RURAL ECONOMY

Reducing Investment Risk in Tractors and Combines with

Improved Terminal Asset Value Forecasts

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Staff Paper 96-02

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Abstract

Secondary asset market data for combines and tractors are used to estimate and separate out historical economic depreciation, embodied technological change and time value change. Combines and tractors generally exhibit constant geometric economic depreciation on a year to year basis. Depreciation rates vary by manufacturer. Farm investors can use these manufacturer specific depreciation rates reported here to estimate terminal asset values. The study found significant seasonal differences in machinery depreciation rates. A major source of error in forecasting terminal asset values comes from changes related to time. There is a predictable time component to the constant quality asset index that has not been investigated in previous studies. Unanticipated shocks to demand should be followed by price reversion to long-run average manufacturing costs as industry capacity adjusts to demand. This reversion component is predicable. Investment risk over longer planning horizons may be lower when both depreciation coefficients and time component estimates are employed.

Reducing Investment Risk in Tractors and Combines with Improved Terminal Asset Value Forecasts

Introduction

Forecasts of terminal value are very important in the farm machinery investment decision (Reid and Bradford 1983). Terminal asset values[1] are normally forecast with economic depreciation estimates. Improved terminal asset value forecasts reduce the risk surrounding the machinery investment.

This paper improves the terminal asset value forecasts for North American tractors and combines. It accounts for the estimation problems inherent in time-series, cross-sectional machinery price data and improves upon the statistical methods existing in the literature. It introduces the concept of price reversion common in the finance literature to additionally refine the terminal asset value forecast. It also analyses depreciation differences by manufacturer and by type of technology (in combines). Finally it observes seasonality in depreciation rates.

Secondary market transaction records on combines and tractors from 1972 to 1992 are used to obtain time-independent economic depreciation estimates by manufacturer by half year (an age effect). In this respect the paper updates the tractor literature (Perry, Bayaner and Nixon 1990; Hansen and Lee 1991; McNeill 1979) and provides an alternative to the Cross and Perry (1995) study which includes 1984-1993 data on tractors, combines and other farm machinery. The Perry et al.(1990) results indicated that depreciation rates varied by manufacturer; however their data set only

[1] Terminal asset value is also referred to as the salvage value or the remaining value.

spanned three years while Hansen and Lee (1991) ignored the manufacturer effect. Knowledge of a 3% difference in depreciation rates between manufacturers is useful information for farms which may have several hundred thousand dollars or more invested in machinery.

The model used to estimate the effect of age on machine value also identifies time and technology effects. Other studies investigate the effect of individual machine usage (accumulated hours) and size (horsepower) on expected value change (Perry et al. 1990; McNeill 1979; Cross and Perry 1995) or use the time component to construct historical machinery price indices (Hansen and Lee 1991; Lee 1978). Here, the time component is analysed for ways to improve terminal value forecasts. Information related to the time the forecast is made is combined with economic depreciation estimates to improve the terminal value forecast and thereby reduce the machinery investment risk.

The paper is organized in the following manner. The next section reviews previous work on depreciation estimates. The data is then described and the estimation methods and results follow. Applications to forecasting terminal asset values are then discussed.

Previous Work And The Hall Model

Asset value changes over time include economic depreciation (an age effect), quality changes (a technology effect) and demand changes (a time effect) (Hall, 1968, 1971). The economic depreciation, defined as the rate of change of asset prices with age, is assumed to be independent of time and independent of the individual manager. The quality changes and demand changes are time-dependent but are also independent of the individual manager. Estimation methods must differentiate between these different effects on used asset prices. These different effects are described below when the Hall model is explained.

Two main models have been used to estimate depreciation. One method, the Box-Cox transformation, transforms the variables allowing a flexible functional form for estimation. A second estimation method is based on the work by Hall (1968, 1971) and this model is explained later. The Box-Cox transformation is useful when there are many different asset categories, a small sample size and data does not have any zero observations. Box-Cox estimation problems and biases caused by heteroskedasticity, by autocorrelation and by data scaling (Zarembka 1974; Savin and White 1978; Seaks and Layson 1983; Spitzer 1982 1984) have not been adequately addressed when estimating depreciation. These Box-Cox estimation problems discussed by Spitzer (1982, 1984) and others can seriously bias the transformation variable and invalidate the statistical tests.

Hulten and Wykoff (1981) were among the first to apply the Box-Cox transformation to estimate depreciation. Perry et al. (1990), and Cross and Perry (1995), following Hulten and Wykoff (1981), use the Box-Cox transformation to estimate farm machinery depreciation using auction market data. The Perry et al. (1990) data only spans 1985-1988 which is too brief a time period to reliably estimate any time effect. The Cross and Perry (1995) study still only covers ten years, 1984-1993. Neither of these studies on farm machinery address the concerns raised above about the Box-Cox methodology.

Problems with estimating the Box-Cox transformation are avoided by using the model developed by Hall (1968, 1971) in which asset values are viewed as the present value of the future benefits (economic rents) expected from the use of the asset. Hall

(1971) utilizing this discounted stream of benefits idea, formalized the empirical work done by Cagan (1971) to derive the model

(1) $$p_{t,\ ,v} = P_t^{*} D\ B_v$$

The model states that the observed price $p_{t,\ ,v}$ of the used asset is the underlying constant quality price index P_t^{*} at time t, adjusted for vintage (*v*) or embodied technology by the index B_V and adjusted for economic depreciation by asset age τ by the index D . P_t^{*} is affected by disembodied technological changes (general improvements in the use of existing technology) and by such factors as changes in expected equipment demand or in industry manufacturing capacity. D measures the pure age effect of economic depreciation. B_V captures quality differences, including the effects of different asset sizes. Equation (1) can be applied to machinery in general or to test whether depreciation varies between manufacturers.

This model requires restrictions to separate embodied technology and machine age. Hall (1971) and Lee (1978) surmounted this problem by placing restrictions on technology change over time. Hansen and Lee (1991) use a normalization similar to Cagan (1965) and use the year a model is first manufactured to denote its technology. In the present paper, the embodied technology term, B_V, denotes the manufacturer's model series number (e.g. John Deere 6600 combine) rather than the year of model introduction on the assumption that manufacturers signal new technology by introducing new models. This normalization on model number distinguishes technology and depreciation effects by manufacturer even when competing machinery model series numbers have been introduced in the same year. For example, it separates value effects of “rotary” versus “conventional” combines from depreciation differences between manufacturers.

Following Hansen and Lee (1991) the model is expressed as:

(2) $$\ln(p_{t,\ ,v}) = \sum_t \ln(P_t^*)T_t + \sum_m \sum \ \ln(D_{\ ,m})G_{\ ,m} + \sum_v \ln(B_v)V_v + u$$

where T, G and V are vectors of zero/one dummy variables that identify the observation year, age and manufacturer's series. Subscripts on each vector T, G, and V represent the elements associated with each vector. There are spring and fall observations for both age and time. For example, the combine equation has times of T_{1972}, $T_{1972.5}$,...T_{1992}, ages of G_1, $G_{1.5}$,...$G_{8.5}$ and models from V_1,...V_{20}. The manufacturers are designated by the subscript *m*. The first summation on the right hand side of equation (2) captures the time effect. The time effect is constrained to be the same for all manufacturers. Economic depreciation by manufacturer is captured by the double summation. The final summation compares the embodied technology between assets. There are 130 coefficients in the combine model and 234 coefficients in the tractor model after normalizations[2]. The data are described next.

[2] Estimation of equation (2) requires the normalization of the embodied technology of one combine (tractor) model, $ln(B_v)$, to be 0 and this provides the technology comparison for each model. The age τ=1 depreciation index $ln(D)$ (spring and fall) is normalized to be zero for each manufacturer. Thus all depreciation factors, D are measured relative to one year old assets by manufacturer. This normalization forces depreciation for assets aged 1 (spring) and 1.5 (fall) to be the same and gives them a depreciation index of 1.

Data

Used combine and tractor prices were collected for the period of spring 1972 to spring 1992. The prices are averaged-as-is dealer selling prices from across North America reported in spring and fall issues of the *Official Guide: Tractors and Farm Equipment*. Perry et al. (1990) discussed the limitations of this data source; however it is the best time series source of secondary market asset prices for tractors and combines. Data for actual initial (time zero) selling prices are not included in the *Official Guide*. Studies such as Perry et al. (1990) and Cross and Perry (1995) use list prices for initial prices, but list prices are not observed transaction prices and confound depreciation estimates with the manufacturer's marketing methods.

Asset prices on 20 combine series-numbers representing small to medium sized combines with either conventional or rotary technology from 5 different manufacturers were collected from asset age 1 (spring) to 8.5 (fall). There are 2265 observations on 170 cohorts on the combine data. Asset prices on 34 two wheel drive tractor series-numbers in the 100 to 150 horsepower range from 8 manufacturers were collected from asset age 1 (spring) to 11.5 (fall). There are 174 cohorts with 3202 total observations. Additional data on older equipment were available but were omitted out of concern for the censoring problem described by Hulten and Wykoff (1981).

