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An empirical depreciation model for agricultural tractors in Spain

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Abstract

This work analyses the market value of second hand agricultural tractors in Spain for the period 1999-2002, with the aims of obtaining the most appropriate valuation models (through the use of ordinary least squares regression) and proposing an empirical model that estimates the true depreciation of these vehicles. Differences in tractor depreciation were studied in terms of the three horsepower groups normally employed (< 60, 60-90, > 90 hp), as well as in terms of a new power classification (< 80, 80-133 and > 133 hp) that appears to better reflect the influence of horsepower on the change in market value. The results show tractor depreciation to be exponential, with larger, more powerful tractors depreciating more quickly than smaller machines.

Additional key words: agricultural machinery, Box-Cox models, power groups, remaining value.

Resumen

Modelos empíricos de amortización de tractores agrícolas en España

En el presente trabajo se analiza el valor de mercado de los tractores agrícolas de segunda mano en España, durante el periodo 1999-2002, con el fin de obtener, por métodos de regresión mínimos cuadrados, los modelos de valoración más apropiados y proponer un método empírico de amortización que estime la depreciación real. Asimismo, se estudian diferencias de comportamiento de los tractores según los tres grupos de potencia utilizados normalmente en el mercado (<60, 60-90, > 90 CV) y se propone una nueva clasificación de potencias (< 80, 80-133, > 133 CV) que refleja mejor los cambios del valor. Se demuestra que la depreciación es de tipo exponencial y mayor en los tractores de mayor tamaño o potencia que en los pequeños.

Palabras clave adicionales: grupos de potencias, maquinaria agrícola, modelos Box-Cox, valor residual.

Introduction

The mechanization of agriculture has led to remarkable advances in the competitiveness of agricultural products, reducing the costs of their production and increasing the profits enjoyed by farmers. Manual labour costs have been gradually (although greatly) reduced, but machinery costs have increased, particularly those associated with fuel and lubricants, insurance, housing/storage, maintenance, repairs and the depreciation rate. These last three components are often confused by managers, who frequently, yet erroneously, understand them to be synonymous. Maintenance and repair cost are relatively easy to obtain and a number of studies in this area have been published [e.g., see Frank (2003), who studied these costs in combine harvesters in Argentina]. However, the depreciation in the value of farm machinery (the consequence of its use and the passage of time) is without doubt more difficult to understand. It is now common for business managers to use theoretical models to try to estimate this. However, rather than rely on such theory-based models, it would be better to take into account the change in the real market price of these vehicles.

Theoretical models of depreciation can be classified into three main groups depending on the weight assigned to each year of usage: linear, increasing or decreasing. In Spain, only certain methods of determining the theoretical depreciation are officially accepted with a view to fiscal effects, but these models cannot guarantee a true reflection of the depreciation suffered.

In the USA, several authors have studied the depreciation of the value of farm machinery using the «present value method» (Audsley and Wheeler, 1978; Musser *et al*., 1986). Other American authors (see below)

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have sought to estimate the value of used machinery and thus determine its true depreciation. This has involved the use of economic regression methods, which are well developed in the USA due to the large amount of information available. For example, Peacock and Brake (1970), McNeill (1979), Leatham and Baker (1981), Reid and Bradford (1983), Perry *et al.* (1990), Hansen and Lee (1991), Cross and Perry (1995), and Unterschultz and Mumey (1996) used information from manufactures' catalogues and concessionaires. All of these authors used the regression method to estimate the remaining value of machinery, taking into account variables such as age and technical characteristics. Table 1 provides a brief summary of these im-

Table 1. Previous studies reporting equipment depreciation functions

Author	Data	Variables	Function
Peacock and Brake (1970)		Age	V = 65.6 – 4.1 * X
ASAE (1979)		Age	V = 68 * (0.923) X
McNeill (1979)	32	Age and state	$V = e^{-4299 - 0.0436*Age + 0.0691*State}$
Leatham and Baker (1981)	1,454	Age, power, motor type, traction and manufacturer	$Ct = \beta o * \beta 1\ At * It\ \beta 2 * C0 * e^{\varepsilon 1}$
Reid and Bradforf (1983)	411	Age, power, manufacturer, increasing usage and technological changes	V = 368.7 * (X) – 0.273 * (hp) – 0.242 * (NF) – – 0.305 * (MX) – 0.121 * (MY) 0.263 * (T1) – – 0.621 * (T2) – 0.205
Weersink and Stauber (1988)			Combined exponential
Perry *et al.*(1990)	1,030	Age, power, manufacturer, usage, care and macroeconomic variables	Box-Cox
Hansen and Lee (1991)	1,612	Age, year of manufacture, and purchase year	$LP_{tgv} = \sum_{t=1960}^{1988} T_t LP_t + \sum_{g=1}^{10} G_g LD_g + \sum_{y=1917}^{1985} V_y LB_y$
Cross and Perry (1995)		Age, usage, manufacturer, care, type of auction, region and macroeconomic variables	Box-Cox
Unterschultz and Mumey (1996)	2,265 Combine 3,202 Tractor	Age, manufacturer	Ratified by Hansen and Lee model
Cross and Perry (1996)		Age, usage, manufacturer, care and macroeconomic variables	Box-Cox (double square root)
Dumler *et al.* (2003)		Age, inspection year, power, manufacturer and depreciation method	Compares depreciation methods by regression.
Wu and Perry (2004)		Age, production year, manufacturer and other	Box-Cox (for different machines)

