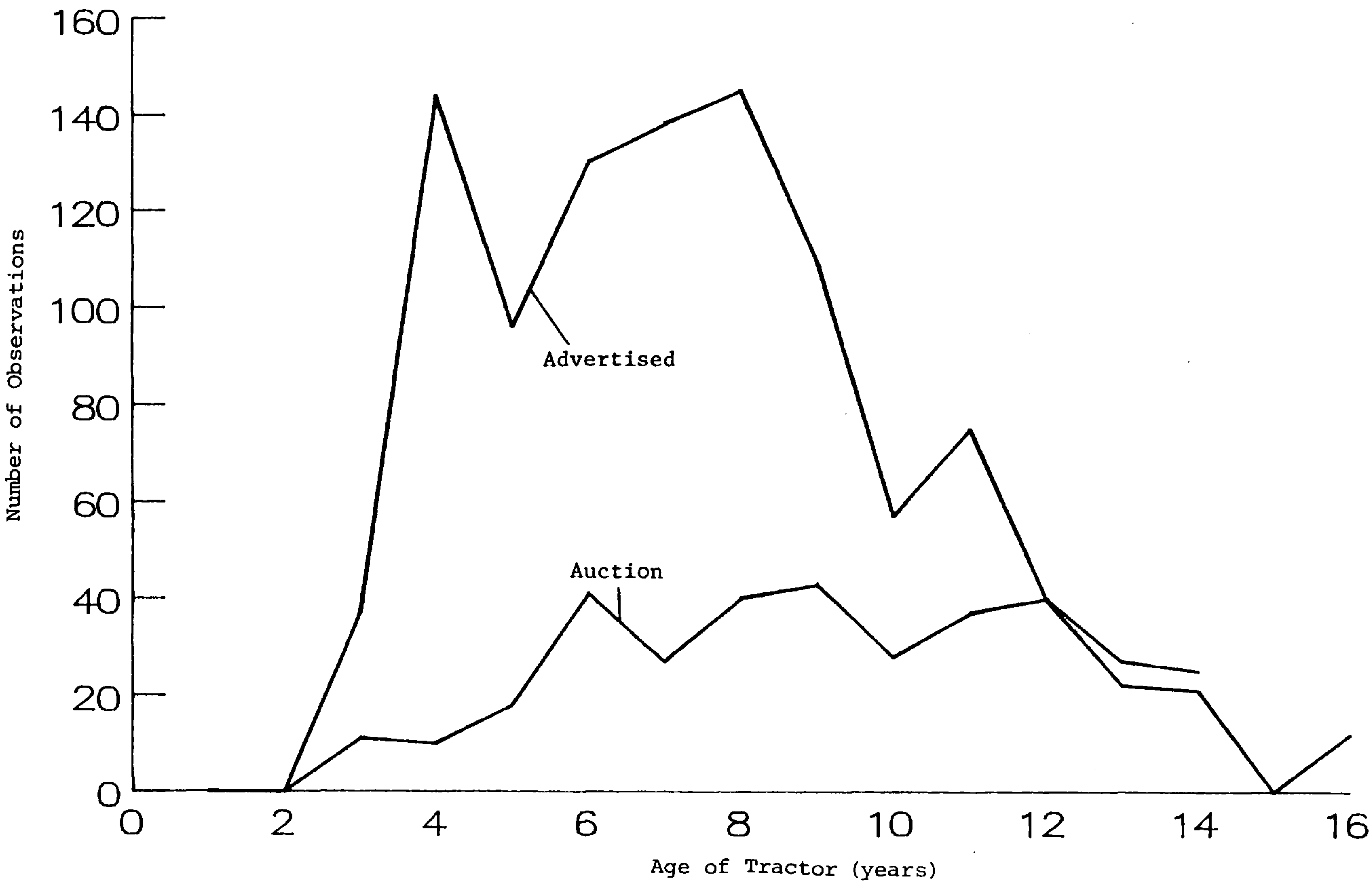
[1] Reasons for this are discussed in Chapter 2.

Figure 3.1. The distribution of the number of observations for 1987 by data type.



downward for both advertised and auction tractors, particularly after the age of 10 years. This result can partly be attributed to retirement of high use tractors, leaving only tractors with low annual use still in operation after 10-15 years. This declining pattern may also be indicative of declining tractor use, resulting from technological obsolescence and lower reliability. The average usage per year distribution for 1986 is shown in figure 3.2.

Average tractor condition tended to decline with age in both advertised and auction data. The average conditions are the same or higher for advertised versus auction data. The condition distribution for 1985 advertised and auction data are presented in figure 3.3.

Average remaining values are also reported in the tables. Again, RV of advertised data is higher than that of auction data, supporting the idea that advertised prices are above actual transaction prices. Average horsepower was higher for advertised versus auction tractors suggesting farmers may also be less willing to trade in smaller tractors because they are not sufficiently compensated.

Tables 3.4 and 3.5 also include statistical breakdown of data by auction type. The analysis was not done for 1985 data because auction type was not reported. The dominant auction type is for a farmer retiring, representing 67% of all 1987 observations and 77% of all 1986 observations. Consignment, bankruptcy, and dealer closeout auction follow farmer retirement in number. Tractors sold in dealer closeout auctions are younger than other auction types, consistent

Figure 3.2. The average usage per year distribution for 1986 by data type.

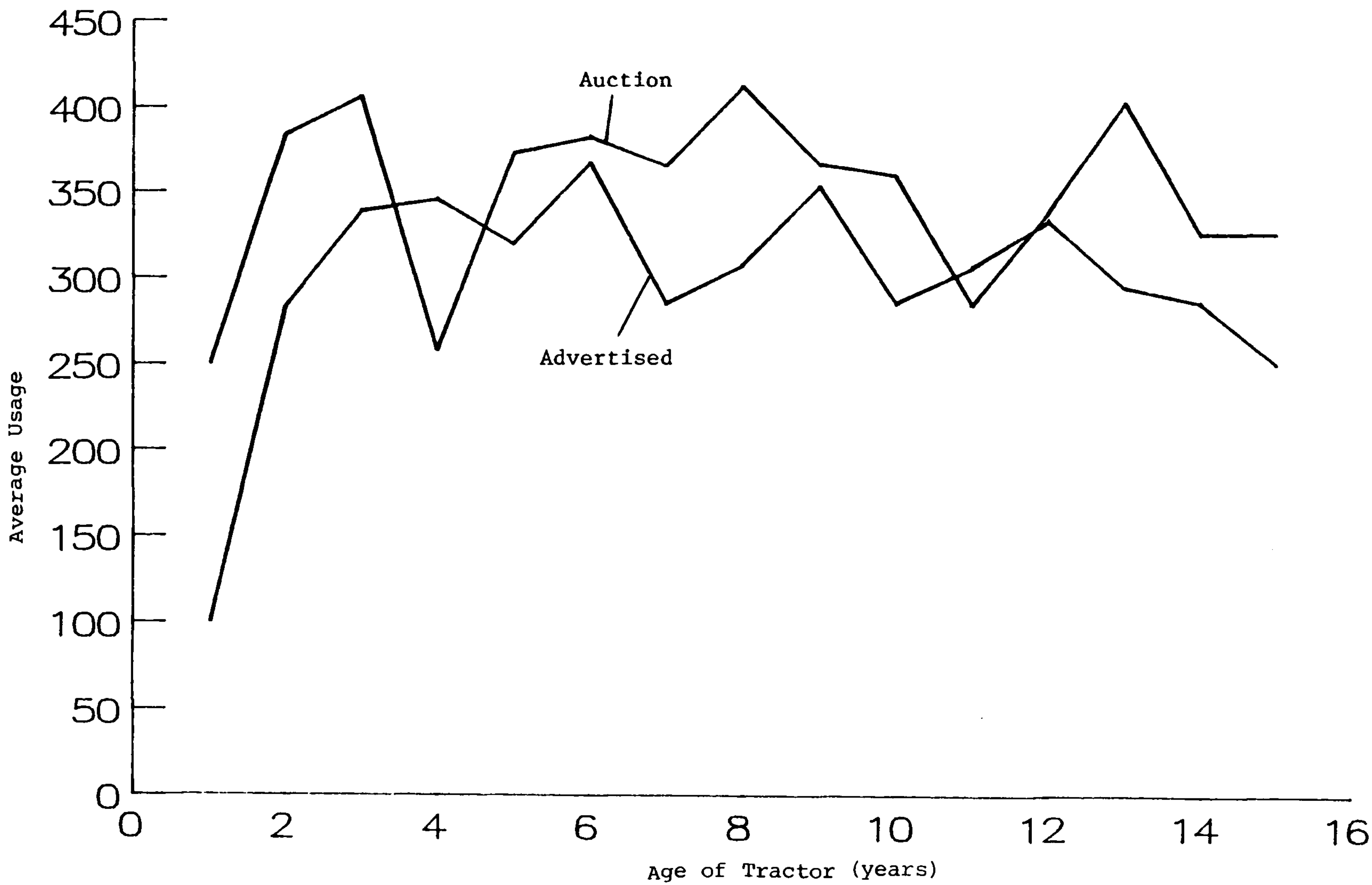
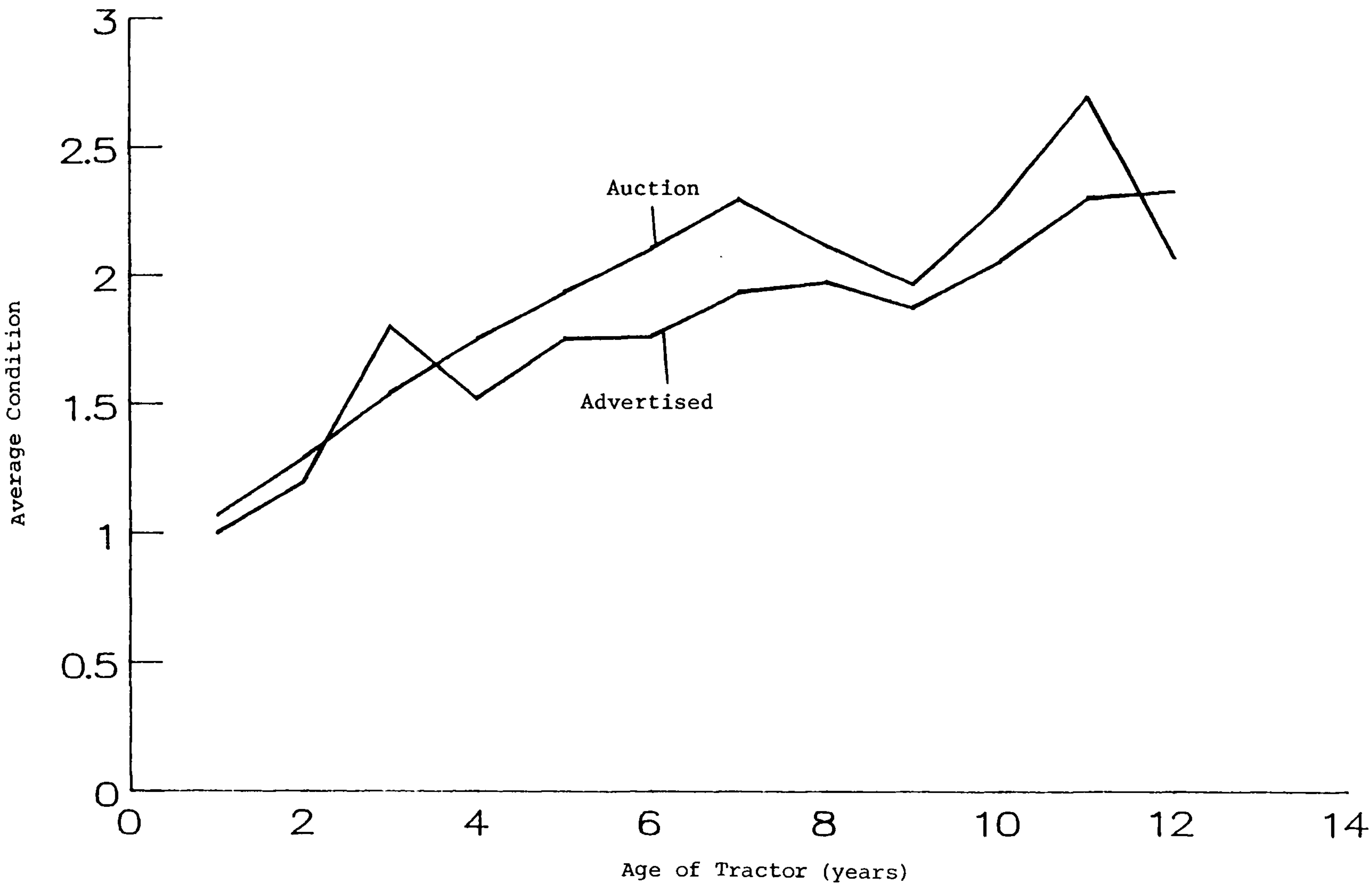


Figure 3.3. The average condition distribution for 1985 by data type.



with the pattern demonstrated in the advertised data. Tractors from bankruptcy sales had an average usage level that was well above average.

Seven companies are represented in the data set. A percentage breakdown of the data set by company is reported in Table 3.6. Statistical analyses of key variables by company are reported in Tables 3.7, 3.8, and 3.9 for each year. John Deere dominates in the data set with roughly half of all observations. This result clearly shows that John Deere dominates the market for large tractors.

The second dominant company in 1985 is International Harvester with 26.7% of advertised data and 26.8% of auction data. International Harvester decreased to 11.1% of 1986 advertised data, and increased to 29.1% of auction data. Case was the dominant company in 1986 and 1987 advertised data (16.9% and 14.4%, respectively). The drop in International Harvester tractors advertised by dealer after 1985 may be the result of the company's buy out by JI Case in 1986.

Ford and Massey-Ferguson tractors were generally older than average and John Deere tractors were newer. Ford tractors were much smaller than average, reflecting the company's lack of market share in larger tractors. Case tractors were on average larger than tractors manufactured by other companies.

Average usage varies from company to company, as well as average condition. John Deere tractors generally had the highest average usage. One possible hypothesis to explain this difference is that

Table 3.6. Percentage Breakdown of Data Set by Company.*

COMPANIES	1985	1986	1987
	Advertised		
AC	7.2%	4.8%	5.6%
CASE	14.5%	16.9%	14.4%
FORD	2.9%	0.5%	0.7%
DEERE	40.5%	64.3%	63.7%
IH	26.7%	11.1%	10.8%
MF	4.1%	2.4%	3.4%
WHITE	4.1%	0.0%	1.4%
	Auction		
AC	3.3%	6.3%	7.8%
CASE	9.6%	8.9%	6.5&
FORD	2.7%	3.2%	2.9%
DEERE	55.0%	46.8%	52.3%
IH	26.8%	29.1%	24.7%
MF	2.0%	4.4%	2.9%
WHITE	0.6%	1.3%	2.9%

*All observations not reporting usage were excluded.

Table 3.7. Statistical Analysis for 1985 Advertised Versus Auction Data by Company.*

MAKE	AGE	N	USAGE	CONDITION	REMAINING VALUE	HORSE POWER
				Advertised		
AC	6.2	37	247.2	1.97	0.400	144.6
CASE	6.5	75	276.5	2.15	0.392	170.3
FORD	7.4	15	298.9	1.53	0.399	110.5
DEERE	5.9	209	334.5	1.86	0.550	146.4
IH	7.2	138	264.8	2.01	0.336	142.1
MF	7.4	21	199.8	2.78	0.311	147.5
WHITE	7.3	21	191.3	2.24	0.355	137.4
				Auction		
AC	6.6	10	257.5	1.60	0.243	154.0
CASE	7.0	29	299.0	1.76	0.247	154.1
FORD	8.6	8	308.7	2.25	0.256	107.0
DEERE	8.6	166	367.6	1.85	0.342	136.0
IH	7.6	81	354.0	1.94	0.211	138.2
MF	10.0	6	346.1	2.17	0.172	138.8
WHITE	9.0	2	400.6	1.50	0.120	129.0

*All observations not reporting usage were excluded.

