EFFECTS OF TAXES AND AGE ON DEPRECIATION:
THE CASE OF COMBINE HARVESTERS

by
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APPROVAL

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Economic depreciation of the total capital stock of a physical asset is determined by the flow of services used in productive activities and by the size of the capital stock. Previous research studies have attempted to analyze economic depreciation by modeling the flow of services. These studies have often failed to fully specify the model by not including important asset specific explanatory variables, and their models were often estimated with restricted functional forms, which implicitly limited the pattern of economic depreciation.

This study, on the other hand, uses a flexible functional form which models price as an exponential quadratic function of age, and thus allows the pattern of economic depreciation to be derived within the model. The behavior of used asset prices are also estimated as an explicit dynamic process which permits a stronger statistical test of the results. In examining the economic depreciation of combine harvesters, this study utilizes specific explanatory variables to account for the effects of changes in the tax code, shocks in demand, and quality and technology differences across combine harvester models.

The major empirical results of this study state that depreciation rates are not constant across different ages of combine harvesters and that depreciation rates and patterns are not stable with respect to changes in tax codes. These results present evidence that if further examination of either economic depreciation or optimal replacement problems are to be solved in an internally consistent manner, a more flexible functional form of the used asset price equation must be utilized such as the flexible functional form used in this study, and changes in the tax code must be included as a specific explanatory variable.
CHAPTER 1

INTRODUCTION

Economic depreciation is an important factor in measuring net capital accumulation in the aggregate and in determining investment and replacement decisions for a physical asset at the firm level. Economic and technological variables that affect the value of capital services will also affect the economic rate of depreciation, assuming that the rate of depreciation of a physical asset is determined by the flow of capital services into productive activities. Accurately measuring economic depreciation has important implications with respect to current agricultural issues such as the capital/labor ratio, farm size, and efficient firm management investment decisions.

These implications are important in that government tax policies have been legislated and firm management decisions have been made using remaining value functions that have often assumed a constant rate of depreciation. The constant rate of depreciation hypothesis has been used in several previous studies. This study, however, questions the validity of the constant rate hypothesis. In addition, previous studies have failed to consider several important factors that affect the value of capital services and therefore asset price. One such
factor is the potential effect of tax policy changes upon asset values and costs.

The objective of this analysis is to statistically test two hypotheses. The first hypothesis is that economic depreciation occurs at a constant rate or (more simply) that the rate of depreciation does not change with the age of an asset. The second hypothesis is that the pattern and rate of depreciation are not affected by different tax regimes (major changes in the tax policy). This study examines the depreciation schedule for a major farm production asset, combine harvesters. An estimation model for used asset price is developed using a flexible functional form and is estimated as a dynamic process. The model includes asset specific explanatory variables to account for the effects of changes in the tax laws, shocks in demand, and quality and technology differences across combine harvester models.

This study is innovative in that it is the first study to use a flexible functional form that estimates the behavior of used asset prices as an explicitly dynamic process. This procedure permits a more powerful statistical test of the constant depreciation hypothesis because the effects of age can be examined at the margin and permits the data to reflect various depreciation patterns that might exist. The study also examines the effect of tax and demand shift variables on asset prices.
The thesis is organized as follows. In Chapter 2, a review of previous studies of used asset prices is presented, and the findings of these studies are discussed. In Chapter 3, a general theoretical model of the determinants of prices is presented and an expression for the rate of depreciation is derived. Changes in the tax code are shown to have potentially complex effects upon the rate and pattern of depreciation. In addition, four explicit models of asset prices are presented. The data used for the econometric estimation of parameters of explicit used asset price models for combine harvesters are described in Chapter 4. In Chapter 5, the estimated parameters of the combine harvester models are presented, and the implications of the results are examined. The summary and conclusions of the combine harvester case study are presented in Chapter 6.
CHAPTER 2

REVIEW OF LITERATURE

Understanding of depreciation is important at both the macro and micro level. Depreciation of the total capital stock of a physical asset is determined by the size of the capital stock and the flow of services used in productive activities. Understanding depreciation is also important in decisions about asset replacement at the firm level (Reid and Bradford, 1983, 1987). For analytical convenience, the rate of depreciation is often assumed to be constant over the asset's life. This assumption has been justified by an appeal to renewal theory (Jorgenson, 1976). Several empirical studies of asset prices have supported the constant depreciation rate hypothesis (Hulten and Wykoff, 1981; Hall, 1973), although Lee (1978) provided evidence that the hypothesis does not hold in the case of Japanese fishing vessels. Recently, examining tractor auction data, Perry and Glyer (1990) have concluded that while individual tractors may not depreciate at a constant rate, the aggregate depreciation rate for all tractors is "near constant."

In contrast, Feldstein and Rothschild (1974) provided a theoretical critique of the plausibility of assuming constant rate of depreciation for the aggregate capital stock. In
addition, Feldstein and Foot (1971) and Eisner (1972) showed that in U.S. manufacturing industries the ratio of replacement investment to gross investment varied in a manner completely inconsistent with a constant depreciation rate. Econometric analyses of physical depreciation also suggest that the depreciation rate is not constant at the sector level (Bitros, 1976; Bitros and Kelejian, 1974; Cowing and Smith, 1977). Penson et al. (1977), using engineering data, argued that for individual tractors the rate of depreciation increases.

Four of the above studies are particularly relevant to this analysis: Hall (1973), Reid and Bradford (1983, 1987), Hulten and Wykoff (1981), and Perry and Glyer (1990). These studies utilized one or both of two concepts examined by this present study. These concepts are: (1) the use of a flexible functional form which allows empirical estimation of depreciation rates and patterns (Hall, Reid and Bradford, Hulten and Wykoff, Perry and Glyer), and (2) the incorporation of tax variables (Reid and Bradford).

Reid and Bradford (1983, 1987), in large part following Hall (1973), developed a model to solve situation specific optimal replacement problems. In their model, they developed a used asset price equation which included age, net farm income, dummy variables for tractor models, and dummy variables for technology differences. Reid and Bradford's optimal replacement model accounted for the effects of
different tax policies when computing the optimal replacement solution.

Hulten and Wykoff (1981) applied the Box-Cox power transformation to the problem of estimating the rate and the form of the economic depreciation pattern for commercial and industrial structures. The Box-Cox transformation is a flexible functional form capable of discriminating among geometric, linear, and "one-hoss-shay" depreciation patterns. The Box-Cox power transformation has the following form:

\[ F_i = a + \beta g_i + \gamma c_i + u_i \quad i=1,\ldots,N \]  

(2.1)

where

\[ \hat{F}_i = \frac{(P_i^{s-1})}{\theta_1}, \quad g_i = \frac{(s_i^{s-1})}{\theta_2}, \quad c_i = \frac{(t_i^{s-1})}{\theta_3} \]  

(2.2)

In equation (2.1), \( P_i \) represents the market price of an asset of age \( s \) in year \( t \) for observation \( i \). Hulten and Wykoff concluded that for commercial and industrial structures asset price depreciation followed either an accelerated, straight-line, or (possibly) geometric pattern. However, it was definitely not a decelerated, linear, or "one-hoss-shay" pattern. In a cross-section analysis, Hulten and Wykoff estimated their model using different years of their data set and compared the resulting parameters. They concluded that depreciation rates were reasonably stable over time, suggesting that the rate of depreciation is constant.
Perry and Glyer (1990) attempted to explain why both non-constant rates of depreciation and constant rate geometric depreciation patterns for tractors could be empirically consistent. They hypothesized that while the aggregate depreciation rate for all tractors may well be "near constant," an individual tractor may have a non-constant depreciation rate.