All prices from the Official Guide are in nominal United States dollars. The CPI (Bureau of Labour and Statistics, 1982-1984=100) for the United States is used to deflate the used asset prices. Use of the CPI is consistent with the general concept that investment is an exchange of consumption opportunities across time.

Method and Results

Not surprisingly, considering the time series and cross sectional nature of the data, preliminary ordinary least squares (OLS) estimates revealed first order autocorrelation and heteroskedasticity. The autocorrelations were assumed to be related to each manufacturer. Estimation of serial correlations between manufacturers was not attempted. The OLS residuals were used to estimate a sample autocorrelation coefficient in each cohort. Following Kmenta (1986 p.816) the coefficient was constrained to be between -1 and 1 and a simple mean of these autocorrelation coefficients for the cohorts in each manufacturer group was taken. This provided a consistent AR(1) estimate for each manufacturer. A Prais-Winsten transformation (retaining all observations) using these manufacturer autocorrelations was performed on the data, cohort by cohort. OLS was used on this transformed data. White's heteroskedasticity consistent estimator for the variance-covariance matrix was used to overcome the heteroskedasticity problem. The model still exhibited some non-normality in the residuals after these adjustments. The coefficient and variance estimates are still consistent with non-normal residuals but may no longer be efficient. The student-t test and the F test still have asymptotic justification (Judge et al. p. 824).

Observations about the equation (2) results for P_t, B_v and D_τ follow below. Due to the large number of coefficients estimated, only a representative set of model estimates are selected for presentation. All test conclusions reported are significant at the 5% level and detailed results are available from the authors.

The constant quality asset value, P_t, represents the value of a combine or tractor of constant quality over the time period 1972 to 1992. Figure 1 illustrates this time component and shows a sharp increases in asset values in the 1970's with subsequent value decline. For example, the constant quality combine value increased by 18% during the spring of 1976 and decreased by 10% during the spring of 1979. These value changes are time specific, relatively large, statistically significant and add to investment risk. Statistically significant differences in value changes each time period implies that the returns to holding the constant quality asset are not a random walk[3] and this invites attempts to forecast the time component.

Tables 1 and 2 are the remaining value coefficient estimates, D , and can be used to estimate terminal values or annual depreciation. All depreciation is measured from a beginning point of one year old assets. All combine manufacturers and six of the eight tractor manufacturers exhibit constant yearly spring-to-spring geometric depreciation rates by manufacturer and as such is similar to the results reported by Hansen and Lee (1991) for their tractor data set. John Deere and Allis Chalmer tractors are the manufacturers not exhibiting constant annual spring-to-spring depreciation.

The remaining value results for tractors and combines (Tables 1 and 2) exhibit a seasonal economic depreciation effect and this seasonal effect has not been noted or tested in other studies. The greatest depreciation (loss in value) occurs during the fall-to-spring time period. These spring versus fall differences are significant for John Deere, Massey

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[3] If the returns, r, to owning the constant quality asset are a random walk then $\ln(P_t) = r + \ln(P_{t-1})$. The random walk model, often used in market efficiency tests, is not consistent with a reversion model.

Ferguson and New Holland combines and for Allis Chalmers, Case, John Deere and IH tractor manufacturers. This seasonal effect is likely related to the seasonal nature of North American grain farming. Furthermore manufacturers have significantly different depreciation rates. This supports the conclusions of Perry et al.(1990) that asset value changes vary by manufacturer.

Figure 2 illustrates the difference in annual spring to spring depreciation rates between two manufacturers. New Holland combines hover around 9% annual depreciation rates while John Deere combines vary between 6% and 8%. John Deere tractor depreciation rates vary between 3% and 6%. Case tractor depreciation rates vary between 6.5% and 7.5%. Results for other manufacturers show similar patterns.

The combine and tractor quality comparisons, B_V, generally showed larger capacity, newer models are valued more highly. This technology component picks up the differences in size. Technology is represented in the Hall model by manufacturer series-number and does not enter the manager's forecast once the asset is purchased because the technology is constant across the forecast period. Figures 3 and 4 show the economic value of the technology of the tractor and combine models relative to a base technology. Relevant comparison are between machines of similar capacities. In general newer models have a higher technology value or component. This supports the conclusions of improving technology over the time period.

Figure 5 presents a special comparison between two competing combine technologies, rotary versus conventional. The two technologies are significantly different and the market placed a slight premium on the rotary technology in the used asset market.

Asset values may still decrease more rapidly for rotary combines than for conventional combines because of differences in the manufacturer specific depreciation.

Improving Time Forecasts

The prior results provide historical time-independent, manufacturer-specific depreciation indexes. Managers can use these manufacturer-specific estimates to forecast the future terminal value of the asset assuming no change in the constant quality asset value P_t. The two other value-influencing components besides age in the Hall model are technology and time. Technology is represented in the model by manufacturer series-number and does not enter the manager's forecast because it is constant across the forecast period. This leaves the effect of time as a possible source for improving terminal value forecast. In this section a simulation exercise measures the error reduction obtained by adding the forecastable part of the time component to the depreciation estimates.

Hansen and Lee (1991) suggested long-run changes in tractor prices are supply-determined with competition between manufacturers tending to drive new equipment prices to long-run average total manufacturing cost. However, in the short run, manufacturing capacity is rigid. Unpredictable demand shocks, probably emanating from agricultural commodity markets, can induce capacity surplus or shortage and correspondingly change short-term pricing of new equipment. Eventually, however, capacity responds to the short-term price signals and long-run equilibrium prices for new equipment are restored. This reversion to long-run price is also expected in used equipment since used equipment is a substitute for new and the supply of used equipment is fixed. Figure 1 indicates the time effect on machinery prices. The rapid rise in real commodity prices during the 1970s is a plausible example of a demand shock affecting the machinery price series.

Demand shocks are not predictable. The reversion of prices to some long-run trend after the shock is predictable. Managers can potentially use this reversion in prices to improve terminal asset value forecasts. Fama and French (1998), Poterba and Summers (1988) or Cutler , Poterba and Summers (1991) have used mean reverting models to test the market efficiency (random walk) hypothesis in financial markets. The hypothesis of reversion to long-run average costs suggests the use of similar reverting models for machinery. Results discussed in the prior section rejected the random walk hypothesis for returns to holding constant quality machines. This result is compatible with a model that includes a reversion component.

The Hansen and Lee (1991) results indicated a downward trend in the long-run average manufacturing costs for sixty horsepower tractors. A model that incorporates a constant geometric trend in manufacturing costs and a reversion to trend during one period is:

(3) $$P_t^{**} = P_{t-1}^{**} e \quad + \quad (C_0 e^{\{ \quad (t-1)\}} - P_{t-1}^{**}) + \quad {}_t$$

where the P_t^{**} are the actual constant quality asset coefficient estimates from equation (2), δ is the trend in manufacturing costs,   is the rate of reversion in one time period and C_0 is the long-run manufacturing costs at time t=0. The   is expected to be positive in sign. The manufacturing trend term, δ is expected to be small and this makes it difficult to distinguish this model from alternative forms. A negative δ indicates declining manufacturing costs.

Estimation and testing of this model presents several problems. Results from equation (2) estimates are used to eliminate the errors-in-variables estimation problem[4] in (3). The model is nonlinear in δ and a grid search is used to estimate δ. Finally, knowledge of the manufacturing costs are required at time t=0. Using information from Hansen and Lee (1991), the first observation P_1 (spring 1972) is chosen equal to $C_0 e$ to coincide with a period of relative price stability. The constant quality coefficient estimates from equation (2) were first converted to an index with 1982=100 before estimation.

Results from equation (3) are in Table 3. The reversion parameter 's of .075 for tractors and 0.35 for combines are not significant but they are of the expected sign. Lack of significance is not surprising considering the long nature of these time trends and the only twenty year span of the data. These are still the best estimates of the reversion parameters and can be used to improve forecasts thereby reducing risk. The tractor reversion of 0.075 per six months implies that if the tractor price index were 20 % above its trend value, prices would revert down by about 3% over the next year. This reversion would be independent of and additive to economic depreciation.

Long-run trend estimates in manufacturing cost δ's are -0.27% and 0.51% for tractors and combines respectively over a six month period. The tractor δ agrees with the Hansen and Lee (1991) data that costs are declining. The combine δ suggests prices were increasing over this period. The difference between tractors and combines could, in addition to differences in manufacturing technology, result from increased concentration and declining competition in combine manufacturing during the period.

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[4] Details on the correction used are available from the authors.