Table 3.8. Statistical Analysis for 1986 Advertised Versus Auction Data by Company.*

MAKE	AGE	N	USAGE	CONDITION	REMAINING VALUE	HORSE POWER
			Advertised			
AC	9.3	10	277.8	2.00	0.281	155.4
CASE	6.7	35	273.3	2.18	0.371	166.9
FORD	10.0	1	320.0	2.00	0.492	106.0
DEERE	6.2	133	354.8	1.99	0.529	153.6
IH	7.8	23	272.5	2.09	0.281	153.4
MF	6.2	5	219.6	2.00	0.326	152.0
WHITE	0	NA	NA	NA	NA	NA
			Auction			
AC	7.7	10	397.4	1.80	0.157	152.3
CASE	8.4	14	291.5	1.93	0.218	153.6
FORD	9.0	5	461.1	1.80	0.220	94.0
DEERE	7.8	74	363.4	1.79	0.335	136.9
IH	8.0	46	338.7	2.15	0.216	134.8
MF	10.6	7	276.9	2.29	0.156	141.3
WHITE	6.0	2	213.2	3.00	0.134	144.0

*All observations not reporting usage were excluded.

Table 3.9. Statistical Analysis for 1987 Advertised Versus Auction Data by Company.*

MAKE	AGE	N	USAGE	CONDITION	REMAINING VALUE	HORSE POWER
			Advertised			
AC	8.6	58	228.7	1.97	0.321	149.1
CASE	7.4	150	271.5	1.74	0.381	170.1
FORD	10.4	7	254.3	2.00	0.287	106.3
DEERE	7.0	663	348.1	1.72	0.527	156.8
IH	8.5	112	270.1	1.87	0.313	143.4
MF	9.2	35	218.0	2.00	0.285	153.3
WHITE	10.1	15	237.6	2.20	0.251	135.2
			Auction			
AC	9.3	27	236.8	1.63	0.205	137.1
CASE	8.4	22	264.2	1.55	0.262	153.1
FORD	11.3	10	257.9	1.80	0.229	105.0
DEERE	8.9	180	376.3	1.83	0.368	136.3
IH	9.8	85	288.6	1.75	0.229	132.4
MF	10.1	10	218.1	1.60	0.225	125.6
WHITE	9.9	10	219.0	1.75	0.204	131.4

*All observation not reporting usage were excluded.

John Deere tractors are sold to larger farming operations and are used more heavily by these operations.

John Deere tractors seemed to maintain their value over time much better than tractors manufactured by others, although caution is in order since average age is lower for John Deere. Allis-Chalmers seemed to lose their value at the fastest rate, perhaps because the company was in serious financial trouble during this period.

A statistical analysis by horsepower was also conducted. Horsepower was divided into eight categories and statistical analyses were done by year and by data type. The results are presented in Table 3.10.

One of the most interesting observations here is the dominance of the auction data set by 120-135 horsepower tractors. Also noticeable is the decline in average age and the increase in average usage as horsepower increases. In part this pattern may be the result of a continued desire by farmers to buy larger tractors than they previously owned. Presuming larger firms are buying the larger tractors suggests they may use them more heavily and trade them in sooner than smaller tractors.

Finally, a statistical analysis by region was performed. as noted earlier, the U.S. was divided into nine regions (see figure 2). A percentage breakdown of data set was done by year and by data type. The results are presented in Table 3.11.

Region 4 dominates in both advertised and auction data sets with roughly one third of all observations, followed by region 2 with 21% of advertised and 17% of auction data. Although region 9 had a

Table 3.10. Statistical Analysis for 1985-1987 Advertised Versus Auction Data by Horsepower.*

HORSEPOWER	AGE	N	USAGE	CONDITION	REMAINING VALUE
			Advertised		
80-100	7.9	90	271.27	2.01	0.46
100-120	7.7	196	276.17	1.98	0.44
120-135	7.7	399	316.50	1.92	0.47
135-150	6.7	246	267.93	1.83	0.44
150-165	7.8	341	319.26	1.93	0.39
>160- 2WD	6.1	367	307.79	1.81	0.48
160-200 4WD	7.5	101	301.52	1.75	0.38
>200- 4WD	6.6	183	357.90	1.70	0.41
			Auction		
80-100	10.1	81	323.59	1.92	0.29
100-120	8.9	141	304.63	1.73	0.30
120-135	8.5	286	351.16	1.81	0.30
135-150	8.6	105	325.04	1.94	0.22
150-165	8.3	127	342.04	1.93	0.26
>160-2WD	6.1	86	338.83	1.71	0.32
160-200 4WD	7.8	28	438.10	1.82	0.29
>200-4WD	7.3	29	367.33	2.13	0.25

*All observations not reporting usage were excluded.

Table 3.11. Percentage Breakdown of Data By Region
Advertised Versus Auction Data.

Regions	1985	1986	1987	Pooled
		Advertised		
1 Western Great Plains	7.88%	5.34%	12.39%	8.53%
2 Central Great Plains	15.86%	20.11%	27.11%	21.03%
3 Southern Great Plains	5.95%	2.95%	9.36%	6.09%
4 Western Corn Belt	26.43%	55.45%	28.22%	36.70%
5 Eastern Corn Belt	10.91%	3.64%	10.56%	8.37%
6 Northeast	8.73%	2.61%	5.81%	5.72%
7 Southeast	3.87%	0.34%	0.12%	1.45%
8 South Central	5.70%	0.80%	0.47%	2.33%
9 West	14.63%	8.75%	5.94%	9.77%
		Auction		
1 Western Great Plains	6.37%	6.00%	8.38%	6.92%
2 Central Great Plains	16.91%	23.97%	12.11%	17.66%
3 Southern Great Plains	7.20%	8.20%	5.13%	6.84%
4 Western Corn Belt	29.54%	28.71%	34.47%	30.91%
5 Eastern Corn Belt	16.81%	14.51%	18.01%	16.44%
6 Northeast	2.71%	0.00%	3.73%	2.15%
7 Southeast	7.83%	10.41%	7.76%	8.67%
8 South Central	9.60%	7.89%	5.13%	7.54%
9 West	3.03%	0.00%	5.28%	2.77%

number of observations in 1985 advertised data, neither it nor region 6 were represented in 1986 auction data. This suggests few auctioneers in the West are participating in Hot Line's data gathering process.

Statistical analyses of key variables by region for the pooled data set is reported in Table 3.12. Average age is the lowest in region 9 in both advertised and auction data sets. The oldest tractors were in region 5 for advertised data and in region 6 for auction data. The highest average usage was 514 hours in region 3 in auction data. Usage tended to be higher than average in the Southern regions for auction data. In advertised data, however, the highest average usage is 357 hours in regions 2 and 3. Region 9 had the highest RV, no doubt reflecting the distance from the West to the factories in the Midwest.

A number of insights were gained as a result of this statistical analysis. Average usage is well below the level assumed by Reid and Bradford and others. Average usage for auction data is about 350 hours per year and 300 hours for advertised data. Average usage tends to decline over time, particularly after the tractor reaches 10 years of age. Average usage is highest for John Deere tractors. Total usage levels suggest virtually all tractors are retired before 7,000-8,000 hours. This result implies a 10,000 hour equipment life (which is the ASAE standard) probably represents its maximum or engineered life.

Table 3.12. Statistical Analysis for Pooled Data by Region Advertised Versus Auction Data.*

REGION	AGE	N	USAGE	CONDITION	REMAINING VALUE
			Advertised		
1	6.9	206	317.04	1.83	0.50
2	6.7	433	357.29	1.87	0.48
3	6.5	150	357.86	1.90	0.46
4	7.5	554	274.17	1.90	0.44
5	7.9	157	246.30	1.78	0.41
6	7.4	128	321.57	1.76	0.38
7	7.2	13	240.17	2.15	0.37
8	6.9	32	269.13	2.00	0.35
9	6.4	90	299.82	1.77	0.51
			Auction		
1	8.9	54	379.40	2.03	0.30
2	8.0	144	336.12	1.65	0.33
3	7.8	63	514.78	1.90	0.29
4	8.4	357	309.90	1.87	0.28
5	9.1	69	252.97	1.65	0.27
6	9.2	22	384.65	1.64	0.24
7	8.1	72	353.54	2.11	0.28
8	8.3	24	390.52	1.88	0.25
9	5.8	4	319.58	1.50	0.41

* All observations not reporting usage were excluded.

Advertised tractors are larger than those sold at auction. Case tractors are larger than average, and Ford, Massey-Ferguson, and White are smaller. Larger tractors tend to be used more heavily and traded-in sooner than smaller tractors. John Deere tractors dominate in the market, and they are on average newer. They also seem to maintain their value over time better than others. The dominant auction type is a farmer retirement auction. Tractors sold by dealers are newer. Auction and advertised data from the Midwest dominate the data set.

CHAPTER 4

EMPIRICAL RESULTS AND IMPLICATIONS

In this chapter the results of the econometric analysis are presented. The analysis is divided into two parts: (1) cross-sectional estimates for each year of data and (2) time series cross-sectional (pooled) estimates for the combined data set. Because so many observations do not report usage, separate estimates were made with and without usage as a variable.

CROSS-SECTIONAL MODELS

Single Year Models without Usage or Condition

Initially, models were estimated for 1985, 1986, and 1987 data. Independent variables were age, horsepower, company dummies, age-company dummies, and regional dummies. Results are reported in Tables 4.1, 4.2, and 4.3 for both auction and advertised data.

The R^2 statistics were above 0.73 for all but one of the models, indicating a good fit for this type of data. The estimates for advertised data consistently exhibited a higher R^2, an expected result given advertised data represents an asking (rather than transaction) price. The highest R^2 was observed in 1985 advertised data (0.8009). Virtually all estimated coefficients were significant at a 99 percent level of confidence.

Age was a very influential variable in all six models, a result consistent with previous depreciation studies. An inverse relationship between age and RV was present in all of the models.

Table 4.1. Econometric Results of Tractor Depreciation Patterns Using 1985 Data.

	Auction		Advertised	
Variables	Coefficient	Std. Error	Coefficient	Std. Error
Intercept	-0.40609*	0.07126	-0.16474*	0.02855
Age	-0.12296*	0.01184	-0.10363*	0.00395
Horsepower	-0.00178*	0.00019	-0.00106*	0.00010
Age dummies				
AC	-0.01165	0.02089	-0.00191	0.00600
Case	-0.00157	0.01567	0.00011	0.00525
Deere	0.01029	0.01275	0.01285*	0.00430
IH	0.00730	0.01321	0.01009**	0.00462
Companies				
AC	0.02861	0.11080	-0.00098	0.03566
Case	0.05421	0.08560	0.06028**	0.03241
Deere	0.22304*	0.07091	0.16027*	0.02688
IH	-0.02978	0.07343	-0.08729*	0.02924
Regions				
R1	0.06733*	0.01571	0.00223	0.00879
R2	-0.00552	0.02393	-0.07238*	0.01492
R4	0.01808	0.01662	-0.05357*	0.00934
R5	-0.00709	0.01729	-0.07512*	0.01219
Power Transformations for:				
RV (λ)	0.35		0.36	
Age (γ)	0.76		0.89	
Statistics:				
$\bar{R}^2$	0.6526		0.8009	
Log-Likelihood	1235.45		2236.46	
N	958		2017	

* Significant at the 0.01 level.
** Significant at the 0.05 level.

Table 4.2. Econometric Results of Tractor Depreciation Patterns Using 1986 Data.

Variables	Auction		Advertised	
	Coefficient	Std. Error	Coefficient	Std. Error
Intercept	-0.50749*	0.09017	0.04917	0.07728
Age	-0.10380*	0.01561	-0.13668*	0.01449
Horsepower	-0.00096*	0.00027	-0.00159*	0.00016
Age dummies				
AC	0.01154	0.03299	0.04675*	0.01982
Case	-0.05921**	0.02740	0.00908	0.01617
Deere	-0.02993**	0.01730	0.01095	0.01492
IH	-0.02982	0.01624	0.01870	0.01659
Companies				
AC	-0.15625	0.15672	-0.32371*	0.10377
Case	0.27065**	0.14187	-0.07814	0.08155
Deere	0.35727*	0.08907	0.11481	0.07658
IH	0.11803	0.10024	-0.18060**	0.08543
Regions				
R1	0.00070	0.02129	-0.00734	0.01235
R2	-0.10957*	0.03240	0.01061	0.03153
R4	-0.03175	0.02626	-0.01941	0.02203
R5	-0.12838*	0.02462	-0.15172*	0.04991
Power Transformations for:				
RV (λ)	0.45		0.45	
Age (γ)	0.65		0.71	
Statistics:				
$\bar{R}^2$	0.7321		0.7687	
Log-Likelihood	443.486		845.822	
N	317		880	

* Significant at the 0.01 level.
** Significant at the 0.05 level.

Table 4.3. Econometric Results of Tractor Depreciation Patterns Using 1987 Data.

	Auction		Advertised	
Variables	Coefficient	Std. Error	Coefficient	Std. Error
Intercept	-0.14603	0.10310	-0.17741*	0.06534
Age	-0.13182*	0.01486	-0.12036*	0.01143
Horsepower	-0.00252*	0.00025	-0.00188*	0.00009
Age dummies				
AC	0.01162	0.02127	-0.02253	0.01410
Case	-0.02650	0.01970	-0.04059*	0.01260
Deere	0.00102	0.01582	-0.02124**	0.01165
IH	-0.00394	0.01673	-0.02411**	0.01261
Companies				
AC	-0.15674	0.13462	0.15481*	0.07777
Case	0.16687	0.12434	0.34496*	0.06919
Deere	0.31637*	0.10237	0.44556*	0.06459
IH	0.01919	0.10988	0.13669**	0.07035
Regions				
R1	-0.03204**	0.01827	-0.01399**	0.00732
R2	-0.10075*	0.03179	-0.04853*	0.01157
R4	-0.06202*	0.01829	-0.02636*	0.00939
R5	-0.19584*	0.02200	-0.09450*	0.04062
Power Transformations for:				
RV (λ)	0.27		0.32	
Age (γ)	0.74		0.69	
Statistics:				
$\bar{R}^2$	0.7957		0.7995	
Log-Likelihood	939.0		2725.6	
N	644		2339	

* Significant at the 0.01 level.
** Significant at the 0.05 level.

The sign of the company dummies for age are varied. In 1986, for example, John Deere and Case have positive and statistically significant coefficients in the auction model, indicating that these companies' tractors depreciated at a slower rate over time than did the default companies. On the other hand, in the 1987 advertised price model, all intercept dummies are positive but all company-age dummies are negative, suggesting that companies included as default (Ford, Massey-Ferguson, and White) have a larger drop in RV when initially sold but depreciate more slowly after that point. The difference in RV between companies for 1987 auction prices is shown in figure 4.1. The values for John Deere lie above all other companies, while those for Allis-Chalmers are the lowest. The default companies follow a depreciation pattern that is virtually identical to International Harvester.

Horsepower had a significant and negative sign in all of the models. This result may have occurred because list prices were relatively higher than initial sales price for larger versus smaller tractors. Or, it may suggest that demand for large size tractors is not as great as is the case for smaller tractors.

The difference in depreciation patterns between advertised and auction data by year are shown in figure 4.2 for John Deere tractors[2]. As expected, RV for advertised data lie above that for

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[2] Throughout the text, depreciation patterns for John Deere tractor are graphed because of its dominance among the companies examined. Horsepower was held constant at 130 in all figures, approximately the average horsepower level in the data.

Figure 4.1. Depreciation patterns for 1987 auction data by company.