After Fenollosa (2006).

portant studies. The first concentrated mainly on tractors and involved the use of linear models, but with time they evolved and expanded to other types of machinery and the use of more sophisticated, non-linear models.

Cooper (1994) conducted similar studies in England, using econometric models. In Spain, such studies have only been performed by Arias (2001) and Guadalajara (2002), and both were based on information obtained from a second hand marketing publication «*Marketing Ocasión de Maquinaria Agrícola* (MOMA)». The first of these studies dealt with the depreciation in the value of tractors using data corresponding to the last six months of 1997. The main conclusions were that depreciation was most intense during the first year, and worse for four-wheel rather than two-wheel drive tractors. The second study estimated depreciation in tractors in Spain and Italy during the years 2000 and 2001. In both countries the power, traction, and age of the machines were the most influential variables. It was also shown that the life of a tractor in Spain is longer – in fact almost double that of a tractor in Italy.

Two promotions/legislations dating from 2005 have lent support towards making use of the real depreciation in the value of agricultural machinery in Spain: the *Plan Renove* promoted by the Spanish Ministry of Agriculture, Fisheries and Food (MAPA), and the introduction of the International Accounting Standards (IAS). The *Plan Renove* provides a series of subsidies for the renovation of Spain's tractors; this is managed by the Autonomous Regions of Spain and supported by the *Asociación Nacional del Sector de Maquinaria Agrícola y Tractores* (ANSEMAT). The IAS system was introduced to better reflect the true market value of farm equipment etc. The value set is meant to be the most probable market price obtainable on a theoretical day of sale. It is recommended that this value be determined by an independent expert.

Information regarding the situation of agricultural machinery in Spain is provided by two official sources: the MAPA [for example in the publication *«Análisis del parque de tractores agrícolas»* (1996), and the *Registro Oficial de Maquinaria Agrícola en España* (ROMA)], and a private source, the ANSEMAT. Both sources recognize the importance of agricultural tractors in the farm machinery family, a consequence of their major presence in the sector and their rising retail price.

In 2002 there were 946,053 tractors in Spain (73.57% of all agricultural machines in the country), while in 1994 there were only 789,747. The second hand tractor market in Spain is very important. Figure 1 shows the number of title changes in 2003 by machine age, and draws attention to the fact that tractors over 20 years old account for the largest number of transactions. Spain's agricultural tractor population is therefore largely obsolete. The average age of a working tractor is 16 years, and nearly one third (31.7%) are over 20 years old.

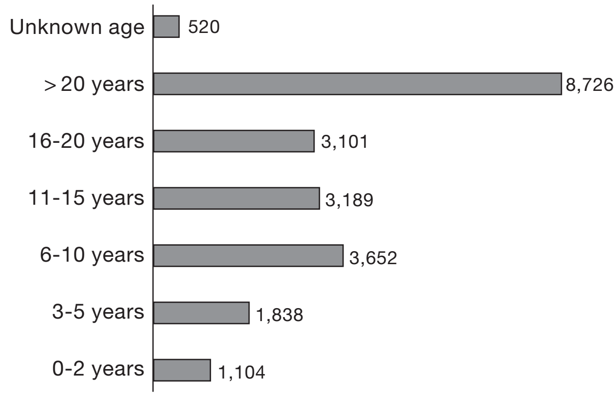

Figure 1. Total number of tractor title changes in 2003 in Spain, grouped by vehicle age. *Source:* ANSEMAT and MAPA data.

The main aim of the present study was to determine the behaviour of the market value of second hand agricultural tractors in Spain, and to obtain models that estimate their value over their lifespan with respect to their horsepower. This study shows that traditional horsepower grouping appears to have no influence on second hand value; a more suitable horsepower classification is therefore proposed.

Data sources

The source of information used for obtaining the market price of used tractors was the MOMA catalogue. The MOMA acts as an intermediary, buying and selling tractors, and publishes lists of prices each semester. In the present study, seven catalogues were used, dating from December 1999 to December 2002.