Perry and Glyer (1990) first examined an aggregate simulation model which was used to calculate used asset prices in a controlled decision making environment. The simulation model is:

\[
RV = \sum_{t=0}^{n} [ (\overline{P}_t \cdot \overline{C}_t - \overline{R}_t - \overline{B}_t) \cdot (1-a) + a \overline{D}_t ] \cdot e^{r(t_1-t)} \tag{2.3}
\]

where \( P \) is the value of output, \( C \) is the productivity capacity, \( R \) is the repair and maintenance cost, \( B \) is the reliability costs, \( a \) is the marginal tax rate, \( r \) is the discount rate, and \( D \) is the amount of tax depreciation allowance claimed in time \( t \). \( \overline{P}, \overline{R}, \overline{B}, \) and \( \overline{D} \) are all proportions of the purchase price. Using this model, Perry and Glyer concluded that the aggregate depreciation rate from such a model was constant. They then proceeded to estimate a Box-Cox power transformation used asset price equation function. Assuming that the depreciation rate is influenced by the age, usage, and care of a particular machine, Perry and Glyer transformed the three variables and derived power transformation parameters for each using auction data for
individual tractors. Aggregate depreciation rates for all tractors were also calculated by using weighted averages. Perry and Glyer concluded that even if an individual asset had an accelerated depreciation pattern, it would not be inconsistent to expect a geometric pattern in the aggregate. By visual inspection, they also concluded that the econometric results they obtained were not greatly different from their simulation results which they claimed could be used for assets that are not commonly traded.

The analysis presented here takes into consideration the effects of taxes by including a tax variable in the used asset price equation together with other situation specific variables. The used asset price equation utilized in this analysis is not the flexible Box-Cox power transformation functional form, but an alternative polynomial flexible functional form which allows for many different depreciation patterns. This flexible form is also attractive in that its parameters can be estimated using more powerful statistical methods than those used in most previous studies.
CHAPTER 3

MODEL DEVELOPMENT

Theoretical Model

The equilibrium price of an asset is assumed to equal the present value of the net revenue stream it generates (Faustmann, 1849; Fisher, 1907, 1930; Taylor, 1923; Hotelling, 1925). Ignoring tax recapture and scrap value, let \( P(s) \) denote the asset price at age \( s \), \( D \) the present value of the depreciation allowances permitted per dollar of the price of the asset, \( T \) the marginal tax rate, \( i \) the percent of the asset price allowed as an investment tax credit, \( R(a) \) the net returns for the asset at age \( a \), and \( \rho \) the after-tax discount rate. Therefore, the price of an asset of age \( s \) can be written as:

\[
P(s) = (1-T) \int_s^\infty R(a) e^{-\rho(a-s)} \, da + iP(s) + TD\cdot P(s)
\]  

In equation 3.1, all investment tax credits \((i\cdot P(s))\) are used immediately, thus avoiding complications due to investment tax credit carryover. Investment tax credits directly reduce income tax and are added directly back into net returns. \( TD\cdot P(s) \) is the net present value of tax reductions induced by tax depreciation allowances.
Two important implications of the above model are as follows. First, any event that increases (decreases) net revenues will increase (decrease) the asset’s price. Second, taxes have a complex and indirect effect on the net revenue stream.

The second implication can be illustrated by solving equation (3.1) for \( P(s) \); that is,

\[
P(s) = \frac{(1-T)}{(1-TD-i)} \int_s^\infty R(a) e^{-p(a-s)} da
\]

(3.2)

Taking the derivative of the above equation with respect to age, the following result is obtained:

\[
\frac{\partial P(s)}{\partial s} = \frac{(1-T)}{(1-TD-i)} \int_s^\infty \frac{\partial R(a)}{\partial a} e^{-p(a-s)} da
\]

(3.3)

Dividing equation (3.3) by \( P(s) \), substituting appropriately for \( P(s) \) using equation (3.2) and rearranging terms, the rate of economic depreciation can be expressed as:

\[
\frac{[\partial P(s)/\partial s]}{P(s)} = \frac{\int_s^\infty (\partial R(a)/\partial a) e^{-p(a-s)} da}{\int_s^\infty R(a) e^{-p(a-s)} da}
\]

(3.4)

Equation (3.4) appears to suggest that the rate of economic depreciation is independent of the tax structure. However, in this case, appearances are deceptive because the components of the net revenue stream (the \( R(a) \)'s and the after-tax discount rate, \( \rho \)) themselves are in part determined by the tax structure.

The after-tax discount rate, \( \rho \), will be affected by changes in the marginal tax rate, \( T \), although the precise
effects depend on general equilibrium considerations (for a discussion of this issue see Alston, 1986, or Darby, 1975). The effects of changes in the tax code on the R(a)'s are more subtle.

Suppose, to facilitate the discussion, that the price of a new asset, \( P(0) \), is constant with respect to changes in tax policy. (This assumption would hold if the industry purchases a small share of the total supply of the asset or, alternatively, the asset is produced with a constant returns to scale technology using inputs that are in elastic supply and intra-firm adjustment costs are not related to the level of investment in new equipment.) If the asset is new (that is, \( s=0 \)) then equation (3.2) can be rewritten as:

\[
P(0) = \frac{(1-T)}{(1-Td-1)} \int_0^\infty R(a) e^{-pa} da
\]

(3.5)

or, rearranging terms,

\[
\int_0^\infty R(a) e^{-pa} = \frac{(1-Td-1)}{(1-T)} \cdot P(0)
\]

(3.6)

If \( P(0) \) is constant, then the net revenue stream depends on the tax structure. For example, an increase in either \( D \) or \( i \) will reduce the present value of the net revenue stream for the new asset. Qualitatively similar results are obtained if \( P(0) \) changes in response to changes in the level of gross investment as long as the elasticity of supply of the asset is positive. \( T \) has no predictable effect on the revenue stream.
if $D$ and $i$ are assumed to be less than one and greater than zero.

These results can be explained in terms of what happens to the user cost of a unit of service from capital equipment. If $D$ or $i$ increase, the user cost or rental price of services from the asset falls. The result is substitution of the asset for other inputs (typically labor) and expansion of the industry in which the asset is used because production costs have declined. The former effect reduces the marginal physical product of the asset; the latter reduces the price of the industry's output. Both effects lower the value of the marginal product for the services of the asset, and net revenues from the services fall. The decline in the marginal value product of asset services also reduces net revenues associated with older machines and thus affects the pattern of economic depreciation.

