# The Pricing and Depreciation Patterns of Used Tractors

Nathan Daninger

Dr. Michael Gunderson

Purdue University

ndaninge@purdue.edu

Selected Paper prepared for presentation at the 2017 Agricultural & Applied Economics Association Annual Meeting Chicago, Illinois, July 30 – August 1, 2017

**Abstract**

This paper examines the role of attributes in used tractor depreciation including physical attributes and brand. The goal of this paper is to examine the role of recent agricultural technologies in tractor depreciation and update the literature regarding branding and depreciation after a significant wave of mergers and acquisitions lasting up to the early 2000s. This paper finds that tractor depreciation across age varies nonlinearly across horsepower yet increasing and nearly linearly in hours. Tractor depreciation over age and hours also varies significantly across brands, with John Deere and Case IH retaining value best. Several attributes seem to change value substantially in used tractors including horsepower, brand, age, hours, drivetrain system (wheel, track or quad track), and whether there was a single owner. Other attributes such as warranty status, articulation and if it was an online sale seemed to have little importance after controlling for other variables. Functional form choices made in Wu and Perry (2004) are also compared and their results validated.

## 1) Introduction

The United States experienced a second golden age of agriculture between 2011 and 2014 when the combination of a growing world population, the emergence of biofuels and an emerging global middle class brought commodity prices to unprecedented levels. However, the USDA’s Economic Research Service projects 2017 Net Farm Income at $62.3 billion, down 49.7% from the 2013 high of $123.8 billion (Schnepf, 2017). The last three years have left agricultural businesses looking for solutions to tighter profit margins caused by depressed farm incomes. Shrinking returns in agriculture corresponded with a plethora of mergers and acquisitions in 2016, and the equipment-manufacturing sector is one industry that seems poised for further consolidation.

In August 2016, the Department of Justice sued John Deere & Company to block their acquisition of Precision Planting LLC from Monsanto on antitrust grounds (Department of Justice, 2016). The fifteen years prior to 2000 saw substantial consolidation in US tractor manufacturing; however, the industry has been relatively stable since. The IBIS World database states the tractor and agricultural equipment-manufacturing sector is moderately competitive, with John Deere & Company, CNH Industrial NV, and AGCO Corporation leading in production (Miles, 2016). Understanding how tractor attributes retain value informs agricultural equipment manufacturers how best to meet the needs of farmers. Additionally, the network of independent agricultural equipment retailers can incorporate this information into decisions about trade-ins and used equipment inventory management. Understanding why brand premiums vary across subsectors may also assist regulators as they safeguard the public interest.

This paper contributes to the existing literature in three main ways. First, it adds to the existing depreciation literature through use of a more extensive sample than has been available to many past researchers. This gives an opportunity for higher precision when determining functional forms and estimating coefficients. Second, it is an update to the literature regarding branding and its role in used machinery markets. Substantial consolidation occurred in the machinery-manufacturing sector through the 1980s and 1990s, peaking with the formation of CNH NV in 1999 from the constituent manufacturers of Case and New Holland, and finishing in 2002 with the acquisition of Caterpillar's equipment line by AGCO. Except for the break-through by Kubota into the utility tractor market, the tractor-manufacturing sector has remained relatively stable for the past fifteen years. This large wave of consolidation alongside technological advances may have changed brand premiums and depreciation patterns. Third, new attributes have hit the tractor market in the same period and relatively few studies have examined how they affect used tractor values. The options available to farmers include larger horsepower tractors, the option to use online sales platforms, the advancement of precision agriculture systems, and development in the use of tracked, articulated, and bareback tractors. These areas leave ample room to add information about how and why tractors depreciate.

## 2) Literature Review

The agricultural machinery manufacturing industry is highly consolidated. Three major companies are the key manufacturers in this sector, namely Deere & Company, CNH Global NV, and AGCO Corporation (Miles, 2016). A fourth company that has been increasingly important and is therefore included in this analysis is Kubota Corporation. IBIS World notes that brand recognition is an important factor in deterring new entrants to the industry; combining this with the high capital expenditure required for entry leads to difficulty in entering the industry (Miles, 2016). In the agricultural manufacturing sector, tractor manufacturing is easily the most important subsector, accounting for approximately 26.8% of new sales (Miles, 2016).

In 2015, average farm equipment assets in the US were $108,775 per farm, which amounted on average to 10.55% of total equity. This makes it the second most important asset category after land and buildings (USDA, 2015). For farms with more than $1,000,000 in sales, equipment was even more important at $746,234 worth of assets and 15.50% of equity. In contrast, farms in the $100,000-$249,999 of sales category only had $171,924 of equipment equating to 10.09% of equity on average (USDA, 2015). Most tractors in the United States are concentrated in just a few regions of the country, primarily the Corn Belt and neighboring states. Table 1 shows

*Table 1: Regional Shares of US Tractor Inventory*

| Tractor Percent of US Inventory | | |
|---|---|---|
| | 100+ HP | 40-99 HP |
| Southeast | 3.54% | 7.28% |
| Mountain | 6.92% | 5.35% |
| Delta | 4.01% | 5.53% |
| Corn Belt | 28.07% | 19.34% |
| Lake | 15.13% | 11.87% |
| Pacific | 4.51% | 6.52% |
| North Plains | 17.56% | 7.42% |
| Northeast | 5.66% | 9.20% |
| Appalachia | 5.46% | 15.17% |
| South Plains | 9.14% | 12.32% |

that the USDA Farm Production Regions of Corn Belt, North Plains, and Lake States alone made up 38.63% of the small tractor inventory (40-99 horsepower) and 60.76% of the large tractor inventory (100+ horsepower) according to the 2012 National Agricultural Statistics Service (NASS) survey of agriculture (USDA, 2012).

A study of the United Kingdom tractor market by Walley et. al (2007), found that brand is the single most important aspect of machinery purchases by UK farmers. The researchers estimated brand accounted for 38.95% of the purchase decision, with price being of secondary importance (25.98%) and service coming in third (14.90%). A survey conducted by farm equipment magazine found that 68.8% of US farmers considered themselves brand loyal in 2014, a 6.2% increase over 2011 (Kanicki, 2014). According to the same author, 74.3% of Case IH customers considered themselves brand loyal (up 35.3% from 2011), followed by John Deere at 71.2%, New Holland at 62.5% (up 18.1% from 2011) with AGCO at 33.3%. The survey article also queried about farmers' primary brand of tractors, with 54.1% considering John Deere their primary brand, 32.1% naming Case IH, 7.3% choosing New Holland, and AGCO taking 5.5%. This above distribution is comparable to the distribution of tractors in this sample although John Deere appears more often and Case IH appears less often. Purdue's 2013 Large Commercial Producer Survey also indicates that crop farmers have a high level of brand loyalty when it comes to capital equipment while livestock farmers considered themselves considerably less brand loyal than their cropping counterparts. Figure 1 gives perspective to the consolidation and restructuring of the US tractor industry over the previous thirty years.

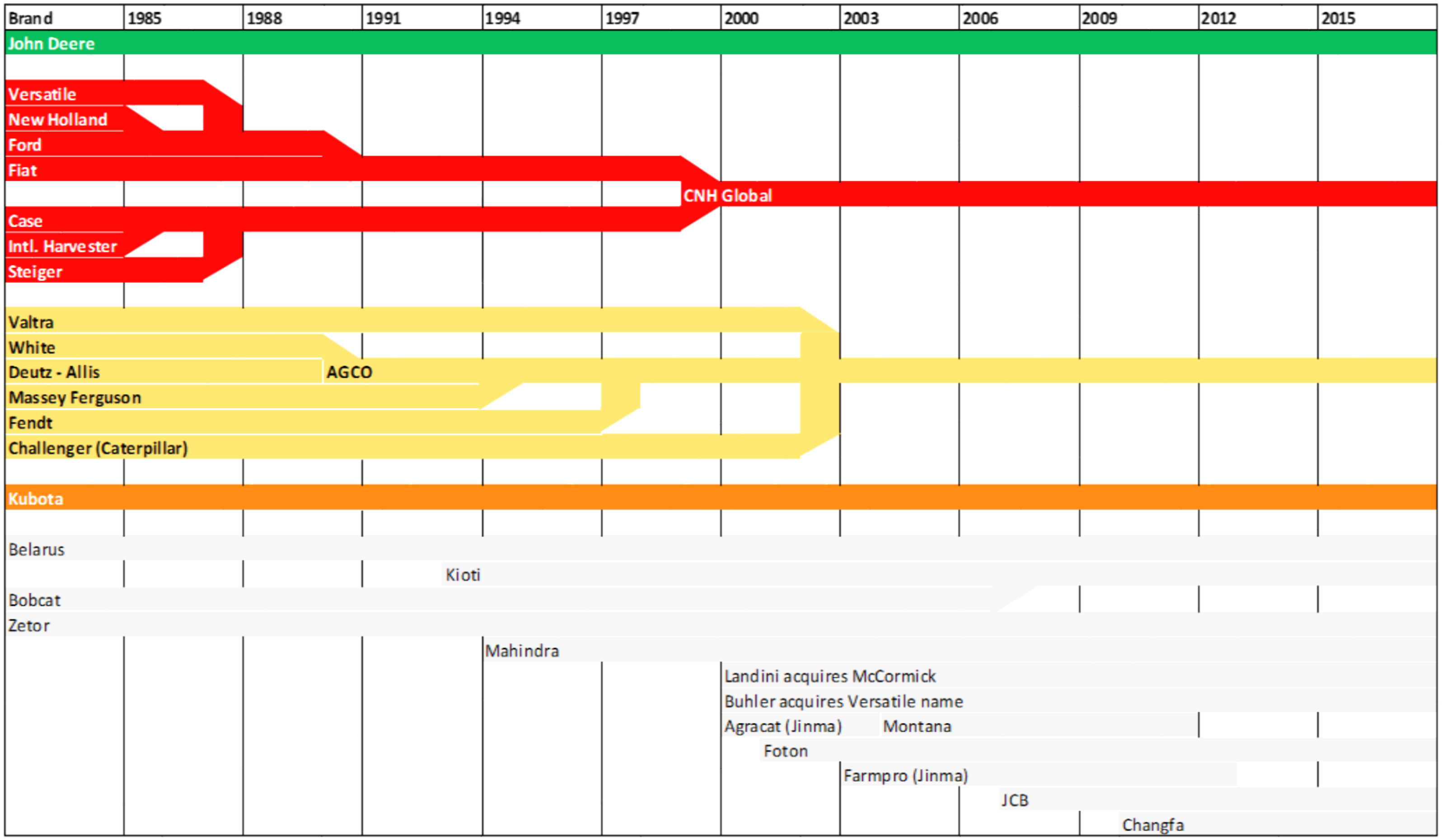


*Figure 1: Consolidation in Tractor Manufacturing*

**3) Functional Forms**

Which functional forms are most appropriate for equipment depreciation models received extensive examination from the early 1990s to the mid-2000s. Wu and Perry compare functional forms across several studies by appealing to a mean absolute percentage error (MAPE) criterion (2004). The authors conclude that Box-Cox, double square root, and sum-of-year's digits models were likely to be the most efficient models for depreciation calculations. Their conclusion is supported by a paper that found Cross and Perry's 1995 work on depreciation with a Box-Cox functional form to be the optimal criterion among the six options they evaluated (Dumler et. al, 2003). In contrast, a study by Mumey and Unterschultz validates the use of constant depreciation rates (1996). Another article written on functional forms for tractor depreciation models argues that a linear system is likely the best option for measuring depreciation due to a relatively small efficiency gain and its simplicity (Wilson, 2010). However, linearizing transformations, if appropriate, may be simpler to interpret than third-degree polynomials and also correct for heteroscedasticity. Another difference between the estimation in Wilson's study and others is the use of absolute dollar amounts rather than a remaining value percentage (see also: Mumey and Unterschultz, 1996).

Another area that has garnered attention in analysis of the tractor market is the role the internet has played over the past decade. A plethora of sites have appeared for the sale of agricultural and construction equipment. Several of the most prominent sites in the used tractor market are MachineryPete, TractorHouse, eBay, IronPlanet, Fastline, EquipmentTrader and IronSearch. The advent of the internet has changed the way farmers are able to buy and sell machinery by providing more options while driving down search costs. A 2014 study examined the characteristics affecting a farmer's likelihood to engage in online sales or purchasing of machinery found the most important factors in a farmer's probability of engaging in online machinery transactions is their perception of whether their dealer treats them fairly (Roe, Batte & Diekmann, 2014). In addition to the farmer-dealer relationship, the authors found that the individual characteristics of farmers influenced their likelihood of online transactions. Farmers who had proclivities to be more trusting and price shop more were more likely to buy equipment online than their more suspicious and brand-loyal counterparts.

Other studies have analyzed the effects of the internet on the sale price of tractors, including an estimation that the effect of selling a tractor on eBay is significant and negative, which is partially attributable to differences in buyer values and partially to a risk premium via a market for lemons phenomenon (Diekmann, Roe & Batte, 2008). The same authors conclude that old and cheap tractors, which can be covered by eBay's $20,000 guarantee fraud protection program, are likely to be sold online. Tractors that are more expensive, however, will earn a higher price if sold in person due to a trust premium incurred by an auctioneer. This study re-examines the role of the internet in the sale of used tractors (See also: Diekmann, Roe & Batte, 2008; Roberts 2011). Some attention has also been paid to the effect of warranties (Roberts, 2011) and risk in used tractor markets (Roe, Batte & Diekmann 2014).

**4) Conceptual Framework**

Understanding why depreciation patterns function as they do depends partially on understanding what subsectors of farming are using which tractors. The USDA collected price data on seven horsepower ranges of new tractors between 1999 and 2014. Regressing these against a one year lagged livestock and crop price index (USDA, 2017), an indexed steel price (BLS, 2017) and the Bank Prime Rate (FRED, 2017) gives an idea about which aspects may be important in each subsector of the market. Figure 3 depicts price level changes indexed to 2002 levels. In approximately 2007 – 2008, the price increases between low and high horsepower tractors diverge, with high horsepower tractor prices increasing more quickly.