A matrix was then created with 12,570 observations and with the 42 variables shown in Table 2. The first two variables, the price the MOMA paid for a tractor, and the MOMA sale price (values homogenised to 2001 figures to avoid the effect of inflation), are the variables the proposed model hopes to explain. Two models were constructed, one to explain the MOMA

Table 2. Variables in the used tractor database

Number	Variable	Type	Variable significance
1	Vp	Quantitative	Purchase list price, in euros
2	V	Quantitative	Sale list price, in euros
3	Year	Quantitative	The homologation year; varies between 1973 and 1995
4	Appraisal year	Quantitative	The publication year of the guide or appraisal year of the tractor; varies between 1999 and 2002
5	Semester	Binary	Semester of the year; takes the value of 0 if the first semester, 1 if the second semester
6	Age	Quantitative	Difference between the appraisal year (in the guide) and the homologation year. Values available from 4 to 29 years
7	Power	Quantitative	Power, in hp; varies from 13 to 263
8	Cylinder	Quantitative	Number of cylinders; 1-8
9	Cil.turb	Binary	Indicates if the motor has turbo or not; 1 if yes, 0 if no
10	Traction	Binary	Type of traction; takes value of 0 if two-wheel drive and 1 if four-wheel drive
11	Wheel/chain	Binary	Takes value of 0 if tractor uses chains and 1 if uses wheel
12	Standard version	Binary	Takes value of 1 if standard version, 0 if not
13	Vers. fruit	Binary	Takes value of 1 if fruit version, 0 if not
14	Vers. vine	Binary	Takes value of 1 if vine version, 0 if not
15	Vers. art	Binary	Takes value of 1 if articulate version, 0 if not
16	Vers. rigid	Binary	Takes value of 1 if rigid version, 0 if not
17	Cabin	Binary	Takes value of 1 if there is a cabin, 0 if not
18	Air. cond	Binary	Takes value of 1 if air conditioned, 0 if not
19	Other charact.	Binary	Takes value of 1 if other special features are present, 0 if not
20	Manufacturer 1	Binary	Manufacturer: Agria
21	Manufacturer 2	Binary	Manufacturer: Antonio Carraro
22	Manufacturer 3	Binary	Manufacturer: Avto
23	Manufacturer 4	Binary	Manufacturer: Belarus
24	Manufacturer 5	Binary	Manufacturer: Case Internacional
25	Manufacturer 6	Binary	Manufacturer: Deutz
26	Manufacturer 7	Binary	Manufacturer: Deutz-Fahr
27	Manufacturer 8	Binary	Manufacturer: Ebro
28	Manufacturer 9	Binary	Manufacturer: Fendt
29	Manufacturer 10	Binary	Manufacturer: Fiat
30	Manufacturer 11	Binary	Manufacturer: Fiatagri
31	Manufacturer 12	Binary	Manufacturer: Ford
32	Manufacturer 13	Binary	Manufacturer: International
33	Manufacturer 14	Binary	Manufacturer: John Deere
34	Manufacturer 15	Binary	Manufacturer: Kubota
35	Manufacturer 16	Binary	Manufacturer: Lamborghini
36	Manufacturer 17	Binary	Manufacturer: Landini
37	Manufacturer 18	Binary	Manufacturer: Massey Ferguson
38	Manufacturer 19	Binary	Manufacturer: Pasquali
39	Manufacturer 20	Binary	Manufacturer: Renault
40	Manufacturer 21	Binary	Manufacturer: Same
41	Manufacturer 22	Binary	Manufacturer: UTB
42	Manufacturer 23	Binary	Manufacturer: Zetor

Source: Own elaboration.

purchase price, and one to explain the sale price. However, these models were very similar, and only the latter is therefore presented. The first four explanatory variables are of a temporal nature: the homologation year (which is supposed to coincide with the year the tractor is sold new), the appraisal year (or the year when the catalogue was published), the publication semester, and finally the age of the tractor (estimated as the difference between the appraisal and homologation years).

A second group of variables refers to the mechanical characteristics of the tractors: power (hp), number of cylinders, and whether the engine has turbo capability.

In a third group, the locomotive characteristics of the machine are taken into account: whether the tractor is two-wheel or four-wheel drive, and whether it has wheels or tracks. The model (standard, fruit, vineyard, articulated or rigid) is also taken into account.

The fourth group of variables refers to safety and comfort (the existence of a cabin, air-conditioning, wide or thin wheels, field of vision, old or modern front, etc.).

Finally the tractor manufacturer appears as a dummy or binary variable; this has also been taken into account in other studies (for references see Table 1).

The number of hours of use of the tractors was a further variable employed by some authors in their models, e.g., Perry *et al.* (1990), but this information was not available for the present study.