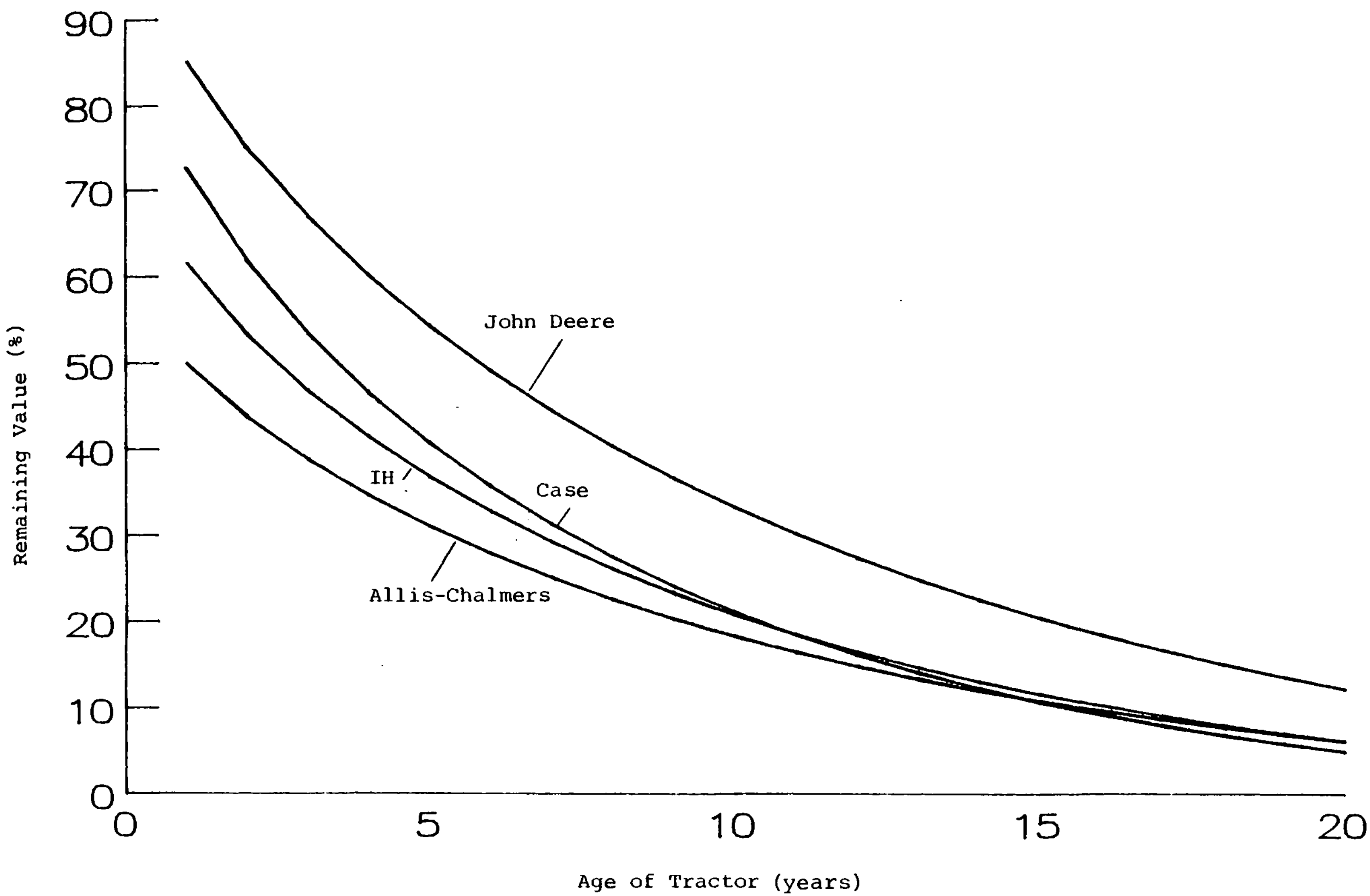
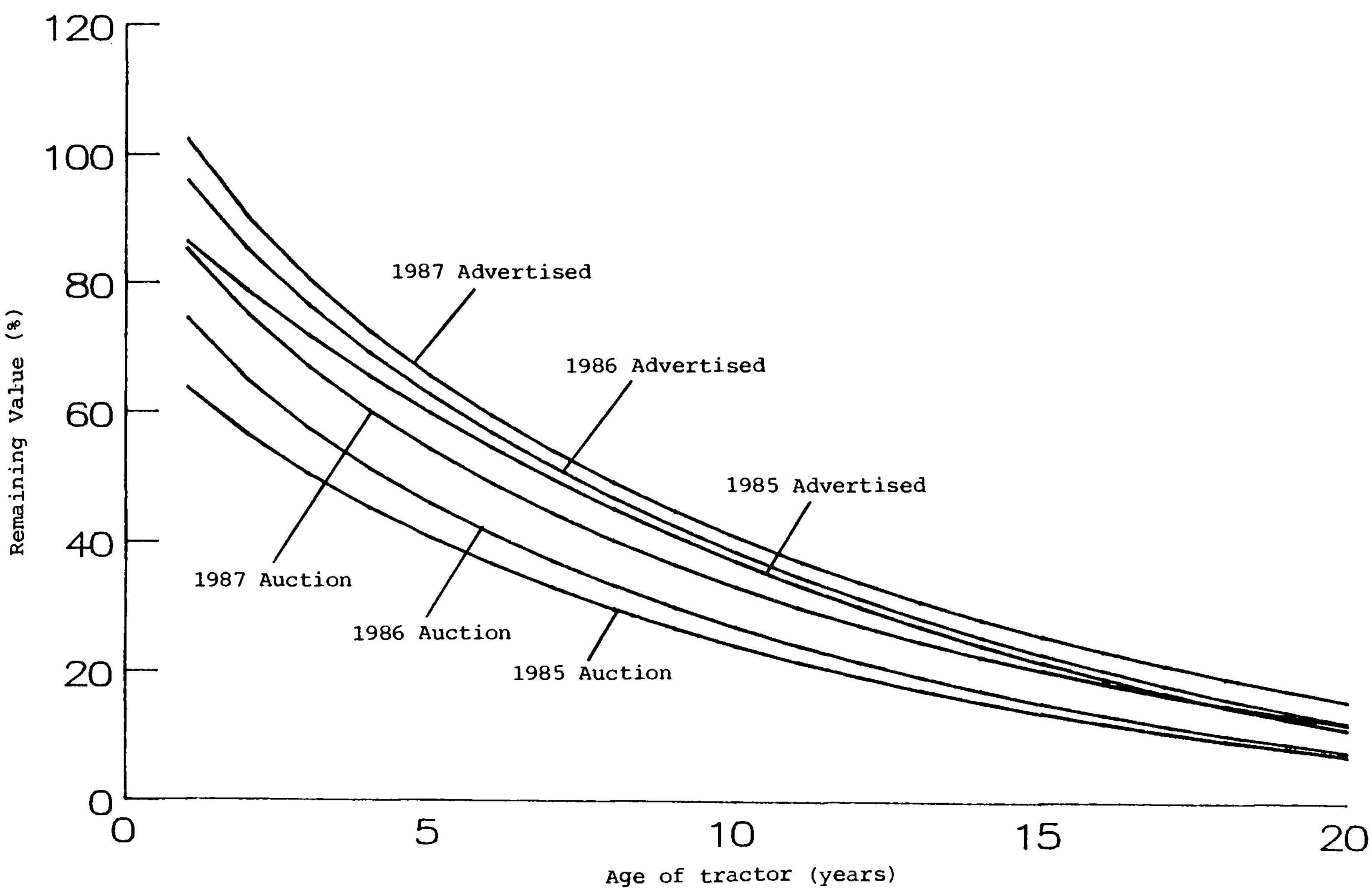


Figure 4.2. Depreciation patterns for John Deere tractor by year and data type.



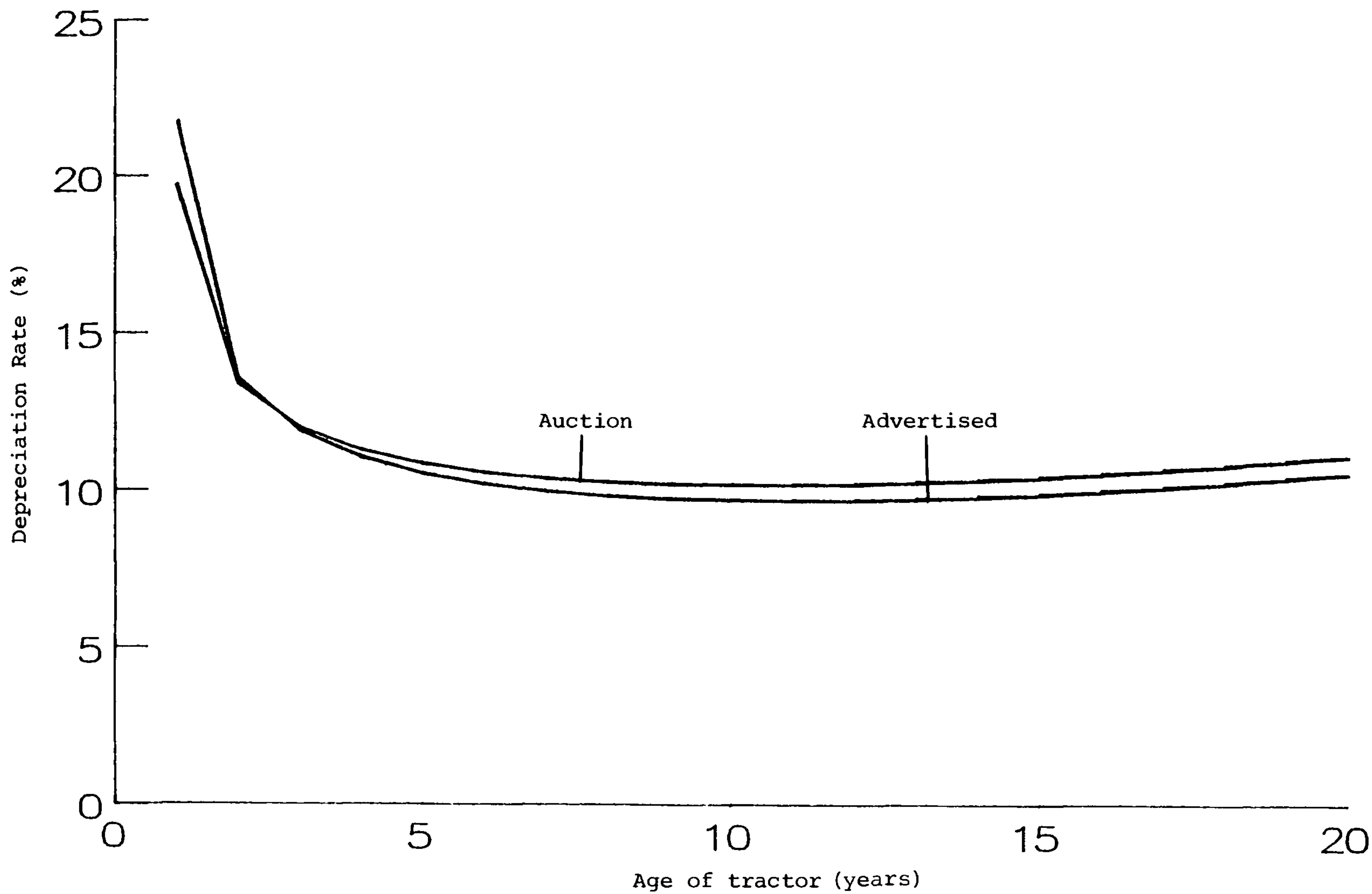
auction data. A yearly upward shift can be seen for both types of data and is attributed to the improving farm economy during that period.

There was a marked difference in RVs for different years of the same type of data, but depreciation patterns were similar. Tractors sold in 1985 were initially discounted more heavily and seemed less influenced by age than those sold in 1986 or 1987. The year-to-year changes in auction depreciation patterns was much larger than changes in the advertised depreciation patterns.

The difference between advertised and auction data patterns for 1985 is quite wide within the first several years, but narrows thereafter. Convergence of depreciation patterns for 1987 data in later years is also of interest. In this case, the gap is much narrower, suggesting an increase in demand for tractors at the auction level that was not fully reflected in 1987 advertised prices. The difference between advertised and auction data patterns for 1986 is also narrow and approximately the same each year.

The data exhibited a decreasing rate of depreciation with respect to an increase in age for both auction and advertised data in each year considered. Depreciation rates for 1987 for John Deere tractors are shown in figure 4.3. Because power transformations did not exhibit a so-called geometric pattern, a constant depreciation rate was rejected. Depreciation rates were higher for auction versus advertised data after year three. Initially the rates were higher for advertised data, however.

Figure 4.3. Depreciation rates for John Deere tractor for 1987 by data type.



Regions had some effect on explaining differences in RV, particularly in 1987. Almost all the coefficients for both auction and advertised data were negative, indicating that prices were generally highest in the default region (Western Corn Belt).

The differences in RV were not very large between regions. For an average aged tractor (9 years) in 1987, for instance, the difference between default region (Western Corn Belt) and region R1 (Northern High Plains) was 0.02 (or $1,000 for a $50,000 list price tractor). It was 0.014 between R1 and R4 (Eastern Corn Belt). The biggest difference was 0.09 for the R5 (South). These results suggest there was not much difference in RV from region to region, and that most of the difference probably represents transportation costs and regional supply and demand.

It was hypothesized that depreciation patterns for advertised tractors were equal to those for auction tractors within the same year. This hypothesis was tested using the log likelihood ratio test. The test is computationally more demanding than others (Wald test and Langrangian multiplier) because it requires both restricted and unrestricted estimates (Judge et al.). The test statistics were 1340.1 for 1985, 355.9 for 1986, and 583.7 for 1987. The hypothesis that the auction and advertised data exhibited the same depreciation patterns was rejected in all years at the 99 percent confidence level (Chi-square test statistics for 15 degrees of freedom is 30.9).

Single Year Models without Condition

Usage was next added to the model, and observations not reflecting usage were removed from the data. Estimation results are presented in Tables 4.4, 4.5, and 4.6 for both auction and advertised data. All $\bar{R}^2$ statistics were above 0.75. There was quite a large increase in $\bar{R}^2$ in 1985 and 1986 for both auction and advertised data models. However, 1987 data exhibited a slightly lower $\bar{R}^2$ [3]. Most of the estimated coefficients were statistically significant at a 99 percent level of confidence.

Other differences are also noticeable. The RV transformation coefficients increased and age transformation coefficients generally declined when usage was added to the auction data model. Just the opposite effect occurred for the advertised data model. Even though the coefficients of usage were significant, usage was not as important an explanatory variable as age.

The power transformation for age in 1986 advertised data increased from 0.71 to 1.12, indicating (in combination with the RV transformation) that the depreciation patterns exhibited an accelerated depreciation rate when usage was constant. The depreciation rates for 1987 for a John Deere tractor are presented in figure 4.4. Usage was held constant at an average of 350 hours per year. A comparison with figure 4.3 suggests a constant usage level

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[3] Because the Box-Cox technique optimizes the log-likelihood function it is possible that $\bar{R}^2$ statistics may decline as additional variables are added.

Table 4.4. Econometric Results of Tractor Depreciation Patterns Using 1985 Data Reporting Usage Information.

Variables	Auction		Advertised	
	Coefficient	Std. Error	Coefficient	Std. Error
Intercept	-0.24173	0.17570	-0.18254*	0.05485
Age	-0.08537*	0.02115	-0.11205*	0.01038
Use	-0.00427*	0.00064	-0.00022*	0.00007
Horsepower	-0.00128*	0.00026	-0.00107*	0.00016
Age dummies				
AC	0.02854	0.03035	-0.02996**	0.01631
Case	0.02210	0.02439	-0.02762**	0.01437
Deere	0.01151	0.02145	-0.00236	0.01157
IH	0.01318	0.02192	-0.01590	0.01218
Companies				
AC	0.04989	0.20892	0.11178	0.06956
Case	-0.14890	0.18267	0.16772*	0.06302
Deere	0.13196	0.16873	0.25083*	0.05178
IH	-0.14913	0.17178	0.03585	0.05598
Regions				
R1	0.12169*	0.02092	0.00639	0.01450
R2	0.10461*	0.03139	-0.07266*	0.02411
R4	0.04736**	0.02728	-0.07272*	0.01647
R5	0.06549**	0.03203	-0.07798*	0.02427
Power Transformations for:				
RV (λ)	0.41		0.44	
Age (γ)	0.96		0.71	
Use (θ)	0.58		0.89	
Statistics:				
$\bar{R}^2$	0.7579		0.8021	
Log-Likelihood	414.7		597.040	
N	302		517	

* Significant at the 0.01 level.
** Significant at the 0.05 level.

Table 4.5. Econometric Results of Tractor Depreciation Patterns Using 1986 Data Reporting Usage Information.