The changes in depreciation rates across ages may be very complex if intricate changes in net revenue levels (the $R(a)$'s) occur as a result of changes in tax policy. This study, therefore, seeks to examine two testable hypotheses. The first hypothesis is that depreciation rates of combine harvesters are constant over the life of the combine. The second hypothesis is that changes in tax policy do not affect rates or the patterns of depreciation. Testing the hypothesis is tantamount to testing whether the integral expression in
equations (3.2) and (3.3) is unaffected by changes in tax policy.

Flexible Functional Forms for Asset Price Models

Estimating equations (3.2) and (3.3) directly will be extremely difficult due to the complexity of the integral expressions, and data problems with respect to quasi-rents and after the tax discount rate. However, equation (3.2) can be approximated with various flexible functional forms replacing the right-hand side of (3.2).

Previous Functional Forms

Flexible functional forms have been utilized in empirical used asset price models, but the extent of their flexibility has been somewhat limited. Some of the studies that have used a flexible functional form are Hall (1973), Lee (1978), Hulten and Wykoff (1981), and Perry and Glyer (1990). One of the more commonly used flexible functions has been the Box-Cox power transformation.

The Box-Cox power transformation allows the joint estimation of parameters that determine specific functional forms and also parameters which determine the slope and intercept of the equation. The Box-Cox power transformation function specified by Hulten and Wykoff (1981) is:

\[ \hat{\beta}_i = \alpha + \beta \gamma_i + \gamma \epsilon_i + u_i \quad i=1, \ldots, N \]  

(3.7)
where

\[ P(s)_{i} = \frac{(P(s)^{\theta_1})^{\theta_1} - 1}{\theta_1}, \quad s_{i} = \frac{(s_{i}^{\theta_2})^{\theta_2} - 1}{\theta_2}, \quad t_{i} = \frac{(t_{i}^{\theta_3})^{\theta_3} - 1}{\theta_3} \] (3.8)

and \( \alpha, \beta, \gamma, \) and \( \theta=(\theta_1, \theta_2, \theta_3) \) are constant parameters. \( P(s)_{i} \) represents the market price of an asset of age \( s_{i} \) in year \( t_{i} \) for observation \( i \).

In equation (3.7), the unknown parameters \( (\alpha, \beta, \gamma) \) determine the intercept and slope(s) of the model, while in equation (3.8) the unknown vector \( \theta=(\theta_1, \theta_2, \theta_3) \) determines the functional form. Thus, as the elements of \( \theta \) take on different values, the functional form of equation (3.7) changes. As a result, the model may reflect a linear, decelerated, or geometrically constant depreciation pattern.

A linear form exists if \( \theta=(1,1,1) \). The Box-Cox function then becomes:

\[ P(s)_{i} = (\alpha - \beta - \gamma + 1) + \beta s_{i} + \gamma t_{i} + u_{i} \quad i=1,...,N \] (3.9)

This model has frequent accounting and tax applications. A geometric decay model can also be derived by restricting \( \theta=(0,1,1) \). In this case a semi-log function results:

\[ \ln P(s)_{i} = (\alpha - \beta - \gamma) + \beta s_{i} + \gamma t_{i} + u_{i} \quad i=1,...,N \] (3.10)

This form of economic depreciation has been justified by appeals to renewal theory (for example, Jorgenson, 1976).

Another commonly assumed depreciation pattern is a one-hoss shay pattern in which the price of an asset declines
gradually in the early years of asset life and accelerates rapidly as the date of retirement approaches. A similar model can be derived by the Box-Cox function by restricting $\theta=(1,3,1)$; that is,

$$P(s)_i = (\alpha - \frac{1}{3} \beta - \gamma + 1) + \frac{1}{3} \beta (s_i)^3 + \gamma t_i + u_i \quad i = 1, \ldots, N \quad (3.11)$$

In this case, the function becomes cubic in age which causes depreciation to be slow during the early years while being rapid at the end of the asset's life.

The Box-Cox power transformation is a flexible form that represents a dynamic process. However, the Box-Cox function was estimated only in price levels and was not estimated as a dynamic process.

**Alternative Functional Forms**

In this study, a different functional form is considered which also models asset price behavior as a dynamic process. The first model, Model 1, is the following declining balance function, which is functionally equivalent to the remaining value function in the Agricultural Engineers Yearbook:

$$P(s) = \alpha \beta^s \quad (3.12)$$

where $\alpha$ and $\beta$ are constants. In order to represent the behavior of the asset price as a dynamic process, equation 3.12 is lagged one period $P(s-1)$, $P(s)$ is subtracted by $P(s-1)$, the terms are rearranged, and the following model is derived:
\[ P(s) = \beta P(s-1) \quad (3.13) \]

This function has little flexibility in its structure, because it implicitly assumes that the asset loses a constant fraction of its value \((1-\beta)\) each time period. The instantaneous rate of depreciation for Model 1 is constant; that is,

\[ \frac{d(\ln P(s))/ds}{P(s)} = \ln \beta \quad (3.14) \]

Model 2 differs from Model 1 only in that an intercept term \((\delta)\) is added. This allows for increased flexibility in that it no longer imposes the restriction that the rate of depreciation be constant. Model 2 is:

\[ P(s) = \delta + \alpha \beta^s \quad (3.15) \]

Model 2 contains a constant exponential component in the equation; however, the depreciation base is no longer \(P(s)\), but \(P(s)-\delta\). Solving for \(P(s)\) in terms of \(P(s-1)\), it follows that:

\[ P(s) = \theta + \beta \cdot P(s-1) \quad (3.16) \]

where \(\theta = \delta(1-\beta)\). The instantaneous rate of economic depreciation implied by Model 2 is:

\[ \frac{dP(s)/ds}{P(s)} = \frac{\alpha \beta^s \ln \beta}{\delta + \alpha \beta^s} \quad (3.17) \]

Thus if \(\delta \neq 0\), then the rate at which the asset price depreciates is not constant. However, if \(\delta = 0\), then the rate
of depreciation is constant. Thus it can be noted that Model 1 is nested within Model 2.

Model 3 contains additional properties. In Model 3, price is assumed to be an exponential quadratic function of age; that is,

$$P(s) = a e^{\beta s + \gamma s^2}$$  \hspace{1cm} (3.18)

where $\alpha$, $\beta$, and $\gamma$ are constants. The change in asset price over time for equation (3.18) can be found in the same manner as the first two models. After subtracting $P(s)-P(s-1)$ and rearranging terms, the following expression is derived:

$$P(s) = P(s-1) e^{\phi + \theta s}$$  \hspace{1cm} (3.19)

where $\phi = \beta + \gamma$; $\theta = 2\gamma$. Note that:

$$\frac{dP(s)}{ds} / P(s) = (\beta + 2\gamma s)$$  \hspace{1cm} (3.20)

Model 3 is a relatively inflexible functional form in that the rate of depreciation is a linear function of age.