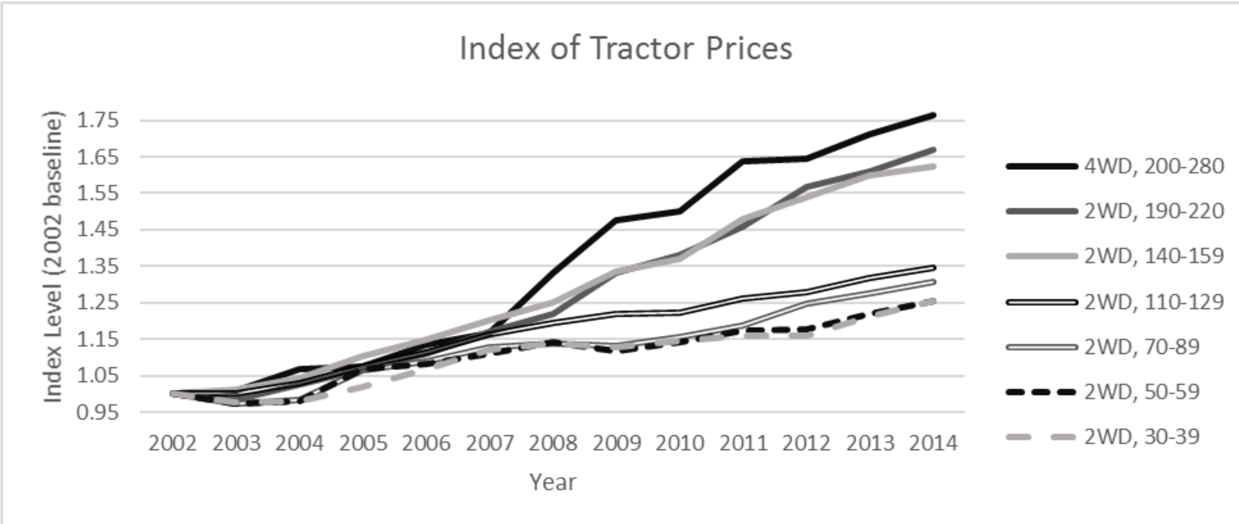


*Figure 2: Indexed Price Changes of Tractors*

The coefficients are not particularly useful because this is a reduced form model without a structural counterpart. Nonetheless, correlation of price with other factors can help give insight into which indices correlate with different tractor sizes. Table 2 below indicate which independent variables were statistically significant at a 10% level or lower, and which have t scores greater than 1, respectively. With a few exceptions, they generally follow what would be expected; high and medium horsepower tractors (all of those over 110 drawbar horsepower) had statistically significant positive coefficients with the crop index. Low and medium horsepower tractors meanwhile correlated well with interest rates. This may reflect the importance of credit in these types of new tractor purchases; interestingly, this is insignificant for large row crop tractors. The livestock index was only mildly statistically significant for low horsepower tractors.

*Table 2: P Values and T Statistics for Simple Linear Regressions*

| | P Values | | | | | | |
|---|---|---|---|---|---|---|---|
| | 30-39 HP | 50-59 HP | 70-89 HP | 110-129 HP | 140-159 HP | 190-220 HP | 200-280 HP |
| **Bank Prime Rate** | 0.049 | 0.023 | 0.013 | 0.011 | | | |
| **Steel Price Index** | | | | | | | |
| **1 Yr Lag Crop Price Index** | | | | 0.011 | 0.028 | 0.037 | 0.018 |
| **1 Yr Lag Livestock Price Index** | | | 0.057 | | | | |
| **Time Trend** | 0.049 | 0.094 | 0.001 | 0.000 | 0.014 | 0.024 | 0.039 |
| **Adj R Squared** | 0.914 | 0.950 | 0.977 | 0.991 | 0.969 | 0.961 | 0.971 |

*Each regression has n = 16, k = 5, df = 10. Only the largest class has 4 wheel drive.

| | T Statistics | | | | | | |
|---|---|---|---|---|---|---|---|
| | 30-39 HP | 50-59 HP | 70-89 HP | 110-129 HP | 140-159 HP | 190-220 HP | 200-280 HP |
| **Bank Prime Rate** | 2.245 | 2.673 | 3.030 | 3.098 | 1.056 | | |
| **Steel Price Index** | | | | | | | |
| **1 Yr Lag Crop Price Index** | | 1.627 | | 3.127 | 2.561 | 2.406 | 2.815 |
| **1 Yr Lag Livestock Price Index** | | 1.198 | 2.146 | | | | |
| **Time Trend** | 2.803 | 1.848 | 4.853 | 6.691 | 2.962 | 2.663 | 2.368 |
| **Adj R Squared** | 0.914 | 0.950 | 0.977 | 0.991 | 0.969 | 0.961 | 0.971 |

This exercise helps form a priori expectations regarding the tractor market. In general, crop-farming conditions seem to be more important than livestock-farming conditions in determining aggregate tractor prices although livestock farming conditions, though less important than crop farming conditions, may matter for medium and low horsepower tractors. This suggests there may be differences in the intensity effects across horsepower ranges based on different underlying markets and consequently there may be little reason to assume easily defined linear relationships across the entire domain of used tractor prices.

## 5) Data

The data used in this study is based on tractor sales data collected from 1996 to 2016 collected by Greg Peterson at www.machinerypete.com. His data yielded a set of 11,349 complete tractor sale observations. After cleaning the data, the initial results included observations for model, make, model year, price, auction date, condition[1], hours, location and an

[1] Possible conditions are Excellent, Good (reference), Fair and Poor.

other specifications column. Variables were added for age[2] and USDA Agricultural Region[3] (See the appendix for state aggregation method). Engine horsepower levels were found by matching it to observations of tractor model and year (TractorData, 2017).

Tractors were then consolidated by their manufacturer. CNH was split into Case and New Holland because they service substantially different segments of the market, with Case typically making larger equipment and New Holland having a more extensive presence in utility and mid-range tractors. This gives six brand categories: John Deere, Case, New Holland, Kubota, AGCO, and Other. Brands were split based on year of acquisition by their parent company- because of this many early Caterpillar tractors are in the "Other" category, while later models fall under the AGCO brand. A summary of the sample split by manufacturers is below.

*Table 3: Tractor Shares by Brand*

| Sample Breakdown | | | | | | |
|---|---|---|---|---|---|---|
| | John Deere | AGCO | Case | Kubota | New Holland | Other |
| Size | 6791 | 496 | 2493 | 85 | 984 | 500 |
| Share | 59.8% | 4.4% | 22.0% | 0.7% | 8.7% | 4.4% |

The dataset used in this analysis is unique in its scope and size. More information than what was explicitly collected was extracted from the comments line containing tractor-specific characteristics. The size of the dataset also makes it easier to estimate attributes which research frequently ignores due to small sample size or unavailability. In particular, searches were conducted for cab, warranty status, if it sold with a bucket and/or loader, if it was an online sale, whether it had four-wheel drive or four wheel assist, if it had tracks, if it was a quad track, if it had a monitor, the presence of a guidance system, if it was auto-steer ready, if it was an articulated tractor, whether it was a bareback tractor (no PTO or 3 – point hitch) and whether it

[2] Age is the difference between sales date and the start of the model year

[3] USDA Region is aggregated from state observations.

had a single owner. All of these regressors are likely measured with error (since a characteristic may not be recorded), and therefore the coefficient may be somewhat attenuated. However, it is still preferable to include the imperfectly measured counterparts than simply dismiss them as incomplete. The second option would put all unobservable attributes into the error term and likely increase bias overall. Many of these dummy variables likely serve as an approximate lower bound for positive coefficients and an upper bound for negative coefficients attenuating to zero. Nonetheless, caution is in order as this depends on an assumption of the regressors being approximately orthogonal.

Crop price indices from NASS serves as a control proxy for the broader agricultural economic conditions affecting tractor demand (USDA, 2017). The index is the average index price of the preceding twelve months. Appending the prime rate from the Federal Reserve Economic Database to the dataset helps control for the cost of financing (FRED, 2017). A livestock price index was initially included but later dropped due to multicollinearity issues.

Several structural choices made in the data cleaning process are noteworthy. First, the model years were truncated at 1990. The primary reason for that is that the focus of this paper is modern tractors, and changes in the tractor industry from manufacturer consolidation could affect the results. Since no sale observations were collected prior to 1996, it is difficult to determine whether the market is comparable before and after the 1999 merger of Case and New Holland. Another reason for this truncation is that it was necessary to exclude collectors' items. To ensure that a variety of ages is available, the sales date observations prior to 2000 (when the CNH merger was completed) are also omitted. To ensure that tractors as sufficiently alike for comparison, a model where the truncation rolls forward throughout the dataset (so that no tractors older than 10 years are included) is compared to one which calculates coefficients from the full pooled cross-section. Another issue encountered in this dataset is that reliable cab observations were not available for many of the small and medium horsepower tractors. Although it is probable that cab observations were more likely to be recorded on tractors with cabs than open station tractors, it is improbable that within each group observation status is correlated to price, and therefore these observations were deleted as missing at random. The highest cabless observation was a 155 horsepower. Therefore, tractors over 155 horsepower were assumed to have a cab. Sales price was deflated to 2009 dollars using the GNP Implicit Price Deflator, a similar approach to that taken by Wu and Perry (2004).

Unlike most past studies concerning tractor depreciation modeling, this paper elected to forgo a remaining value approach. The core reasons for tis are similar to those cited by Mumey and Unterschultz (1996). The most pressing reason for choosing this approach is that the used tractor market closely correlates to the new market, which is not perfectly competitive. Since strategic moves in the primary market will affect used market prices, a remaining value approach is dependent on the marketing and strategic pricing decisions of firms in the reference period.

Another reason for deciding against a remaining value approach is the difficulty associated with determining the starting value of tractors. Dealers frequently sell at discounts off list price, and used tractors are a highly heterogeneous product category. Although a remaining value approach certainly has an intuitive appeal for interpretation, the diversity of modern tractor features makes it difficult to choose a sound reference price for new tractors without introducing error into the model.

**6) Model**

In order to check for multicollinearity issues, a simple correlation coefficient matrix was calculated. The variables livestock index, hours per year, and model year had strong multicollinearity issues and were dropped. The livestock index and hours per year variable also had little relationship to price to begin with.

*Table 4: Simple Correlation Coefficients*

| Simple Correlation Coefficients | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | Price | *Model Year* | Hours | Age | HP | Crop Index | *Livestock Index* | *Hours Per Year* |
| Price | 100.0% | | | | | | | |
| *Model Year* | 60.1% | 100.0% | | | | | | |
| Hours | -48.3% | -47.9% | 100.0% | | | | | |
| Age | -58.8% | -71.4% | 63.8% | 100.0% | | | | |
| Horsepower | 64.9% | 23.5% | -1.2% | -19.0% | 100.0% | | | |
| Crop Index | 19.4% | 41.5% | 8.8% | 18.7% | 10.2% | 100.0% | | |
| *Livestock Index* | 14.4% | 50.6% | 7.9% | 16.6% | 11.1% | 72.6% | 100.0% | |
| *Hours Per Year* | 0.0% | 9.2% | 51.2% | -15.8% | 18.1% | -5.0% | -5.1% | 100.0% |

The base model used in this paper is summarized below. For clarity, β indicates numeric variables, γ indicates dummy variables, α indicates categorical variables, and σ indicates interactions. In order to account for the possibility of nonlinear interactions between hours, age, and horsepower, different horsepower tractors were broken down into SizeClass dummies, which were then interacted with age, crop index and horsepower. Brand was interacted with horsepower, age and hours. The reference category for Brand is John Deere because it accounted for a majority of the sample. Other reference categories are less than or equal to 70 horsepower for SizeClass, the Corn Belt for the USDARegion variable, and “good” for condition.

$$Price = \mu + \beta_1 Hrs + \beta_2 Engine\ HP + \beta_3 Age + \beta_4 Crop\ Index + \beta_5 Interest\ Rate + \gamma_1 No\ Cab + \gamma_2 Online\ Sale + \gamma_3 Duals + \gamma_4\ Auto\ Steer + \gamma_5\ Auto\ Steer\ Ready + \gamma_6 Display + \gamma_7\ Tracks + \gamma_8\ Quad\ Track + \gamma_9 MFWD\ or\ FWA + \gamma_{10}\ Articulated + \gamma_{11}\ Bareback + \gamma_{12} Loader\ or\ Bucket + \gamma_{13}\ Single\ Owner + \gamma_{14}\ Warranty + \alpha_i \sum_{i=1}^{4} Condition_i + \alpha_j \sum_{j=1}^{10} USDA\ Region_j + \alpha_k \sum_{k=1}^{6} Brand_k + \alpha_l \sum_{l=1}^{9} SizeClass_l + \sigma_m \sum_{m=1}^{6} Brand_m * Hours + \sigma_n \sum_{n=1}^{6} Brand_n * HP + \sigma_o \sum_{o=1}^{6} Brand_o * Age + \sigma_p \sum_{p=1}^{9} SizeClass_p * Hours + \sigma_q \sum_{q=1}^{9} SizeClass_q * Age + \sigma_r \sum_{r=1}^{9} SizeClass_r * Crop\ Index + \varepsilon$$

**7) Results**

Several functional forms were compared to both ensure result robustness and compare results of functional form fit to previous work. The most pertinent formulations compared in Wu and Perry (2004) are the exponential or semilog, Cobb – Douglas, sum-of-year's-digits, square root, double square root and linear formulations. The variables transformed in these models were price, age, horsepower and hours. The crop price index and interest rate were assumed to enter linearly into all formulations.