In practical applications, a manager might use manufacturer and age specific economic depreciation estimates from the Hall model (e.g. Tables 1 and 2). Forecasts are refined by determining the current value of the constant quality asset using equation (2) and then using the coefficient estimates from equation (3) to estimate the amount of value reversion over the expected machinery holding period.

A simple test, while in-sample, provides supporting evidence on investment error reduction by adding time-reversion estimates to depreciation estimates. Error is measured as the deviation of the actual value from the forecast value. One set of forecast asset values is generated with manufacture-specific depreciation estimates only. A second set of forecasts is enhanced with time-reversion estimates. Root Mean Square Errors[5] (RMSE) measure the forecast errors, in dollars.

The RMSE for forecasts made when the tractors and combines are one year old are shown in Figure 6. RMSE for forecasts based on other ages are similar. Absolute forecast errors or risk exceeds $8,000 for combines and $3000 for tractors when the investment holding period is over four years. This dollar error as a percentage of the mean value of five year old machines is 28% and 17% for combines and tractors respectively[6]. Errors are greater on combine investments than tractor investments.

Including time reversion decreases the investment error for both combines and tractors but the error reduction is much greater for tractors. This is emphasized in Table 4

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[5] RMSE is defined as RMSE= $\sqrt{\sum_i (ActualValue_i - ForecastValue_i)^2 / n}$ where n is the number of forecasts.

[6] Mean one year old tractor and combine values are $24,180 and $41,098 respectively and five year old tractor and combine mean values are $17,673 and $28,774 when measured in constant dollars.

where error reduction through the addition of time reversion can approach 50% for tractors and only 20% for combines. The benefits of including time-reversion increase as the intended holding period (forecast horizon) increases.

Profiles of RMSE for one, three, five and eight year holding periods are exhibited in Figures 7, 8, 9, and 10. Asset age at the start of the forecast periods varies in these figures. Error for one year holding periods (Figure 7) are much lower than for three, five or eight year holding periods (Figures 8, 9 and 10). Comparing Figures 7 through 10 show investment error initially increases with the intended holding period but it may decrease for investment horizons over 5 years as machinery values become relatively small. Adding time reversion has almost no impact on one year holding period error (Figure 7). The benefits of including time reversion appear for holding periods of three years or more. The percentage decrease in error improves with longer intended holding periods and with the age of the machine (Table 4). Slow reversion of asset prices favours the use of time forecasts over longer intended holding periods.

These test results suggest that machinery investors can reduce risk by including time reversion forecasts with depreciation forecasts. This technique may be especially relevant after major demand shocks from the commodity market.

Conclusions

Secondary asset market data for combines and tractors are used to estimate and separate out historical economic depreciation, embodied technological change and time value change. Combines and tractors generally exhibit constant geometric economic depreciation on a year to year basis which supports the findings of Hansen and Lee

(1991). Depreciation rates vary by manufacturer as suggested by Perry et al. (1990). Farm investors can use these manufacturer specific depreciation rates reported here to estimate terminal asset values. The study found significant seasonal differences in machinery depreciation rates. The model used for estimating farm machinery depreciation could be used on other assets where secondary markets exist.

A major source of error in forecasting terminal asset values comes from changes related to time. There is a predictable time component to the constant quality asset index that has not been investigated in previous studies. Unanticipated shocks to demand should be followed by price reversion to long-run average manufacturing costs as industry capacity adjusts to demand. This reversion component is predicable. A forecasting trial using root mean square error measures supports this hypothesis. Investment risk over longer planning horizons may be lower when both depreciation coefficients and time component estimates are employed.

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Table 1
Combine Remaining Value Factors Based On Age 1 Combines
By Manufacturer

Age[a]	Gleaner	John Deere	Case-I.H.	M.F.	N.H.
2.0	91.9%	93.1%	91.6%	92.3%	91.3%
2.5	90.6%	93.1%	90.6%	92.1%	89.8%
3.0	84.3%	86.9%	83.5%	85.2%	82.6%
3.5	82.1%	86.4%	82.8%	84.4%	80.7%
4.0	77.3%	80.6%	76.4%	78.8%	74.9%
4.5	73.7%	79.8%	75.8%	78.3%	72.3%
5.0	69.0%	74.4%	69.6%	73.3%	67.9%
5.5	65.3%	73.4%	68.6%	72.0%	65.1%
6.0	61.7%	69.4%	63.6%	67.7%	61.7%
6.5	58.1%	67.9%	61.7%	65.6%	58.8%
7.0	55.1%	64.6%	57.3%	61.9%	56.1%
7.5	52.1%	62.8%	55.7%	59.5%	52.9%
8.0	49.7%	60.2%	52.4%	56.3%	51.0%
8.5	46.9%	58.3%	49.9%	53.8%	47.9%

a. An age 2.5 Gleaner combine has 0.906 the value of a one year old combine. Ages ending in a half (2.5 or 3.5 etc.) are fall values. Ages ending in a 0 are spring values.

Table 2
Tractor Remaining Value Factors Based On Age 1 Tractors
By Tractor Manufacturer

Age[a]	Allis	Case	John Deere	Deutz	Ford	I.H.	M.F.	White
2.0	92.8%	92.2%	94.8%	91.2%	95.3%	94.7%	94.2%	93.9%
2.5	92.8%	92.9%	96.6%	90.3%	95.0%	90.8%	92.9%	93.6%
3.0	87.9%	85.7%	91.7%	83.2%	90.4%	87.4%	87.4%	88.9%
3.5	87.5%	86.3%	92.8%	81.9%	90.7%	83.5%	85.6%	88.7%
4.0	82.9%	80.0%	88.5%	77.1%	84.7%	81.7%	80.9%	83.8%
4.5	82.6%	80.6%	89.4%	76.1%	85.8%	76.8%	79.0%	83.3%
5.0	78.6%	74.7%	86.5%	72.0%	80.2%	76.3%	73.1%	77.6%
5.5	77.1%	74.9%	87.2%	70.6%	80.7%	71.2%	71.2%	76.9%
6.0	72.8%	69.3%	84.0%	66.0%	76.9%	69.0%	66.3%	71.0%
6.5	71.3%	69.1%	83.9%	64.7%	77.1%	65.5%	64.0%	69.1%
7.0	65.9%	64.4%	80.4%	60.6%	74.1%	63.7%	60.1%	63.9%
7.5	63.3%	64.1%	79.5%	59.2%	74.3%	60.6%	58.2%	62.0%
8.0	58.2%	60.1%	76.2%	55.5%	70.7%	58.5%	55.3%	57.8%
8.5	55.8%	59.6%	75.5%	53.9%	69.9%	55.7%	53.5%	56.6%
9.0	52.0%	56.0%	72.2%	50.4%	66.3%	52.9%	50.8%	52.8%
9.5	49.2%	55.5%	71.4%	48.8%	65.8%	51.2%	49.2%	51.5%
10.0	45.1%	52.4%	68.6%	45.8%	62.3%	48.4%	46.5%	48.0%
10.5	44.2%	51.6%	68.4%	44.5%	62.1%	47.6%	44.9%	46.7%
11.0	40.6%	48.7%	66.4%	41.8%	58.2%	44.5%	42.2%	43.8%
11.5	40.1%	47.6%	66.4%	40.9%	58.1%	44.1%	41.0%	42.8%

a. An age 6.0 Allis Tractor has 0.728 the value of a one year old tractor. Ages ending in a half (2.5 or 3.5 etc.) are fall values. Ages ending in a 0 are spring values.

Table 3

Constant Quality Asset Index (P_t) Reverting Model Parameter Estimates

(Quality Index 1982=100)

Coefficient	Tractors	Combines
	-0.0027	.0051
	0.075(.061)	0.035(.038)
$C_0 e \; = P_1$	95.01	65.91

These are the estimates for equation 3, the reversion to trend model for the constant quality asset time component. The coefficient for the rate of reversion for a half year, is estimated by using linear least squares adjusted to remove the errors-in-variables inconsistency. The long-run trend in manufacturing costs, δ, is estimated by using a grid search that minimizes the least squares. The P_1 is the first data point in the index (spring 1972) and it is assumed that price equals manufacturing cost at this time. The numbers in brackets are standard deviations conditional on P_1 and δ. Neither estimate is significant using a conventional t test.

