REFEREED ARTICLE

ESTIMATING TRACTOR DEPRECIATION: THE IMPACT OF CHOICE OF FUNCTIONAL FORM

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Using 1223 observations of second-hand tractor prices in the UK, an OLS model of depreciation, which is cubic in all continuous independent variables, is compared to a Box-Cox model. The results of the preferred cubic OLS model explain 87% of the variation in depreciation and indicate that the rate of change in depreciation varies over particular data ranges of both the year of life and hours worked. Moreover, over a particular data range, the relationship between depreciation and horsepower is negative, contrasting with previous findings generated from more restrictive models. Tables of estimated percentage remaining values are presented for use by farmers and managers.

Keywords: Depreciation, Modelling, Functional Form, Box-Cox, Cubic Linear-Regression, Tractors.

1. Introduction

Improvements in many agricultural commodity prices in 2007 and 2008 led to an upsurge in demand for agricultural machinery as farmers and managers sought to re-new their aging machinery fleets. The demand for tractors is generally acknowledged as a barometer of the demand for agricultural machinery in general; with economic downturn around the globe, agriculture and food is one sector that is remaining buoyant (Economist, 2009). Registration of new tractors within the UK was 15,540 in 2007 and

Table 1: Tractor registrations by brand in 2007

	Units	Total Percentage
John Deere	5000	29.3
New Holland	2809	16.4
Massey Ferguson	2766	16.2
Case IH	957	5.6
Class	926	5.4
McCormick	845	4.9
Same Deutz-Fahr	755	4.4
Kubota	667	3.9
Valtra	662	3.9
Fendt	402	2.4
JCB	237	1.4
Landini	210	1.2
Other Brands	853	5.0
Total UK	17,089	100.0

Source: AEA (2008). Data includes Compact Tractors (<= 50 hp) and Agricultural tractors (> 50 hp): Case includes Steyr, MF includes Challenger.

17,104 in 2008, the latter representing a 10% increase on the previous year (AEA, 2009). The UK market is dominated by three brands accounting for 61.9% of the market as shown in Table 1.

The market for new and second hand tractors is heavily influenced by actual and anticipated profitability within the industry and the equilibrium between demand and supply for second-hand tractors is a determining factor in establishing the residual, or 'trade-in', value of agricultural tractors. Farmers and managers seeking to invest in new tractors generally make some assessment of the anticipated future value of their investment in a new tractor in order to determine the asset's depreciation over its period of ownership within the business.

Farmers and managers have traditionally used a variety of methods for assessing the likely future value of tractors, including the use of 'standard' depreciation rates often used in accounting procedures for tax purposes, and the use of UK industry standards (e.g. Nix pocketbook (various), or the depreciation rate used within the Farm Business Survey (FBS) (Defra, 2009)). However, the depreciation of a 'working' fixed asset such as a tractor is only one element of the cost of ownership and farmers and managers must also take into account running costs, finance charges, service costs and anticipated repair costs over the life time of ownership. Whilst this paper does not explicitly address these points, depreciation represents a substantial cost of ownership and the standard tables (e.g. Nix) or interactive CD computer packages (Agro-Business Consultants, 2010) available to farmers reinforce the importance of understanding ownership costs at the outset of making an investment. Moreover, in seeking to make an informed decision between buying new or second hand, managers require knowledge of the relative depreciation costs involved alongside other costs of ownership that may differ (e.g. repairs) between buying new and second hand. Whilst this research therefore seeks to examine only one area of tractor ownership cost, it is arguably an area of great importance and one that has led previous authors to seek to more fully explain the factors that influence tractor depreciation.

Recent examples of research into UK tractor depreciation include Wilson and Davis (1999) and Wilson and Tolley (2004) where tables of estimated remaining values are provided as a function of age, horsepower and hours of work, with results additionally provided to tailor the anticipated depreciation according to tractor brand. The tables provided by Wilson and Tolley (2004) were found to provide a significantly improved estimation of depreciation / remaining value than could be determined by using either Nix's pocketbook or the depreciation rate utilised within the FBS. Hence, in recent years, farmers, managers and consultants have had access to these publicly available tables for the UK.

Research into tractor depreciation, and factors influencing the price of tractors more generally, includes an examination of tractor price-quality indices (Rayner, 1968; Cooper *et al.*,1993) for new tractors, whilst studies of depreciation include: Musser *et al.,* (1986), Reid and Bradford (1983), Perry *et al*., (1990), Cross and Perry (1995), Unterschultz and Mumey (1996), Dumler *et al*., (2000; 2003), and Wu and Perry (2004) within the US; Williams (1980), Cunningham and Turner (1988), Wilson and Davis (1998), and Wilson and Tolley (2004) in the UK; McNeill (1979) and Hansen and Lee (1991) in Canada; Fenolloas and Guadalajara (2007) in Spain. The importance of understanding and predicting depreciation rates in tractors is thus internationally recognised, and has led several authors to empirically quantify depreciation rates.

The approach taken in empirical depreciation studies is to undertake regression analysis which seeks to explain depreciation (e.g. total percentage depreciation or remaining value) as a function of multiple independent variables. Whilst different approaches are adopted by various researchers, there is general consensus that the independent variables of age, hours of work and power rating of the tractor significantly influence depreciation. Where data exists on the tractor manufacturer or brand (e.g. Wilson and Tolley 2004; Fenolloas and Guadalajara, 2007), care and condition of the tractor, additional features, or regional influences (e.g. Cross and Perry, 1995) these have been incorporated within the estimation procedure. Data for these studies has been drawn from either published data sources from intermediaries (e.g. auction data) in the tractor market (e.g. Fenolloas and Guadalajara, 2007; Perry *et al.,* 1990), or published trade advertisements (e.g. Wilson and Tolley 2004).