Model 4 differs from Model 3 only in that it includes a constant term, $\delta$; that is,

$$P(s) = \delta + a e^{\beta s + \gamma s^2}$$  \hspace{1cm} (3.21)

where $\alpha$, $\beta$, $\delta$, and $\gamma$ are constants. Through recursive substitution, the following equation is derived:

$$P(s) = \left[P(s-1) - \delta\right] e^{\phi + \theta s} + \delta$$  \hspace{1cm} (3.22)
where $\phi=\beta+\gamma$; $\theta=2\gamma$. This model has the most flexible function form. The rate of depreciation is:

$$\frac{dP(s)}{ds} = \frac{\alpha(\beta+2\gamma s)e^{(\beta+\gamma s)}}{\delta+\alpha e^{(\beta+\gamma s)}}$$

(3.23)

For example, if $\delta=0$, then a test for Model 3 is available, because the rate of depreciation is variable but in a linear fashion. If $\gamma$ is positive, the rate of depreciation increases in a linear fashion; if $\gamma$ is negative, the inverse is true. If $\theta=0$ (which implies $\gamma=0$) and $\delta=0$, then Model 4 represents a declining balance function in which the rate of depreciation is constant ($\beta$). The model becomes:

$$P(s) = p(s-1)e^\beta$$

(3.24)

where $\beta$ is negative. If $\theta=0$ and $\delta\neq0$, then the constant exponential component of the equation is adjusted by $\delta$ which means the depreciation rate is no longer constant. An equation similar to Model 2 (equation 3.16) is thus derived:

$$P(s) = \delta(1-e^\beta) + e^\beta P(s-1)$$

(3.25)

If both $\theta$ and $\delta$ are non-zero, Model 4 holds. Thus a direct test to reject the hypothesis, that the rate of depreciation is constant over time, is available. In other words, if either $\theta$ or $\delta$ is a non-zero value, age directly affects the rate of depreciation.

In this chapter, alternative models of asset price behavior have been presented. The models were based on a
dynamic specification of the behavior of the asset's price over its life, while still having somewhat flexible functional forms. These estimation models, however, are not asset specific. The development of a specific estimation equation for combine harvesters requires an understanding of what factors influence the prices for these assets, and the nature of data sets available for estimating the used asset price function.

The data sets selected to estimate models of asset prices for combine harvesters are presented in Chapter 4. Specific asset estimation equations and econometric estimates are presented in Chapter 5.
CHAPTER 4

DATA

The purpose of this study is to estimate used asset price functions for combine harvesters in order to test the hypothesis that the rate of economic depreciation is constant. In addition, the hypothesis that changes in tax policy affect economic depreciation rates is examined. Data were gathered on prices and other characteristics of 23 combine harvesters for the time period 1979-1989. The combines included in the sample were chosen because they are relatively homogeneous with respect to harvesting capacities and model technologies. Data were obtained from the 1979-1989 issues of the National Farm and Power Equipment Dealers Association (NFPEDA) publication, Official Guide for Tractors and Farm Equipment, and consisted of first year manufacturers' list prices and resale prices. The 1987-1989 issues of Quick Reference Guide for Farm Tractors and Combines, which is published by Hot Line, Inc., was also used as a source of data to facilitate the selection of combines to be used in the study because of the detailed information it contained on tested horsepower and field capacities.

The 23 combine models included in the sample were manufactured by six different firms. The manufacturers were
Allis-Chalmers, John Deere, International Harvester-McCormick, Massy-Ferguson, New Holland, and White. A list of each of the combine harvester models included in the data set, together with their characteristics, is presented in Table (1).

The data set contains 2,323 different observations of which 2,144 are relevant to prices for used machines. The prices reported by NFPEDA in the Official Guide for Tractors and Farm Equipment are based on the average of actual farm dealers' selling prices after adjusting for reconditioning costs. This data set is listed in Appendix A.

Price information included in this data set was obtained in the following manner. In any given year, spring and fall prices were available for each age of a given combine model. Thus, for example, in the fall of 1982, prices were collected for new, one year old, two year old, and three year old John Deere model 7720 combines (the model having been introduced in 1979).

Two concerns about the data set are: (1) average prices for traded combine harvesters may reflect the sale of a disproportionate number of "lemons," especially in the case of newer machines (Akerlof, 1970); and (2) new machinery prices are manufacturers' list prices instead of market negotiated selling prices (Perry and Glyer, 1990). Reported average used combine prices will be biased downward as a measure of the average value of all assets if a disproportionate number of "lemons" are being disposed of in the market. The lemons
Table 1. Combine model information.

<table>
<thead>
<tr>
<th>Manufacturer</th>
<th>Model</th>
<th>Horse Power</th>
<th>Bushel Cap.</th>
<th>Weight</th>
<th>Years</th>
<th>Type</th>
</tr>
</thead>
<tbody>
<tr>
<td>ALLIS-CHALMERS</td>
<td>L2</td>
<td>145</td>
<td>200</td>
<td>16177</td>
<td>1976-82</td>
<td>C</td>
</tr>
<tr>
<td></td>
<td>L3</td>
<td>145</td>
<td>200</td>
<td>16177</td>
<td>1983-85</td>
<td>C</td>
</tr>
<tr>
<td></td>
<td>M2</td>
<td>130</td>
<td>180</td>
<td>15207</td>
<td>1976-80</td>
<td>C</td>
</tr>
<tr>
<td></td>
<td>M3</td>
<td>130</td>
<td>180</td>
<td>15552</td>
<td>1983-85</td>
<td>C</td>
</tr>
<tr>
<td></td>
<td>N5</td>
<td>190</td>
<td>200</td>
<td>21405</td>
<td>1979-85</td>
<td>C</td>
</tr>
<tr>
<td>JOHN DEERE</td>
<td>6620</td>
<td>125</td>
<td>166</td>
<td>18048</td>
<td>1979-88</td>
<td>C</td>
</tr>
<tr>
<td></td>
<td>7700</td>
<td>128</td>
<td>129</td>
<td>16256</td>
<td>1970-78</td>
<td>C</td>
</tr>
<tr>
<td></td>
<td>7720</td>
<td>145</td>
<td>190</td>
<td>19834</td>
<td>1979-88</td>
<td>C</td>
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<tr>
<td>INTERNATIONAL HARVESTER-McCORMICK</td>
<td>815</td>
<td>125</td>
<td>133</td>
<td>15587</td>
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<td>C</td>
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<td>915</td>
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<td>17373</td>
<td>1969-79</td>
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<td></td>
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<td>145</td>
<td>18818</td>
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<td>A</td>
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<tr>
<td></td>
<td>1460</td>
<td>170</td>
<td>180</td>
<td>19558</td>
<td>1978-85</td>
<td>A</td>
</tr>
<tr>
<td>MASSY-FERGUSON</td>
<td>550</td>
<td>125</td>
<td>125</td>
<td>14908</td>
<td>1978-88</td>
<td>C</td>
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<td></td>
<td>760</td>
<td>145</td>
<td>180</td>
<td>21516</td>
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<td>C</td>
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<td></td>
<td>850</td>
<td>150</td>
<td>140</td>
<td>23231</td>
<td>1982-88</td>
<td>C</td>
</tr>
<tr>
<td>NEW HOLLAND</td>
<td>1500</td>
<td>125</td>
<td>133</td>
<td>15402</td>
<td>1973-80</td>
<td>C</td>
</tr>
<tr>
<td></td>
<td>TR-70</td>
<td>160</td>
<td>145</td>
<td>17241</td>
<td>1975-80</td>
<td>A</td>
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<tr>
<td></td>
<td>TR-75</td>
<td>155</td>
<td>140</td>
<td>21718</td>
<td>1979-85</td>
<td>A</td>
</tr>
<tr>
<td></td>
<td>TR-85</td>
<td>175</td>
<td>190</td>
<td>21944</td>
<td>1979-85</td>
<td>A</td>
</tr>
<tr>
<td>WHITE</td>
<td>8600</td>
<td>130</td>
<td>150</td>
<td>14896</td>
<td>1974-77</td>
<td>C</td>
</tr>
<tr>
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<td>8800</td>
<td>145</td>
<td>170</td>
<td>16571</td>
<td>1974-77</td>
<td>C</td>
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<tr>
<td></td>
<td>8900</td>
<td>145</td>
<td>170</td>
<td>19761</td>
<td>1978-81</td>
<td>C</td>
</tr>
</tbody>
</table>