In addition to these formulations, a functional form that was nearly a Box-Cox transformation (rounded to common power family transformations) was compared. A comparison of the functional forms for the restricted ten-year rolling sample and full sample Mean Average Percent Error (MAPE) calculations are given in Tables 5 and 6. The second table includes categorical SizeClass indicators while the first one does not. Comparing the options reveals that several functional forms provided similar levels of fit. The tables below are based on the average of 100 random subsamples where 90% of the data is used for model estimation and the remaining 10% is treated as the out-of-sample comparison to calculate the MAPE.

*Table 5: MAPE for Various Functional Forms*

| Mean Average Percent Error for Various Functional Forms | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | | Nearly Box-Cox | Cobb - Douglas | Semilog - Exponential | Double Sq.Root | Sum of Yrs. Digits | Square Root | Linear |
| Endog. Power Transform | | 0 | 0 | 0 | 0.5 | 0.5 | 1 | 1 |
| Exog. Power Transform | | * | 0 | 1 | 0.5 | 1 | 0.5 | 1 |
| | Measure | Mean Average Percent Error** | | | | | | |
| <= 10 years | Mean | 16.2% | 18.5% | 22.2% | 17.4% | 20.6% | 18.5% | 21.2% |
| n = 717 | Median | 10.3% | 12.6% | 14.6% | 11.3% | 12.4% | 10.5% | 11.6% |
| | 95th % | 45.0% | 49.0% | 61.0% | 49.6% | 62.4% | 56.2% | 71.5% |
| | Adj. R Sq. | 89.2% | 85.5% | 79.9% | 88.3% | 85.4% | 89.3% | 87.4% |
| full sample | Mean | 20.0% | 23.8% | 24.0% | 20.8% | 23.2% | 22.4% | 25.5% |
| n = 1,135 | Median | 12.2% | 16.1% | 15.3% | 12.9% | 13.7% | 12.3% | 13.5% |
| | 95th % | 56.8% | 65.4% | 65.2% | 60.6% | 68.2% | 69.7% | 84.5% |
| | Adj. R Sq. | 89.2% | 81.7% | 80.8% | 88.5% | 86.6% | 90.0% | 87.9% |

* Price and age are sqrt transformed, hp is log transformed, hours is linear

** To ensure accurate estimates, the MAPE is based off of the average of 100 iterations

*Table 6: MAPE for Various Functional Forms With SizeClass Indicators*

| Mean Average Percent Error for Various Functional Forms* | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | | Nearly Box-Cox | Cobb - Douglas | Semilog - Exponential | Double Sq.Root | Sum of Yrs. Digits | Square Root | Linear |
| Endog. Power Transform | | 0 | 0 | 0 | 0.5 | 0.5 | 1 | 1 |
| Exog. Power Transform | | ** | 0 | 1 | 0.5 | 1 | 0.5 | 1 |
| Group | Measure | Mean Average Percent Error*** | | | | | | |
| <= 10 years | Mean | 14.7% | 16.6% | 14.8% | 14.9% | 15.1% | 16.3% | 17.3% |
| n = 717 | Median | 9.7% | 11.3% | 9.9% | 9.8% | 9.8% | 10.0% | 10.3% |
| | 95th % | 38.9% | 43.8% | 38.8% | 39.7% | 41.3% | 45.0% | 49.2% |
| | Adj. R Sq. | 90.9% | 87.7% | 89.4% | 90.8% | 90.7% | 90.6% | 90.2% |
| full sample | Mean | 18.0% | 22.1% | 17.9% | 18.3% | 18.3% | 20.3% | 21.9% |
| n = 1,135 | Median | 11.4% | 15.0% | 11.8% | 11.6% | 11.4% | 11.8% | 12.4% |
| | 95th % | 50.8% | 60.6% | 47.5% | 51.5% | 53.0% | 61.3% | 67.8% |
| | Adj. R Sq. | 90.5% | 83.4% | 87.8% | 90.3% | 90.4% | 90.9% | 90.0% |

*Crop index and interest rate enter all formulations linearly, so strictly speaking they are C-D Additive, Exponential Additive, etc.

** Price and age are sqrt transformed, hp is log transformed, hours is linear

*** To ensure accurate estimates, the MAPE is based off of the average of 100 iterations

These tables indicate that the double square root and square root formulations consistently perform well. When SizeClass indicators are included, the variability between functional forms largely disappears. On average, including SizeClass indicators decreases the average MAPE by 1.5 percentage points at the median, 3.3 percentage points at the mean, and 11.1 percentage points at the 95th percentile over the full sample.

Although most functional forms fit the model fairly well with SizeClass indicators included, at least three analytical and intuitive reasons support the double square root model. First, it is in the top three for both adjusted $R^2$ and MAPE (along with the sum-of-year's-digits formulation). Second, the double square root formulations consistently outperformed other functional forms when the sample or model was changed in the tables above. Third, unlike the sum-of-year's-digits formulation, it does not have a substantial portion of the horsepower range where price is decreasing in horsepower as tractors age (see figures 3 and 4). Intuitively, it makes little sense for horsepower to be decreasing in price unless there is an extreme lack of secondary uses for large tractors. Comparing theses formulations visually shows extremely tight fits for relatively new tractors, but some deterioration as tractors depreciate. From this point forward, analysis is done primarily with the double square root model, but some comparisons are made to a semilog (exponential) model to check for consistency.

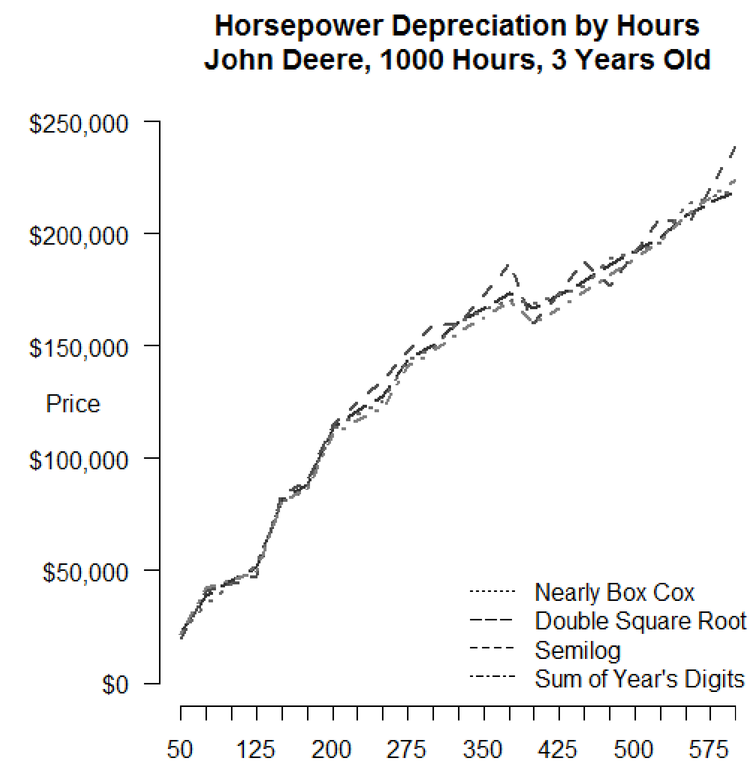


*Figure 3: Functional Form Comparison - New Tractor*

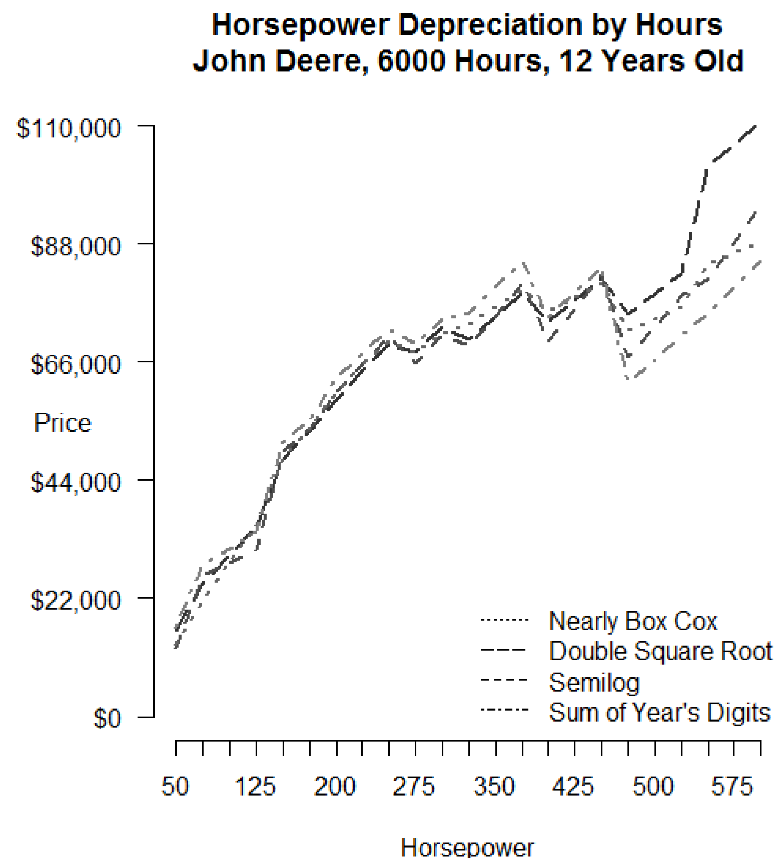


*Figure 4: Functional Form Comparison - Old Tractor*

Comparing the full sample to the rolling ten-year average shows some change, yet many coefficients are similar. See the appendix for full regression estimates (standard errors are white adjusted). Perhaps the most substantial change is that the coefficient on age appears to have increased in the larger model, which is larger for the full estimation. Though unsurprising, this suggests that the smaller model may not fully account for the real effects of age on depreciation because it is truncated.

Another curiosity in the models is how hours enters - the uninteracted coefficient on hours is statistically insignificant for both formulations, but when interacted with SizeClass of tractors, most interactions are highly significant. Horsepower seems to be a key factor in how hours affect the value of tractors, with larger tractors losing more value per hour of use. Age also has highly significant interactions with horsepower.

Figures 5 and 6 demonstrate the effect of increasing tractor age across different horsepower levels of tractors while holding all else constant (top), and increasing age across horsepower levels holding all else constant (bottom). The bottom graph is somewhat intuitive – large John Deere tractors lose substantially more value as a percentage from a large increase in hours than do small tractors, and the relationship seems nearly linear. This may arise from larger costs associated with breakdowns of machinery for the farmers using large equipment. Farmers tend to own several small tractors so the marginal cost of lost work from one breaking down may be low. However if the primary tillage tractor breaks, it could cause substantial yield loss.

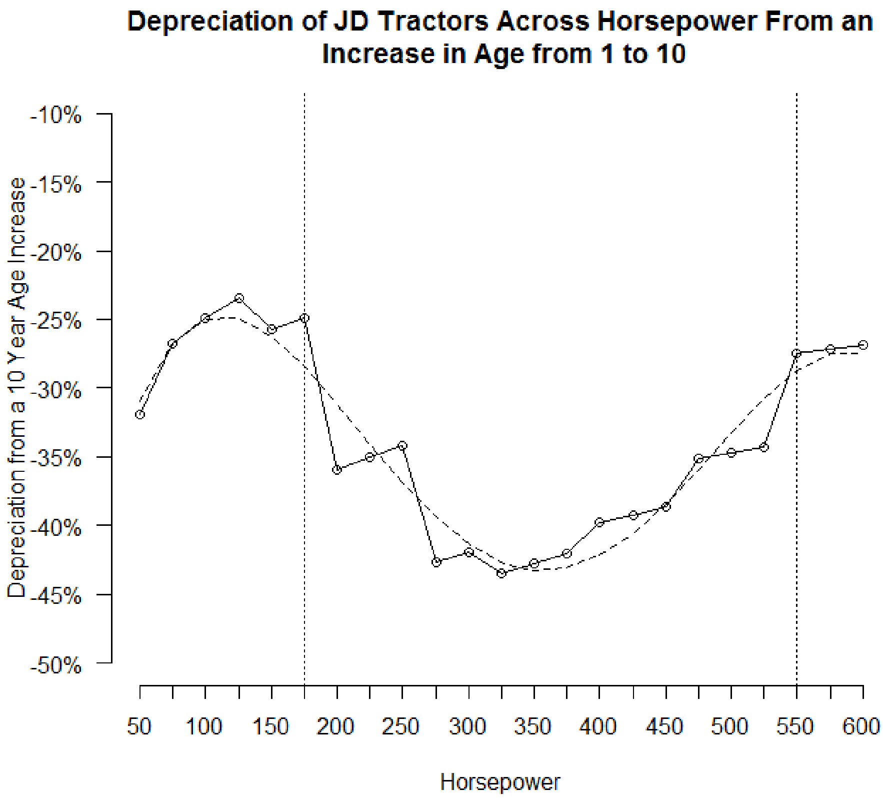


*Figure 5: Depreciation Across Age*

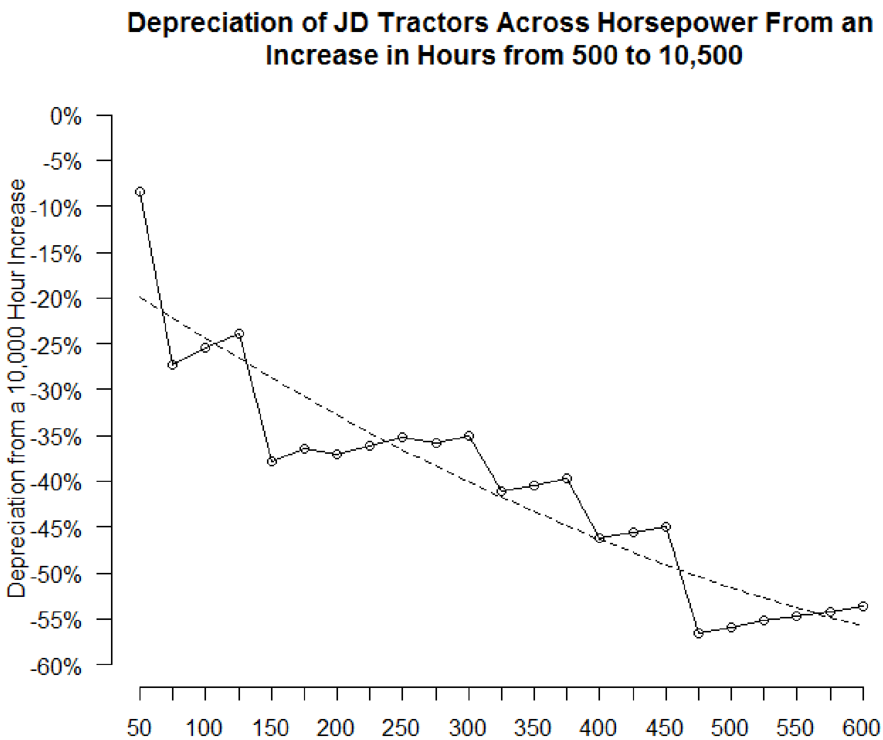


*Figure 6: Depreciation Across Hours*

In contrast, the Age graph is not intuitive. A quadratic curve of best fit suggests that tractors smaller than 175 horsepower and larger than 550 horsepower age substantially better than those between those horsepower levels. One potential explanation for why small tractors age well is that medium and small tractors have less to gain from advances in recent technology such as precision planting and guidance systems. Why very high horsepower tractors retain value better over age is uncertain. It could be the effects of a survivorship bias – the median age for tractors greater than 530 horsepower in the sample is only 2.8 years old. In contrast, the median age of all tractors in the sample was 8.4 years old.