Auction data typically provides a data source that reflects the market value of the second-hand tractor, although data on farm retirement sales have been argued to bias prices upwards, reflecting a combination of value from 'known' tractors to potential purchasers from retirement sales, when compared to purchases made in the general market from dealers (Perry *et al*., 1990). Published second-hand asking prices from tractor dealers typically include an element of warranty, have an element of price built in to allow for 'bartering' in the sale of the second-hand tractor, and thus typically do not reflect the residual, or trade-in, value of the tractor received by the vendor when selling to a dealer; in this case manipulation of the data is required to estimate the trade-in value prior to estimation of depreciation (Wilson and Tolley, 2004).

Depreciation studies also note the difficulties of using new "list" prices for tractors as the actual purchase price when new. Typically, the marketing of new tractors includes offering substantial discounts off the advertised list price. This marketing technique is well known in the industry, yet for the purposes of determining a depreciation rate, a methodology for converting the new list prices to a real new price is required.

Within the literature seeking to explain depreciation rates for capital goods, the methodological approaches have largely focused upon the use of ordinary least squares (OLS) regressions and Box-Cox transformations. The non-linear Box-Cox transformation (e.g. Perry *et al*., 1990; Cross and Perry, 1995; Unterschultz and Mumey, 1996; Wu and Perry, 2004) allows for the assumed non-linearity between depreciation and age, commonly known to exist, by not specifying a functional relationship for this key independent variable at the outset. By contrast, the use of OLS in depreciation studies requires transformation of the data on age of the tractor prior to model estimation; a general approach to this being to take the natural logarithm of age, or year of life, of the machine (e.g. Wilson and Davis, 1999; Wilson and Tolley, 2004). The theoretical advantage of the Box-Cox approach, by allowing the data to determine the functional form has been argued to be countered by the disadvantage of the difficulty of interpretability of the estimated results (Wilson and Tolley, 2004), whilst Wu and Perry (2004) conclude that the complexity of the Box-Cox model does not provide any practical advantage with respect to estimating depreciation over two simpler functional forms. By contrast the advantage of the ease of interpretability from the OLS modelling approach is accompanied by the restricted nature of imposing a functional form on the relationship at the outset, and the exact specification of the OLS model is of crucial importance in this respect.

Comparing OLS and Box-Cox approaches requires a methodology that overcomes the lack of directly comparable goodness of fit statistics produced from the two techniques. One accepted approach is the pairwise comparison method provided by the mean absolute percentage error (MAPE) methodology which compares predicted depreciation from the model results to actual depreciation (see Dumler *et al*., 2003; Wilson and Tolley; 2004; Wu and Perry, 2004). The restrictions imposed by the functional form are argued to be of importance for other independent variables beyond the age of the tractor; Perry *et al*., (1990) specify age, hours and horsepower as non-linear independent variables. OLS models have, by contrast, generally only sought to transform the 'age' variable prior to estimation, restricting the model to impose a linear relationship on both hours and horsepower (Wilson and Tolley, 2004).

Whilst studies have considered the merits of different approaches to estimating and predicting tractor depreciation, these have often involved comparison of an empirical approach (e.g. Box-Cox or OLS) against standard depreciation methods and calculations. Modelling approaches that directly compare Box-Cox depreciation models with OLS models are few in number, with empirical analysis largely restricted to US data (e.g. Wu and Perry, 2004). Moreover, OLS models previously estimated do not generally examine the possibility of non-linear relationships between hours and horsepower rating in the case of tractors. One exception to this is Wu and Perry's (2004) analysis that considers different functional forms against a Box-Cox specification; this analysis includes double square root and sum-of-years digits models. Wu and Perry note that the Box-Cox model allows for the change in depreciation rate to be positive or negative with respect to age, whilst the sum-of-years digit model also allows for depreciation rates to increase over time. However, these models do not allow for the possibility of (total *cf*. rate of) depreciation to decrease as tractors age, or as other continuous independent variables (e.g. horsepower) increase.

This paper aims to address the main aspects noted above by presenting both Box-Cox and OLS depreciation models for UK tractors. Within this comparison the paper extends previous research by examining the influence of extra factors found on modern tractors, these being the presence of: cab or axle suspension, front linkage, and front-end loaders. Moreover, the paper presents an OLS model whereby the age, hours and horsepower rating are neither restricted to be linear in relation to depreciation, nor non-increasing (e.g. as specified by logarithmic functions), but which allows for the possibility of depreciation decreasing in age, hours or horsepower independently, over particular data ranges. Whilst this functional specification allows for the possibility of capturing non-linear relationships between these variables, the functional form specified within the preferred model does impose a structure to the model within which the data are assumed to fit, as is the case with all parametric models.

The remainder of the paper is structured as follows. The following two sections respectively present the data used and methodological approaches adopted. Results of the models are then presented, including results of comparative testing, together with tables of estimated remaining values to aid interpretation of the results for practical business use. The following section then discusses the results, placing these in context of previous research, whilst the final section provides concluding comments and identifies future areas for research.

2. Data

Data on second-hand tractors were obtained from the trade magazine advertisements in Classic Tractor (various) and Farmers Weekly (various) from January to June 2008 inclusive, and from web-sites of tractor dealers in the UK during June 2008. The advertised price, age, number of hours worked, make and model of each tractor was recorded together with data on front-end loaders, front linkage, and cab or front axle suspension, where present. An age boundary was imposed, with only tractors registered from 1988 to 2007 inclusive being included in the data set. Private sales data were excluded to ensure that data were only taken from dealer or trade advertisements. A total of 1223 usable observations were recorded.