* Thresher type-Cylinder (C) or Axial Rotor (A).
problem is intractable. However, it seems likely that asset values of non-traded combines move in the same direction as asset prices for traded combines. A separate and more tractable problem is that the manufacturers' list prices overstate actual market prices for new machines. Therefore, care should be taken to account for the list price problem in econometric models of asset price behavior. This issue is discussed in more detail later in this analysis.

In order to account for demand shocks that affect the structure and level of asset prices, annual data on gross farm income for field crops were gathered for the period 1979-1989. The data were obtained from various issues of the USDA publication, Economic Indicators of the Farm Sector: National Financial Summary, for the period 1979-1988. Information on gross farm income for field crops for 1989 was not available. Instead the most recent USDA estimate for gross farm income of field crops was obtained from the USDA September, 1989 issue of Agricultural Outlook. The nominal combine harvester price and gross farm income data were converted into real terms by the Gross National Product implicit price deflator.

One of the objectives of this analysis was to examine what effect different tax policies have on used asset prices. For this study, the specific estimation equation includes variables that account for different tax regimes; that is, periods which differ significantly with respect to the structure of the tax code.
The federal tax code contains several provisions that affect investment and capital use decisions: the tax rate schedules, tax depreciation schedules, the allowance of investment tax credit (ITC), ITC recapture, ITC carryover, and expensing. A major change in any of the above as part of the tax code may affect the pattern of used asset prices, and thus alter the tax regime under which such decisions are made.

In 1979, the tax policy consisted of a 10% ITC of the eligible base up to $25,000 and 7% of the base over $25,000, ITC recapture, either a straight-line or double-declining depreciation schedule with an additional first year depreciation, and an eight year tax life for combines. The tax code was relatively stable until 1981. In 1981, the Economic Recovery Tax Act (ERTA) was enacted. The ERTA expanded the ITC to 10% of the eligible base up to $25,000 and 9% of the base over $25,000. The ERTA also introduced accelerated depreciation schedules under which, for example, a combine harvester would have the following percentages of asset price as a depreciation: 15%, 22%, 21%, 21%, 21%. In addition, under ERTA the additional first year depreciation provision was replaced with an expensing option, which in turn reduced the ITC basis. Finally, the ERTA also reduced marginal tax rates, and shortened the depreciation tax life for combines to five years from eight years.

Further significant tax revisions were enacted in 1984 with the modification of depreciation schedules and consequent
reductions in their net present values. This took the form of the Modified Accelerated Cost Recovery System (MACRS) which combined the double-declining balance schedule with the half year convention method. A third set of major tax code revisions took place in 1986 under the provisions of the Tax Reform Act (TRA). The TRA abolished the ITC and ITC carryovers, extended the depreciation tax life for combines from five to seven years, and lowered marginal tax rates for agricultural producers. Since the enactment of the TRA, tax policies have remained relatively stable.

Thus, data in this sample were generated under four distinct tax regimes. These tax regimes consist of the following periods: 1979-81, 1982-84, 1985-86, and 1987-89. The assumption is made that the changes in the tax codes affected asset prices the year after Congress passed the tax legislation, as the legislation was usually enacted late in the calendar year. The four tax regimes are accounted for in the econometric analysis through the use of three tax dummy variables.

Economic depreciation rates may differ across combine models or manufacturers because of slight differences in the technologies embodied in each model or manufacturer product. If each individual combine model is assumed to have a slightly different depreciation pattern, the effects of these differences may (in part) be explained by 22 model dummy variables. However, if it is assumed that there is no
significant difference in the depreciation patterns for the models of a particular manufacturer, but that there exist slight differences between manufacturers, then only five manufacturer dummy variables are required.

The following variables thus are incorporated into the estimation models presented in Chapter 5. Real gross farm income from field crops (GFI) is included in the model to account for demand shocks that affect the structure and level of asset prices. The corresponding coefficient is expected to be positive. Three slope and intercept tax dummies (T) are included to account for the effects of tax changes on asset prices. The problem of manufacturer's list price is accounted for by a new price dummy variable (D1). D1 is expected to have a negative coefficient. Either combine model or manufacturer dummy variables (M₁'s) are used to account for the slight technology differences that might exist between individual models or across manufacturers. Model and manufacturer dummies cannot be included in the same equation because of singularity between the sets of dummies. Thus the symbol M is used interchangeably in the following discussion. Finally, a dummy variable (SF) is included to test for systematic differences in combine prices between spring and fall. SF is expected to have a negative coefficient which is equal to the interest cost of holding a combine six months, from December to June.
CHAPTER 5

ESTIMATION MODEL DEVELOPMENT
AND EMPIRICAL RESULTS

Specific estimation models are developed in this chapter for the four asset price models presented in Chapter 3 using the explanatory variables that were discussed in Chapter 4. The order and procedure by which these models are analyzed is examined, and the results of the econometric estimates are presented in detail. Finally, major implications of these results are discussed.

Estimation Model Development

Specific estimation models are developed for the following four asset price models:

Model 1

\[ P(s) = \beta P(s-1) \]  \hspace{1cm} (5.1)

Model 2

\[ P(s) = \theta + \beta \cdot P(s-1) \]  \hspace{1cm} (5.2)

Model 3

\[ P(s) = P(s-1) \cdot e^{(\delta + \theta s)} \]  \hspace{1cm} (5.3)
Model 4

\[ P(s) = [P(s-1) - \delta] e^{\theta \delta} + \delta \]  \hspace{1cm} (5.4)

The following variable notation is used in specifying the estimation equations. \( P(s)_{i,t} \) denotes the asset price for model \( i \) at time period \( t \), \( D_1 \) the new machine list price dummy variable, \( SF \) the spring/fall dummy variable, \( GFI_t \) real gross farm income for time period \( t \), \( M_k \) the \( k \)'th model or manufacturer dummy variable, \( T_j \) the \( j \)'th tax regime dummy variable, and \( s \) the age of the machine. \( D_1 \) equals one for new machine list prices and zero for used combine resale prices; \( SF \) equals zero for spring prices and one for fall prices.