Table 4
Relative Decrease in RMSE For Different Machinery Investment Holding Periods when Time Reversion is Added to Depreciation Estimates

Age of Asset at time of Forecast	1 Year Holding Period Tractor	1 Year Holding Period Combine	3 Year Holding Period Tractor	3 Year Holding Period Combine	5 Year Holding Period Tractor	5 Year Holding Period Combine	8 Year Holding Period Tractor	8 Year Holding Period Combine
1	2.9%	0.5%	13.4%	10.3%	28.4%	8.7%	42.0%	na
1.5	3.5%	0.5%	13.4%	10.3%	27.5%	8.0%	43.7%	
2	3.5%	0.5%	15.2%	11.6%	32.3%	9.6%	48.6%	
2.5	3.8%	0.5%	15.4%	11.8%	32.5%	9.0%	48.0%	
3	4.1%	0.6%	19.0%	14.6%	36.7%	10.8%	54.6%	
3.5	4.7%	0.6%	19.0%	14.5%	37.6%	10.4%	54.0%	
4	4.5%	0.6%	20.8%	15.9%	41.5%			
4.5	5.3%	0.6%	21.1%	16.2%	42.7%			
5	5.9%	0.7%	22.7%	17.4%	47.4%			
5.5	6.8%	0.8%	25.1%	19.2%	49.9%			
6	6.9%	0.9%	26.9%		55.6%			
6.5	8.0%	1.0%	30.6%		57.8%			
7	7.8%	1.1%	31.2%					
7.5	9.4%	1.2%	36.4%					
8	8.4%		34.1%					
8.5	10.3%		40.2%					
9	9.4%							
9.5	10.8%							
10	10.9%							
10.5	12.7%							

Figure 1

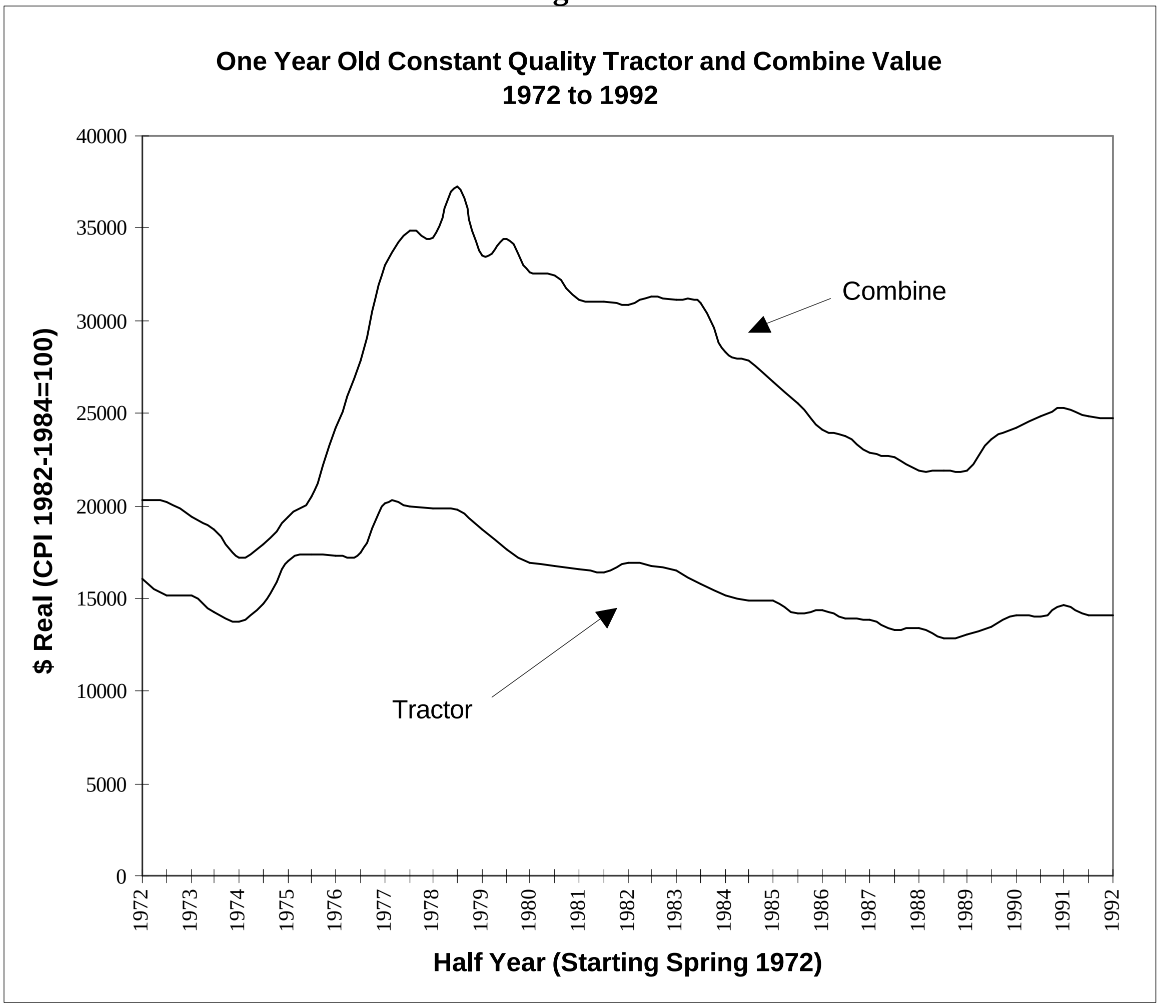

One Year Old Constant Quality Tractor and Combine Value
1972 to 1992
$ Real (CPI 1982-1984=100)
40000
35000
30000
25000
20000
15000
10000
5000
0
Combine
Tractor
1972
1973
1974
1975
1976
1977
1978
1979
1980
1981
1982
1983
1984
1985
1986
1987
1988
1989
1990
1991
1992
Half Year (Starting Spring 1972)

Figure 2

Manufacturers were selected to represent commonly available equipment in the secondary market.

Figure 3

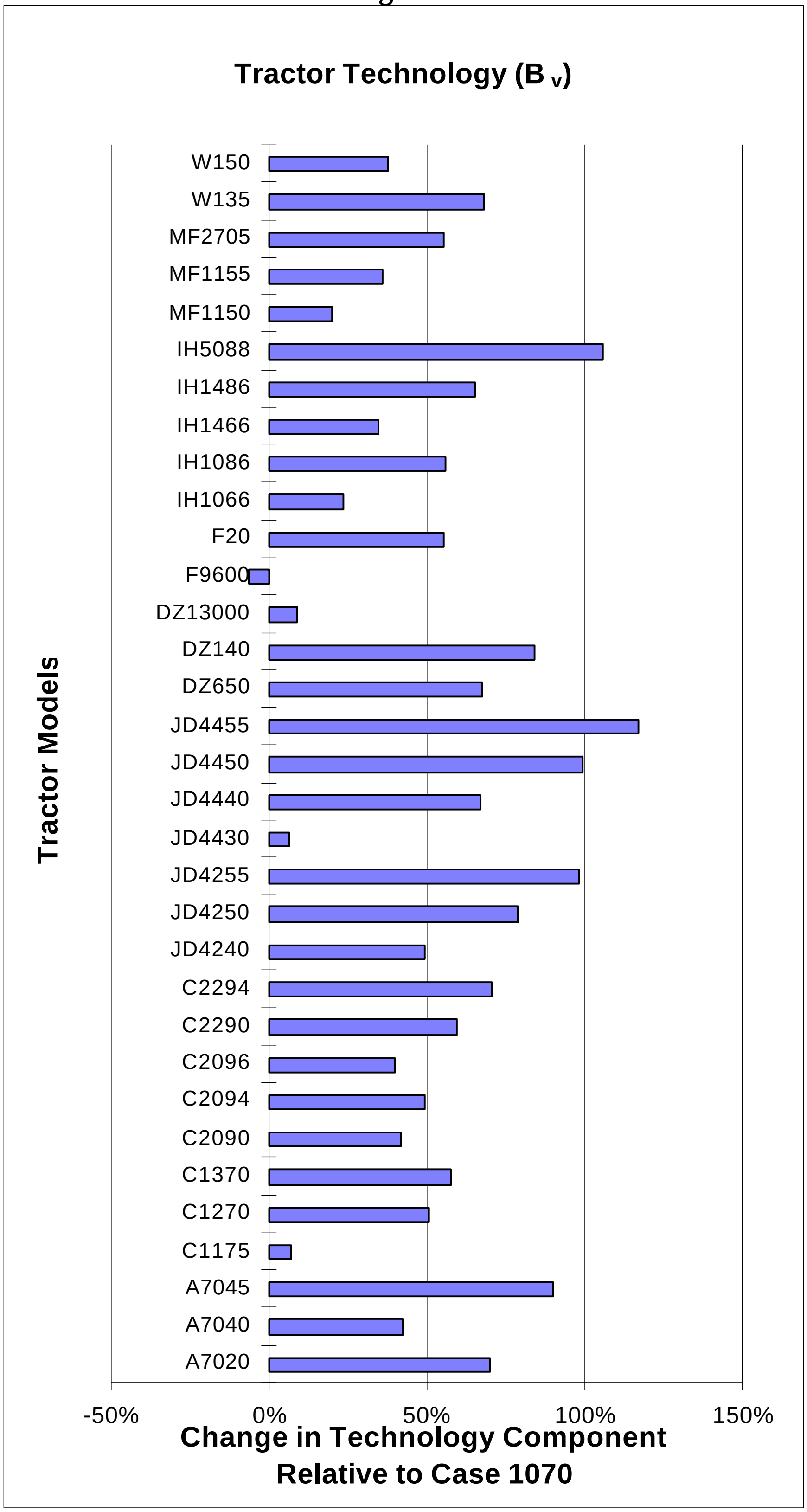

Tractor Technology (B v)
Tractor Models
W150
W135
MF2705
MF1155
MF1150
IH5088
IH1486
IH1466
IH1086
IH1066
F20
F9600
DZ13000
DZ140
DZ650
JD4455
JD4450
JD4440
JD4430
JD4255
JD4250
JD4240
C2294
C2290
C2096
C2094
C2090
C1370
C1270
C1175
A7045
A7040
A7020
-50%
0%
50%
100%
150%
Change in Technology Component
Relative to Case 1070