Following the methodology adopted by Wilson and Tolley (2004) in their assessment of the UK tractor market, a margin of £500 plus 10% of the advertised price was taken as the margin between the trade-in value of a second-hand tractor, and the advertised sale price. This margin was then deducted from the advertised sale price to generate a price for each tractor net of the used-tractor-dealer-mark-up. List prices for tractors, together with their advertised horsepower rating when new were obtained from Power Farming and Farmers Weekly. The list price was then adjusted for inflation using the price index for agricultural tractors (Defra, 2008) to produce a real-terms list price for each tractor. The addition of a front-end loader, front linkage, and cab or axle suspension were assumed to add £6060, £4117 and £2165 respectively to the real-terms price of a tractor when new for tractors where these features were non standard for the make and model specified.[1]

Due to the nature of marketing tractors in the UK, considerable discounts are offered off the retail list price. To overcome this issue the methodology and results of Wilson and Tolley (2004) were used which accounted for variation in discount offered by year and for each of the manufacturers of Case, JCB, John Deere, Ford / New Holland and Massey Ferguson. Discounts for other makes of tractors were assumed to be represented by the average discount calculated by Wilson and Tolley's methodology. Manufacturer specific discounts are given in Table 2 for 1988-2007.

1. Based upon retail price of these additional features for a 125 horsepower rated tractor. Data obtained from a UK tractor dealer supplying one of the top three brands of tractors.

Table 2. Calculated percentage discount rate by manufacturer 1988-2008

Year	Discount Rate Calculated From Nix	Adjusted Discount Rate	Case	Ford/NH	MF	JD	JCB	Other
1988	18.08	27.47	35.76	17.59	27.75	26.14	30.13	27.47
1989	20.24	29.63	37.92	19.75	29.91	28.3	32.29	29.63
1990	16.16	25.55	33.84	15.67	25.83	24.22	28.21	25.55
1991	15.54	24.93	33.22	15.05	25.21	23.6	27.59	24.93
1992	15.34	24.73	33.02	14.85	25.01	23.4	27.39	24.73
1993	19.95	29.34	37.63	19.46	29.62	28.01	32.00	29.34
1994	24.14	33.53	41.81	23.64	33.8	32.19	36.18	33.53
1995	23.53	32.92	41.21	23.04	33.2	31.59	35.58	32.92
1996	22.98	32.37	40.66	22.49	32.65	31.04	35.03	32.37
1997	23.35	32.74	41.02	22.85	33.01	31.04	35.39	32.74
1998	19.89	29.28	37.57	19.40	29.56	27.95	31.94	29.28
1999	13.72	23.11	31.4	13.23	23.39	21.78	25.77	23.11
2000	19.47	28.86	37.15	18.98	29.14	27.53	31.52	28.86
2001	19.44	28.83	37.12	18.95	29.11	27.55	31.49	28.83
2002	17.95	27.34	35.63	17.46	27.62	26.06	30.00	27.34
2003	18.42	27.81	36.10	17.93	28.09	26.53	30.47	27.81
2004	14.26	23.65	31.94	13.77	23.93	22.37	26.31	23.65
2005	17.03	26.42	34.71	16.54	26.7	25.14	29.08	26.42
2006	15.24	24.63	32.92	14.75	24.91	23.35	27.29	24.63
2007	14.01	23.4	31.69	13.52	23.68	22.12	26.06	23.40

The total depreciation for each tractor was calculated from the difference in the new price, net of discount and adjusted for inflation (new real price), and the used price net of the dealer mark up, divided by the new real price and expressed as a percentage. Binary variables were constructed for six of the manufacturers,[2] together with binary variables to indicate the presence or absence of a front-end loader, front linkage and cab or front axle suspension. Table 3 provides summary statistics for the data set, indicating the large range of variation around the means for each of the variables listed.

Table 3: Summary statistics of continuous data

	New price (net of discount) £	Used price (net of dealer markup) £	Total depreciation	Year of life (yr)	Hours worked (HRS)	Horsepower rating (HP)
Mean	39,086	19,335	50.39	7.13	4,229	131.78
SD	14,063	10,712	19.07	4.77	2,595	42.44
Min	11,492	3,910	1.71	1.00	22	45
Max	152,862	80,275	96.40	20.00	18,200	500

2. Case (207 observations) was set as the base and binary variables were constructed for Ford/New Holland (226), Massey-Ferguson (164), John Deere (321), JCB (42), Fendt (48) and "other" (215). It is necessary to have k-1 dummy variables (where k = number of categories of the qualitative variable (e.g. make)) to avoid perfect co linearity in the estimation of the regression equation.

3. The year of life is included in preference to the age of a tractor, as a tractor enters its first year of life as soon as it is purchased from new, whereas it does not become aged one until after its first year of life.

3. Methodology

The methodological approach taken was designed to examine the advantages and disadvantages of using OLS and Box-Cox. The rationale behind this approach lies in the general ease of interpretation that OLS estimates can provide, versus the flexibility and thus potential for a better explanation of the variation within the data, that Box-Cox models may provide. Consequently, one preferred OLS and one preferred Box-Cox specifications are presented. The details of these models are given below.

Ordinary Least Squares

Recognising the linear relationship imposed by OLS, the preferred OLS equation allows for the possibility of year of life, hours and horsepower rating all to be independently non-increasing, and potentially inflective, in their relationship with total depreciation. Equation (1) thus specifies a relationship which is cubic in all continuous independent variables. Equation (1) differs from previous models (e.g. Wilson and Tolley, 2004) by not specifying the year of life (or age) as a linear-logarithmic relationship, and additionally not specifying hours and horsepower as strictly linear. Equation (1) is thus presented from a theoretical starting point which allows for both non-increasing relationships as noted above. Binary variables are included for all non-continuous variables.

$$\begin{aligned} Dep = {} & \alpha_o + \alpha_1 Y1 + \beta_1 yr + \beta_2 yr^2 + \beta_3 yr^3 + \beta_4 HP + \beta_5 HP^2 + \beta_6 HP^3 + \beta_7 HRS \\ & + \beta_8 HRS^2 + \beta_9 HRS^3 + \delta_1 F + \delta_2 JCB + \delta_3 JD + \delta_4 MF + \delta_5 NH + \delta_6 O \\ & + \delta_7 SUS + \delta_8 FL + \delta_9 L + e \end{aligned} \tag{1}$$

Where:

a_0, a_1, b_k and d_j (k=1,…9, j=1,…9) are coefficients to be estimated.