A related finding is how the sales price curve flattens as tractors depreciate. For tractors between 250 and 525 horsepower, the curve flattens substantially as the tractors depreciate. Nonetheless, tractors above and below this range generally retain a similar shape to early depreciation patterns. The pattern is similar for all tractor brands as one can see in Figure 7 below:

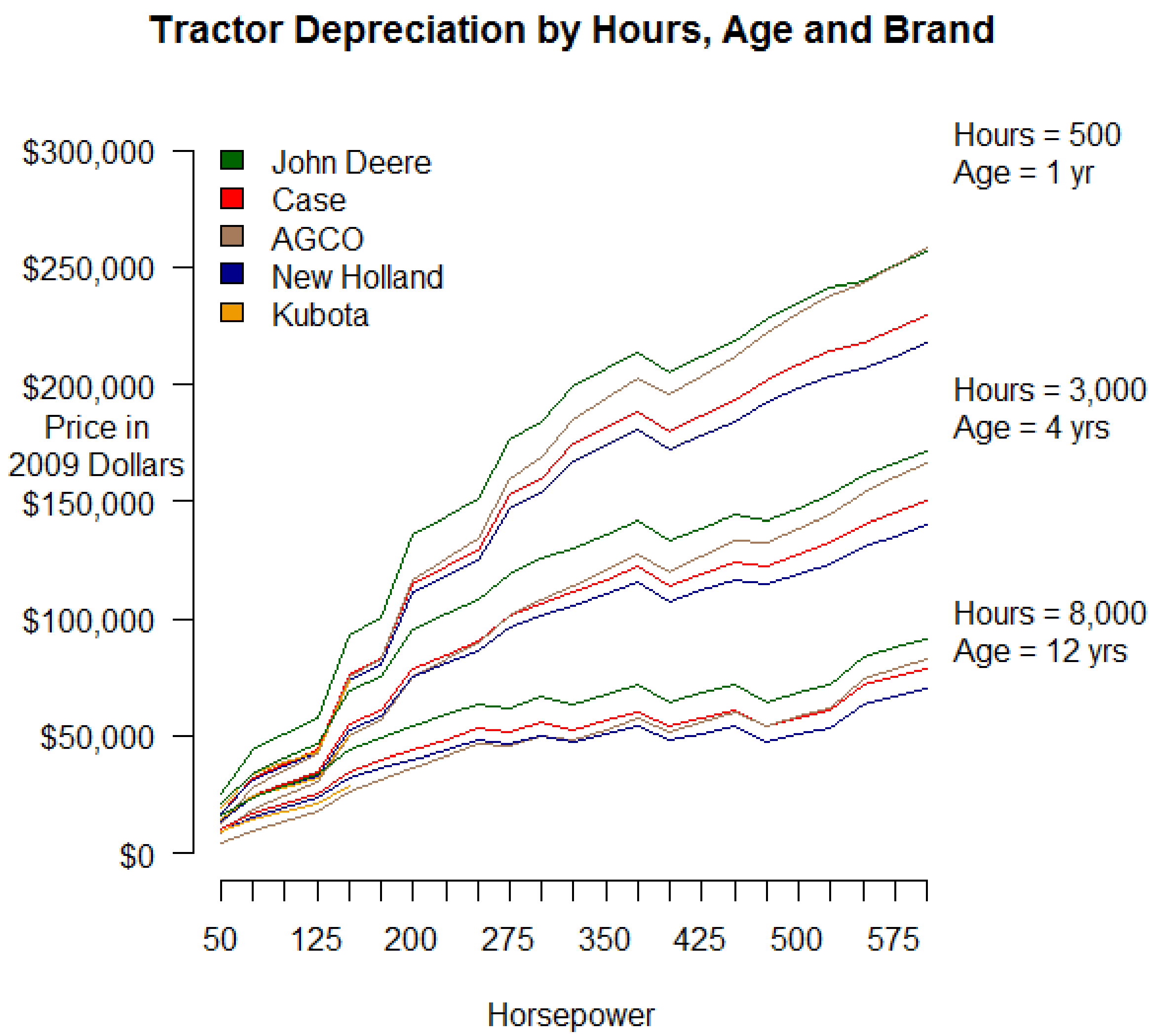


*Figure 7: Tractor Depreciation vs Brands*

*Table 7: Depreciation by Brand Across Age*

| Depreciation Across Age for a 225 HP Tractor with 1,000 Hours | | | | | | |
|---|---|---|---|---|---|---|
| Age (Yrs) | John Deere | Case | AGCO | New Holland | Kubota* | Other |
| 1 | 100.0% | 100.0% | 100.0% | 100.0% | 100.0% | 100.0% |
| 2 | 93.2% | 94.7% | 92.5% | 93.4% | 92.4% | 90.3% |
| 3 | 88.1% | 90.8% | 87.0% | 88.4% | 86.8% | 83.2% |
| 4 | 83.9% | 87.6% | 82.4% | 84.3% | 82.3% | 77.5% |
| 5 | 80.4% | 84.7% | 78.5% | 80.8% | 78.3% | 72.6% |
| 6 | 77.2% | 82.2% | 75.1% | 77.7% | 74.8% | 68.3% |
| 7 | 74.3% | 80.0% | 72.0% | 75.0% | 71.7% | 64.5% |
| 8 | 71.7% | 77.9% | 69.1% | 72.4% | 68.9% | 61.0% |
| 9 | 69.3% | 75.9% | 66.5% | 70.0% | 66.3% | 57.8% |
| 10 | 67.0% | 74.1% | 64.1% | 67.8% | 63.8% | 54.9% |
| 11 | 64.9% | 72.4% | 61.8% | 65.8% | 61.5% | 52.2% |

*Kubota is calculated with a 135 HP tractor, the largest in-sample tractor observed

*Table 8: Depreciation by Brand Across Hours*

| Depreciation Across Hours for a 3 Year Old 225 HP Tractor | | | | | | |
|---|---|---|---|---|---|---|
| Hours | John Deere | Case | AGCO | New Holland | Kubota* | Other |
| 400 | 100.0% | 100.0% | 100.0% | 100.0% | 100.0% | 100.0% |
| 800 | 95.9% | 94.5% | 94.6% | 94.4% | 94.3% | 97.3% |
| 1200 | 92.9% | 90.4% | 90.6% | 90.2% | 90.0% | 95.2% |
| 1600 | 90.3% | 87.0% | 87.3% | 86.7% | 86.5% | 93.5% |
| 2000 | 88.1% | 84.0% | 84.4% | 83.7% | 83.4% | 92.0% |
| 2400 | 86.1% | 81.4% | 81.9% | 81.0% | 80.7% | 90.7% |
| 2800 | 84.3% | 79.0% | 79.5% | 78.6% | 78.3% | 89.4% |
| 3200 | 82.6% | 76.9% | 77.4% | 76.4% | 76.0% | 88.3% |
| 3600 | 81.1% | 74.8% | 75.4% | 74.3% | 73.9% | 87.2% |
| 4000 | 79.6% | 73.0% | 73.6% | 72.4% | 72.0% | 86.2% |
| 4400 | 78.3% | 71.2% | 71.9% | 70.6% | 70.2% | 85.3% |

*Kubota is calculated with a 135 HP tractor, the largest in-sample tractor observed

*Table 9: Depreciation across Hours and Age*

| | | Depreciation by Year and Average Hours Per Year | | | | | |
|---|---|---|---|---|---|---|---|
| Age (Yrs) | Hours | John Deere | Case | AGCO | New Holland | Kubota* | Other |
| 1 | 380 | 100.0% | 100.0% | 100.0% | 100.0% | 100.0% | 100.0% |
| 2 | 760 | 89.7% | 89.9% | 88.1% | 89.2% | 87.2% | 88.2% |
| 3 | 1140 | 82.3% | 82.6% | 79.4% | 81.3% | 77.9% | 79.6% |
| 4 | 1520 | 76.2% | 76.6% | 72.5% | 74.9% | 70.5% | 72.7% |
| 5 | 1900 | 71.0% | 71.5% | 66.6% | 69.5% | 64.3% | 66.9% |
| 6 | 2280 | 66.5% | 67.1% | 61.5% | 64.8% | 59.0% | 61.9% |
| 7 | 2660 | 62.5% | 63.2% | 57.0% | 60.6% | 54.2% | 57.4% |
| 8 | 3040 | 58.9% | 59.6% | 53.0% | 56.8% | 50.0% | 53.4% |
| 9 | 3420 | 55.6% | 56.3% | 49.3% | 53.4% | 46.2% | 49.8% |
| 10 | 3800 | 52.6% | 53.3% | 46.0% | 50.3% | 42.7% | 46.5% |
| 11 | 4180 | 49.8% | 50.6% | 43.0% | 47.4% | 39.6% | 43.4% |

*Kubota is calculated with a 135 HP tractor, the largest in-sample tractor observed

Calculating depreciation across age shows substantial variation across brands, with Case retaining value best when referencing a 1-year-old tractor. Over a ten-year period, Case depreciates 7.5 percentage points less than John Deere on average. This is nearly the opposite of depreciation across hours where John Deere holds a 7.1 percentage point advantage over Case when 4,000 engine hours are added. However, when calculating at the mean hours per year (approximately 380), Case and John Deere depreciate at almost identical rates, while other brands depreciate more quickly. Of the four major brands, AGCO depreciates most quickly and it appears Kubota also depreciates quickly but it cannot be compared at 225 horsepower since they do not make tractors that large. With the exception of the Table 11, referenced tractors include four wheel drive or four-wheel assist and duals.

Although relative depreciation rates appear to be similar across Case, New Holland and John Deere, absolute dollar values for John Deere tractors are consistently higher than all other brands. It should be noted that much of the Other brand category is composed of pre-2002 Caterpillar tractors. In the utility tractor segment, Kubota tractors appear to hold values comparable to New Holland and Case, while AGCO brands sell at a substantial discount to other major brands. Another interesting result is that the value for AGCO tractors surpasses that for Case at approximately 250 horsepower, and appears to approach John Deere values near the top of its horsepower range. However, AGCO tractors also depreciated more quickly than other brands.

Several new technologies in tractor manufacturing correlate with higher resale values as shown in Table 11. For a 3-year-old, 250 engine horsepower John Deere tractor with 1,000 hours, a guidance system likely increases the resale value by approximately $4,650 and being guidance ready increases the resale value by $1,972 or 42% of that value. Having a display in the cab also appeared to have a positive impact on price comparable to that of being auto-steer ready. Although not shown here, interacting the auto-steer and auto-steer ready variables with horsepower yields a component resale value for auto-steer which is highest in the 150 to 250 horsepower range, peaking around $6,486 (200 horsepower). A similar pattern appears in the semilog model, which peaks around $7,899 (200 horsepower) and is highest in the 200 to 300 horsepower range.