The most general estimation equation associated with Model 1 assumes that \( \theta \) (the parameter associated with \( P(s-1) \)) is a linear function of \( D_1 \), \( SF \), \( GFI \), model/manufacturer and tax dummy variables. The general estimation model is:

\[ P(s)_{i,t} = \left[ \beta_0 + \beta_{D1} D_1 + \beta_{SF} SF + \sum_{k=1}^{k_m} \beta_{M_k} M_k + \sum_{j=1}^{J_3} \beta_{T_j} T_j \right] P(s-1)_{i,t} + \epsilon_{i,t} \]  \hspace{1cm} (5.5)

where \( \epsilon_{i,t} \) is an additive error term. Note that the above model has no intercept term, and thus it corresponds exactly to Model 1.

Model 2 is similar to Model 1 except that it includes an intercept term. The most general estimation equation corresponding to Model 2 assumes that both \( \theta \) and \( \beta \) are functions of the exogenous variables. The general estimation model associated with Model 2 can therefore be specified as:
where $\epsilon_{i,t}$ is an additive error term.

Equations (5.5) and (5.6) are linear in their parameters and are assumed to have additive error structures. These two models therefore can be estimated using the Ordinary Least Squares (OLS) procedure in SHAZAM, Version 6.1 (White et al., 1988).

In Model 3, the rate of depreciation is an exponential function of age. The estimation equation associated with Model 3 assumes that the parameters of the exponential function, $\phi$ and $\theta$, are themselves functions of the exogenous variables. Thus,

\[
P(s)_{i,t} = P(s-1)_{i,t} \left[ \exp(\phi_0 + \phi_{DI}D + \phi_{SF}SF + \sum_{k=1}^{K} \phi_k M_k + \sum_{j=1}^{J} \theta_j T_j \right] + \epsilon_{i,t}
\]

Equation (5.7) assumes that the error structure is additive. Consequently, because the estimation equation is non-linear in its parameters, it must be estimated using a non-linear estimation procedure.

If Model 3 is assumed to have a multiplicative error structure ($v_{i,t}$), the estimation equation can be written as:

\[
P(s)_{i,t} = P(s-1)_{i,t} \left[ \exp(\phi_0 + \phi_{DI}D + \phi_{SF}SF + \sum_{k=1}^{K} \phi_k M_k + \sum_{j=1}^{J} \theta_j T_j \right] \cdot v_{i,t}
\]

Taking logs of both sides of equation (5.8), the following expression is obtained:
\[ \ln P(s)_{i,t} = \ln P(s-1)_{i,t} + \left[ \phi_o + \phi_{DL}D1 + \phi_{SF}SF + \sum_{k=1}^{k=m} \phi_k M_k \right] + \sum_{j=1}^{j=3} \phi_j T_j + \phi_{GFI}GFI + \theta_0 + \sum_{k=1}^{k=m} \theta_k M_k + S + \sum_{j=1}^{j=3} \theta_j T_j + \varepsilon_{i,t} \]  

(5.9)

where \( \varepsilon_{i,t} = \ln v_{i,t} \). Equation (5.9) is also linear in its parameters and can be estimated using OLS.

Model 4 differs from Model 3 in that Model 4 contains a constant, \( \delta \). The estimation equations associated with Model 4 assume \( \delta \) is not a function of the exogenous variables while assuming \( \phi \) and \( \theta \) are functions of the exogenous variable. Under these assumptions and with the additional assumption that the error structure (\( \varepsilon_{i,t} \)) is additive, the estimation equation of Model 4 is:

\[ P(s)_{i,t} = \left[ P(s-1)_{i,t} - \delta \right] \cdot \exp(\phi_o \phi_{DL}D1 + \phi_{SF}SF + \sum_{k=1}^{k=m} \phi_k M_k + \sum_{j=1}^{j=3} \phi_j T_j + \phi_{GFI}GFI + \theta_0 + \sum_{k=1}^{k=m} \theta_k M_k + S + \sum_{j=1}^{j=3} \theta_j T_j + S) + \delta + \varepsilon_{i,t} \]  

(5.10)

If the error structure is assumed to be multiplicative (\( v_{i,t} \)), the estimation equation associated with Model 4 is:

\[ P(s)_{i,t} = \left[ P(s-1)_{i,t} - \delta \right] \cdot \exp(\phi_o \phi_{DL}D1 + \phi_{SF}SF + \sum_{k=1}^{k=m} \phi_k M_k + \sum_{j=1}^{j=3} \phi_j T_j + \phi_{GFI}GFI + \theta_0 + \sum_{k=1}^{k=m} \theta_k M_k + S + \sum_{j=1}^{j=3} \theta_j T_j + S) + \delta \cdot \varepsilon_{i,t} \]  

(5.11)

Taking logs on both sides of equation (5.11) the following expression is obtained:

\[ \ln P(s)_{i,t} = \ln \left[ P(s-1)_{i,t} - \delta \right] \cdot \exp(\phi_o \phi_{DL}D1 + \phi_{SF}SF + \sum_{k=1}^{k=m} \phi_k M_k + \sum_{j=1}^{j=3} \phi_j T_j + \phi_{GFI}GFI + \theta_0 + \sum_{k=1}^{k=m} \theta_k M_k + S + \sum_{j=1}^{j=3} \theta_j T_j + S) + \delta \cdot \varepsilon_{i,t} \]  

(5.12)

where \( \varepsilon_{i,t} = \ln v_{i,t} \). Model 4 is clearly nonlinear in its parameters, irrespective of whether the error structure is additive or multiplicative, and therefore must be estimated.
using a nonlinear estimation procedure such as the nonlinear Quasi-Newton maximum likelihood procedure in SHAZAM which is used in this analysis.

Equation (5.12) has a form that permits a direct test of the two hypotheses. The first hypothesis can be rejected if any of the coefficients on age \((S)\) are statistically significant. The second hypothesis can be rejected if any of the coefficients on either tax intercept or slope dummies \((T)\) are statistically significant. If, however, the coefficients on all \(T\) and \(S\) are statistically insignificant, both hypotheses cannot be rejected.

**Empirical Results**

Models 1, 2, and 3 are, in effect, special cases of Model 4 as shown in Chapter 3. Estimation equations based on Model 4 are inherently nonlinear. Thus in order to obtain starting values and reduce the dimensions of the nonlinear estimation problem (because of a convergence problem), several versions of each estimation equation associated with Models 1, 2, and 3 (that is equations 5.5, 5.6, 5.9) are estimated. Each version of any given model differs with respect to tax, model, and manufacturing dummy variables that are included on the slope and intercept terms. The results obtained from estimating Models 1, 2, and 3 are used to screen potential explanatory variables in particular model dummy variables, and thus reduce the complexity of the nonlinear model at a
relatively low cost. Regression equations based on Model 3 are also estimated in order to provide starting values for Model 4. The parameter estimates and statistical results for Models 1, 2, and 3 are listed in Appendix B.

**Preliminary Results from Models 1, 2, and 3**

The interesting estimation results from Models 1, 2, and 3 are as follows. First, coefficients associated with the five manufacturer dummy variables on either the slopes or the intercept terms appear to provide as much explanatory power as any combination of the 22 model dummy variables on both the slopes and intercepts or equations which included both manufacturer slope and intercept dummies.