Figure 4

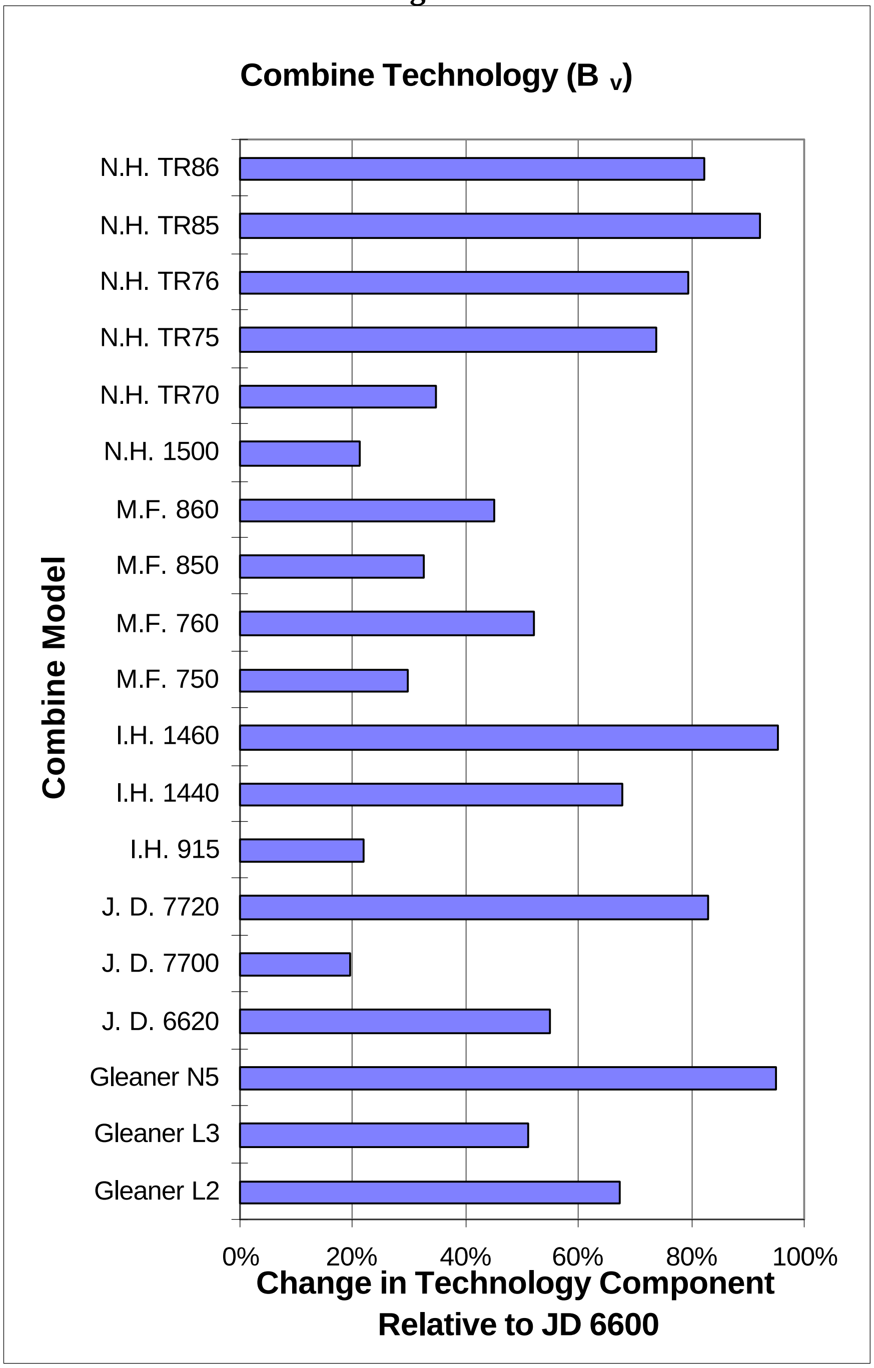
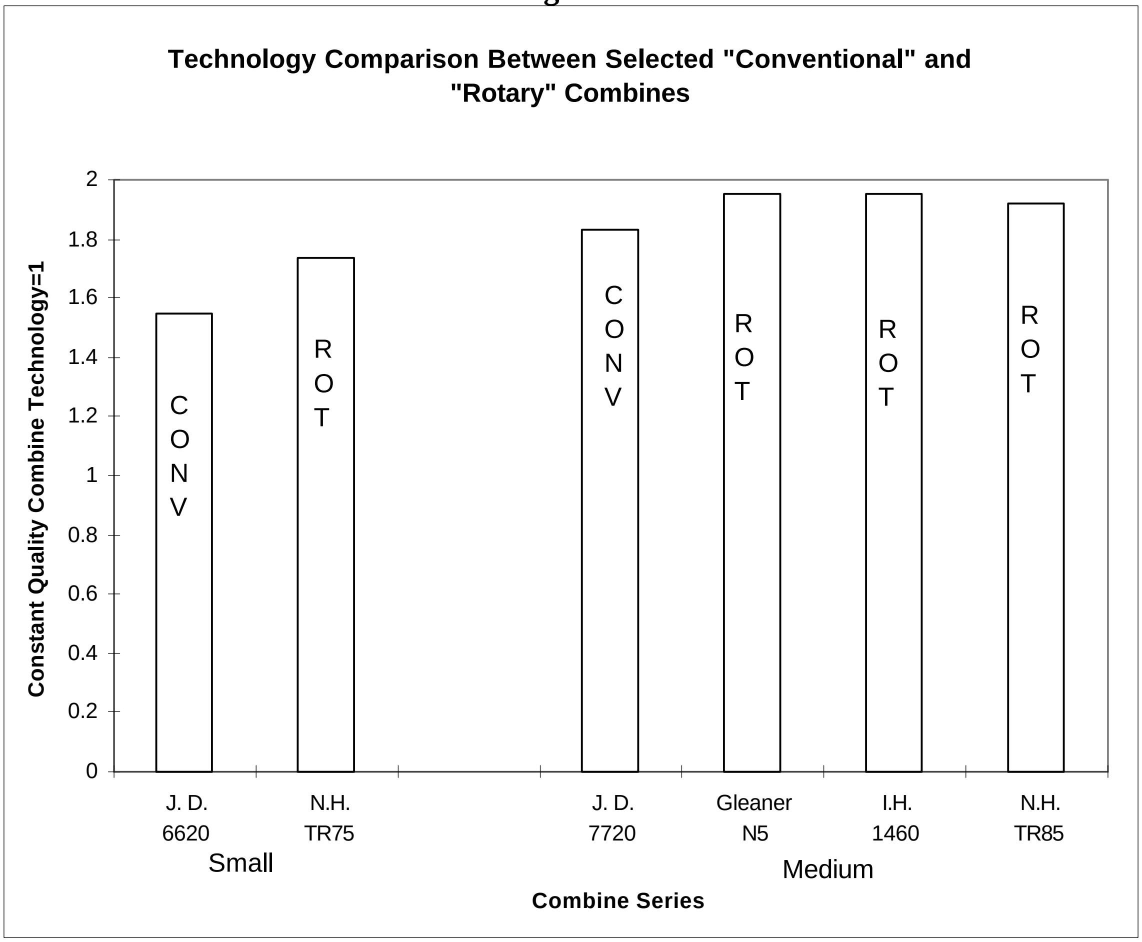

Combine Technology (B v)
N.H. TR86
N.H. TR85
N.H. TR76
N.H. TR75
N.H. TR70
N.H. 1500
M.F. 860
M.F. 850
M.F. 760
M.F. 750
I.H. 1460
I.H. 1440
I.H. 915
J. D. 7720
J. D. 7700
J. D. 6620
Gleaner N5
Gleaner L3
Gleaner L2
Combine Model
0%
20%
40%
60%
80%
100%
Change in Technology Component
Relative to JD 6600