*Table 10: Point Estimates Prices for Used Tractors*

| Point Estimates for Price Across Brands and Horsepower for a 3 Year Old Tractor with 1000 Hours | | | | | | |
|---|---|---|---|---|---|---|
| HP | John Deere | Case | AGCO | New Holland | Kubota | Other |
| 50 | $ 22,787 | $ 15,638 | $ 10,545 | $ 14,813 | $ 16,857 | $ 11,451 |
| 75 | $ 38,750 | $ 29,308 | $ 23,377 | $ 27,807 | $ 29,496 | $ 24,178 |
| 100 | $ 45,420 | $ 35,222 | $ 29,861 | $ 33,236 | $ 34,098 | $ 30,256 |
| 125 | $ 51,735 | $ 40,882 | $ 36,229 | $ 38,420 | $ 38,428 | $ 36,174 |
| 150 | $ 81,370 | $ 67,683 | $ 63,020 | $ 64,131 | $ 63,079 | $ 62,365 |
| 175 | $ 88,311 | $ 74,109 | $ 70,553 | $ 70,030 | | $ 69,297 |
| 200 | $ 113,981 | $ 97,851 | $ 95,194 | $ 92,771 | | $ 93,128 |
| 225 | $ 121,124 | $ 104,564 | $ 103,222 | $ 98,937 | | $ 100,477 |
| 250 | $ 128,079 | $ 111,118 | $ 111,114 | $ 104,951 | | $ 107,685 |
| 275 | $ 143,811 | $ 125,887 | $ 127,288 | $ 118,950 | | $ 123,027 |
| 300 | $ 150,683 | $ 132,405 | $ 135,226 | $ 124,928 | | $ 130,253 |
| 325 | $ 160,965 | $ 142,138 | $ 146,441 | $ 134,029 | | $ 140,686 |
| 350 | $ 167,665 | $ 148,519 | $ 154,282 | $ 139,876 | | $ 147,804 |
| 375 | $ 174,259 | $ 154,810 | $ 162,041 | $ 145,636 | | $ 154,838 |
| 400 | $ 167,154 | $ 148,193 | $ 156,553 | $ 138,894 | | $ 148,941 |
| 425 | $ 173,322 | $ 154,080 | $ 163,874 | $ 144,271 | | $ 155,555 |
| 450 | $ 179,418 | $ 159,905 | $ 171,143 | $ 149,590 | | $ 162,114 |
| 475 | $ 186,256 | $ 166,439 | $ 179,156 | $ 155,595 | | $ 169,395 |
| 500 | $ 192,239 | $ 172,169 | $ 186,349 | $ 160,823 | | $ 175,874 |
| 525 | $ 198,164 | $ 177,852 | $ 193,500 | $ 166,006 | | $ 182,309 |
| 550 | $ 206,138 | $ 185,483 | $ 202,696 | $ 173,071 | | $ 190,726 |
| 575 | $ 211,991 | $ 191,109 | $ 209,809 | $ 178,200 | | $ 197,118 |
| 600 | $ 217,798 | $ 196,695 | $ 216,887 | $ 183,291 | | $ 203,475 |

Track and quad track tractors held their values well relative to their wheeled counterparts. Point estimates for a 3-year-old, 250 engine horsepower John Deere with tracks compared to one with duals indicate a $5,722 benefit in resale value for tracked tractors over the wheeled version. For quad track tractors, the benefit was even larger: point estimates indicate between a $21,570 (350 engine horsepower) and $24,810 (600 engine horsepower) marginal benefit over a tracked system for a Case tractor. This result was large and highly statistically significant for both the semilog and double square root formulations of the model[4].

The specialized nature of bareback tractors correlates with a substantially decreased resale value. A 250 horsepower John Deere bareback sells for approximately $7,315 less than a standard version (a 5.9% discount). The semilog model estimates a discount of 8.2%. A single owner tractor had a higher resale value by approximately 6.6% in the semilog model and between $2,099 (50 horsepower) to $6,723 (600 horsepower) in the double square root model. Although this is not an attribute of the machine directly, it may signal unobservable qualities of the machine such as operator care, maintenance history, while giving a signal that the tractor is not a lemon.

Open station tractors had a large, negative, statistically significant coefficient in both semilog and double square root models as one would expect. In the semilog model, lack of a cab accounted for a 26.6% decrease in sales price for a 3 year old 75 horsepower John Deere with 1,000 hours. In the double square root model it accounts for a 23.4% decrease in price. In the semilog model an online sale corresponded to approximately a 2.2% discount in sale price, which was a similar magnitude to the double square root model (between a 4.4% and 1.4% discount depending on horsepower). This discount is substantially smaller than most estimates in previous studies dealing with the impact of online sales on tractor prices (see: Diekmann, Roe & Batte, 2008). Although tractors sold online sell for an average of $7,262 less ($78,711 in-person vs $71,449 online), most of the difference can be accounted for by an average size difference of

[4] Only Case quad track tractors were available in the sample, but Table 11 extrapolates to John Deere for consistency of the table

34 horsepower (280 in-person and 246 online). In addition, tractors sold online had a lower incidence of excellent condition scores, were less likely to have cabs, were less likely to have four-wheel driver or four-wheel assist, and were less likely to have a single owner.

Likewise, warranty status was statistically significant (2.9%) for the semilog model but insignificant (~0%) for the double square root model. Although having an active warranty may alter prices slightly, this analysis indicates the effects are probably relatively small. Unfortunately, the subset of articulated tractors was too small to get significant results (n = 17) so nothing substantial can be determined about their effect on price.

*Table 11: Marginal Attribute Values*

| Marginal Attribute Effects for a 3 Year Old John Deere with 1,000 Hrs* | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Engine HP | No Cab | Online | Duals | Auto Steer | Auto Steer Ready | Display | Track | FWD/ FWA | Quad Track | Bareback | Loader | 1 Owner | Condition (Relative to Good) | | |
| | | | | | | | | | | | | | Exc. | Fair | Poor |
| 50 | -$6,554 | -$969 | NA | NA | NA | NA | NA | $2,405 | NA | NA | $2,990 | $1,986 | $2,174 | -$5,668 | -$9,126 |
| 75 | -$8,812 | -$1,278 | NA | NA | NA | NA | NA | $3,143 | NA | NA | $3,901 | $2,628 | $2,874 | -$7,709 | -$12,631 |
| 100 | -$9,612 | -$1,388 | $1,820 | $2,758 | $1,165 | $964 | NA | $3,404 | NA | NA | $4,224 | $2,855 | $3,122 | -$8,433 | -$13,874 |
| 125 | -$10,317 | -$1,484 | $1,944 | $2,945 | $1,245 | $1,031 | NA | $3,635 | NA | NA | $4,509 | $3,056 | $3,341 | -$9,070 | -$14,969 |
| 150 | -$13,159 | -$1,873 | $2,446 | $3,700 | $1,567 | $1,297 | NA | $4,564 | NA | NA | $5,657 | $3,864 | $4,224 | -$11,641 | -$19,383 |
| 175 | -$13,745 | -$1,954 | $2,549 | $3,856 | $1,634 | $1,352 | $7,308 | $4,755 | NA | NA | $5,893 | $4,030 | $4,405 | -$12,171 | -$20,293 |
| 200 | NA | -$2,226 | $2,900 | $4,385 | $1,859 | $1,539 | $8,300 | $5,405 | NA | NA | $6,697 | $4,596 | $5,023 | -$13,969 | -$23,382 |
| 225 | NA | -$2,296 | $2,990 | $4,521 | $1,917 | $1,587 | $8,555 | $5,573 | NA | -$7,108 | $6,903 | $4,741 | $5,182 | -$14,432 | -$24,177 |
| 250 | NA | -$2,362 | $3,075 | $4,650 | $1,972 | $1,633 | $8,797 | $5,731 | NA | -$7,315 | $7,099 | $4,879 | $5,332 | -$14,870 | -$24,930 |
| 275 | NA | -$2,506 | $3,260 | $4,929 | $2,091 | $1,731 | $9,320 | $6,074 | NA | -$7,765 | $7,523 | $5,178 | $5,658 | -$15,820 | -$26,560 |
| 300 | NA | -$2,566 | $3,338 | $5,046 | $2,141 | $1,773 | $9,540 | $6,218 | NA | -$7,954 | $7,701 | $5,303 | $5,795 | -$16,218 | -$27,244 |
| 325 | NA | -$2,654 | $3,451 | $5,216 | $2,213 | $1,833 | $9,860 | $6,428 | NA | -$8,228 | $7,960 | $5,485 | $5,993 | -$16,797 | -$28,239 |
| 350 | NA | -$2,710 | $3,523 | $5,324 | $2,259 | $1,871 | $10,062 | $6,561 | $23,303 | -$8,402 | $8,124 | $5,600 | $6,120 | -$17,165 | -$28,870 |
| 375 | NA | -$2,764 | $3,592 | $5,428 | $2,304 | $1,908 | $10,258 | $6,689 | $23,747 | -$8,570 | $8,282 | $5,712 | $6,241 | -$17,519 | -$29,479 |
| 400 | NA | -$2,706 | $3,517 | $5,316 | $2,256 | $1,868 | $10,047 | $6,551 | $23,268 | -$8,389 | $8,111 | $5,592 | $6,110 | -$17,137 | -$28,822 |
| 425 | NA | -$2,756 | $3,582 | $5,413 | $2,298 | $1,903 | $10,230 | $6,671 | $23,684 | -$8,546 | NA | $5,696 | $6,224 | -$17,469 | -$29,393 |
| 450 | NA | -$2,805 | $3,645 | $5,508 | $2,338 | $1,936 | $10,408 | $6,787 | $24,089 | -$8,699 | NA | $5,798 | $6,335 | -$17,792 | -$29,948 |
| 475 | NA | -$2,859 | $3,714 | $5,613 | $2,383 | $1,973 | $10,605 | $6,916 | $24,535 | -$8,868 | NA | $5,909 | $6,457 | -$18,148 | -$30,558 |
| 500 | NA | -$2,905 | $3,774 | $5,703 | $2,421 | $2,005 | $10,773 | $7,027 | $24,918 | -$9,013 | NA | $6,006 | $6,562 | -$18,453 | -$31,083 |
| 525 | NA | -$2,950 | $3,832 | $5,790 | $2,458 | $2,036 | $10,938 | $7,134 | $25,292 | -$9,154 | NA | $6,099 | $6,664 | -$18,752 | -$31,596 |
| 550 | NA | -$3,010 | $3,909 | $5,906 | $2,508 | $2,077 | $11,155 | $7,277 | $25,786 | -$9,341 | NA | $6,223 | $6,800 | -$19,146 | -$32,273 |
| 575 | NA | -$3,053 | $3,965 | $5,990 | $2,543 | $2,106 | $11,312 | $7,380 | $26,143 | -$9,476 | NA | $6,313 | $6,897 | -$19,431 | -$32,762 |
| 600 | NA | -$3,095 | $4,019 | $6,072 | $2,578 | $2,135 | $11,466 | $7,481 | $26,492 | -$9,608 | NA | $6,400 | $6,993 | -$19,709 | -$33,240 |

*The effects on warranty and tractor articulation were not statistically significant

**8) Discussion and Conclusions**

The interaction terms for tractor SizeClass presented in this paper give a conundrum – model brevity is beautiful for its ease of interpretation, but the complexities of size interaction across age and hours compels a more complicated formulation. It appears that tractors under 175 horsepower hold their value substantially better than larger models, but extremely large tractors may do somewhat better than tractors between 250 and 525 horsepower. Among old tractors, there is little price difference between 250 and 525 horsepower. One possible explanation for this depreciation curve is that repair and downtime costs for most crop farms is too high to justify buying a worn tractor, while livestock farms may face lower downtime costs. This in turn may cause utility and mid-range horsepower tractors to depreciate over a longer period of time and hours. The substantial differences in depreciation patterns across horsepower by age suggests that mid and high range tractors may also be substantially more sensitive to technological change than small tractors. Several variables that seem relatively unimportant are whether the sale was online or face to face, warranty status, and whether or not the tractor has a display. Nonetheless, these attributes may have a mild effect on price. Typically considered attributes such as horsepower, age, hours, brand, four-wheel drive or four-wheel assist, and whether the tractor had a loader or bucket were all significant in the regression estimates in the logical directions.

The conclusions regarding functional form use in this paper are similar to those found by Wu and Perry (2004). This paper finds that the double square root and sum-of-year's-digits functional forms provided the best forecast accuracy. This is consistent with a λ Box-Cox transformation of 0.43 obtained from this dataset.

Perhaps the most interesting findings were that tracks and especially quad track systems had significantly higher resale values when compared to a wheeled drivetrain system. Likewise, there seems to be significant value associated with selling a tractor owned by only one farmer–perhaps for information availability or as a quality signal. In contrast, bareback tractors sold at a substantial discount relative to standard tractors, supporting the idea that livestock farmers may play an important role in supporting the resale value of midrange used tractors, or that many field tractors may be going to uses other than heavy fieldwork in the secondary market.

Finally, depreciation across brands varied substantially - Case and John Deere appear to depreciate at nearly identical rates, with Case depreciating more slowly across time while John Deere holds its value better over use. John Deere maintains higher values in absolute terms than Case, but when compared at the median hours per year, they appear to depreciate at similar rates while other brands depreciate more quickly relative to the two largest manufacturers.

This study suggests several practical implications. First, there could be value in retrofitting 175 to 300 horsepower tractors with auto-steer systems. This could appeal to farmers who need smaller row crop tractors but buy used and want auto-steer systems. From a regulatory perspective, brand depreciation patterns across age suggest view the tractor market as three segments may make sense. The following could be a potential delineation: utility and mid-range tractors (< 200 horsepower), row crop tractors (200 – 525 horsepower), and large row crop tractors (> 525 horsepower). Third, if the small discount associated with online tractor sales is accurate, the expanding role of the internet may provide farmers easy integration into a regional or national resale market rather than just a local one. Consequently, the growing prominence of online tractor sales may increase the competitive pressure faced by local retailers.

## References

Diekmann, F., B. Roe, and M. Batte. 2008. "Tractors on eBay: Differences between Internet and In-Person Auctions". *American Journal of Agricultural Economics*, 90(2): 306-320.

Dumler, T. 2003. "Predicting Farm Tractor Values through Alternative Depreciation Methods". *Review of Agricultural Economics*, 25(2): 506-523.

Federal Reserve Economic Database. 2017. *Economic Research Database.* https://fred.stlouisfed.org/

Kanicki, D. 2014. "Farmers Still Loyal to Their Brands". *Farm Equipment Magazine.* https://www.farm-equipment.com/articles/9805

Miles, R. 2016. "Tractor & Agricultural Machinery Manufacturing in the US". *IBIS World Database.*

Mumey, G., and J. Unterschultz. 1996. "Reducing investment risk in tractors and combines with improved terminal asset value forecasts". *Canadian Journal of Agricultural Economics,* 44(3): 295-309.

Roberts, J. 2011. "Can Warranties Substitute for Reputations?". *American Economic Journal: Microeconomics*, 3(3): 69-85.