Second, the real gross farm income coefficients are positive and significant at the one percent level, while the list price dummy variable coefficients are negative and significant at the one percent level in all of the 62 model versions.

Third, the coefficients attached to the spring/fall dummies are negative and significant at the one percent level in all of the estimation equations associated with Models 1 and 2, while being insignificant at the 10 percent level in all of the estimation equations associated with Model 3.

Fourth, tax dummies appear to affect both intercept and slope terms. For example, in the six variations of equation (5.5), Model 1, all the tax slope dummies are significant at the one percent level. The tax slope dummy coefficients $T_1$
(1982-84) and T3 (1987-89) are positive but negative for T2 (1985-86). In the 28 versions of equation (5.6), Model 2, T2 slope dummy coefficients are also negative and significant at the one percent level. However, the slope coefficients associated with T1 are positive and significant in only six of the fourteen estimated equations which include tax slope dummies, while the coefficients for the other eight are negative in sign and insignificant at the five percent level. It should be noted that six of the T1 slope coefficients are negative and insignificant at the 10 percent level when tax dummies are included on both the slope and intercept terms. Coefficients associated with the T3 slope dummy are significant at the one percent level in 10 of the 14 models, with two more coefficients being significant at the 10 percent level; however, the signs change across equations. T1 and T3 intercept coefficients for Model 2 are positive and significant at the one percent level, while T2 intercept coefficients are positive and significant at the one percent level for 11 of the 14 models, with the other three coefficients being negative and insignificant at the 10 percent level. The 28 variations of equation (5.9), Model 3, have tax slope dummy variable coefficients that are all positive and significant at the one percent level. The results for coefficients of the tax intercept dummies of Model 3 are more mixed. T1 intercept coefficients are positive and significant at the one percent level in five of the 14 models,
while seven of the T1 coefficients are negative and insignificant at the 10 percent level. The remaining two coefficients are positive and significant at the 10 percent level. T2 intercept coefficients are negative and significant at the one percent level in nine of the 14 models, while the other five T2 coefficients are negative; four are insignificant and one is significant at the 10 percent level. T3 intercept dummy coefficients are positive and significant at the one percent level for half of the 14 models, while the other half are insignificant at the 10 percent level with different signs across the models.

Finally, it should be noted that tax and model interaction variables were examined in several variations of the above models, but these variables were found to have no explanatory power, and therefore were not considered further in this analysis.

The regression results from Models 1, 2, and 3 indicate that manufacturer dummies provide as much information on either the slope or intercept term as any combination of model dummies on the slope and intercept terms, and thus allow a reduction in the dimensionality of the nonlinear problem. Tax dummies have important simultaneous effects on both intercept and slope terms. D1, SF, and GFI also account for important effects in the used asset price equations. Estimation results from various equations based on Model 3 also provide starting values for Model 4.
Results from Model 4

The parameters of Model 4, as presented in equation (5.10), were estimated using the parameter estimates of Models 1, 2, and 3, as starting values. The estimated equation included manufacturing dummy variables on either the slope or intercept term in the exponential portion of the equation and included tax dummies on both the intercept and slope terms of the exponential. D1, SF, and GFI were also included in the exponential, but only on the intercept term. Two versions of Model 4 are thus estimated using equation (5.10) in which an additive error term is assumed. Inspection of the residuals from the estimated equations indicate possible presence of heteroscedasticity as is shown in Figures 1 and 2. This implies that there is probably a multiplicative error structure in terms of the level of price variables instead of the assumed additive error structure. Thus equation (5.12), the natural log equation based on Model 4, is also estimated.

Parameter estimates and statistical results for the four estimated equations of Model 4 are presented in Table 2. Equations 4a and 4b are estimated assuming an additive error structure, while equations 4c and 4d are estimated assuming a multiplicative error structure. Equations 4a and 4c are estimated with manufacturing dummy variables on the intercept term, φ, while equations 4b and 4d are estimated with the manufacturing dummy variables located on the slope term, θ.

Major empirical results obtained from the four different
### Table 1. Model 4a residual points

<table>
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</tr>
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<td>0.00E+00</td>
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<tr>
<td>0.10E+05</td>
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<td>0.60E+05</td>
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<tr>
<td>0.70E+05</td>
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</tr>
<tr>
<td>0.80E+05</td>
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**Figure 1.** Model 4a residual plot, where RESID4A equals one of the 2323 residual points from equation 4a.
Figure 2. Model 4b residual plot, where RESID4B equals one of the 2323 residual points from equation 4b.
### Table 2. Model 4 results.

<table>
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<th>Variable</th>
<th>Model 4a</th>
<th>Model 4b</th>
<th>Model 4c</th>
<th>Model 4d</th>
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<td>1346.2</td>
<td>1658.8</td>
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<tr>
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<td>(12.38)*</td>
<td>(12.68)</td>
<td>(2.077)</td>
<td>(2.591)</td>
</tr>
<tr>
<td>D1</td>
<td>-.3432</td>
<td>-.34361</td>
<td>-.33132</td>
<td>-.33209</td>
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<td></td>
<td>(-40.60)</td>
<td>(-41.18)</td>
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MAXIMUM LIKELIHOOD ESTIMATE OF SIGMA SQUARED
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*T-Ratios are contained in parentheses.

estimation equations for Model 4 are as follows. First, for each estimation equation, the age coefficients are negative and significant at the one percent level. Second, the constant term, δ, is negative and significant. Thus the null hypothesis that economic depreciation takes place at a constant rate is rejected.

Different tax regimes also have statistically significant effects on the rate and pattern of depreciation, and therefore the second hypothesis is also strongly rejected. For example, the coefficients for T2 intercept dummies (1985-86) are negative and significant at the one percent level in all four models, while T2 (1985-86) and T3 (1987-89) slope dummy coefficients are positive and significant at the one percent level. Results are mixed in the case of the other two tax intercept dummies (T1 and T3) and the T1 slope dummy coefficients. For example, the T1 intercept and slope dummy
coefficients are positive in all four equations; but both T1 intercept and slope dummy coefficients are significant at the one percent level in only two of the four equations, while the T3 intercept dummy coefficients are not significant at the 10 percent level with different signs across the four equations.

In each estimation equation based on Model 4, the real gross farm income coefficient is positive and significant at the one percent level, while the list price dummy variable is negative and significant at the one percent level. These results are as expected.

The manufacturer intercept and slope dummies, in general, are not significant. M2 (John Deere) is the only exception. The coefficient associated with M2 is positive and significant at the one percent level on the slope or intercept of every model in which it is included.

The coefficients associated with the spring/fall dummy variables are negative and significant at the 10 percent level. In the additive error structure equations, 4a and 4b, the spring/fall dummy variables are, however, significant at the one percent level. Moreover the signs of the coefficients in these regressions are also more realistic, implying a real discount rate for six months of about 1.77 percent.

The plotted regression residual results from equations 4c and 4d indicate that the heteroscedasticity problems in equations 4a and 4b appear to have been ameliorated through the use of a multiplicative error structure in equations 4c
and 4d. Residual plots for equations 4c and 4d are presented in Figure 3 and 4.