Figure 5



Technology Comparison Between Selected "Conventional" and "Rotary" Combines
Constant Quality Combine Technology=1
2
1.8
1.6
1.4
1.2
1
0.8
0.6
0.4
0.2
0
CONV
ROT
CONV
ROT
ROT
ROT
J. D. 6620
N.H. TR75
J. D. 7720
Gleaner N5
I.H. 1460
N.H. TR85
Small
Medium
Combine Series

Figure 6

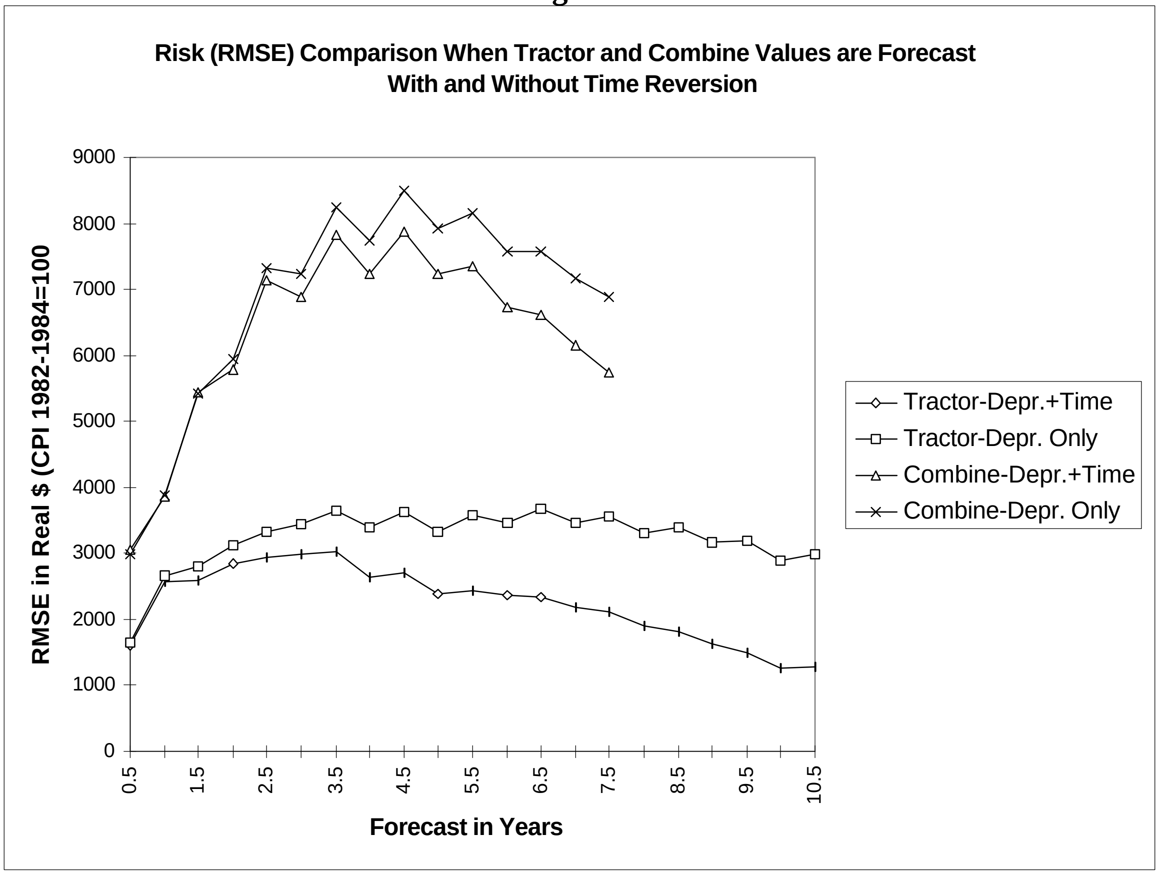

Risk (RMSE) Comparison When Tractor and Combine Values are Forecast
With and Without Time Reversion
RMSE in Real $ (CPI 1982-1984=100
9000
8000
7000
6000
5000
4000
3000
2000
1000
0
0.5
1.5
2.5
3.5
4.5
5.5
6.5
7.5
8.5
9.5
10.5
Forecast in Years
Tractor-Depr.+Time
Tractor-Depr. Only
Combine-Depr.+Time
Combine-Depr. Only

Figure 7

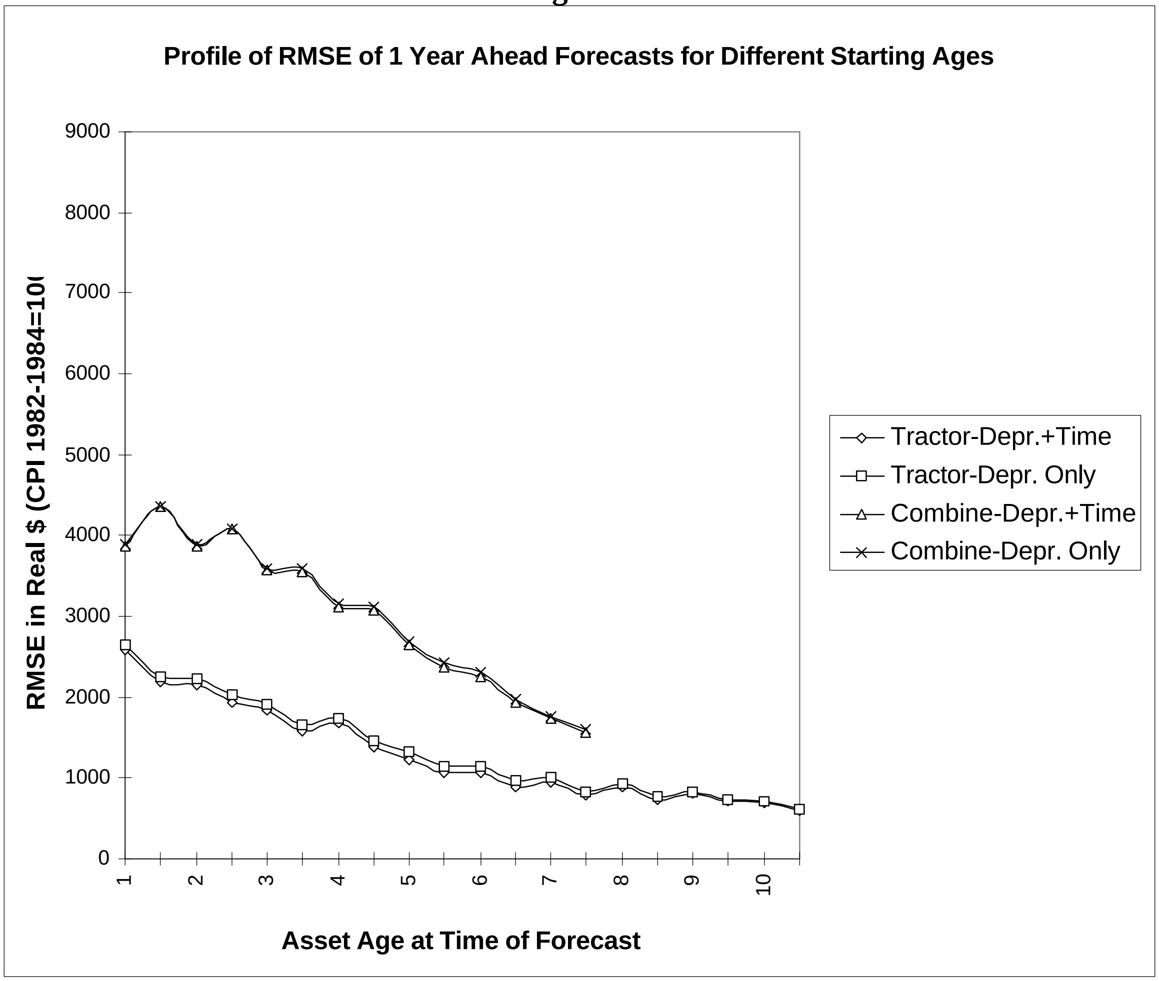

Profile of RMSE of 1 Year Ahead Forecasts for Different Starting Ages
RMSE in Real $ (CPI 1982-1984=10
Asset Age at Time of Forecast
9000
8000
7000
6000
5000
4000
3000
2000
1000
0
1
2
3
4
5
6
7
8
9
10
Tractor-Depr.+Time
Tractor-Depr. Only
Combine-Depr.+Time
Combine-Depr. Only