Roe, B., M. Batte, and F. Diekmann. 2014. "Competition Between Local Dealerships and Internet Markets: The Role of Local Relationships, Risk Tolerance, and Trust in Used Farm Machinery Markets". *Agribusiness*, 30(3): 225-243.

Schnepf, R. 2017. "U.S. Farm Income Outlook for 2017". *Congressional Research Service*. https://fas.org/sgp/crs/misc/R40152.pdf

US Bureau of Labor Statistics, Mid-Atlantic Field Office. 2017. "Producer Price Index – Metals and Metal Products". Philadelphia, PA.

US Department of Agriculture, National Agricultural Statistics Service. 2017. NASS QuickStats Survey Data. Washington DC, May. https://quickstats.nass.usda.gov/

US Department of Justice. 2016. "Justice Department Sues to Block Deere's Acquisition of Precision Planting". https://www.justice.gov/opa/pr/justice-department-sues-block-deere-s-acquisition-precision-planting (accessed May 23, 2017).

TractorData. 2017. Farm Tractor Database (Various Tractors). http://www.tractordata.com/farm-tractors

Walley, K., P. Custance, S. Taylor, A. Lindgreen, and M. Hingley. 2007. "The importance of brand in the industrial purchase decision: A case study of the UK tractor market". *Journal of Business & Industrial Marketing*, 22(6), 383-394.

Wilson, P. 2010. "Estimating Tractor Depreciation: The Impact of Choice of Functional Form". *Journal of Farm Management*, 13(12), 799-818.

Wu, J. and G. Perry. 2004. Estimating Farm Equipment Depreciation: Which Functional Form Is Best? *American Journal of Agricultural Economics* 86(2): 483-492.

## Appendix

*Table 12: SizeClass Breakdown*

| Horsepower Classes | | |
|---|---|---|
| **General Use** | **Size Class** | **Engine Horsepower** |
| Compact Utility | SizeClass1 | 70 or less |
| Utility | SizeClass2 | 71 - 135 |
| Mid - Range | SizeClass3 | 136 - 180 |
| Small Row Crop | SizeClass4 | 181 - 250 |
| Medium Row Crop | SizeClass5 | 251 - 320 |
| Large Row Crop | SizeClass6 | 321 - 390 |
| Small Commercial | SizeClass7 | 391 - 460 |
| Medium Commercial | SizeClass8 | 461 - 530 |
| Large Commercial | SizeClass9 | 531 or more |

*Table 13: USDA Farm Production Regions*

| USDA Farm Production Regions | | | | | |
|---|---|---|---|---|---|
| **Region** | **States** | | | | |
| Appalachia | Kentucky | North Carolina | Tennessee | Virginia | West Virginia |
| Corn Belt | Illinois | Indiana | Iowa | Missouri | Ohio |
| Delta | Arkansas | Louisiana | Mississippi | | |
| Lake | Michigan | Minnesota | Wisconsin | | |
| Mountain | Arizona | Colorado | Idaho | Montana | Nevada |
| | New Mexico | Utah | Wyoming | | |
| North Plains | Kansas | Nebraska | North Dakota | South Dakota | |
| Northeast | Conneticut | Deleware | Maine | Maryland | Massachusets |
| | New Hampshire | New Jersey | New York | Pennsylvania | Rhode Island |
| | Vermont | | | | |
| Pacific | California | Oregon | Washington | | |
| South Plains | Oklahoma | Texas | | | |
| Southeast | Alabama | Florida | Georgia | South Carolina | |

*Table 14: Sample Breakdown by Region*

| Sample Breakdown By Region | | | | |
|---|---|---|---|---|
| | Total Tractors | > 150 HP | Total Share | Share > 150 HP |
| Corn Belt | 4141 | 3462 | 36.5% | 36.2% |
| North Plains | 3258 | 2961 | 28.7% | 31.0% |
| Lake Region | 2550 | 2178 | 22.5% | 22.8% |
| South Plains | 481 | 320 | 4.2% | 3.3% |
| Northeast | 258 | 156 | 2.3% | 1.6% |
| Mountain | 246 | 203 | 2.2% | 2.1% |
| Pacific | 238 | 162 | 2.1% | 1.7% |
| Delta | 88 | 66 | 0.8% | 0.7% |
| Appalachian | 59 | 35 | 0.5% | 0.4% |
| Southeast | 30 | 14 | 0.3% | 0.1% |

*Table 15: Variance Inflation Factors*

| Full Regression Variance Inflation Factors | | | |
|---|---|---|---|
| | DF | Double Sq. Root | Semilog |
| sqrt(Hours) | 1 | 11.18 | 17.11 |
| sqrt(HP) | 1 | 6.21 | 6.60 |
| sqrt(Age) | 1 | 9.00 | 8.98 |
| Crop.Index | 1 | 9.31 | 9.31 |
| I.Rate | 1 | 1.44 | 1.44 |
| NoCab | 1 | 1.07 | 1.07 |
| Online | 1 | 1.12 | 1.12 |
| Duals | 1 | 1.20 | 1.20 |
| Auto.Steer | 1 | 1.16 | 1.16 |
| Auto.Steer.Ready | 1 | 1.15 | 1.14 |
| Display | 1 | 1.05 | 1.05 |
| Track | 1 | 1.37 | 1.37 |
| Quad.Track | 1 | 1.29 | 1.30 |
| MFWD | 5 | 1.18 | 1.18 |
| Articulated | 1 | 1.02 | 1.03 |
| Bareback | 1 | 1.05 | 1.05 |
| Loader | 1 | 1.26 | 1.26 |
| X1Owner | 1 | 1.02 | 1.02 |
| Warranty | 1 | 1.07 | 1.05 |
| Cond. | 1 | 1.05 | 1.04 |
| USDARegion | 8 | 1.03 | 1.03 |
| Brand | 3 | 6.45 | 3.51 |
| SizeClass | 9 | 7.62 | 7.13 |
| sqrt(Hours):Brand | 5 | 3.68 | 2.15 |
| sqrt(HP):Brand | 8 | 5.07 | 2.85 |
| sqrt(Age):Brand | 8 | 4.97 | 2.72 |
| sqrt(Hours):SizeClass | 8 | 4.51 | 2.94 |
| sqrt(Age):SizeClass | 1 | 5.54 | 3.27 |
| Crop.Index:SizeClass | 5 | 7.16 | 7.17 |

*Table 16: Full Double Square Root Model*

| **Double Square Root, Full Model** | | | | | |
|---|---|---|---|---|---|
| **Residuals:** | Min | 1Q | Median | 3Q | Max |
| | -304.2 | -14.0 | 0.8 | 15.0 | 278.9 |
| **Variable** | Estimate | Std. Error | t value | Pr(>\|t\|) | sig |
| (Intercept) | 117.72 | 13.52 | 8.71 | < 2e-16 | *** |
| sqrt(Hours) | -0.08 | 0.12 | -0.69 | 0.493 | |
| sqrt(HP) | 12.14 | 0.41 | 29.32 | < 2e-16 | *** |
| sqrt(Age) | -12.06 | 2.16 | -5.57 | 0.000 | *** |
| Crop.Index | -0.36 | 0.14 | -2.66 | 0.008 | ** |
| I.Rate | 0.72 | 0.19 | 3.71 | 0.000 | *** |
| NoCab | -24.59 | 2.14 | -11.51 | < 2e-16 | *** |
| Online | -3.37 | 1.21 | -2.78 | 0.006 | ** |
| Duals | 4.34 | 0.58 | 7.49 | 0.000 | *** |
| Auto.Steer | 6.53 | 0.99 | 6.60 | 0.000 | *** |
| Auto.Steer.Ready | 2.79 | 1.04 | 2.67 | 0.008 | ** |
| Display | 2.31 | 1.34 | 1.73 | 0.084 | . |
| Track | 12.26 | 1.25 | 9.78 | < 2e-16 | *** |
| Quad.Track | 27.87 | 2.73 | 10.19 | < 2e-16 | *** |
| MFWD | 8.04 | 0.60 | 13.30 | < 2e-16 | *** |
| Articulated | -6.15 | 6.35 | -0.97 | 0.333 | |
| Bareback | -10.53 | 1.74 | -6.07 | 0.000 | *** |
| Loader | 9.93 | 1.03 | 9.61 | < 2e-16 | *** |
| X1Owner | 6.99 | 1.26 | 5.56 | 0.000 | *** |
| Warranty | -0.23 | 1.33 | -0.17 | 0.862 | |
| Cond.F | -29.87 | 1.56 | -19.10 | < 2e-16 | *** |
| Cond.G | -7.63 | 0.75 | -10.21 | < 2e-16 | *** |
| Cond.P | -45.82 | 6.47 | -7.08 | 0.000 | *** |
| USDARegionAppalachian | -5.63 | 3.38 | -1.67 | 0.095 | . |
| USDARegionDelta | -16.48 | 2.81 | -5.86 | 0.000 | *** |
| USDARegionLake | -0.68 | 0.67 | -1.02 | 0.306 | |
| USDARegionMountain | -0.80 | 1.71 | -0.47 | 0.639 | |
| USDARegionNortheast | -2.98 | 1.79 | -1.67 | 0.095 | . |
| USDARegionNPlains | 2.64 | 0.64 | 4.13 | 0.000 | *** |
| USDARegionPacific | -26.47 | 1.78 | -14.86 | < 2e-16 | *** |
| USDARegionSoutheast | -20.17 | 4.72 | -4.27 | 0.000 | *** |
| USDARegionSPlains | -17.83 | 1.27 | -14.04 | < 2e-16 | *** |
| BrandAGCO | -59.73 | 7.49 | -7.98 | 0.000 | *** |
| BrandCASE | -35.31 | 3.97 | -8.90 | < 2e-16 | *** |
| BrandKUBOTA | -2.44 | 20.63 | -0.12 | 0.906 | |
| BrandNHOLLAND | -28.94 | 4.74 | -6.10 | 0.000 | *** |
| BrandOTHER | -48.44 | 7.90 | -6.13 | 0.000 | *** |
| SizeClass2 | -1.76 | 13.64 | -0.13 | 0.897 | |
| SizeClass3 | 1.00 | 13.46 | 0.07 | 0.941 | |
| SizeClass4 | 15.88 | 13.46 | 1.18 | 0.238 | |
| SizeClass5 | 15.54 | 14.07 | 1.10 | 0.269 | |

| **Variable** | Estimate | Std. Error | t value | Pr(>\|t\|) | sig |
|---|---|---|---|---|---|
| SizeClass6 | 39.57 | 14.31 | 2.77 | 0.0057 | ** |
| SizeClass7 | 42.11 | 14.74 | 2.86 | 0.00429 | ** |
| SizeClass8 | 44.95 | 20.54 | 2.19 | 0.02863 | * |
| SizeClass9 | 36.87 | 32.04 | 1.15 | 0.24995 | |
| sqrt(Hours):BrandAGCO | -0.21 | 0.07 | -2.94 | 0.00331 | ** |
| sqrt(Hours):BrandCASE | -0.24 | 0.04 | -6.18 | 6.47E-10 | *** |
| sqrt(Hours):BrandKUBOTA | -0.23 | 0.20 | -1.17 | 0.24303 | |
| sqrt(Hours):BrandNHOLLAND | -0.10 | 0.06 | -1.64 | 0.10166 | |
| sqrt(Hours):BrandOTHER | 0.36 | 0.08 | 4.54 | 5.81E-06 | *** |
| sqrt(HP):BrandAGCO | 2.71 | 0.35 | 7.72 | 1.22E-14 | *** |
| sqrt(HP):BrandCASE | 0.16 | 0.21 | 0.76 | 0.4494 | |
| sqrt(HP):BrandKUBOTA | -2.51 | 1.76 | -1.43 | 0.1542 | |
| sqrt(HP):BrandNHOLLAND | -0.53 | 0.24 | -2.20 | 0.02774 | * |
| sqrt(HP):BrandOTHER | 1.63 | 0.39 | 4.19 | 2.82E-05 | *** |
| sqrt(Age):BrandAGCO | -0.70 | 1.80 | -0.39 | 0.69701 | |
| sqrt(Age):BrandCASE | 9.25 | 0.88 | 10.51 | < 2e-16 | *** |
| sqrt(Age):BrandKUBOTA | 3.67 | 5.00 | 0.73 | 0.46332 | |
| sqrt(Age):BrandNHOLLAND | 3.78 | 1.33 | 2.84 | 0.00447 | ** |
| sqrt(Age):BrandOTHER | -10.56 | 2.04 | -5.17 | 2.4E-07 | *** |
| sqrt(Hours):SizeClass2 | -0.29 | 0.12 | -2.34 | 0.0191 | * |
| sqrt(Hours):SizeClass3 | -0.69 | 0.12 | -5.61 | 2.04E-08 | *** |
| sqrt(Hours):SizeClass4 | -0.81 | 0.12 | -6.72 | 1.97E-11 | *** |
| sqrt(Hours):SizeClass5 | -0.88 | 0.13 | -7.01 | 2.5E-12 | *** |
| sqrt(Hours):SizeClass6 | -1.12 | 0.13 | -8.66 | < 2e-16 | *** |
| sqrt(Hours):SizeClass7 | -1.32 | 0.14 | -9.75 | < 2e-16 | *** |
| sqrt(Hours):SizeClass8 | -1.83 | 0.16 | -11.26 | < 2e-16 | *** |
| sqrt(Hours):SizeClass9 | -1.85 | 0.22 | -8.50 | < 2e-16 | *** |
| sqrt(Age):SizeClass2 | -0.75 | 2.32 | -0.32 | 0.74623 | |
| sqrt(Age):SizeClass3 | -5.76 | 2.31 | -2.49 | 0.01274 | * |
| sqrt(Age):SizeClass4 | -19.00 | 2.24 | -8.47 | < 2e-16 | *** |
| sqrt(Age):SizeClass5 | -31.03 | 2.38 | -13.03 | < 2e-16 | *** |
| sqrt(Age):SizeClass6 | -34.52 | 2.45 | -14.11 | < 2e-16 | *** |
| sqrt(Age):SizeClass7 | -30.49 | 2.70 | -11.31 | < 2e-16 | *** |
| sqrt(Age):SizeClass8 | -26.61 | 4.05 | -6.57 | 5.3E-11 | *** |
| sqrt(Age):SizeClass9 | -18.50 | 6.47 | -2.86 | 0.00425 | ** |
| Crop.Index:SizeClass2 | 0.39 | 0.14 | 2.70 | 0.00689 | ** |
| Crop.Index:SizeClass3 | 1.02 | 0.14 | 7.29 | 3.4E-13 | *** |
| Crop.Index:SizeClass4 | 1.43 | 0.14 | 10.41 | < 2e-16 | *** |
| Crop.Index:SizeClass5 | 1.79 | 0.14 | 12.64 | < 2e-16 | *** |
| Crop.Index:SizeClass6 | 1.73 | 0.14 | 12.17 | < 2e-16 | *** |
| Crop.Index:SizeClass7 | 1.53 | 0.15 | 10.48 | < 2e-16 | *** |
| Crop.Index:SizeClass8 | 1.61 | 0.19 | 8.38 | < 2e-16 | *** |
| Crop.Index:SizeClass9 | 1.58 | 0.28 | 5.58 | 2.44E-08 | *** |
| Signif. | 0: ‘***’ | .001:'**' | .01: '*' | .05: '.' | |