**Implications of Results**

Empirical evidence provided here indicates that rates of depreciation are not constant across different ages of combine harvesters. The evidence also suggests that depreciation rates are not stable with respect to major changes in the tax code. Figure 5 illustrates the behavior of the rate of economic depreciation for a representative combine under each of the four tax regimes when GFI is set at its mean.

In Figure 5, the rate of economic depreciation (the absolute value of the percentage change in the combine harvester's price as it ages one year) is measured on the vertical axis and combine harvester age on the horizontal axis. If the depreciation rate were constant across ages, the depreciation curve would be flat (parallel to the horizontal axis). None of the four depreciation curves in Figure 5 conform to this pattern. Under the 1979-81 and 1982-84 tax regimes, depreciation sharply diverges from this pattern. For the 1979-81 regime, the depreciation rate increases from an initial rate of about 12 percent to a maximum of 17 percent in the eleventh year before declining. Under the 1985-86 regime, the initial depreciation rate is 22.75 percent. It steadily declines by about one percent per year until year 12 and thereafter declines more slowly. These three depreciation
Figure 3. Model 4c residual plot, where RESID4C equals one of the 2323 residual points from equation 4c.
Figure 4. Model 4d residual plot, where RESID4D equals one of the 2323 residual points from equation 4d.
Figure 5. Combine harvester depreciation rates under alternative tax regimes.
patterns in no way correspond to the pattern associated with a constant rate of depreciation. Under the most recent tax structure (1987-89), the rate of depreciation is initially 12 percent and thereafter declines by about .15 percentage points each year over the first 15 years of life. In this case, the depreciation pattern is much closer to the constant rate. It is interesting to note that under the 1987-89 tax regime created by the Tax Reform Act (TRA), the benefits obtained from depreciation allowances and investment tax credits are much lower than under the other tax regimes.

These findings imply that studies of depreciation that ignore tax effects should be interpreted with caution. Studies that use remaining value functions based on asset price data in order to estimate the effects of changes in the tax code on optimal replacement rates are also problematic in that the remaining value function is assumed to be exogenous. This study, however, indicates that remaining value functions are in fact affected by the tax regime in which the remaining value function is observed. This means that the optimal replacement problem can no longer be solved using conventional methods.

These results offer further important ramifications. Hulten and Wykoff (1981) conclude that depreciation rates for buildings could be estimated using time-series data with models that do not account for demand and supply shocks and changes in tax regimes. The findings of this study suggest
that their conclusions are not generally valid. In the case of combine harvesters, the pattern of depreciation has been different across time when including age, the demand shocks from real gross farm income from field crops, and changes in the tax regimes between 1979-1989.

The coefficients on the manufacturer dummies implied that technology dummy variables were not an important factor in the used price equation. This, in part, could be explained by the fact that the manner in which the data were selected was intended to minimize the effects on depreciation caused by technological differences.

The list price dummy variable, on the other hand, was an important factor in the used asset price model. One of the objectives of this analysis was to develop a complete used asset price model which started at age zero. However, including the list price without a dummy variable would lead to a serious residual outlier problem. Two approaches to this problem were considered. The first was to omit list price data (Perry and Glyer, 1990), and the second was to include list price data with a dummy variable. A comparison of regression results between these two approaches using estimation equations based on Model 4 appeared to show no major differences in coefficient values after the first year. Thus, the approach including list price data with an instantaneous dummy variable was selected. The list price
dummy variable was, therefore, an important factor in this analysis.

Finally, the spring/fall dummy variable was relatively important in that it indicated fall prices to be lower in real terms relative to spring prices of combine harvesters.
CHAPTER 6

SUMMARY AND CONCLUSIONS

This study developed a used asset price model which is dynamic and utilizes a flexible functional form. An econometric model of used asset prices for combine harvesters was developed. The model incorporates demand shock variables specific to the asset (for example, gross farm income and tax regime dummy variables). The parameters of the specific model were estimated. Tests of the constant economic depreciation rate hypothesis and whether the pattern of depreciation is invariant with respect to changes in the tax code were then carried out. The results of the analysis provide important information about how changes in age, taxes, demand shocks, and technology affect the rate and pattern of economic depreciation in the case of combine harvesters. They also raise important questions about the validity of the conclusions of previous simulation studies of the effects of changes in tax regimes and asset replacement decisions.

The foundation of the theoretical model in this study rests on the assumption that the equilibrium price of an asset is assumed to equal the present value of the net revenue stream it generates. Two important insights were derived from the theoretical model. First, any event that affects net
revenues will also affect asset prices, and secondly, tax regimes have a complex and indirect effect on the net revenue stream. The theoretical results thus suggest that, because of the intricate structure of the net revenue stream over the life of an asset, the rate of depreciation will not necessarily be constant across ages. In addition, changes in tax regimes may have complex effects on net revenue streams and thus the pattern of depreciation is not likely to remain the same when changes are made to the tax code.

Flexible functional forms were used to model the dynamic asset price behavior. The asset price model that was chosen allowed the rate and pattern of depreciation to be flexible by modeling price as an exponential quadratic function of age.

The estimation model is inherently nonlinear. Thus the parameters of three linear models, each of which is nested within the quadratic model, were estimated in order to obtain starting values for and, by screening explanatory variables, reduce the dimensionality of the nonlinear model.

The major empirical results of this study are as follows. First, depreciation rates are not constant across different ages of combine harvesters. Second, depreciation rates and patterns are not stable with respect to changes in tax codes. Third, increases (decreases) changes in real gross farm income from fields crops have significant, positive (negative) effects on combine harvester prices. Fourth, the list price dummy is negative and significant. This suggests that
estimation models that include new machine list prices in the data set should incorporate dummy variables to take into account the instantaneous new list price effect. Finally, the spring/fall dummy variable is also significant, identifying systematic differences between fall and spring prices. These differences can be explained by the interest charge associated with buying an asset approximately six months before it is needed (for example, purchasing a combine harvester in the fall after harvest instead of in the following spring for that summer's use).

The general asset price model used in this study to test the constant rate of economic depreciation hypothesis could be applied to other specific physical assets such as trucks, tractors, and fishing vessels. Data sets on these specific assets have previously been examined, but with models that were based on different functional forms and that were estimated with different procedures.

Finally, this study has shown that used asset prices are in fact affected by changes in tax regimes. Thus remaining value functions based on a given data set include the effects of the tax regime under which the new or used asset prices were generated. The analysis raises questions about the validity of conventional methods used in previous asset replacement studies which assume constant rates of depreciation and do not include taxes as an explanatory variable in the remaining value functions. This study
indicates that new methods must be developed in which this problem is accounted for if the optimal replacement problem is to be solved in an internally consistent manner.
REFERENCES


APPENDIX A

COMBINE HARVESTER DATA
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(1) YEAR (F89) means fall data from 1989.
(2) AC  Allis-Chalmers 
JD  John Deere 
IH  International Harverter 
MF  Massy-Ferguson 
NH  New Holland 
WHITE  White
APPENDIX B

RESULTS FROM MODELS 1, 2, AND 3
Table 4. Model 1 results.

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