Dep	the total depreciation
Y1	1 if tractor is in the first year of life, 0 otherwise
yr	year of life of tractor
HP	the manufacturers rated horsepower of tractor
HRS	the number of hours the tractor has worked
F	1 if the tractor is a Fendt (F), 0 otherwise
JCB	1 if the tractor is a JCB, 0 otherwise
JD	1 if the tractor is a John Deere (JD), 0 otherwise
MF	1 if the tractor is a Massey-Ferguson (MF), 0 otherwise
NH	1 if the tractor is a Ford/New Holland (NH), 0 otherwise
O	1 if the tractor is a not a Case, F, JD, MF, NH or JCB, 0 otherwise
SUS	1 if the tractor has cab or front axle suspension, 0 otherwise
FL	1 if the tractor has front linkage, 0 otherwise
L	1 if the tractor has a front-end loader, 0 otherwise
e	disturbance term with usual properties
n	1…1223

Box-Cox

The general specification of the Box-Cox regression is given in equation (2). Kmenta (1986) provides an accessible description of the Box-Cox transformation and the functional specifications that can be achieved by setting *q* and *l* to particular values. The flexibility of the Box-Cox specification lies in the ability to allow the data to determine the values of *q* and *l*, to specify that *q* and *l* are equal, or to allow the data to determine one of these parameters (e.g. *l*) whilst specifying the value of *q*. For example, Kmenta notes that when *q* =1 and *l*=0, the equation represents a semilogarithmic model, and when *q* =1 and *l*=1, the equation represents a simple linear model of $Y_i = \alpha * + \beta X_i + e_i$ where $\alpha * = \alpha - \beta + 1$ (Kmenta, 1986, pp519-520).

$$\frac{Y_i^{\theta} - 1}{\theta} = \alpha + \beta\left(\frac{X_i^{\lambda} - 1}{\lambda}\right) + e_i \qquad (2)$$

Where

Y	dependent variable
X	independent variable
a, b	coefficients to be estimated
q and *l*	may be specified or determined by the data
e_i	disturbance term
n	1…1223

The preferred specification of the Box-Cox model is detailed below (subscript *i* removed and notation as specified above unless otherwise stated). Equation (3) allows the transformation of the year of life, hours and horsepower variables to be determined rather than specifying these at the outset as in the OLS model (1). Equation (3)[4] was estimated to allow θ and λ are to be determined simultaneously, where and $\theta \neq \lambda$

$$\frac{DEP^{\theta} - 1}{\theta} = \alpha_0 + \alpha_1 Y1 + \beta_1\left(\frac{yr^{\lambda} - 1}{\lambda}\right) + \beta_4\left(\frac{HP^{\lambda} - 1}{\lambda}\right) + \beta_7\left(\frac{HRS^{\lambda} - 1}{\lambda}\right)$$
$$+ \delta_1 F + \delta_2 JCB + \delta_3 JD + \delta_4 MF + \delta_5 NH + \delta_6 O + \delta_7 SUS + \delta_8 FL + e \qquad (3)$$

In addition to the estimated parameter results from the two preferred models, the correlation coefficient and the mean absolute percentage error (MAPE) (see Gençay and Yang, 1996; Dumler *et al.,* 2003; Wilson and Tolley, 2004) were calculated.[5]

4. Different specifications of the Box-Cox model included the binary variable *L*, however the parameter estimates were not significantly different from zero under the Box-Cox specification, and hence this variable was not included in the final preferred Box-Cox model (3).

5. Absolute percentage error (APE) is calculated here by APE= |(O-P)/O| *100 where O is the observed percentage depreciation and P is the predicted percentage depreciation.

4. Results

Table 4 presents the results of the estimated equations (1) and (3). The use of OLS generally provides an ease of interpretation of the parameter estimates over other, more complex functional forms (e.g. Box-Cox). However, the OLS model (1) above was developed from a theoretical starting point which allowed for the possibility that increases in the year of life, horsepower and hours worked could each lead to total depreciation (measured in total percentage depreciation) increasing or decreasing, rather than specifying a more restricted model which only allowed for the possibility of total depreciation increasing with age, hours worked and horsepower; this was achieved by specifying a functional form which was cubic in these three variables.

The results from equations 1 and 3 cannot be directly interpreted from the parameter estimates provided in Table 4. However a methodology for determining the preferred model or equation is required. The normal "goodness of fit" measure, the R^2, is 0.87 for model (1) and indicates that model explains 87% of the variation in total deprecation. Other measures of the models performance include the correlation coefficient between observed and predicted total depreciation of 0.933 and the mean absolute percentage error (MAPE) of 16.091 (i.e. the average error in the estimated total depreciation against actual total depreciation is 16.091%).

For the Box-Cox model (3) the usual goodness of fit parameter, R^2, is not bounded between 0 and 1 and hence comparability with the model (1) is not possible on this basis. However, the MAPE does provide a directly comparable measure of performance with the MAPE for model (3) equalling 16.781. The correlation coefficient between observed and predicted total depreciation is 0.927. These results indicate that model (3), with a slightly larger MAPE and slightly lower correlation coefficient, performs marginally less well than model (1). On the basis of the above model performance measures there is no evidence to favour the more complex Box-Cox model (3) over the OLS model (1), and hence the preferred model is determined to be the OLS model. This finding also correlates with previous research that concludes there is no additional benefit to be gained by choosing the more complex Box-Cox model (Wu and Perry, 2004).