*Table 17: 10 Year Double Square Root Model*

| **Double Square Root, 10 Year Model** | | | | | |
|---|---|---|---|---|---|
| **Residuals:** | Min | 1Q | Median | 3Q | Max |
| | -294.3 | -13.6 | 0.5 | 13.7 | 174.0 |
| **Variable** | Estimate | Std. Error | t value | Pr(>\|t\|) | sig |
| (Intercept) | 89.52 | 15.71 | 5.70 | 0.000 | *** |
| sqrt(Hours) | -0.18 | 0.15 | -1.24 | 0.215 | |
| sqrt(HP) | 13.66 | 0.50 | 27.47 | < 2e-16 | *** |
| sqrt(Age) | -7.10 | 3.46 | -2.05 | 0.040 | * |
| Crop.Index | -0.31 | 0.15 | -2.06 | 0.040 | * |
| I.Rate | 0.95 | 0.22 | 4.24 | 0.000 | *** |
| NoCab | -26.97 | 2.60 | -10.37 | < 2e-16 | *** |
| Online | 1.32 | 1.52 | 0.87 | 0.383 | |
| Duals | 2.80 | 0.72 | 3.90 | 0.000 | *** |
| Auto.Steer | 6.16 | 1.10 | 5.60 | 0.000 | *** |
| Auto.Steer.Ready | 2.72 | 1.10 | 2.47 | 0.014 | * |
| Display | 3.40 | 1.38 | 2.46 | 0.014 | * |
| Track | 13.71 | 1.43 | 9.57 | < 2e-16 | *** |
| Quad.Track | 30.11 | 2.92 | 10.31 | < 2e-16 | *** |
| MFWD | 4.58 | 0.77 | 5.95 | 0.000 | *** |
| Articulated | 10.43 | 8.49 | 1.23 | 0.219 | |
| Bareback | -10.38 | 2.41 | -4.31 | 0.000 | *** |
| Loader | 11.10 | 1.24 | 8.98 | < 2e-16 | *** |
| X1Owner | 4.28 | 1.59 | 2.70 | 0.007 | ** |
| Warranty | 4.26 | 1.32 | 3.24 | 0.001 | ** |
| Cond.F | -25.20 | 2.42 | -10.41 | < 2e-16 | *** |
| Cond.G | -3.55 | 0.84 | -4.22 | 0.000 | *** |
| Cond.P | -30.49 | 8.81 | -3.46 | 0.001 | *** |
| USDARegionAppalachian | -4.48 | 4.82 | -0.93 | 0.353 | |
| USDARegionDelta | -13.50 | 3.35 | -4.03 | 0.000 | *** |
| USDARegionLake | -0.05 | 0.80 | -0.06 | 0.955 | |
| USDARegionMountain | 3.61 | 2.20 | 1.64 | 0.101 | |
| USDARegionNortheast | -1.17 | 2.37 | -0.49 | 0.622 | |
| USDARegionNPlains | 4.83 | 0.78 | 6.18 | 0.000 | *** |
| USDARegionPacific | -15.67 | 2.29 | -6.85 | 0.000 | *** |
| USDARegionSoutheast | -24.16 | 5.73 | -4.22 | 0.000 | *** |
| USDARegionSPlains | -10.68 | 1.55 | -6.89 | 0.000 | *** |
| BrandAGCO | -50.95 | 9.52 | -5.35 | 0.000 | *** |
| BrandCASE | -25.42 | 4.98 | -5.11 | 0.000 | *** |
| BrandKUBOTA | -3.16 | 23.03 | -0.14 | 0.891 | |
| BrandNHOLLAND | -13.32 | 6.85 | -1.95 | 0.052 | . |
| BrandOTHER | -64.16 | 10.71 | -5.99 | 0.000 | *** |
| SizeClass2 | 3.95 | 15.90 | 0.25 | 0.804 | |
| SizeClass3 | -1.36 | 16.26 | -0.08 | 0.933 | |
| SizeClass4 | -8.71 | 15.78 | -0.55 | 0.581 | |
| SizeClass5 | -20.98 | 16.38 | -1.28 | 0.200 | |

| **Variable** | Estimate | Std. Error | t value | Pr(>\|t\|) | sig |
|---|---|---|---|---|---|
| SizeClass6 | -0.45 | 17.07 | -0.03 | 0.979056 | |
| SizeClass7 | 20.67 | 17.27 | 1.20 | 0.23146 | |
| SizeClass8 | 43.73 | 21.91 | 2.00 | 0.045997 | * |
| SizeClass9 | -2.85 | 32.49 | -0.09 | 0.930132 | |
| sqrt(Hours):BrandAGCO | -0.22 | 0.09 | -2.56 | 0.010394 | * |
| sqrt(Hours):BrandCASE | -0.24 | 0.05 | -4.39 | 0.0000118 | *** |
| sqrt(Hours):BrandKUBOTA | -0.38 | 0.24 | -1.62 | 0.106004 | |
| sqrt(Hours):BrandNHOLLAND | -0.04 | 0.08 | -0.43 | 0.668182 | |
| sqrt(Hours):BrandOTHER | 0.51 | 0.10 | 5.04 | 4.72E-07 | *** |
| sqrt(HP):BrandAGCO | 2.49 | 0.38 | 6.55 | 6.3E-11 | *** |
| sqrt(HP):BrandCASE | -0.22 | 0.24 | -0.92 | 0.359879 | |
| sqrt(HP):BrandKUBOTA | -1.10 | 1.87 | -0.59 | 0.556063 | |
| sqrt(HP):BrandNHOLLAND | -1.45 | 0.30 | -4.89 | 1.05E-06 | *** |
| sqrt(HP):BrandOTHER | 1.18 | 0.44 | 2.71 | 0.006807 | ** |
| sqrt(Age):BrandAGCO | -3.98 | 3.18 | -1.25 | 0.210593 | |
| sqrt(Age):BrandCASE | 7.34 | 1.66 | 4.43 | 9.69E-06 | *** |
| sqrt(Age):BrandKUBOTA | 0.05 | 7.30 | 0.01 | 0.994255 | |
| sqrt(Age):BrandNHOLLAND | 1.21 | 2.55 | 0.48 | 0.633961 | |
| sqrt(Age):BrandOTHER | -6.14 | 3.67 | -1.67 | 0.094437 | . |
| sqrt(Hours):SizeClass2 | -0.17 | 0.15 | -1.12 | 0.261746 | |
| sqrt(Hours):SizeClass3 | -0.58 | 0.16 | -3.69 | 0.000229 | *** |
| sqrt(Hours):SizeClass4 | -0.93 | 0.15 | -6.18 | 6.98E-10 | *** |
| sqrt(Hours):SizeClass5 | -1.03 | 0.16 | -6.63 | 3.72E-11 | *** |
| sqrt(Hours):SizeClass6 | -1.26 | 0.16 | -7.77 | 9.23E-15 | *** |
| sqrt(Hours):SizeClass7 | -1.38 | 0.17 | -8.17 | 3.75E-16 | *** |
| sqrt(Hours):SizeClass8 | -1.78 | 0.18 | -9.69 | < 2e-16 | *** |
| sqrt(Hours):SizeClass9 | -1.88 | 0.23 | -8.16 | 3.84E-16 | *** |
| sqrt(Age):SizeClass2 | -3.48 | 3.73 | -0.93 | 0.350153 | |
| sqrt(Age):SizeClass3 | -5.46 | 3.84 | -1.42 | 0.155371 | |
| sqrt(Age):SizeClass4 | -10.93 | 3.63 | -3.01 | 0.002592 | ** |
| sqrt(Age):SizeClass5 | -19.08 | 3.77 | -5.06 | 4.38E-07 | *** |
| sqrt(Age):SizeClass6 | -26.64 | 4.03 | -6.61 | 4.16E-11 | *** |
| sqrt(Age):SizeClass7 | -24.52 | 4.28 | -5.73 | 1.03E-08 | *** |
| sqrt(Age):SizeClass8 | -30.04 | 4.85 | -6.19 | 6.25E-10 | *** |
| sqrt(Age):SizeClass9 | -16.66 | 6.87 | -2.43 | 0.015324 | * |
| Crop.Index:SizeClass2 | 0.30 | 0.16 | 1.90 | 0.057238 | . |
| Crop.Index:SizeClass3 | 0.89 | 0.16 | 5.67 | 1.45E-08 | *** |
| Crop.Index:SizeClass4 | 1.49 | 0.15 | 9.89 | < 2e-16 | *** |
| Crop.Index:SizeClass5 | 1.87 | 0.15 | 12.11 | < 2e-16 | *** |
| Crop.Index:SizeClass6 | 1.92 | 0.16 | 12.25 | < 2e-16 | *** |
| Crop.Index:SizeClass7 | 1.46 | 0.16 | 9.21 | < 2e-16 | *** |
| Crop.Index:SizeClass8 | 1.44 | 0.20 | 7.28 | 3.65E-13 | *** |
| Crop.Index:SizeClass9 | 1.73 | 0.28 | 6.15 | 7.99E-10 | *** |
| Signif. | 0: '***' | .001:'**' | .01: '*' | .05: '.' | |

*Table 18: Full Semilog Model*

| **Semilog, Full Model** | | | | | |
|---|---|---|---|---|---|
| **Residuals:** | Min | 1Q | Median | 3Q | Max |
| | -2.9 | -0.1 | 0.0 | 0.1 | 2.0 |
| **Variable** | Estimate | Std. Error | t value | Pr(>\|t\|) | sig |
| (Intercept) | 10.35 | 0.12 | 89.46 | < 2e-16 | *** |
| Hours | 0.00 | 0.00 | -1.15 | 0.248 | |
| HP | 0.00 | 0.00 | 24.82 | < 2e-16 | *** |
| Age | -0.04 | 0.00 | -12.49 | < 2e-16 | *** |
| Crop.Index | -0.01 | 0.00 | -4.32 | 0.000 | *** |
| I.Rate | 0.01 | 0.00 | 4.46 | 0.000 | *** |
| NoCab | -0.31 | 0.02 | -15.67 | < 2e-16 | *** |
| Online | -0.02 | 0.01 | -2.06 | 0.040 | * |
| Duals | 0.04 | 0.01 | 8.06 | 0.000 | *** |
| Auto.Steer | 0.04 | 0.01 | 4.33 | 0.000 | *** |
| Auto.Steer.Ready | 0.02 | 0.01 | 1.89 | 0.059 | . |
| Display | 0.01 | 0.01 | 0.54 | 0.588 | |
| Track | 0.11 | 0.01 | 9.67 | < 2e-16 | *** |
| Quad.Track | 0.14 | 0.03 | 5.61 | 0.000 | *** |
| MFWD | 0.08 | 0.01 | 14.55 | < 2e-16 | *** |
| Articulated | -0.07 | 0.06 | -1.15 | 0.250 | |
| Bareback | -0.09 | 0.02 | -5.35 | 0.000 | *** |
| Loader | 0.13 | 0.01 | 14.12 | < 2e-16 | *** |
| X1Owner | 0.06 | 0.01 | 5.22 | 0.000 | *** |
| Warranty | 0.03 | 0.01 | 2.35 | 0.019 | * |
| Cond.F | -0.33 | 0.01 | -22.68 | < 2e-16 | *** |
| Cond.G | -0.08 | 0.01 | -12.15 | < 2e-16 | *** |
| Cond.P | -0.58 | 0.06 | -9.76 | < 2e-16 | *** |
| USDARegionAppalachian | -0.05 | 0.03 | -1.61 | 0.106 | |
| USDARegionDelta | -0.16 | 0.03 | -6.09 | 0.000 | *** |
| USDARegionLake | 0.00 | 0.01 | -0.21 | 0.834 | |
| USDARegionMountain | -0.02 | 0.02 | -1.45 | 0.147 | |
| USDARegionNortheast | -0.04 | 0.02 | -2.27 | 0.023 | * |
| USDARegionNPlains | 0.02 | 0.01 | 2.98 | 0.003 | ** |
| USDARegionPacific | -0.31 | 0.02 | -18.46 | < 2e-16 | *** |
| USDARegionSoutheast | -0.20 | 0.04 | -4.49 | 0.000 | *** |
| USDARegionSPlains | -0.18 | 0.01 | -14.99 | < 2e-16 | *** |
| BrandAGCO | -0.48 | 0.04 | -13.11 | < 2e-16 | *** |
| BrandCASE | -0.24 | 0.02 | -12.00 | < 2e-16 | *** |
| BrandKUBOTA | -0.26 | 0.10 | -2.57 | 0.010 | * |
| BrandNHOLLAND | -0.35 | 0.02 | -14.27 | < 2e-16 | *** |
| BrandOTHER | -0.53 | 0.04 | -12.84 | < 2e-16 | *** |
| SizeClass2 | 0.05 | 0.12 | 0.44 | 0.658 | |
| SizeClass3 | -0.07 | 0.12 | -0.61 | 0.543 | |
| SizeClass4 | -0.11 | 0.12 | -0.97 | 0.335 | |
| SizeClass5 | -0.20 | 0.12 | -1.61 | 0.107 | |