Figure 8

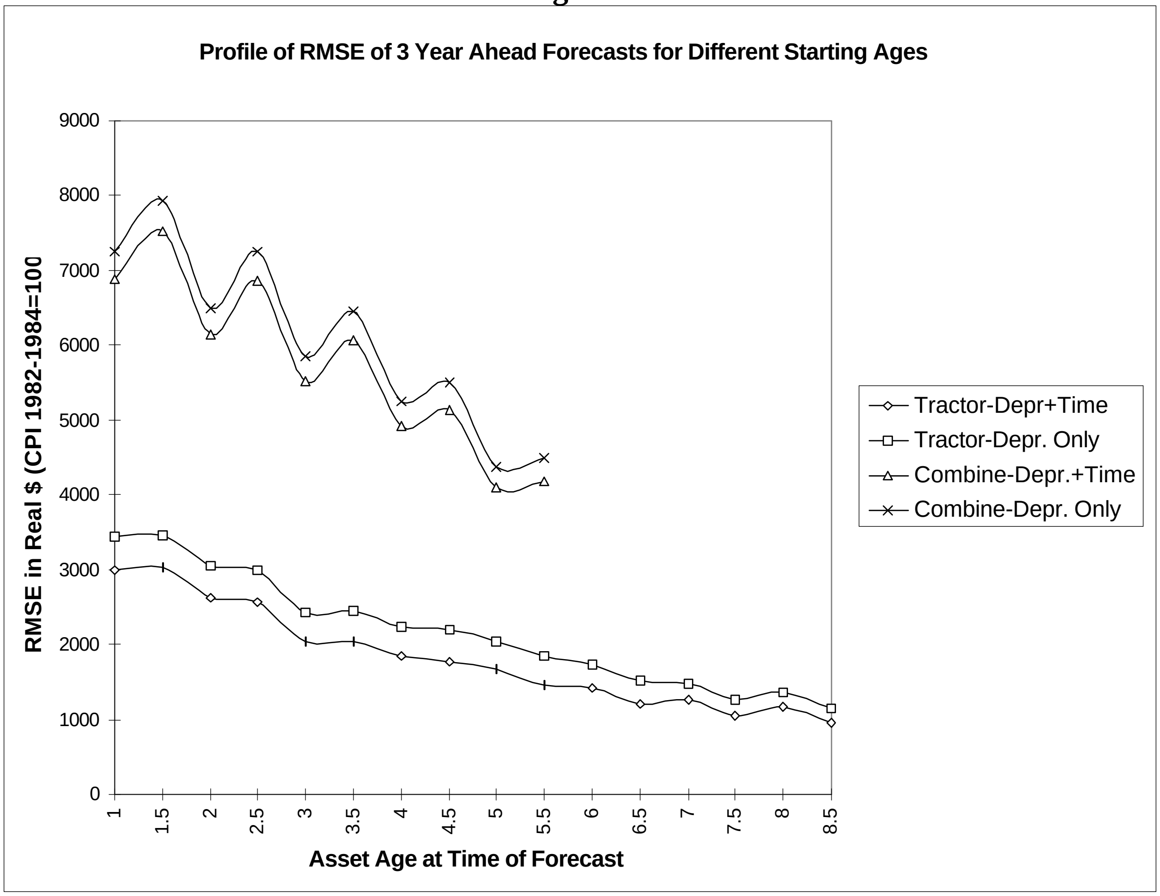

Profile of RMSE of 3 Year Ahead Forecasts for Different Starting Ages
9000
8000
7000
6000
5000
4000
3000
2000
1000
0
RMSE in Real $ (CPI 1982-1984=100
1
1.5
2
2.5
3
3.5
4
4.5
5
5.5
6
6.5
7
7.5
8
8.5
Asset Age at Time of Forecast
Tractor-Depr+Time
Tractor-Depr. Only
Combine-Depr.+Time
Combine-Depr. Only

Figure 9

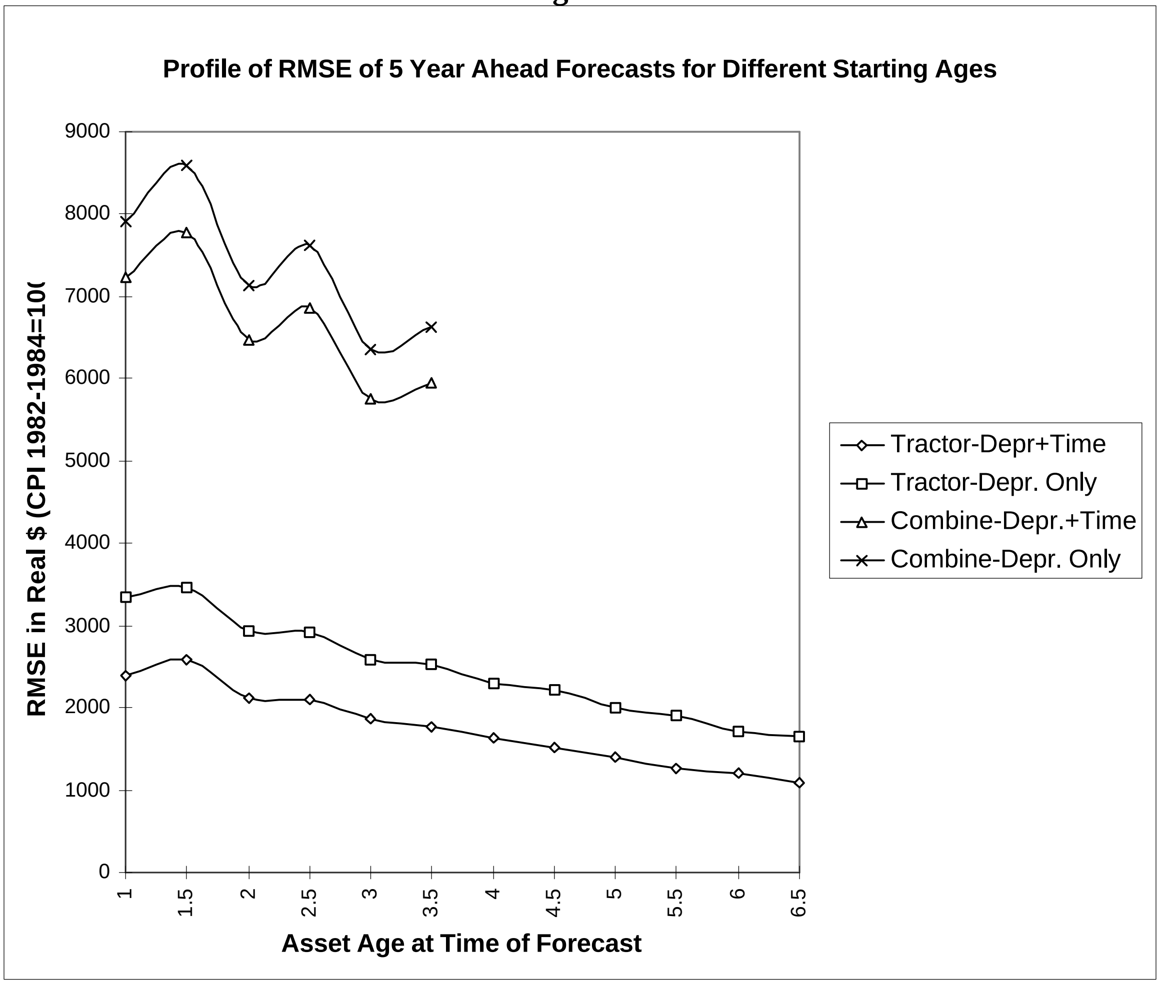
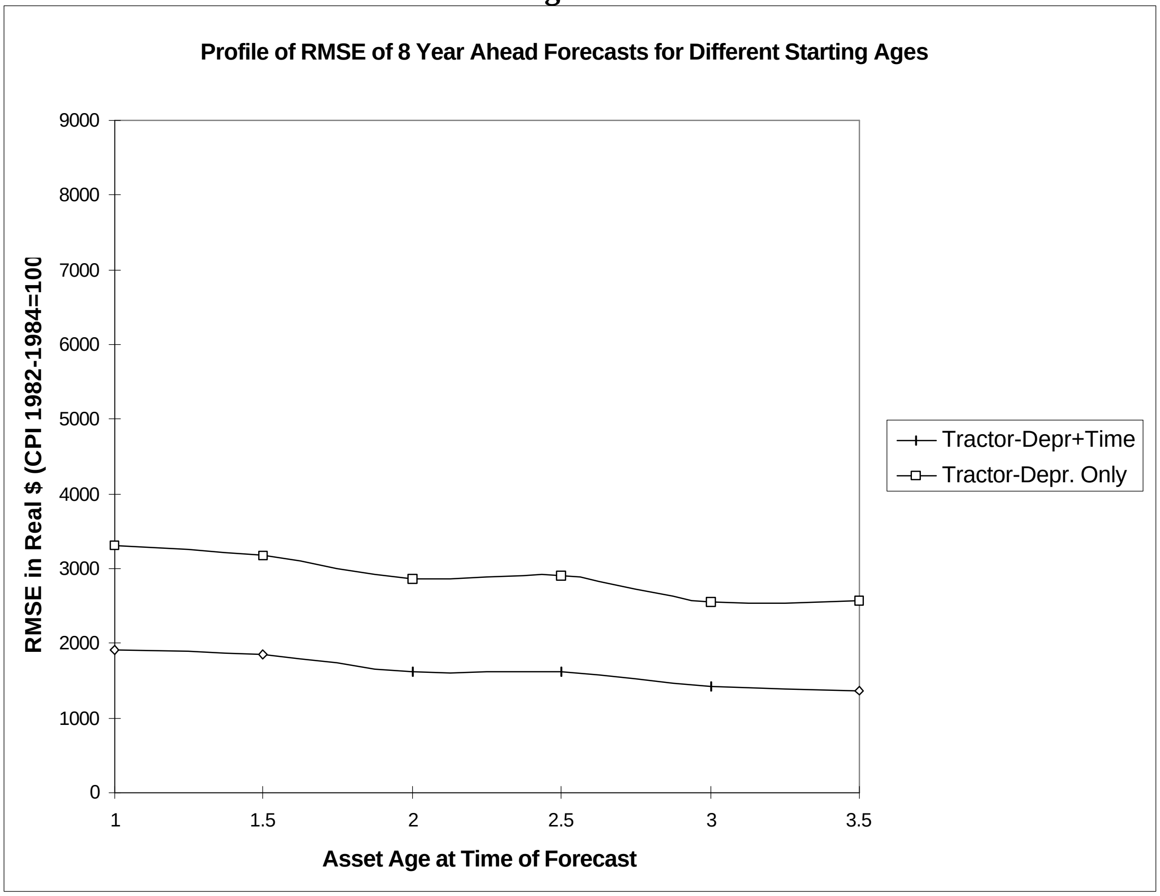