On the basis of the results from model (1), figures 1 and 2 respectively provide example results for the influence of age and hours worked (Figure 1) and horsepower (Figure 2) on both the total depreciation and change in depreciation, for a pre-specified tractor. Figure 1 shows that as the tractor increases in age (year of life) total depreciation increases, but the annual change in depreciation decreases as would be expected *a priori* and as found in previous UK studies (e.g. Wilson and Tolley, 2004). Two example depreciation scenarios are provided, one for a tractor undertaking 500 hours work per annum, and the second for a tractor that has undertaken a total of 5000 hours work, irrespective of its age. With respect to the influence of age on the annual change in depreciation, whilst this decreases across most of the age range, beyond 19.8 years of life, the annual change in depreciation

Table 4: Parameter estimates of depreciation models

Model (Eq)	OLS (1)			Box-Cox (3)		
Parameter	**Estimate**	***t* statistic**		**Estimate**	***t* statistic**	
Intercept	-21.844	-6.65	*	-46.925	-4.57	*
Y1	4.102	3.61	*	13.641	4.84	*
Yr	6.037	9.69	*	15.352	5.98	*
yr^2	-0.2466	-3.85	*	-	-	
yr^3	0.004194	2.11	#	-	-	
HP	0.3422	7.37	*	2.949	4.26	*
HP^2	-0.001265	-5.53	*	-	-	
HP^3	0.1447E-05	4.47	*	-	-	
HRS	0.004603	7.59	*	1.111	3.48	*
HRS^2	-0.2809E-06	-3.07	*	-	-	
HRS^3	0.5947E-11	1.44		-	-	
F	-0.709	-0.60		-1.105	-0.70	
JCB	2.961	2.47	#	5.399	2.94	*
JD	2.860	4.51	*	4.166	4.10	*
MF	2.947	3.98	*	3.957	3.46	*
NH	5.793	8.64	*	7.823	5.17	*
O	7.064	10.25	*	9.065	5.43	*
SUS	1.192	1.94	~	1.593	1.92	~
FL	1.762	2.95	*	2.342	2.68	*
L	1.463	2.01	#	-	-	
R^2	0.870					
Log-likelihood	-4091.89			-4134.47		
θ				1.0667	24.74	*
λ				0.2802	7.08	*
Simga-sq				84.2034	3.06	*
R	0.9329			0.9265		
MAPE	16.091			16.781		

Eq = equation number noted above. * indicates significance at the 99% level; # indicates significance at 95% level; ~ indicates significance at 90% level. *r* = correlation coefficient between observed and predicted total depreciation. *MAPE* = mean absolute percentage error.

increases; note however that this is at the upper boundary of the estimated data set. As hours worked increases, total depreciation increases, as can be observed for the tractor undertaking 500 hours work per year, beyond the 10 year point in comparison to the tractor undertaking 5000 hours of work in total. Results from the model indicate that the change in depreciation decreases as hours worked increases[6]

Figure 1: Total and Marginal Depreciation for a 150 HP Case Tractor under two hours worked scenarios

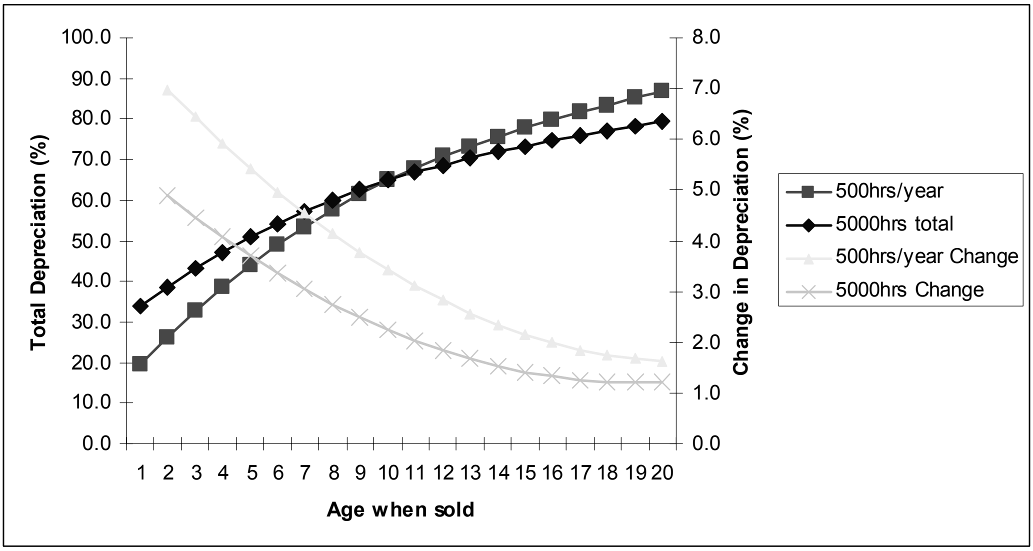
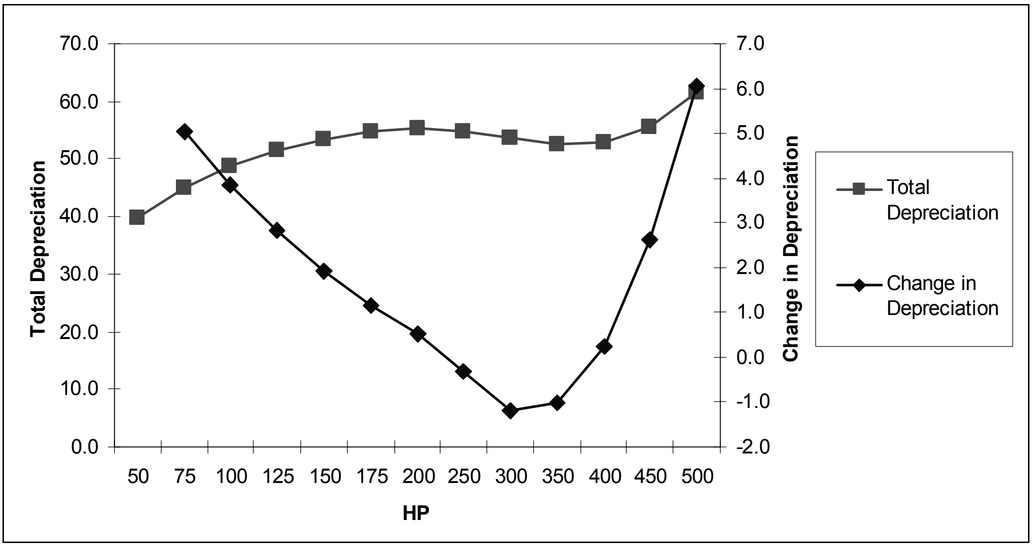