| **Variable** | Estimate | Std. Error | t value | Pr(>\|t\|) | sig |
|---|---|---|---|---|---|
| SizeClass6 | -0.27 | 0.13 | -2.18 | 0.02915 | * |
| SizeClass7 | -0.28 | 0.13 | -2.16 | 0.0311 | * |
| SizeClass8 | -0.35 | 0.18 | -1.97 | 0.04867 | * |
| SizeClass9 | -0.30 | 0.27 | -1.12 | 0.26293 | |
| Hours:BrandAGCO | 0.00 | 0.00 | -2.34 | 0.01921 | * |
| Hours:BrandCASE | 0.00 | 0.00 | -7.86 | 4.3E-15 | *** |
| Hours:BrandKUBOTA | 0.00 | 0.00 | -5.28 | 1.3E-07 | *** |
| Hours:BrandNHOLLAND | 0.00 | 0.00 | -2.94 | 0.00326 | ** |
| Hours:BrandOTHER | 0.00 | 0.00 | 2.60 | 0.00922 | ** |
| HP:BrandAGCO | 0.00 | 0.00 | 11.22 | < 2e-16 | *** |
| HP:BrandCASE | 0.00 | 0.00 | 4.91 | 9.1E-07 | *** |
| HP:BrandKUBOTA | 0.00 | 0.00 | 1.11 | 0.26763 | |
| HP:BrandNHOLLAND | 0.00 | 0.00 | 6.92 | 4.9E-12 | *** |
| HP:BrandOTHER | 0.00 | 0.00 | 12.12 | < 2e-16 | *** |
| Age:BrandAGCO | -0.01 | 0.00 | -2.67 | 0.0077 | ** |
| Age:BrandCASE | 0.01 | 0.00 | 8.11 | 5.6E-16 | *** |
| Age:BrandKUBOTA | 0.01 | 0.01 | 0.78 | 0.43517 | |
| Age:BrandNHOLLAND | 0.00 | 0.00 | -0.16 | 0.87435 | |
| Age:BrandOTHER | -0.02 | 0.00 | -8.06 | 8.3E-16 | *** |
| Hours:SizeClass2 | 0.00 | 0.00 | -1.45 | 0.1474 | |
| Hours:SizeClass3 | 0.00 | 0.00 | -2.75 | 0.00602 | ** |
| Hours:SizeClass4 | 0.00 | 0.00 | -2.59 | 0.00969 | ** |
| Hours:SizeClass5 | 0.00 | 0.00 | -2.75 | 0.00597 | ** |
| Hours:SizeClass6 | 0.00 | 0.00 | -3.55 | 0.00038 | *** |
| Hours:SizeClass7 | 0.00 | 0.00 | -4.11 | 4E-05 | *** |
| Hours:SizeClass8 | 0.00 | 0.00 | -5.19 | 2.1E-07 | *** |
| Hours:SizeClass9 | 0.00 | 0.00 | -3.03 | 0.00247 | ** |
| Age:SizeClass2 | 0.01 | 0.00 | 4.01 | 6.2E-05 | *** |
| Age:SizeClass3 | 0.01 | 0.00 | 4.13 | 3.7E-05 | *** |
| Age:SizeClass4 | 0.00 | 0.00 | -0.33 | 0.74493 | |
| Age:SizeClass5 | -0.02 | 0.00 | -4.63 | 3.7E-06 | *** |
| Age:SizeClass6 | -0.01 | 0.00 | -3.85 | 0.00012 | *** |
| Age:SizeClass7 | -0.01 | 0.00 | -2.00 | 0.04529 | * |
| Age:SizeClass8 | -0.01 | 0.01 | -0.66 | 0.50714 | |
| Age:SizeClass9 | -0.02 | 0.02 | -1.02 | 0.30572 | |
| Crop.Index:SizeClass2 | 0.01 | 0.00 | 4.20 | 2.7E-05 | *** |
| Crop.Index:SizeClass3 | 0.01 | 0.00 | 9.08 | < 2e-16 | *** |
| Crop.Index:SizeClass4 | 0.01 | 0.00 | 11.21 | < 2e-16 | *** |
| Crop.Index:SizeClass5 | 0.02 | 0.00 | 11.95 | < 2e-16 | *** |
| Crop.Index:SizeClass6 | 0.02 | 0.00 | 11.92 | < 2e-16 | *** |
| Crop.Index:SizeClass7 | 0.01 | 0.00 | 9.75 | < 2e-16 | *** |
| Crop.Index:SizeClass8 | 0.01 | 0.00 | 7.13 | 1.1E-12 | *** |
| Crop.Index:SizeClass9 | 0.01 | 0.00 | 4.39 | 1.2E-05 | *** |
| Signif. | 0: '***' | .001:'**' | .01: '*' | .05: '.' | |

*Table 19: 10 Year Semilog Model*

| Semilog, 10 Year Model | | | | | |
|---|---|---|---|---|---|
| Residuals: | Min | 1Q | Median | 3Q | Max |
| | -2.8 | -0.1 | 0.0 | 0.1 | 1.7 |
| Variable | Estimate | Std. Error | t value | Pr(>\|t\|) | sig |
| (Intercept) | 10.31 | 0.11 | 89.78 | < 2e-16 | *** |
| Hours | 0.00 | 0.00 | -0.97 | 0.330 | |
| HP | 0.00 | 0.00 | 23.94 | < 2e-16 | *** |
| Age | -0.04 | 0.01 | -6.16 | 0.000 | *** |
| Crop.Index | -0.01 | 0.00 | -4.57 | 0.000 | *** |
| I.Rate | 0.01 | 0.00 | 4.56 | 0.000 | *** |
| NoCab | -0.33 | 0.02 | -15.68 | < 2e-16 | *** |
| Online | 0.02 | 0.01 | 1.67 | 0.095 | . |
| Duals | 0.03 | 0.01 | 4.29 | 0.000 | *** |
| Auto.Steer | 0.04 | 0.01 | 3.91 | 0.000 | *** |
| Auto.Steer.Ready | 0.02 | 0.01 | 2.75 | 0.006 | ** |
| Display | 0.02 | 0.01 | 1.55 | 0.120 | |
| Track | 0.11 | 0.01 | 9.60 | < 2e-16 | *** |
| Quad.Track | 0.15 | 0.02 | 6.13 | 0.000 | *** |
| MFWD | 0.05 | 0.01 | 7.99 | 0.000 | *** |
| Articulated | 0.06 | 0.07 | 0.88 | 0.381 | |
| Bareback | -0.08 | 0.02 | -3.91 | 0.000 | *** |
| Loader | 0.13 | 0.01 | 13.15 | < 2e-16 | *** |
| X1Owner | 0.03 | 0.01 | 2.68 | 0.007 | ** |
| Warranty | 0.04 | 0.01 | 3.95 | 0.000 | *** |
| Cond.F | -0.23 | 0.02 | -11.47 | < 2e-16 | *** |
| Cond.G | -0.05 | 0.01 | -6.91 | 0.000 | *** |
| Cond.P | -0.30 | 0.07 | -4.21 | 0.000 | *** |
| USDARegionAppalachian | -0.04 | 0.04 | -1.13 | 0.260 | |
| USDARegionDelta | -0.14 | 0.03 | -5.06 | 0.000 | *** |
| USDARegionLake | 0.00 | 0.01 | -0.61 | 0.539 | |
| USDARegionMountain | 0.01 | 0.02 | 0.67 | 0.504 | |
| USDARegionNortheast | -0.03 | 0.02 | -1.33 | 0.182 | |
| USDARegionNPlains | 0.03 | 0.01 | 4.57 | 0.000 | *** |
| USDARegionPacific | -0.17 | 0.02 | -8.96 | < 2e-16 | *** |
| USDARegionSoutheast | -0.22 | 0.05 | -4.66 | 0.000 | *** |
| USDARegionSPlains | -0.10 | 0.01 | -7.91 | 0.000 | *** |
| BrandAGCO | -0.43 | 0.04 | -10.32 | < 2e-16 | *** |
| BrandCASE | -0.19 | 0.02 | -8.49 | < 2e-16 | *** |
| BrandKUBOTA | -0.29 | 0.10 | -2.86 | 0.004 | ** |
| BrandNHOLLAND | -0.29 | 0.03 | -9.32 | < 2e-16 | *** |
| BrandOTHER | -0.61 | 0.05 | -12.31 | < 2e-16 | *** |
| SizeClass2 | 0.13 | 0.12 | 1.06 | 0.292 | |
| SizeClass3 | 0.08 | 0.12 | 0.64 | 0.524 | |
| SizeClass4 | -0.08 | 0.12 | -0.65 | 0.518 | |
| SizeClass5 | -0.24 | 0.12 | -2.01 | 0.045 | * |

| Variable | Estimate | Std. Error | t value | Pr(>\|t\|) | sig |
|---|---|---|---|---|---|
| SizeClass6 | -0.30 | 0.13 | -2.34 | 0.0194 | * |
| SizeClass7 | -0.21 | 0.13 | -1.62 | 0.1051 | |
| SizeClass8 | -0.25 | 0.17 | -1.46 | 0.1433 | |
| SizeClass9 | -0.46 | 0.24 | -1.95 | 0.0518 | . |
| Hours:BrandAGCO | 0.00 | 0.00 | -2.29 | 0.022 | * |
| Hours:BrandCASE | 0.00 | 0.00 | -6.40 | 2E-10 | *** |
| Hours:BrandKUBOTA | 0.00 | 0.00 | -4.92 | 9E-07 | *** |
| Hours:BrandNHOLLAND | 0.00 | 0.00 | -2.26 | 0.0238 | * |
| Hours:BrandOTHER | 0.00 | 0.00 | 4.66 | 3E-06 | *** |
| HP:BrandAGCO | 0.00 | 0.00 | 10.64 | < 2e-16 | *** |
| HP:BrandCASE | 0.00 | 0.00 | 3.06 | 0.0022 | ** |
| HP:BrandKUBOTA | 0.00 | 0.00 | 1.93 | 0.0539 | . |
| HP:BrandNHOLLAND | 0.00 | 0.00 | 3.46 | 0.0005 | *** |
| HP:BrandOTHER | 0.00 | 0.00 | 11.21 | < 2e-16 | *** |
| Age:BrandAGCO | -0.01 | 0.01 | -2.01 | 0.0443 | * |
| Age:BrandCASE | 0.01 | 0.00 | 2.86 | 0.0042 | ** |
| Age:BrandKUBOTA | 0.00 | 0.01 | -0.02 | 0.9874 | |
| Age:BrandNHOLLAND | 0.00 | 0.00 | -0.29 | 0.7756 | |
| Age:BrandOTHER | -0.02 | 0.01 | -3.42 | 0.0006 | *** |
| Hours:SizeClass2 | 0.00 | 0.00 | -1.35 | 0.1785 | |
| Hours:SizeClass3 | 0.00 | 0.00 | -2.41 | 0.0158 | * |
| Hours:SizeClass4 | 0.00 | 0.00 | -2.62 | 0.0088 | ** |
| Hours:SizeClass5 | 0.00 | 0.00 | -2.90 | 0.0038 | ** |
| Hours:SizeClass6 | 0.00 | 0.00 | -3.38 | 0.0007 | *** |
| Hours:SizeClass7 | 0.00 | 0.00 | -3.23 | 0.0012 | ** |
| Hours:SizeClass8 | 0.00 | 0.00 | -4.68 | 3E-06 | *** |
| Hours:SizeClass9 | 0.00 | 0.00 | -3.42 | 0.0006 | *** |
| Age:SizeClass2 | 0.01 | 0.01 | 1.73 | 0.0846 | . |
| Age:SizeClass3 | 0.02 | 0.01 | 2.34 | 0.0196 | * |
| Age:SizeClass4 | 0.00 | 0.01 | 0.60 | 0.5476 | |
| Age:SizeClass5 | 0.00 | 0.01 | -0.37 | 0.7082 | |
| Age:SizeClass6 | -0.01 | 0.01 | -1.48 | 0.1386 | |
| Age:SizeClass7 | -0.01 | 0.01 | -1.17 | 0.2413 | |
| Age:SizeClass8 | -0.01 | 0.01 | -0.91 | 0.3616 | |
| Age:SizeClass9 | -0.01 | 0.01 | -0.36 | 0.7158 | |
| Crop.Index:SizeClass2 | 0.01 | 0.00 | 3.91 | 9E-05 | *** |
| Crop.Index:SizeClass3 | 0.01 | 0.00 | 7.69 | 2E-14 | *** |
| Crop.Index:SizeClass4 | 0.01 | 0.00 | 11.38 | < 2e-16 | *** |
| Crop.Index:SizeClass5 | 0.02 | 0.00 | 12.58 | < 2e-16 | *** |
| Crop.Index:SizeClass6 | 0.02 | 0.00 | 12.67 | < 2e-16 | *** |
| Crop.Index:SizeClass7 | 0.01 | 0.00 | 9.63 | < 2e-16 | *** |
| Crop.Index:SizeClass8 | 0.01 | 0.00 | 7.23 | 5E-13 | *** |
| Crop.Index:SizeClass9 | 0.01 | 0.00 | 5.69 | 1E-08 | *** |
| Signif. | 0: '***' | .001:'**' | .01: '*' | .05: '.' | |