Variables	Auction Coefficient	Auction Std. Error	Advertised Coefficient	Advertised Std. Error
Intercept	-0.24129	0.15190	-0.31714**	0.15835
Age	-0.09544*	0.03173	-0.02363	0.01898
Use	-0.01337*	0.00184	-0.00501*	0.00089
Horsepower	-0.00063*	0.00026	-0.00175*	0.00032
Age dummies				
AC	-0.01246	0.04132	-0.04047**	0.02223
Case	-0.02497	0.04150	-0.03990**	0.02075
Deere	-0.03811	0.03340	-0.04142**	0.01917
IH	-0.01134	0.03507	-0.00841	0.02199
Companies				
AC	-0.02176	0.16512	0.32658**	0.19018
Case	0.09847	0.17004	0.38172*	0.15474
Deere	0.30769**	0.14131	0.62265*	0.14565
IH	0.03915	0.14696	-0.01930	0.17355
Regions				
R1	0.04379**	0.02012	-0.02846	0.02492
R2	0.04402	0.02826	-0.00040	0.05499
R4	0.04620	0.03218	-0.03523	0.03555
R5	-0.04781*	0.01965	-0.21751*	0.06523
Power Transformations for:				
RV (λ)	0.69		0.26	
Age (γ)	0.49		1.12	
Use (θ)	0.40		0.58	
Statistics:				
$\bar{R}^2$	0.8023		0.8097	
Log-Likelihood	236.5		245.7	
N	157		207	

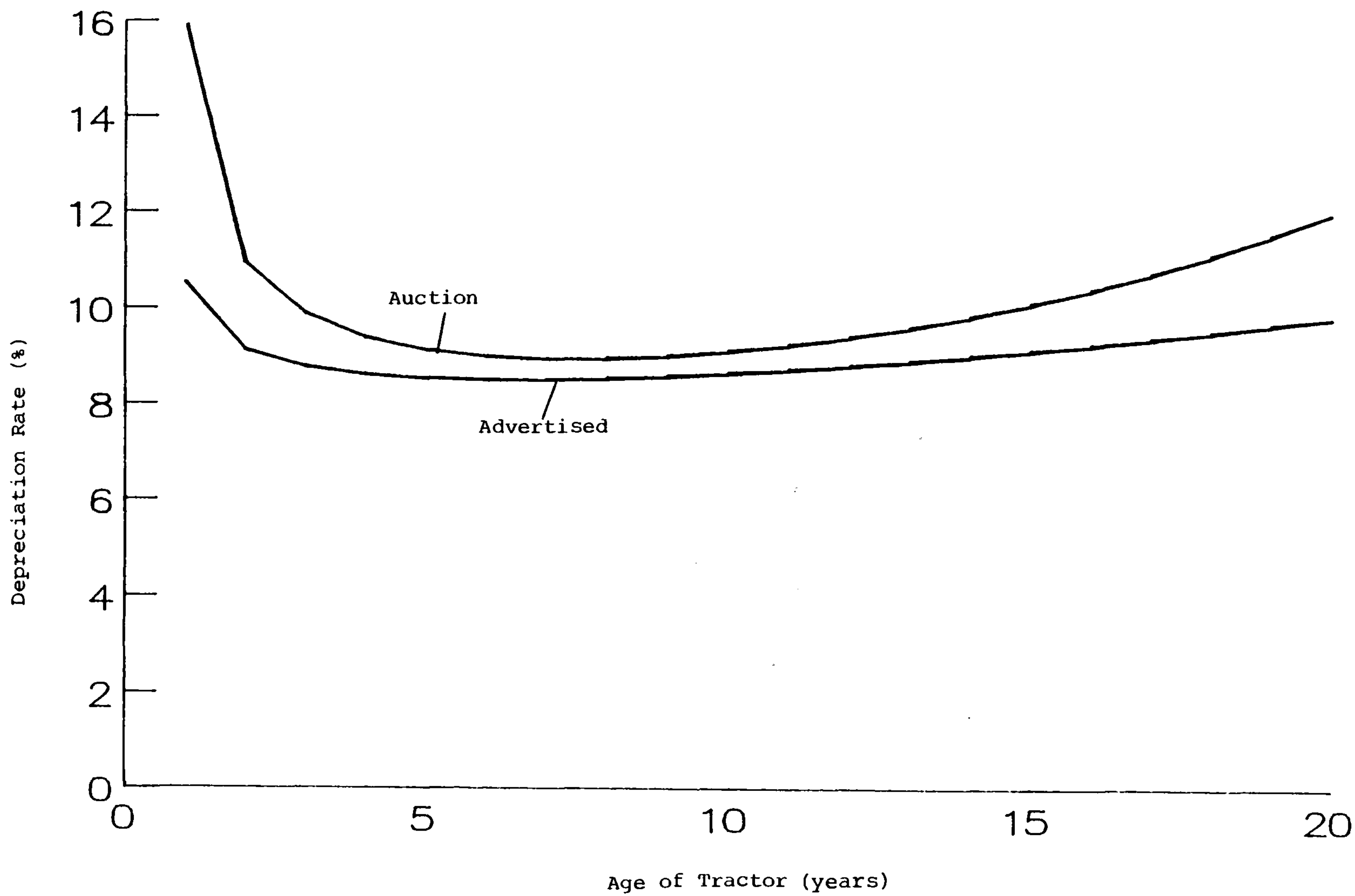
* Significant at the 0.01 level.
** Significant at the 0.05 level.

Table 4.6. Econometric Results of Tractor Depreciation Patterns Using 1987 Data Reporting Usage Information.

Variables	Auction Coefficient	Auction Std. Error	Advertised Coefficient	Advertised Std. Error
Intercept	-0.01586	0.11590	-0.21887*	0.08482
Age	-0.11689*	0.01800	-0.09027*	0.01113
Use	-0.01602*	0.00204	-0.00006*	0.00001
Horsepower	-0.00167*	0.00024	-0.00172*	0.00013
Age dummies				
AC	0.02164	0.02278	-0.02634**	0.01471
Case	0.01364	0.02391	-0.01611	0.01317
Deere	0.00717	0.01870	-0.00650	0.01142
IH	0.00757	0.01983	-0.02784**	0.01287
Companies				
AC	-0.18923	0.13244	0.20927**	0.10439
Case	-0.03942	0.13383	0.24856*	0.09137
Deere	0.22884**	0.11103	0.42028*	0.08316
IH	-0.01630	0.11773	0.19615**	0.09269
Regions				
R1	0.02195	0.01638	0.03019*	0.01170
R2	-0.01443	0.02912	-0.02703	0.01759
R4	-0.02651	0.02036	0.00051	0.01460
R5	-0.08909*	0.02354	-0.12304**	0.06910
Power Transformations for:				
RV (λ)	0.47		0.23	
Age (γ)	0.70		0.88	
Use (θ)	0.32		1.27	
Statistics:				
R^2	0.7804		0.7853	
Log-Likelihood	498.4		1177.6	
N	350		1040	

* Significant at the 0.01 level.
** Significant at the 0.05 level.

Figure 4.4. Depreciation rates for John Deere tractor for 1987 by data type with constant usage.



made a noticeable difference in depreciation rates. The rates were higher for auction versus advertised data over the tractor's life, and the initial drop in auction data was greater than that in advertised data. The usage level can significantly influence depreciation rates.

The effect of usage on the RV of used tractors is illustrated in figures 4.5 and 4.6, for auction and advertised data, respectively. In each figure the effect of usage on a 5-year old tractor versus a 10-year old tractor are shown for 1987. In both figures an increase in usage produces a noticeable decrease in RV. The RV difference between the 5 and 10 year old tractor is quite wide and virtually the same for auction data. For auction data, however, the level of usage tends to have greater influence on RV when the tractor is newer.

The hypothesis that depreciation patterns for advertised tractors were equal to those for auction tractors within the same year was also tested for these models using the log likelihood ratio test. The test statistics were 454.6 for 1985, 153.8 for 1986, and 295.8 for 1987. The hypothesis that the auction and advertised data exhibited the same depreciation pattern was rejected in all years at the 99 percent confidence level for these models, as well.

Full Single Year Models

Next, condition was added to the model, and coefficients were reestimated. Cross-checking the advertised data with source documents suggested that at least some of the condition estimates were made subjectively by Hot Line employees based on advertisement

Figure 4.5. Depreciation patterns for 1987 auction data for John Deere tractor, age is constant.

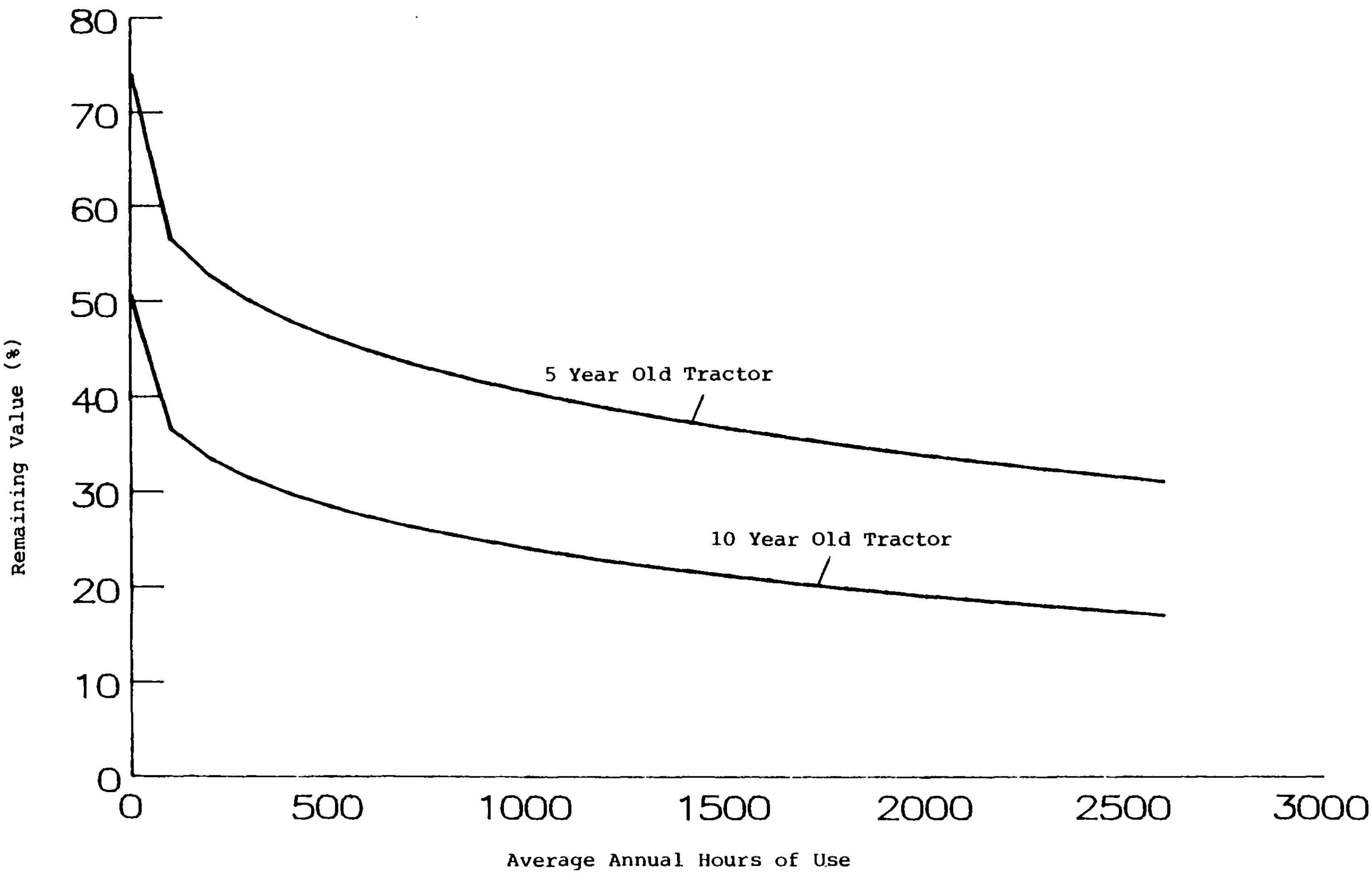
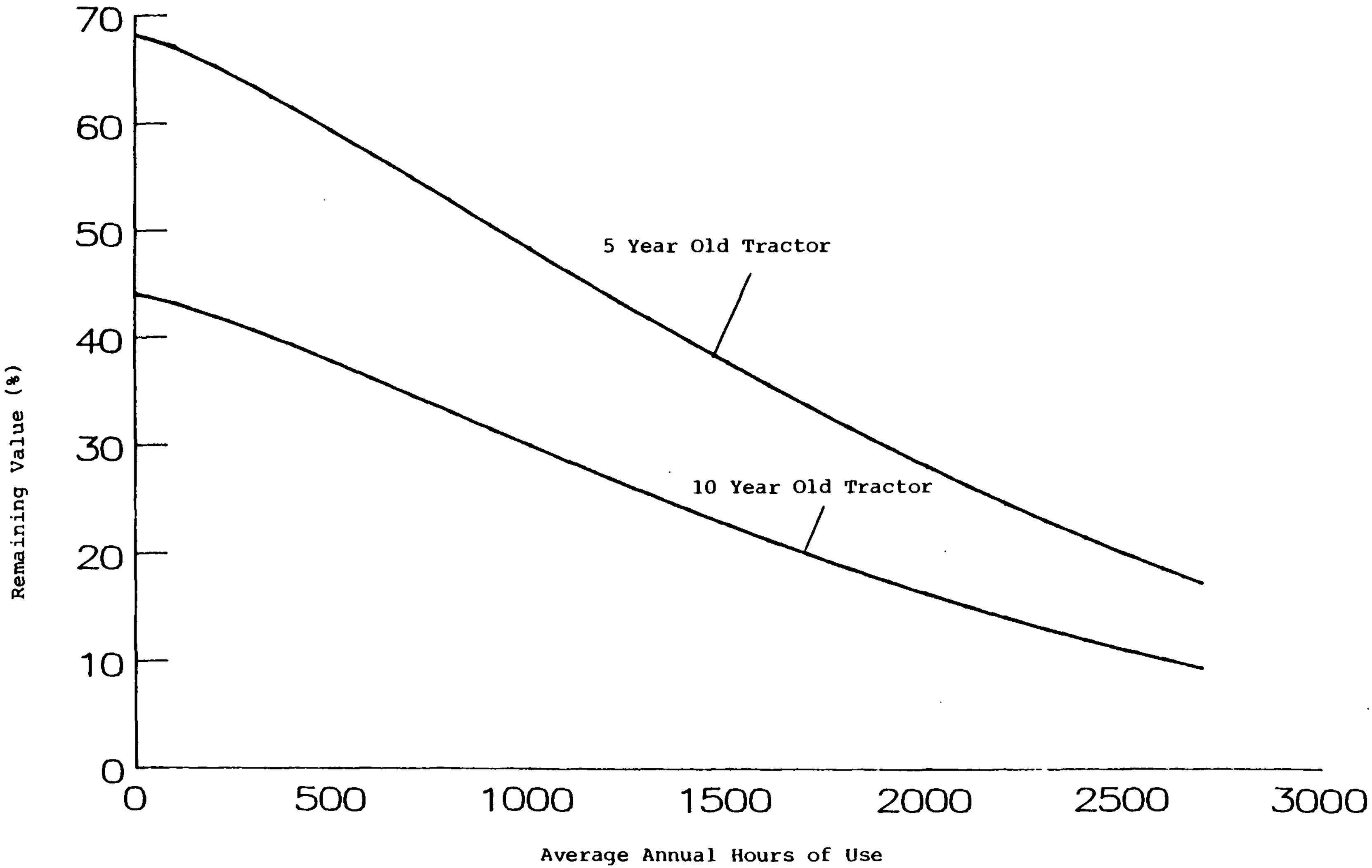


Figure 4.6. Depreciation patterns for 1987 advertised data for John Deere tractor, age is constant.



information. In fact the 1988 monthly reports from Hot Line no longer contain condition estimates for auction data. Therefore, estimation was done for only 1987 auction data. The results are presented in Table 4.7. The condition coefficient was negative (as expected) and highly significant. The result indicates that condition explains some of the variability in tractor prices.

Depreciation patterns for different condition levels are shown in figure 4.7. Patterns suggest a large initial drop in RV with respect to condition, but the difference become less in absolute terms with age. Patterns were very much alike. As tractors age, however, the RV curves converge somewhat. The change in RV with respect to a change in condition is 0.0692 when RV is 0.6 and declines to 0.0245 when R is 0.1. Thus the influence of condition on RV is much greater for new tractors, although the relative influence is greater for older tractors.