Figure 2 shows the total and marginal depreciation for a Case tractor sold at seven years of age, but where the influence of different horsepower ratings is captured. As horsepower increases from 50 to 227.35 HP, total depreciation increases, whilst from 227.35 HP to 369.10 HP total depreciation decreases, only to increase again beyond 369.10 HP. This finding is more clearly demonstrated by the curve indicating the change in depreciation as the HP of tractors change, with a negative rate of depreciation between the 227.35 and 369.10 HP points. Whilst the result above provides some interesting findings with respect to the points at which the change in the rate of depreciation occurs, it is important to note that the domain of data within this study is restricted in terms power ratings of tractors to those typically found in the UK market; thus it is not appropriate to draw strong conclusions about the relationship between total depreciation and horsepower for tractors over 500 horsepower as such high-horsepower tractors are not common within the UK market, and hence they are no common in the data set used in this study.

The remaining variables within equation (1) in Table 4 are easily interpreted under *ceteris paribus* conditions. A tractor in its first year of life

6. This applies up to a high number of hours worked (approx. 15,700), and thereafter change in depreciations increases with hours worked

Figure 2: Total and Marginal Depreciation for Case Tractors at Sold at Seven Years under with 3500 hours of work undertaken for different Horsepower



increases the total depreciation by 4.1% above other factors in the model, whilst tractors of the makes JCB, John Deere, Massey Ferguson, New Holland / Ford, and "other" makes have total deprecation that are respectively 2.96%, 2.86%, 2.95%, 5.80%, 7.06% greater than for Case, with each estimate being statistically significant, whilst Fendt tractors indicate a total deprecation percentage of 0.71% less than Case tractors, although this estimate is not statistically significant. In relation to the additional features of the tractors in the data set, the presence of cab or axle suspension, front linkages, and a front-end loader increase respective total depreciation by 1.19%, 1.76% and 1.46%, with significant parameter estimates observed for each feature.

To aid interpretation and usage of the results by farmers and consultants, Tables 5 – 7 respectively provide remaining value estimates as a percentage of the real price for Case tractors of differing horsepower capacity, over 15 years of age, undertaking 500, 750, and 1000 hours work per annum, respectively. For tractors undertaking 500 hours work per annum (Table 5), remaining value estimates range from 94.4% of real new price for a one-year old 50 horsepower Case tractor that has undertaken 500 hours work, to 14.2% for a 15 year old 500 horsepower Case tractor that has undertaken 7500 hours work; for tractors undertaking 750 and 1000 hours work per annum, the estimated remaining value ranges are 93.3% to 10.7% and 92.3 to 9.5% respectively (Tables 6 and 7). Variations to these Tables according to different manufacturers or additional features can be made by adjusting the tables as noted in the footnote to each table. The caveat to interpretation of the influence of different makes of tractors is that the variation in depreciation (and hence remaining values) according to manufacturer is directly reliant upon the estimated discounts shown in Table 2. These estimated discounts are reliant upon dealer discount information for a single year of interest from

Table 5: Estimated trade-in-value in real terms as a percentage of discounted new price for Case tractors under-taking 500 hours work per annum

	Age when sold														
HP	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
50	94.4	87.4	81.0	75.0	69.6	64.7	60.1	56.0	52.2	48.8	45.7	42.9	40.3	38.0	35.9
75	89.3	82.4	75.9	70.0	64.6	59.6	55.1	51.0	47.2	43.8	40.7	37.9	35.3	33.0	30.8
100	85.5	78.5	72.1	66.2	60.7	55.8	51.2	47.1	43.4	39.9	36.8	34.0	31.5	29.1	27.0
125	82.7	75.7	69.2	63.3	57.9	53.0	48.4	44.3	40.5	37.1	34.0	31.2	28.6	26.3	24.1
150	80.7	73.8	67.3	61.4	56.0	51.0	46.5	42.4	38.6	35.2	32.1	29.3	26.7	24.4	22.2
175	79.6	72.6	66.2	60.3	54.8	49.9	45.4	41.2	37.5	34.1	31.0	28.1	25.6	23.2	21.1
200	79.1	72.1	65.7	59.7	54.3	49.4	44.8	40.7	37.0	33.5	30.4	27.6	25.0	22.7	20.6
250	79.4	72.4	66.0	60.1	54.6	49.7	45.1	41.0	37.3	33.8	30.7	27.9	25.4	23.0	20.9
300	80.6	73.6	67.2	61.3	55.8	50.9	46.4	42.2	38.5	35.1	32.0	29.1	26.6	24.2	22.1
350	81.6	74.6	68.2	62.3	56.9	51.9	47.4	43.3	39.5	36.1	33.0	30.2	27.6	25.2	23.1
400	81.4	74.4	67.9	62.0	56.6	51.7	47.1	43.0	39.2	35.8	32.7	29.9	27.3	25.0	22.8
450	78.7	71.8	65.3	59.4	54.0	49.0	44.5	40.4	36.6	33.2	30.1	27.3	24.7	22.4	20.2
500	72.7	65.7	59.3	53.4	48.0	43.0	38.5	34.3	30.6	27.2	24.1	21.2	18.7	16.3	14.2

For different makes adjust table as follows: Fendt (+0.709); JCB (-2.961); JD (-2.860); MF (-2.947); NH (-5.793); Other (-7.064). For additional features adjust table as follows: Suspension (-1.192); Front linkage (-1.762); Loader (-1.1463). Note: Total hours of work are given by the age multiplied by number of hours undertaken per year (e.g. a tractor aged 1 when sold is assumed to have undertaken 500 hours) HP = horsepower.