Profile of RMSE of 5 Year Ahead Forecasts for Different Starting Ages
RMSE in Real $ (CPI 1982-1984=10
9000
8000
7000
6000
5000
4000
3000
2000
1000
0
1
1.5
2
2.5
3
3.5
4
4.5
5
5.5
6
6.5
Asset Age at Time of Forecast
Tractor-Depr+Time
Tractor-Depr. Only
Combine-Depr.+Time
Combine-Depr. Only

Figure 10


Profile of RMSE of 8 Year Ahead Forecasts for Different Starting Ages
9000
8000
7000
6000
5000
4000
3000
2000
1000
0
RMSE in Real $ (CPI 1982-1984=100
1
1.5
2
2.5
3
3.5
Asset Age at Time of Forecast
Tractor-Depr+Time
Tractor-Depr. Only

Appendix: Additional Material on Statistical Tests

This appendix contains tables providing additional information on this study. Tables A.1 and A.2 name the specific combine and tractor model series. Table A.3 contains the test results on constant geometric depreciation. Test results on differences in depreciation rates between manufacturers are reported in Table A.4. Combine technology comparison tests are in Table A.5.

Table A.1
Combine Manufacturers and Model Series Number Used in the Study

Manufacturer	Model	Technology	Capacity	Year Introduced
Allis Gleaner	L2	conventional	small	1977
Allis Gleaner	L3	conventional	small	1983
Allis Gleaner	N5	rotary	medium	1979
John Deere	6600	conventional	small	1970
John Deere	6620	conventional	small	1979
John Deere	7700	conventional	medium	1970
John Deere	7720	conventional	medium	1979
International Harvester	915	conventional	small	1969
International Harvester	1440	rotary	small	1977
International Harvester	1460	rotary	medium	1977
Massey Ferguson	750	conventional	small	1973
Massey Ferguson	760	conventional	medium	1972
Massey Ferguson	850	conventional	small	1982
Massey Ferguson	860	conventional	medium	1982
New Holland	1500	conventional	small	1973
New Holland	TR70	rotary	small	1975
New Holland	TR75	rotary	small	1979
New Holland	TR76	rotary	small	1985
New Holland	TR85	rotary	medium	1979
New Holland	TR86	rotary	medium	1985

Conventional. represents conventional technology and rotary represents rotary threshing technology. The year of first manufacture uses the Official Guide data and there is not always agreement between the main tables for average as is values and their list of serial numbers on dates of introduction. Small or medium indicate the authors' relative comparison of threshing capacities and are not exact specifications. Deutz bought Gleaner in the 1980's and continued the same combine lines under slightly different names. Case purchased IH in the mid 1980's and continued the same combine lines under slightly different names.

Table A.2
Tractor Manufacturers and Model Series Number Used in the Study

Manufacturer	Model	Horse Power	Year Introduced
Allis Chalmers	7020	100-110	1978
Allis Chalmers	7040	130-140	1975
Allis Chalmers	7045	140-150	1978
Case	1070	100-110	1970
Case	1175	120-130	1971
Case	1270	120-130	1972
Case	1370	140-150	1972
Case	2090	100-110	1978
Case	2094	110-120	1983
Case	2096	110-120	1984
Case	2290	120-130	1978
Case	2294	130-140	1983
John Deere	4240	110-120	1978
John Deere	4250	120-130	1983
John Deere	4255	120-130	1989
John Deere	4430	120-130	1973
John Deere	4440	130-140	1978
John Deere	4450	140-150	1983
John Deere	4455	140-150	1989
Deutz	DX6.50	120-130	1984
Deutz	DX140	130-140	1979
Deutz	D13006	120-130	1972
Ford	9600	130-140	1973
Ford	TW20	130-140	1979
International Harvester	1066	120-130	1971
International Harvester	1086	130-140	1976
International Harvester	1466	140150	1971
International Harvester	1486	140-150	1976
International Harvester	5088	130-140	1981
Massey Ferguson	1150	130-140	1970
Massey Ferguson	1155	140-150	1973
Massey Ferguson	2705	120-130	1978
White	2135	130-140	1976
White	2150	140-150	1975

Table A.3
Summary of Constant Geometric Depreciation Test Results For Combines and Tractors[a] for Differing Time Periods

Manufacturer	Half Year Deprec. Test Stat.	Yearly Spring to Spring Deprec. Test Statistics	Yearly Fall to Fall Deprec. Test Statistics
Combines			
Allis Gleaner	0.88	0.62	0.22
John Deere	2.42*	0.17	0.25
IH	1.75	0.10	0.33
Massey F.	2.37*	0.43	0.51
N. Holland	4.84*	0.12	0.31
Tractors			
Allis C.	5.05*	8.54*	5.40*
Case	3.94*	0.31	0.23
John Deere	2.54*	2.69*	1.85
Deutz	1.21	0.60	0.54
Ford	1.75	0.53	0.31
IH	2.06*	0.95	0.21
Massey F.	1.13	0.81	0.66
White	1.68	0.1.23	0.1.13

a. These F tests are used on equation (2) by restricting the difference $\ln(D) - \ln(D_{-i})$ to be constant for a single manufacturer over all ages. A * indicates significant at the 5% level. The combine F test for half year, spring to spring and fall to fall have (12, 2135), (6, 2135) and (6, 2135) degrees of freedom respectively. The tractor tests for half year, spring to spring and fall to fall have (18, 2968), (9, 2968) and (9, 2968) degrees of freedom respectively.

Table A.4
Testing Depreciation Rates For Differences Between Manufacturers
Comparing $\ln(D\ )_{JD}=...=\ln(D\ )_{MF}$ over different ages τ

Age (τ)[a]	Tractor F-Test	Combine F Test
2	1.43 (7, 2968)	0.94 (4, 2135)
2.5	2.42	1.85
3	3.38	3.44
3.5	5.13	4.98
4	5.45	6.44
4.5	8.55	10.15
5	11.88	10.39
5.5	16.51	16.37
6	23.47	16.53
6.5	26.46	22.87
7	32.76	22.71
7.5	35.72	32.71
8	41.57	29.27
8.5	44.82	39.26
9	48.56	
9.5	53.10	
10	62.22	
10.5	74.97	
11	93.48	
11.5	87.81	

a. This shows the F-test results on age by age tests as to whether the depreciation rates differ by manufacturer. Nearly all tests reject the hypothesis of equal depreciation rates. (Numbers in brackets are F-test degrees of freedom)

Table A.5
Selected Comparison of Rotary Combine Technology to Conventional Technology
Testing $\text{Ln}(B_i)=..=\text{Ln}(B_k)$

Models Compared	F Test (Degrees of Freedom)
N5, JD7720, IH1460, NHTR85	6.7 (3, 2135)
JD6620, TR75	67.6 (1, 2135)

JD7720 and JD6620 represent conventional technology and the tests are significantly different from 0 at the 1% level. T-tests comparing the JD7700 individually to each of the three other combines also indicate significant differences between the technologies.