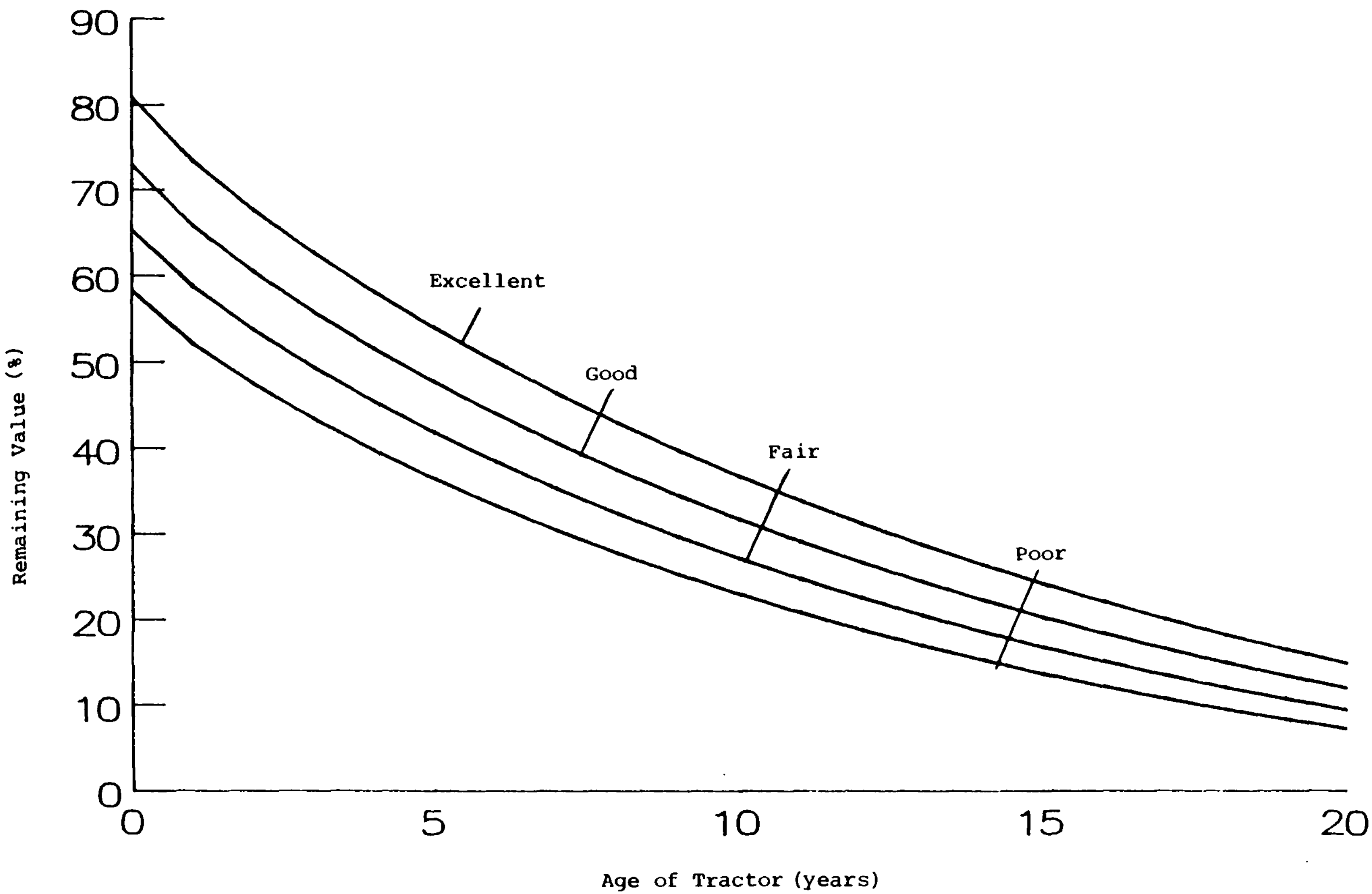
Dummy variables for auction type were added next and the model reestimated. Only 1987 data were used in this analysis because auction type was not reported until mid-1986. The estimated results are presented in Table 4.7. Changes in the magnitudes of the coefficients and in the power transformations were not noticeable. Dealer closeout coefficient was positive but not significant. Bankruptcy and consignment parameters had significant negative coefficients. This result suggests tractors sold in bankruptcy or consignment sale would bring a lower price than if sold by a retiring farmer or a dealer liquidating excess equipment.

Table 4.7. Econometric Results of Tractor Depreciation Patterns Using 1987 Auction Data.

	Estimates With Condition		Estimates With Auction Types	
Variables	Coefficient	Std. Error	Coefficient	Std. Error
Intercept	0.08833	0.11230	0.02171	0.11794
Age	-0.07446*	0.01277	-0.11778*	0.01822
Use	-0.05180*	0.00866	-0.01665*	0.00233
Horsepower	-0.00169*	0.00023	-0.00175*	0.00024
Condition	-0.09304*	0.01138		
Age dummies				
AC	0.00921	0.01611	0.01496	0.02304
Case	0.01017	0.01705	0.02150	0.02415
Deere	0.00068	0.01315	0.00633	0.01887
IH	0.00166	0.01393	0.00725	0.02014
Companies				
AC	-0.13253	0.11800	-0.15611	0.13402
Case	-0.03077	0.11954	-0.07695	0.13508
Deere	0.28684*	0.09853	0.23565**	0.11201
IH	0.01812	0.10434	-0.01494	0.11931
Regions				
R1	0.01339	0.01601	0.02847	0.01659
R2	0.01257	0.02866	-0.01131	0.03090
R4	-0.03064	0.02000	-0.02582	0.02096
R5	-0.06063*	0.02353	-0.08426*	0.02394
Auction Types				
Consignment			-0.03253**	0.01912
Bankruptcy			-0.08409*	0.02117
Dealer Closeout			0.01190	0.03016
Power Transformations for:				
RV (λ)	0.42		0.45	
Age (γ)	0.85		0.70	
Use (θ)	0.05		0.30	
Statistics:				
$\bar{R}^2$	0.8133		0.7895	
Log-Likelihood	528.1		507.7	
N	350		350	

* Significant at the 0.01 level.
** Significant at the 0.05 level.

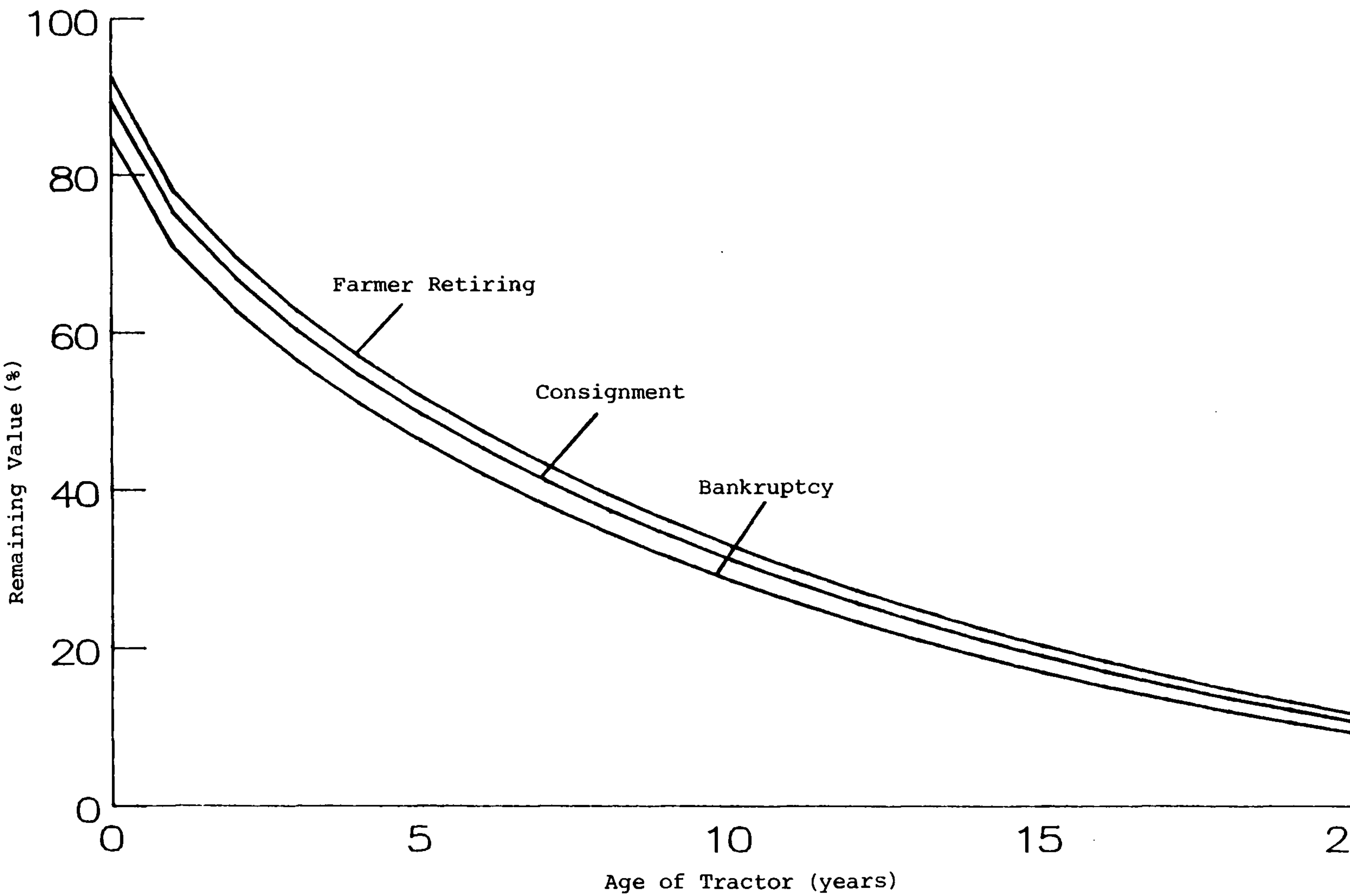
Figure 4.7. Depreciation patterns for 1987 auction data for John Deere tractor by condition, Usage is constant.



Depreciation patterns for the three types of auction are shown in figure 4.8. The patterns are similar, and the gap between them is very narrow. The change in RV when the sale is by consignment is 0.025 when RV is 0.6, and is 0.0092 when RV is 0.1. For bankruptcy, it is 0.063 when RV is 0.6, and is 0.024 when RV is 0.1.

Consignment tractors might be expected to bring a lower price because buyers are concerned the tractor may be a "lemon". Tractors being sold in farmer retirement auctions would not be expected to have any more defects than a tractor randomly chosen from the aggregate tractor capital stock. One might not expect tractors sold at bankruptcy auctions to be any different in quality than when a farmer is retiring; thus the significant negative coefficient was initially puzzling. Verifying this result with an auctioneer suggests a very different sale often exists at a Chapter 11 bankruptcy auctions. In this case the bankrupt farmers themselves are often bidding to buy back some of their own equipment. Their neighbors (who often represent the majority of potential buyers) will not bid against the farmer, either out of sympathy for his financial plight or because they do not want to anger him. Consequently the equipment sells for less than it would under normal circumstances.

Figure 4.8. Depreciation patterns for 1987 auction data for John Deere tractor by auction type.



CROSS-SECTIONAL TIME SERIES MODELS

Multiyear Models without Usage or Condition

Next, the data were pooled to form a cross-sectional time series set. Net farm income was included to explain year-to year changes in RV. Initially estimates were made without usage variable for both auction and advertised data. Results are presented in Table 4.8.

Virtually all coefficients were statistically significant at a 99 percent confidence level. $\bar{R}^2$ for auction data was slightly below 0.7, with the $\bar{R}^2$ for advertised data approaching 0.8. Coefficients for age and horsepower were negative. Net farm income generated a positive and significant coefficient in both auction and advertised models. As hypothesized, net farm income has a positive effect on RV, although its effect was much smaller for the advertised data.

Most of the auction data company-age dummies had negative coefficients, suggesting that the default companies depreciate less rapidly with respect to age. Case and John Deere had positive and statistically significant intercept coefficients, suggesting a higher initial level for RV than occurred with default companies. In advertised data, on the other hand, only Case had a negative coefficient, indicating a more rapid depreciation pattern for this tractor. Allis-Chalmers and International Harvester had negative intercept dummies in both auction and advertised data. This result indicates these two companies had a large initial drop in RV, but slower annual depreciation rate thereafter as compared to the default companies. The initial decline in RV for John Deere was much less

Table 4.8. Econometric Results of Tractor Depreciation Patterns Using 1985-1987 Data.

	Auction		Advertised	
Variables	Coefficient	Std. Error	Coefficient	Std. Error
Intercept	-0.96547*	0.06085	-0.32396*	0.03261
Age	-0.14101*	0.00888	-0.11498*	0.00362
Horsepower	-0.00179*	0.00013	-0.00154*	0.00006
NFI	0.02073*	0.00138	0.00740*	0.00080
Age dummies				
AC	0.00268	0.01473	0.00454	0.00505
Case	-0.01925	0.01230	-0.00098	0.00439
Deere	-0.00214	0.00957	0.01122*	0.00380
IH	-0.00383	0.01000	0.00804	0.00416
Companies				
AC	-0.07127	0.07309	-0.03109**	0.03063
Case	0.11288**	0.06168	0.07813*	0.02666
Deere	0.28443*	0.04906	0.20322*	0.02338
IH	-0.01654	0.05147	-0.07166*	0.02583
Regions				
R1	0.01927**	0.01023	-0.00683*	0.00520
R2	-0.06168*	0.01616	-0.05243*	0.00895
R4	-0.01835**	0.01091	-0.04010*	0.00640
R5	-0.08132*	0.01168	-0.08350*	0.01128
Power Transformations for:				
RV (λ)	0.36		0.34	
Age (γ)	0.65		0.83	
Statistics:				
$\bar{R}^2$	0.6988		0.7897	
Log-Likelihood	2572.0		5709.9	
N	1915		5233	

* Significant at the 0.01 level.
** Significant at the 0.05 level.

than for the other companies. Almost all the regional dummies were negative and strongly significant, suggesting a higher price in the default region.

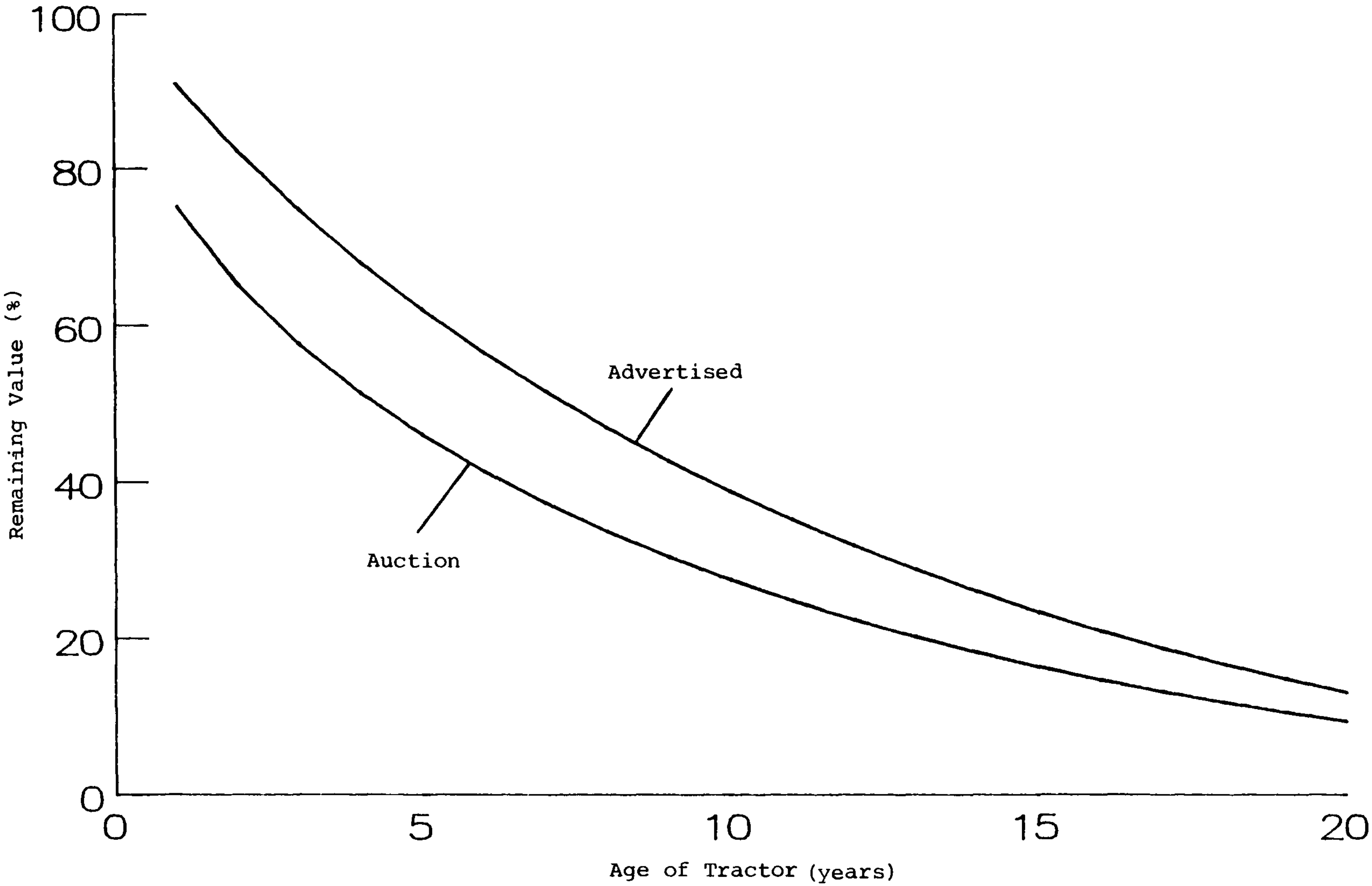
Another Chi-Square test was conducted to determine whether a statistically significant difference exists between auction and advertised data. The test statistic was 2367.7, indicating a strong rejection of the hypothesis.