Table 6: Estimated trade-in-value in real terms as a percentage of discounted new price for Case tractors undertaking 750 hours work per annum

HP	Age when sold														
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
50	93.3	85.4	78.2	71.7	65.8	60.5	55.8	51.5	47.7	44.3	41.3	38.7	36.3	34.3	32.4
75	88.3	80.4	73.2	66.7	60.8	55.5	50.7	46.5	42.7	39.3	36.3	33.7	31.3	29.2	27.4
100	84.4	76.5	69.4	62.8	57.0	51.6	46.9	42.6	38.8	35.4	32.5	29.8	27.5	25.4	23.5
125	81.6	73.7	66.5	60.0	54.1	48.8	44.1	39.8	36.0	32.6	29.6	27.0	24.6	22.5	20.7
150	79.7	71.8	64.6	58.1	52.2	46.9	42.1	37.9	34.1	30.7	27.7	25.1	22.7	20.6	18.8
175	78.5	70.6	63.5	57.0	51.1	45.8	41.0	36.7	32.9	29.6	26.6	23.9	21.6	19.5	17.6
200	78.0	70.1	62.9	56.4	50.5	45.2	40.5	36.2	32.4	29.0	26.0	23.4	21.0	19.0	17.1
250	78.3	70.4	63.3	56.7	50.9	45.6	40.8	36.5	32.7	29.4	26.4	23.7	21.4	19.3	17.4
300	79.5	71.6	64.5	58.0	52.1	46.8	42.0	37.7	33.9	30.6	27.6	24.9	22.6	20.5	18.6
350	80.5	72.7	65.5	59.0	53.1	47.8	43.0	38.8	35.0	31.6	28.6	25.9	23.6	21.5	19.6
400	80.3	72.4	65.2	58.7	52.8	47.5	42.8	38.5	34.7	31.3	28.3	25.7	23.3	21.2	19.4
450	77.7	69.8	62.6	56.1	50.2	44.9	40.2	35.9	32.1	28.7	25.7	23.1	20.7	18.6	16.8
500	71.6	63.7	56.6	50.1	44.2	38.9	34.1	29.8	26.0	22.7	19.7	17.0	14.7	12.6	10.7

For different makes adjust table as follows: Fendt (+0.709); JCB (-2.961); JD (-2.860); MF (-2.947); NH (-5.793); Other (-7.064). For additional features adjust table as follows: Suspension (-1.192); Front linkage (-1.762); Loader (-1.1463).Note: Total hours of work are given by the age multiplied by number of hours undertaken per year (e.g. a tractor aged 1 when sold is assumed to have undertaken 750 hours). HP = horsepower.

Table 7: Estimated trade-in-value in real terms as a percentage of discounted new price for Case tractors undertaking 1000 hours work per annum

	Age when sold														
HP	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
50	92.3	83.6	75.8	68.9	62.7	57.3	52.6	48.4	44.8	41.7	39.0	36.6	34.6	32.8	31.2
75	87.2	78.5	70.8	63.8	57.7	52.3	47.5	43.4	39.8	36.7	33.9	31.6	29.6	27.8	26.1
100	83.4	74.7	66.9	60.0	53.8	48.4	43.7	39.5	35.9	32.8	30.1	27.7	25.7	23.9	22.3
125	80.6	71.9	64.1	57.2	51.0	45.6	40.9	36.7	33.1	30.0	27.3	24.9	22.9	21.1	19.5
150	78.6	70.0	62.2	55.2	49.1	43.7	38.9	34.8	31.2	28.1	25.4	23.0	21.0	19.2	17.5
175	77.5	68.8	61.0	54.1	48.0	42.5	37.8	33.6	30.0	26.9	24.2	21.9	19.8	18.0	16.4
200	77.0	68.3	60.5	53.6	47.4	42.0	37.3	33.1	29.5	26.4	23.7	21.3	19.3	17.5	15.9
250	77.3	68.6	60.8	53.9	47.7	42.3	37.6	33.4	29.8	26.7	24.0	21.7	19.6	17.8	16.2
300	78.5	69.8	62.0	55.1	49.0	43.5	38.8	34.6	31.0	27.9	25.2	22.9	20.8	19.0	17.4
350	79.5	70.8	63.0	56.1	50.0	44.6	39.8	35.7	32.1	28.9	26.2	23.9	21.8	20.0	18.4
400	79.3	70.6	62.8	55.9	49.7	44.3	39.6	35.4	31.8	28.7	26.0	23.6	21.6	19.8	18.2
450	76.6	68.0	60.2	53.3	47.1	41.7	36.9	32.8	29.2	26.1	23.4	21.0	19.0	17.2	15.6
500	70.6	61.9	54.1	47.2	41.1	35.6	30.9	26.7	23.1	20.0	17.3	15.0	12.9	11.1	9.5

For different makes adjust table as follows: Fendt (+0.709); JCB (-2.961); JD (-2.860); MF (-2.947); NH (-5.793); Other (-7.064). For additional features adjust table as follows: Suspension (-1.192); Front linkage (-1.762); Loader (-1.1463).
Note: Total hours of work are given by the age multiplied by number of hours undertaken per year (e.g. a tractor aged 1 when sold is assumed to have undertaken 1000 hours). HP = horsepower.

previous research (Wilson and Tolley, 2004), and the consequent precision of these estimates is open to question and readers should thus use this data with appropriate caution. As noted in section 1, other cost influences also need to be taken into account in determining the choice of an investment in a tractor; however, it is argued that the tables provided above offer a valuable addition to current industry standards available in published and electronic form. The tables of results have been designed for use by a farmer, manager or consultant or to be incorporated into industry standard tables or computer packages to enhance user knowledge of the impact of hours worked and horsepower ratings in addition to age of tractor.

5. Discussion

In order to place the above results in context it is necessary to evaluate the results against previous studies. One direct method for comparability is to use previous results to estimate predicted depreciation of the data set used in this study. The most recent UK study into tractor depreciation is Wilson and Tolley (2004) who generated an OLS model with an R^2 of 0.842, a correlation coefficient of 0.918, and a MAPE of 12.37.[7] Taking Wilson and Tolley's parameter estimates and predicting depreciation on the current data set provides a correlation coefficient of 0.911 and a MAPE of 26.25; this compares with a correlation coefficient of 0.933 and a MAPE of 16.09 from the preferred model presented above.

The performance of previous models can be assessed by their respective MAPE measures that quantify their predictive capability against the data from which the models were estimated. Dumler *et al.,* (2003) present results of different estimation models in the US (using 1986-1995 data) and note that the MAPE ranges from 31.4 for the Cross and Perry (1995) Box-Cox model to 82.9 for the general depreciation system method.[8] Dumler *et al.* compare a number of models and conclude that the Cross and Perry Box-Cox model is the most appropriate to use in estimating depreciation / remaining values of farm tractors. One interesting further observation of Dumler *et al.* is the variation in MAPE across groups of tractors of different age, power rating and intensity of use. Wu and Perry (2004) present MAPE values for tractors respectively ranging from 22.8 to 30.9 (23.0 to 30.4) for their double square root (Box-Cox) specification, with the sum-of-year digits model only marginally poorer in its predictive ability; Wu and Perry conclude that the double square root and sum-of-year digits models are the most practical for applied work, with the Box-Cox model adding "*little additional accuracy*" (p. 491).

Fenolloas and Guadalajara (2007), in their study of Spanish tractors, estimated a linear-logarithmic model over 12,570 observations, recording an R^2 of 0.898 and a typical error of estimation of 18.46%. When compared against these previous studies, the estimated MAPE, R^2 value and correlation coefficient generated from the preferred model (1) above, is argued to provide

7. MAPE estimated over tractors up to 10 years of age in Wilson and Tolley's study.

8. This method allows for most of the depreciation to be accounted in the earliest years of a tractor's life for tax purposes, typically via a diminishing balance method (e.g. 25% per annum).

at least a comparable predictive model to those in the US and Spain, and an advancement on previous UK studies.

The preferred model (1) explains 87% of the variation in total depreciation and over the full range of data presents a MAPE of 16.09. Building upon Dumler *et al.'s* analysis, examining the MAPE from the preferred model (1) across different tractor ages and horsepower ratings demonstrates that the MAPE ranges from 24.61 for tractors from 1 to 5 years of life inclusive, to 6.47 for tractors of 16-20 years of life inclusive. The MAPE for horsepower ratings range from 13.30 for 150-199 horsepower rated tractors, to 36.39 for tractors of 200 horsepower and above.[9] Hence the model performs better for tractors as they age, and for tractors that are less than 200 horsepower capacity. With an R^2 of 0.87, the preferred model leaves 13% of the variation in total depreciation unexplained. However, the analysis above indicates that the preferred model is at least comparable with other predictive models of tractor depreciation, and over low to mid horsepower ranges, and for tractors beyond the first few years of life, the error of estimation is considerably lower than demonstrated for the complete data set. With respect to practical usage by farmers and consultants, it is over this combination of age and horsepower ratings where the majority of second-hand tractor transactions, and thus determinants of remaining value, are likely to take place.

6. Conclusion

The increasing cost of investing in capital goods for agricultural production means there is an increasing need for managers to predict the future value of their investment in these capital items. The above paper has presented two alternative methods of estimating depreciation, extending previous research and taking into account the brand of tractor and the presence or absence of key additional features typically found on contemporary tractors in the UK. The specification of a functional form that is cubic in all continuous independent variables allowed for the possibility of years of life, horsepower and hours worked each to be non-linear and non-increasing in their relationship with total depreciation. The results indicate that the model estimated by OLS is preferred to the Box-Cox model. Tables of remaining values provide farmers and managers with easily interpretable results for practical business use.

However, the buoyancy of UK machinery market is linked to both external (e.g. exchange rate; manufacturing costs) and internal (e.g. profitability of agriculture) influences that lead to changes in the demand, and hence value, of second hand machinery and tractors. Hence whilst this study has provided an indication of the influence of some of the key factors affecting depreciation and remaining values for tractors, it must be borne in mind that results derived from previous market observations are unlikely to accurately predict future price movements in a dynamic market.

The preferred model explains 87% of the variation in total depreciation;

9. The MAPE for tractors of year of life categories are: 1-5 years of life (24.61); 6-10 years of life (9.65); 11-15 years of life (7.45); 16-20 years of life (6.47). The MAPE for horsepower groupings are: 45-99 horsepower (15.18); 100-149 horsepower (15.73); 150-199 horsepower (13.30); 200 horsepower and above (36.39).

whilst this provides an improvement on the explanatory power of previous UK studies, and is at least comparable to results from the US and Spain, 13% of the variation in depreciation remains unexplained. In order to explain a greater percentage of the variation in depreciation, it will be necessary to obtain more detailed information on the discount offered by manufactures for different brands of tractors for each year. Moreover, more information on the differential between advertised second hand prices and residual values provided to vendors, together with variables that capture the condition of the second-hand tractor would also enhance future studies. These aspects are known to have a substantial impact on depreciation, but which have thus far proved difficult to quantify within a large dataset typically required for empirical studies. Nonetheless, in order to achieve an enhanced explanation of depreciation, future research into this area will need to address these issues.

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