The depreciation patterns for auction and advertised data for John Deere tractors are shown in figure 4.9. As the figure indicates, the initial drop in the RV for auction data was larger than that for advertised data. Rates, however, were slower for auction versus advertised data thereafter. Advertised tractors depreciate faster.

It was hypothesized that depreciation patterns for the data not reporting usage were equal to those reporting usage. This hypothesis was tested for auction versus advertised data using a log likelihood ratio test. The test statistics were 55.4 for auction data and 62.7 for advertised data. The hypothesis was rejected at the 99 percent level of confidence.

The result was not surprising for advertised data because one might expect that usage would not be reported if it were above average. The result was somewhat puzzling for auction data, however. One explanation, based on examination of depreciation patterns for the two data sets, is that usage was consistently not reported if below average.

Figure 4.9. Depreciation patterns for 1985-1987 data by data type.



Multiyear Models without Condition

Observations not reporting usage were next removed from the data set, and coefficients were reestimated for both auction and advertised data. Results are reported in Table 4.9. The $\bar{R}^2$ estimates were above 0.75 for both models. The $\bar{R}^2$ for advertised data was higher than that for auction data. Almost all the coefficients were significant at a 99 percent confidence level.

The sign of the coefficients was as expected. Company dummies for age are all negative, except for John Deere in advertised data. Coefficients for intercept dummies were all positive for all companies, suggesting that the default companies had a large initial drop in RV, but a slower depreciation rate thereafter.

The power transformations changed somewhat from the multiyear models without usage. They increased for RV and age in auction data. The power transformation for usage in advertised data was 1.01, implying an approximate sum-of-the-years digits functional relationship between usage and RV. Again, likelihood statistics suggest that auction and advertised data did not exhibit the same depreciation patterns (test statistic is 929.0).

The effect of usage on RV of used tractors is again shown in figure 4.10 and 4.11 for auction and advertised data, respectively. The effect of usage was noticeably different between advertised and auction data. Changes in usage had about the same effect on RV at all usage levels in the advertised data. By contrast, in the auction data low usage levels had a much greater impact on RV, and high usage levels had less impact than occurs in the advertised data. In short,

Table 4.9. Econometric Results of Tractor Depreciation Patterns Using 1985-1987 Data Reporting Usage Information.

Variables	Auction Coefficient	Auction Std. Error	Advertised Coefficient	Advertised Std. Error
Intercept	-0.97653*	0.08141	-0.43971*	0.05637
Age	-0.05316*	0.00849	-0.12163*	0.00784
Use	-0.01109*	0.00085	-0.00021*	0.00002
Horsepower	-0.00122*	0.00015	-0.00148*	0.00009
NFI	0.01896*	0.00151	0.01024*	0.00128
Age Dummies				
AC	-0.02186**	0.01159	-0.02092**	0.01091
Case	-0.01892**	0.01131	-0.01362	0.00993
Deere	-0.02612*	0.00881	0.00209	0.00820
IH	-0.02117**	0.00926	-0.01722**	0.00924
Companies				
AC	0.08600	0.07799	0.11589**	0.05709
Case	0.16995**	0.07408	0.16023*	0.05042
Deere	0.41937*	0.06208	0.29522*	0.04346
IH	0.15432*	0.06483	0.06858	0.04868
Regions				
R1	0.05938*	0.01078	0.01002	0.00835
R2	0.03947**	0.01725	-0.04327*	0.01336
R4	0.00655	0.01431	-0.02724*	0.01039
R5	-0.04785*	0.01401	-0.09132*	0.02260
Power Transformations for:				
RV (λ)	0.52		0.32	
Age (γ)	0.84		0.74	
Use (θ)	0.41		1.01	
Statistics:				
$\bar{R}^2$	0.7592		0.7873	
Log-Likelihood	1099.76		1977.44	
N	810		1763	

* Significant at the 0.01 level.
** Significant at the 0.05 level.

Figure 4.10. Depreciation patterns for 1985-1987 auction data for John Deere tractor, age is constant.

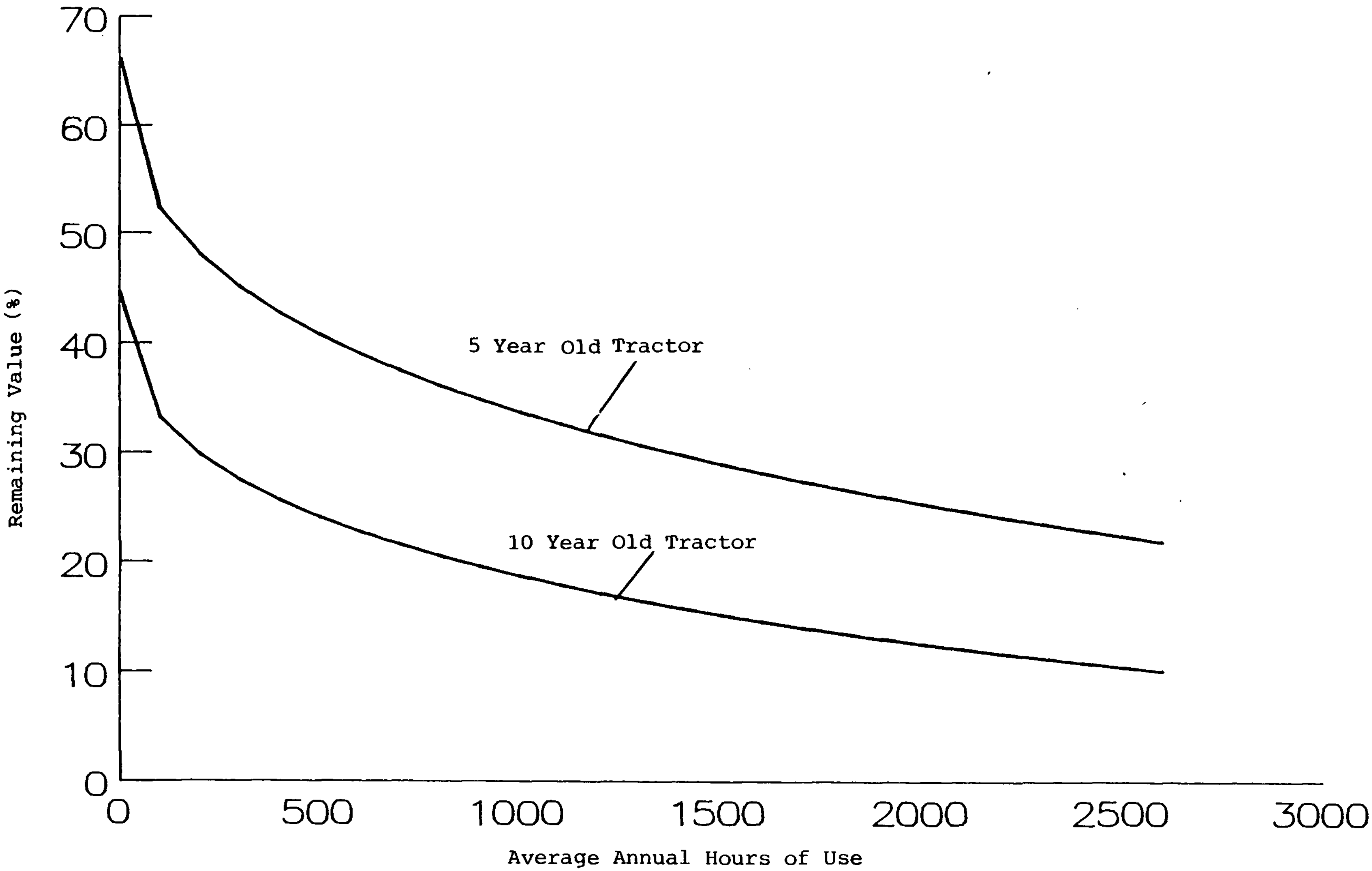
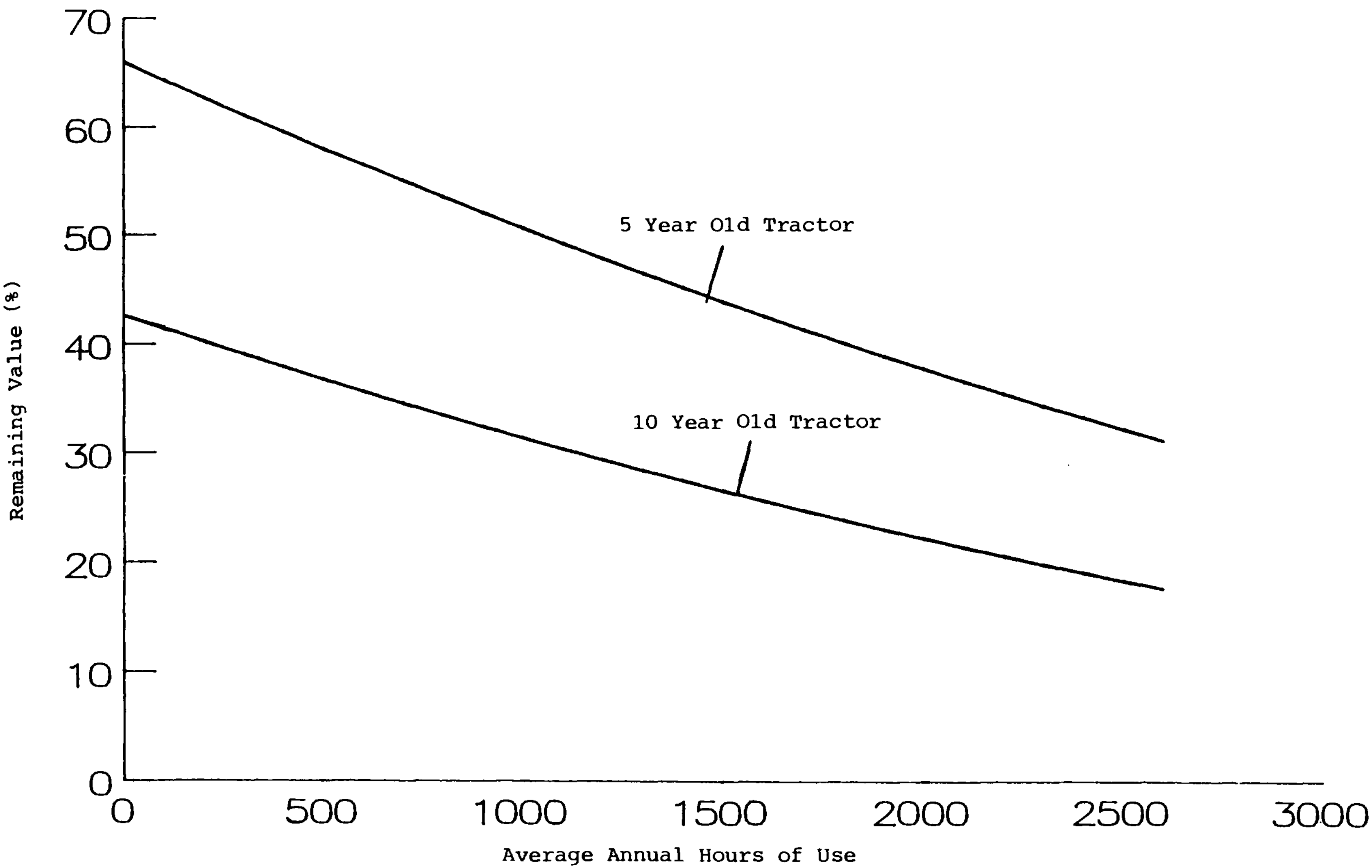


Figure 4.11. Depreciation patterns for 1985-1987 advertised data for John Deere tractor, age is constant.



low usage tractors sold for a premium in the auction market, but high usage did not result in a large penalty on selling price.

Both models initially exhibited a decreasing rate of depreciation with respect to an increase in age (see figure 4.12). Depreciation rates were more accelerated for the auction data than the advertised data. As noted above, dealers were apparently much less willing to discount prices for changes in usage than are buyers at auctions. Consequently, depreciation rates were much higher for older auction tractors than older advertised tractors. These results may be biased by the lack of tractors with high usage in the advertised data.

The difference might also be attributed to the nature of tractor selling by dealers. Older tractors with high usage would be expected to bring a relatively low price. Selling a tractor would generate both variable and fixed costs for a dealer regardless of the tractors size. A relatively larger proportion of fixed selling costs relative to price for older-high use tractors would mean the dealer would have to ask a much higher price than that received in the auction market. This difference accounts for the price wedge which seems to exists between the two markets. The wedge widens as tractors age and accumulate usage.

The RV levels by age are shown in figure 4.13. As expected, the RV values for advertised data lie above that for auction data. The difference between these two patterns is large in the first few years of the tractors' life. The gap narrows as a tractor ages, however.

Figure 4.12. Depreciation rates for 1985-1987 data for John Deere tractor by data type.

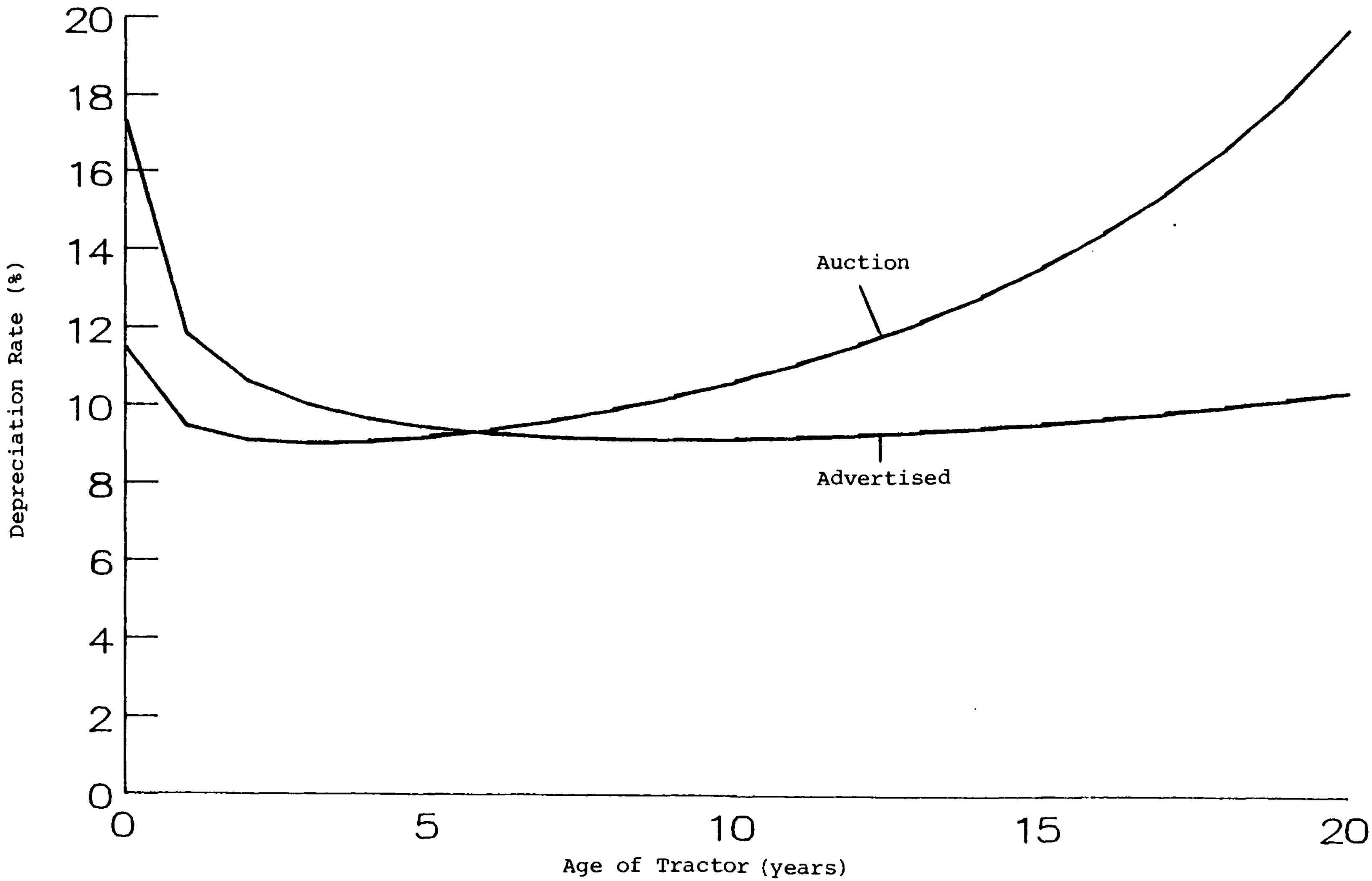
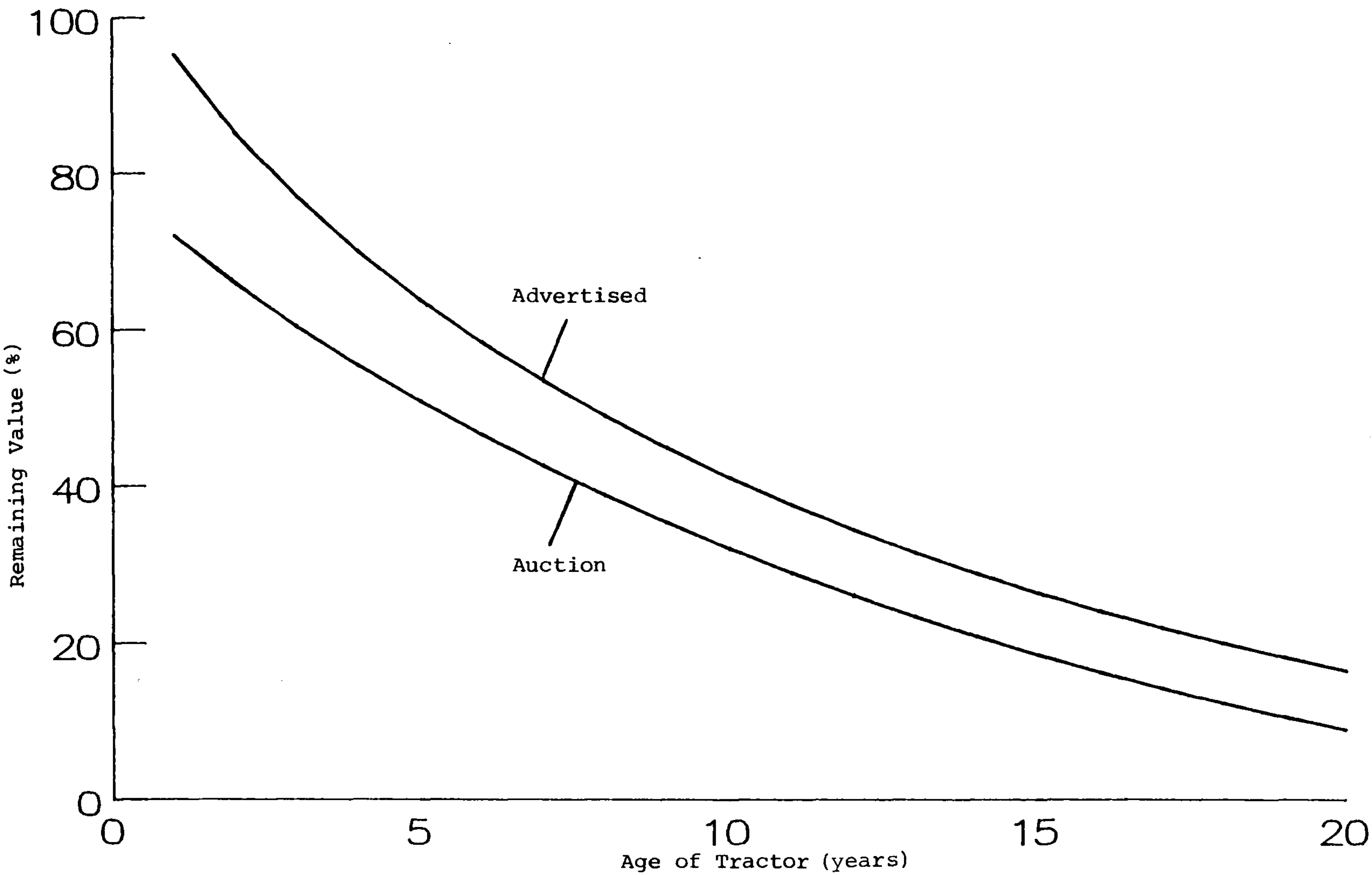


Figure 4.13. Depreciation patterns for 1985-1987 data for John Deere tractor by data type, usage is constant.



Full Multiyear Model

The final analysis was made using only auction data to test the significance of auction type and condition on RV. Results are presented in Table 4.10. There was an increase in $\bar{R}^2$. Most of the coefficients were significant and had the proper sign.

Consignment and bankruptcy sales exhibited virtually identical depreciation patterns in this model. Moreover, the difference between consignment, bankruptcy and farmer retirement auctions was virtually the same at all age levels. The coefficients for consignment and bankruptcy were negative and significant. The estimated depreciation patterns are shown in figure 4.14. In the figure horsepower was held constant at 130 PTO, condition was good, and net farm income was $31 billion. The change in RV with respect to a sale by consignment reduced RV by 0.0421 when RV was 0.6 and 0.0163 when RV was 0.1. The effect of a bankruptcy sale was to reduce by 0.0474 when RV was 0.6 and 0.0183 when RV was 0.1.

A comparison of depreciation patterns for the model (#1) obtained from Table 4.10 versus four other models is given in Perry and Bayaner (See figure 4.15). The other models were estimated and (or) reported by Reid and Bradford (RB), Leatham and Baker (LB), Peacock and Brake (PB), and the ASAE. The model was quite similar to the LB and ASAE models, both of which impose a constant depreciation rate. The RB and PB models exhibited quite different depreciation patterns, probably because of their choice of functional form.

Table 4.10. Econometric Results of Tractor Depreciation Patterns Using 1985-1987 Auction Data.

Variables	Coefficient	Standard Error
Intercept	-0.82166*	0.08393
Age	-0.04643*	0.00762
Use	-0.02511*	0.00272
Horsepower	-0.00113*	0.00015
Condition	-0.06729*	0.00711
NFI	0.01747*	0.00158
Age Dummies		
AC	-0.01865**	0.01037
Case	-0.01002	0.01018
Deere	-0.02143*	0.07884
IH	-0.01680**	0.00831
Companies		
AC	0.06031	0.07550
Case	0.11135	0.07191
Deere	0.40423*	0.06009
IH	0.13031**	0.06285
Regions		
R1	0.04430*	0.01106
R2	0.01597	0.01771
R4	-0.00817	0.01437
R5	-0.04785*	0.01402
Auction Types		
Consignment	-0.05519*	0.01095
Bankruptcy	-0.06217*	0.01737
Dealer Closeout	0.00132	0.02662
Power Transformations for:		
RV (λ)	0.47	
Age (γ)	0.89	
Use (θ)	0.21	
Statistics:		
$\bar{R}^2$	0.7920	
Log Likelihood	1163.6	
N	810	

* Significant at the 0.01 level.
** Significant at the 0.05 level.

Figure 4.14. Depreciation patterns for 1985-1987 auction data by auction type, usage and condition are constant.

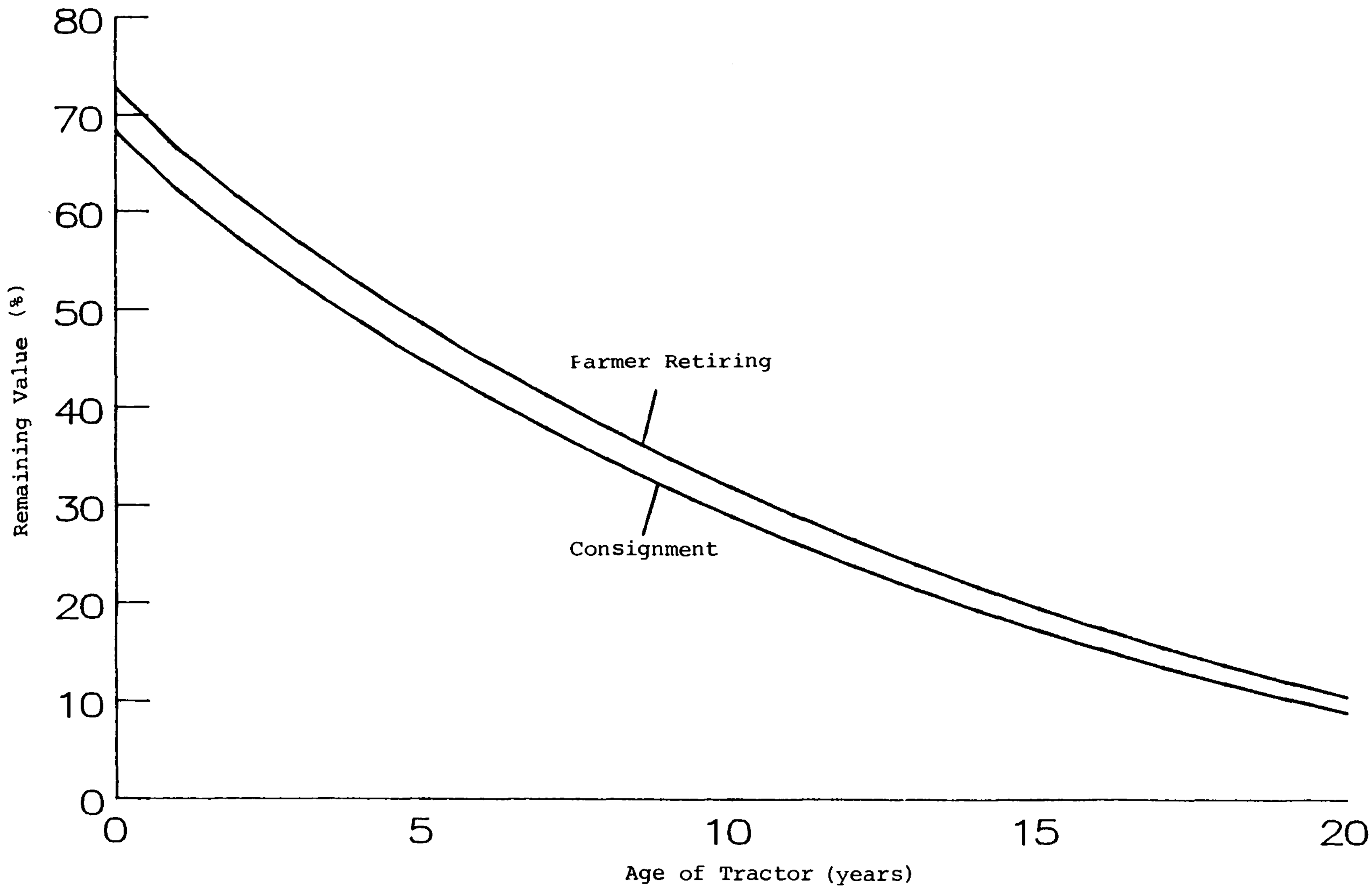
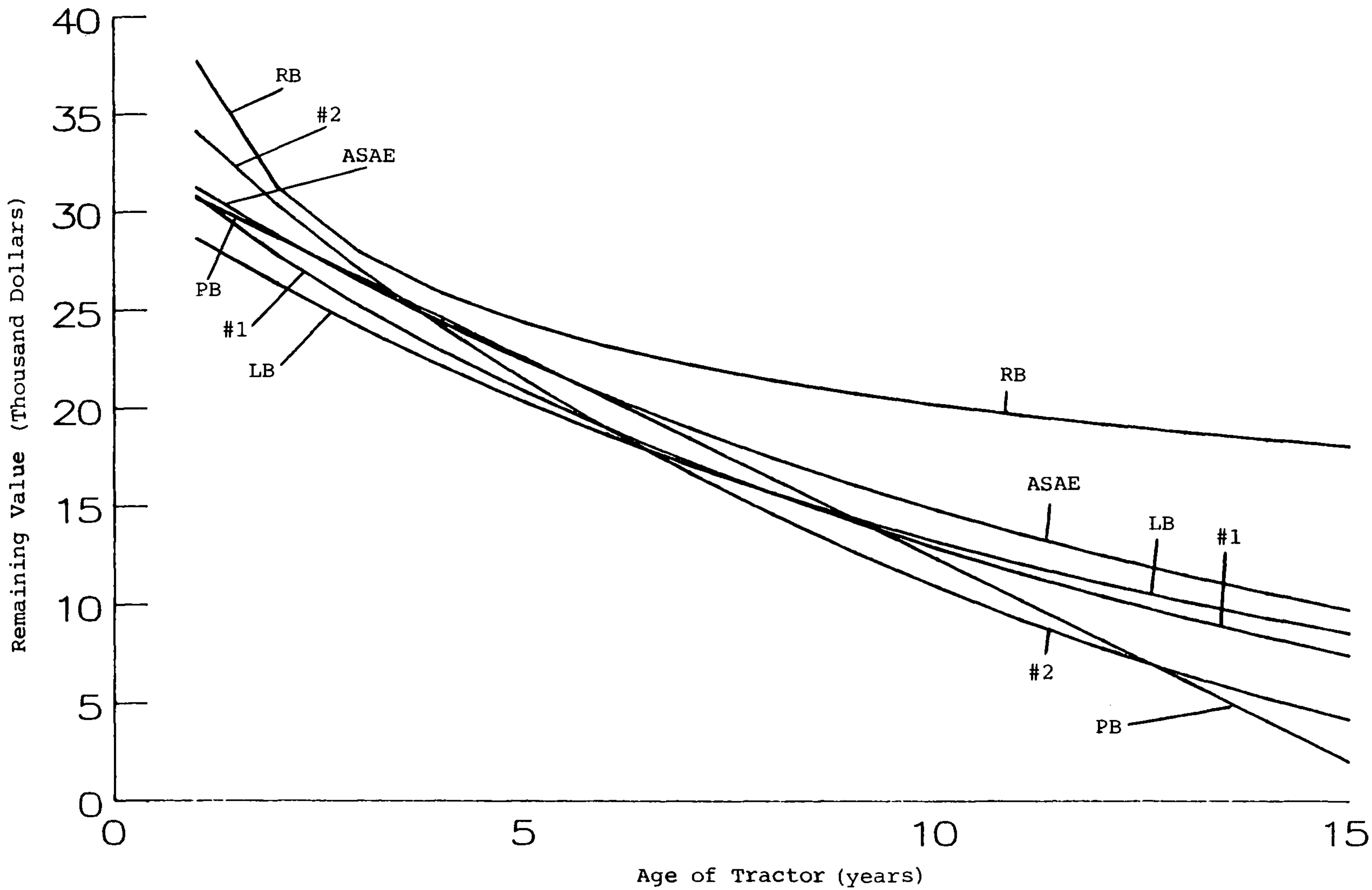


Figure 4.15. A comparison of various depreciation models.



Perry and Bayaner also demonstrated another pattern (#2), representing the effect of beginning with condition 1 and adding 0.2 to the condition variable each subsequent year. The result suggests #2 may more correctly reflect depreciation patterns since the general trend in the data is for condition to decline over time.

SUMMARY

None of the estimated models exhibited a clear depreciation pattern. A number of the models exhibited a pattern similar to sum-of-the-year's digits, particularly the models with the auction data. Of the 18 models, 15 exhibited a pattern with rates initially declining and later accelerating. The convexity result is inheritent in the data and is not imposed by any peculiarities of the Box-Cox model.

Auction and advertised data exhibited different depreciation patterns, and the estimates for advertised data consistently showed a higher $\bar{R}^2$. Also RVs for advertised data were above those for auction data.

It was confirmed that age was the most influential variable in explaining RV of used farm tractors. Usage had a significant effect, especially for auction data when the tractor is newer. Condition explains some of the variability in tractor prices, as well. The effect of condition on RV was much greater for new versus old tractors.

Tractors manufactured by different companies exhibited different depreciation patterns. The RVs for John Deere tractors were above all other companies, while those of Allis-Chalmers were consistently at the lowest levels. There was not much difference in RVs from region to region. Most of the difference probably represents transportation costs and regional supply and demand.

Prices at dealer closeout auctions were higher than other auction sales but not much different than farmer retirement auctions. Results also indicated that demand for large tractors was not as great as the demand for smaller tractors.

CHAPTER 5

OPTIMAL REPLACEMENT OF FARM TRACTORS

In this chapter one of the depreciation models previously presented is used in analyzing an economic problem. One use for a remaining value model is in identifying optimal equipment replacement strategies (Reid and Bradford, 1983; Leatham and Baker; Kay and Rister). These models allow one to determine how often farmers should replace their equipment, and what the annualized expected cost is for this replacement strategy.

Identifying an optimal replacement decision for depreciable assets is important because equipment purchase typically requires substantial capital outlays. Too frequent replacement may greatly increase annualized capital costs because of higher initial depreciation and loss of most tax benefits. Delaying replacement may result in high repair and reliability costs, also resulting in nonoptimal annualized costs. Identifying the optimal replacement decision involves calculating the annualized net revenue or cost for the asset for each potential ownership life.

The optimal ownership life is the number of years with highest annualized net present value of revenues or the life having the lowest annualized net present value of costs when revenue is not considered (Boehlje and Eidman). Perrin indicates that maximizing the present value of residual earnings is equivalent to minimizing the present value of the costs of the machine.

There have been several studies addressing the optimal replacement decision problem. Most of these studies utilized the cost minimization approach over an infinite horizon for each possible replacement year. Reid and Bradford (1987) used Net Present Value (NPV) (or Net Future Value-NFV) concept, demonstrated by Hirshleifer and others, to evaluate investment opportunities in order to maximize the value of the firm.

Because the present value of costs concept is easier than the NPV approach, cost minimization was used in this analysis. Both present value of costs and annualized real costs give the same optimal replacement strategies.

Chisholm suggested that replacement studies can be conducted with both continuous and discrete-time period models. He also observed that a discrete-time period model is well adapted to real world problems involving short-lived assets. Leatham and Baker chose to use a discrete model because of its ease in use. A discrete model was used in this study based on these considerations.

Boehlje and Eidman delineated a number of factors influencing the replacement decision. They are

> (1) the age, efficiency, and reliability of the present machine; (2) the repair and timeliness costs of the present machine; (3) income tax considerations including depreciation allowances and investment tax credit as well as tax recapture provisions; (4) new technology which has resulted in increased efficiency and made the present machine obsolete; (5) the pattern of changes in the salvage value of machinery; and (6) size considerations which may suggest that a larger or smaller machine is needed because of expansion or contraction of the enterprise or farm operation.

Reid and Bradford (1983) pointed out two important parameters influencing replacement of farm tractors. They are (a) tractor's remaining value and (b) income tax incentives. Chisholm, Kay and Rister, and Bates, Rayner, and Custance did some study of tax impact on optimal replacement ages. Leatham and Baker investigated the effects of inflation on RV and optimal replacement of tractors and combines. Reid and Bradford (1983) examined the impact of alternative RVs. The estimated replacement ages for tractors in each of these optimal replacement studies are seven to fourteen years.

In this analysis technological changes and size of a tractor were not considered for simplicity. Based on these previous studies, the proposed model used to estimate optimal replacement ages for farm tractors is

$$An = \frac{r^*}{1 - (1+r^*)^{-n}} \{[C_0 - RV(1+r^*)^{-n}] + (1-T) \sum_{k=1}^{n} R_k(1+r^*)^{-n}$$

$$+ (1-T) \sum_{k=1}^{n} Bk(1+r^*)^{-n} + T \sum_{k=1}^{n} D_k(1+r)^{-n} - T*E_n(1+r)^{-1}$$

$$+ t * RV(1+r^*)^{-n} - t\,(C_0 - E_n - \sum_{k=1}^{n} D_k))(1+r)^{-n}\}$$

where

A_n is the average annual real after-tax cost of a machine held n years,

r^* is the real after-tax discount rate,

r is the nominal after-tax discount rate,

C_0 is the initial purchase price,

RV is the after-tax remaining value at the end of n years in period n dollars,

T is the marginal tax rate,

t is the long term capital gain,

R_k is the repair cost in year k in real dollars,

B^k is the breakdown time opportunity cost in year k in real dollars,

D_k is regular tax depreciation taken in year k, and

E_n is Section 179 expensing.

For this analysis it was assumed the replacement decision involved a 1987 John Deere Model 4450 tractor. The 1987 list price for this 140 horsepower model is $45825. The tractor's trade-in value was calculated using the model given in Table 4.10, assuming the tractor remained in good condition throughout its life, with a constant real net farm income of 35 billion dollars, the trade-in occurring in the Western Corn Belt at a consignment sale. Three different annual usage levels were considered; 350, 400, and 800 hours.

Three hundred and fifty hours per year usage level was assumed because the statistical analysis of auction data revealed an average usage level of 350 hours. Identifying the optimal age is important at high level of usage. The cost of operating a farm tractor incurred by a farmer increases as the usage level increases. Therefore, 400 and 800 hours of usage levels were considered to account for the effect of different usage levels on optimal replacement decisions.

Repair costs are calculated from the following equation for diesel tractors given in the Agricultural Engineers Yearbook (ASAE).

$$Rk = 0.012\ (AHU)^2$$

where average annual hours of usage (AHU) is in thousand hours.

The amount of breakdown time is estimated by the down-time function also given in ASAE Yearbook. The function is

$$B_k = 0.0003234\ (HU)^{1.4147}$$

where HU is annual hours of usage.

A $195 per hour opportunity cost (rental cost per day for the chosen model, assuming that if tractor is down, it takes a day to fix it) was multiplied by annual hours of breakdown to obtain reliability costs. This opportunity cost represents the per day rental rate for a tractor for this size as reported in the Official Guide (NFPEDA).

Tax depreciation was calculated using the 1987 depreciation method, Modified Accelerated Cost Recovery System (MACRS), applied to tangible property placed in service after 1986. Farm machinery and equipment are classified as 7-year property under 1986 Tax Reform Act.

Expensing was assumed zero in the base analysis. Also a 37% tax rate (Federal: 15%; Self employment: 13%; and State tax: 9%), 4% inflation rate and 11% nominal after-tax discount rate were considered. Real after-tax discount rate is calculated from the relationship $(1+r) = (1+r^*)(1+i)$ where i is inflation rate.

The optimal replacement ages for different annual usage levels are given in Table 5.1. As the annual usage level doubles from 400 to 800 hours, the optimal replacement age decreases from 29 to 10 years. Higher usage increases economic depreciation, repair costs, and reliability costs, thereby influencing the optimal replacement decision. Doubling usage increases repair cost by 400 percent and breakdown time opportunity cost by 260 percent in the first year. As a result, repair and reliability costs more quickly react the point at which it is more profitable to replace rather than continue to use the tractor.

A few sensitivity analyses were conducted to determine the importance of different assumptions in generating the base result. Taking $8,000 in expensing at the time of purchase had a significant effect on the optimal replacement age at the lower levels of usage. It reduced the optimal replacement age because expensing decreases annual costs and reduces the value of future depreciation.

Reducing the tax rate to 28% reduced the optimal replacement age by one year at the lower levels of usage but increased the annual costs for two reasons: First, the tax rate represents the proportion of repair costs paid by the government. The higher the tax rate the lower the repair and maintenance costs are for the farmer. Consequently, repair and reliability reach the marginal benefit-cost point sooner than at a higher tax rate. Second, tax depreciation benefits are worth less at the lower tax rate, which also accelerate replacement.

Table 5.1. Optimal Tractor Replacement Ages Under Different Usage levels.

	Average Annual Usage Levels					
	350 Hours		400 Hours		800 Hours	
Scenario	Age	Annual Costs	Age	Annual Costs	Age	Annual Costs
Base	36	4073	29	4473	10	7575
Expensing Option	33	3813	27	4198	9	7077
28% Tax Rate	35	4511	28	4961	10	8386
$100 Oppor. Costs	38	3792	32	4148	11	6937
Expensing X 28% Tax Rate	32	4248	26	4679	9	7871
Expensing X $100 Opp. Cost	36	3536	29	3878	10	6467

High reliability costs may justify more rapid equipment replacement. As a machine ages the probability of breakdown increases. Kay and Rister suggested that the cost of a delay in planting or harvesting may have an impact on the replacement decision. To better understand the effect of reliability costs on replacement decisions a lower per hour opportunity cost ($100) was considered. As expected the lower cost increased optimal replacement age and reduced annual costs at all levels of usage.

The effect of a lower tax rate, combined with $8,000 in expensing, was next examined. The optimal replacement ages were virtually the same as when expensing was in effect at the higher tax rate. This indicates that the effect of expensing on the optimal replacement decision is larger than that of a lower tax rate. In fact, a lower tax rate did not have a significant impact on optimal replacement decision.

In the final scenario the effect of expensing and a lower opportunity cost for breakdowns was analyzed. The optimal replacement ages were not affected. The lower opportunity cost for breakdowns reduced annual costs, resulting in a higher replacement age. Expensing, on the other hand, decreased annual costs thereby reducing the optimal replacement age. The effect a lower opportunity cost offset the effect of expensing. Consequently, no change was ocurred.

CHAPTER 6

SUMMARY AND CONCLUSIONS

Farm equipment represents an important component of total assets owned by farmers. As the substitution of capital for labor continues to occur at the farm level, the importance of an accurate measure of depreciation expenses will increase. The general objective of this thesis was to estimate models that would explain changes in equipment value and to determine what variables were important in these models. Two sets of cross-sectional and cross-sectional time series data--auction and advertised-- were used to estimate remaining value (RV) models for farm tractors. These data (covering tractors manufactured between 1971-1987) were obtained from monthly reports of auction and advertised prices for farm equipment throughout the U.S., as published in the Farm Equipment Guide.

The influence of a number of potentially important factors affecting tractor price were examined. These variables were age, usage, condition, horsepower, manufacturer, region of sale, auction type, national net farm income. Because so many observations did not include usage, separate estimates were made with and without usage as a variable. To reduce the correlation between usage and age, usage was divided by age to create a usage per year variable. Also separate estimates were made for each year of the data set and for all years combined. The Box-Cox power transformation method was used to allow the data to more fully reflect the inherent depreciation patterns.

One of the estimated RV models was incorporated into an optimal replacement model for farm tractors. A statistical analysis of the data set used in the econometric analyses was also presented.

Although age was the most important variable in explaining changes in tractor price, a number of the other variables included in the models also were statistically important in predicting changes in RV. Generally speaking, there was not any statistical difference between depreciation patterns for Case, Allis-Chalmers, International Harvester, and Ford-Massey Ferguson-White group depreciation patterns. John Deere tractors, however, maintained a price that was higher than the other companies for all years of its life. The dominance of John Deere tractors may be attributed to its popularity relative to the other companies and its larger number and wider distribution of dealerships.

Estimates also revealed that some statistical difference existed between prices paid for identical tractors sold at different types of auction. Farmer retirement and Dealer Closeout auctions exhibited virtually identical sale prices which, in turn, were higher than prices received at Consignment and Bankruptcy sales.

The $\bar{R}^2$ statistic was consistently higher for advertised versus auction data, no doubt because the actual transaction prices for the advertised tractor would vary from that advertised.

A Chi-Square test was conducted to determine whether a statistical difference existed between auction and advertised data. Test statistics indicated a strong rejection of the hypothesis that these two sets of data exhibited identical depreciation patterns.

The auction data consistently exhibited higher rates of depreciation, particularly in the first few years after the tractor was manufactured, and later as it neared retirement. This pattern was attributed to a need by dealers to place a much greater percentage markup on older tractors to cover commission and handing costs. The average age of advertised tractors was lower than that of auction tractors. Dealers may find older tractors are less profitable unless they pay a low price when initially purchasing them. It may be more profitable for farmers using older tractors as tradeins to sell them through an auction market rather than receive a tradein value for them.

One important conclusion emerging from this thesis was that none of the estimated models exhibited depreciation patterns that were close to those generally assumed for depreciable assets. Generally speaking, the models were a combination of the geometric and sum-of-the-year's digits functions.

The empirical results strongly suggest the concept of accelerated depreciation in general with a higher initial decline, and an approximation of sum-of-the-year's digits depreciation method, particularly in auction data models.

Analysis of the optimal tractor replacement strategies revealed that the level of usage had a very important effect on the optimal replacement decisions. The section 179 expensing depreciation option also had important influence on replacement decisions. Tax changes, reducing opportunity cost of breakdown time, expensing-tax, and expensing-opportunity cost interactions were not as influential.

IMPLICATIONS

This study provided several insights and implications for managers of capital resources, policy makers, and researchers. Use of a flexible functional form would seem to be a preferred option when estimating tractor depreciation patterns. The data did not exhibited a clear depreciation pattern, principally because depreciation rates exhibited increasing and decreasing rates of depreciation at different stages of the tractor's life. If a traditional form is required, the results suggest it should be sum-of-the-year's digits or perhaps a geometric function.

Farmers benefit from the results in several ways. Farmers can, for instance, estimate what depreciation costs will be for different age tractors. They can also more accurately estimate the value of their farm assets for financial purposes. Furthermore, they can better know what their tractors are worth at the time of trade-in or sale, and how much of a premium or discount they should expect because of hour of use and condition.

Asset appraisers may benefit by having some benchmark to compare against their own estimates. The auction dummies help in identifying the costs when selling on consignment versus other sale types. Advertised versus auction results suggest farmers may be buying and selling older equipment at auctions.

The results are important not only in determining the cost of ownership but also to identify optimal replacement strategies so that the minimum cost could be obtained from that piece of equipment. Farmers in today's economic environment should pay more attention to their machinery resources management since a large amount of financial capital is used in machinery purchases. Using the approach outlined here permits a more accurate estimate for the cost of owning a tractor with alternatives such as leasing. If the cost of owning is higher, farmers may profit by leasing instead, so that they reduce their costs of production and improve their net income position.

The results can also provide useful insight to lenders and borrowers. Knowledge of how well tractors hold their value as they age may be important to farmers purchasing them and also could be important to lenders making loans. Lenders usually require the borrower put 30 percent down and repay the principal and interest in five years. If a tractor looses its value rapidly over time its resale price could be less than the borrower's outstanding principal. Defaulting on the loan at this point could prove costly to the lender. To avoid this problem the lender would need to increase either the downpayment or the interest, shorten the payback period, or simply not make the loan.

The results indicate that tax depreciation schedules do not reflect actual depreciation rates, but depreciate at a rate that is higher than that of actual depreciation rates, assuming that the tractor's life is seven years.

Models presented in this study should not be expected to be without any error and to give completely accurate estimates. The comparison of depreciation patterns estimated versus four other models revealed all exhibited somewhat different patterns. More study in this subject area is needed, although it would not be surprising if different patterns were found because the functional form is very important when estimating economic depreciation patterns for used farm equipment.

The data set used is rich in detail and can be used in a number of research settings. One word of caution, however, is that this analysis is not appropriate for estimating macro depreciation rates because tractors that have been retired were not accounted for (Perry and Glyer, 1988). Moreover, the data set probably overrepresented some regions of the U.S. and underrepresented others.

The influence of usage could be measured better by removing the observations not reporting usage and running the regression with and without usage as a variable. One could also capture the age of a used tractor with more preciseness by considering the month in which the tractor was sold.

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