Methodology

Ordinary least squares (OLS) regression was used to obtain the depreciation model, and cluster analysis to identify the new horsepower groups.

The relationship between the absolute remaining value, V, and the explanatory variables (Table 2) was obtained with the general model shown below [1]:

$$\begin{aligned} V &= b_0 + b_1 \cdot year + b_2 \cdot appraisalyear + b_3 \cdot semester + \\ &+ b_4 \cdot age + b_5 \cdot power + b_6 \cdot cylinder + b_7 \cdot cil\ turb + \\ &+ b_8 \cdot traction + b_9 \cdot wheelchain + b_{10} \cdot cabin + \\ &+ b_{11} \cdot air\ cond + b_{12} \cdot other\ charac + \sum c_i \cdot version + \\ &+ \sum d_i \cdot companies \end{aligned} \quad [1]$$

where $b_0, b_1, \ldots\ldots, b_n$ represent the regression coefficients of the explanatory variables.

It was not possible to obtain the monetary values of tractors under four years of age; the catalogue contained no data for these years. However, using the following expression, it was possible to obtain relative monetary values for any year of usage between 4 and 29 years:

$$\frac{V_{a_1}}{V_{a_2}} = \frac{b_4 \cdot age(a_1) + k}{b_4 \cdot age(a_2) + k} \quad [2]$$

where k = constant, V_{a_1} = value of a tractor model with an age of a_1 years, and V_{a_2} = value of a tractor model with an age of a_2 years ($a_2 > a_1$).

For multivariate techniques to be used, the data and the relationships between the variables must be normally distributed, homocedastic, and linear. Following the same method as other authors (see Table 1), Box-Cox transformations (Box and Cox, 1964) were performed for each variable (dependent and independent). This allows the use of functional forms ranging from geometrical to Cobb-Douglas forms to be obtained. All Box-Cox transformations were performed using the equation below [3]:

$$Y^{(\lambda)} = \begin{cases} \dfrac{y^{\lambda} - 1}{\lambda} & \lambda \neq 0 \\ \ln y & \lambda = 0 \end{cases} \quad [3]$$

When $\lambda = 1$, the variable retains its original form; when $\lambda = 0$, a logarithmic transformation is performed. Consequently, the proposed model can now be represented by expression [4]:

$$\begin{aligned} V^* &= b_0 + b_1 \cdot year^* + b_2 \cdot appraisalyear^* + b_3 \cdot semester + \\ &+ b_4 \cdot age^* + b_5 \cdot power^* + b_6 \cdot cylinder^* + b_7 \cdot cil\ turb + \\ &+ b_8 \cdot traction + b_9 \cdot wheelchain + b_{10} \cdot cabin + \\ &+ b_{11} \cdot air\ cond + b_{12} \cdot other\ charac + \sum c_i \cdot version + \\ &+ \sum d_i \cdot company \end{aligned} \quad [4]$$

in which the quantitative variables may be transformed into equation [5]:

$$\begin{aligned} year^* &= \frac{year^{\lambda} - 1}{\lambda}; \\ appraisalyear^* &= \frac{appraisalyear^{\beta} - 1}{\beta}; \\ age^* &= \frac{age^{\theta} - 1}{\theta}; \quad power^* = \frac{power^{\phi} - 1}{\phi}; \\ cylinder^* &= \frac{cylinder^{\sigma} - 1}{\sigma}; \quad V^* = \frac{V^{\gamma} - 1}{\gamma} \end{aligned} \quad [5]$$

Once the corresponding models were obtained, the adherence to normality, homocedasticity and linearity was checked by means of residual analysis.

Cluster analysis (Peña, 2002) was then used to group elements or variables into homogeneous classes depending in the similarities between them.

General depreciation model

The model[1] constructed is of the linear-logarithmic type; Table 3 shows the results obtained with this model.

Figure 2 shows that, in the model, the requirements of linearity, normality and homocedasticity were adhered to since no clear tendency was seen in the dispersion between the predicted typified values and the typified values of the residuals.

Tractor power, age, type of traction, the presence or not of air-conditioning, and the manufacturer together explained 89.8% of the value of the used tractors. Power alone explained 47.73% of the value, while power and age together explained 73.4%. The variables semester and appraisal year were not included in the proposed model; these factors did not seem to influence tractor value during the period 1999-2002. Neither were the variables number of cylinders, turbo-capability, tractor version, the presence of a cabin, etc. (see Table 2) taken

Table 3. Econometric estimates of variables in remaining value equation

Model	Non-standard coefficients		Standard coefficients	t	Sig.
	B	Typ error	Beta		
Constant	5.601	0.037		150.534	0.000
Ln. Power	0.720	0.005	0.528	132.851	0.000
Age	–0.048	0.000	–0.415	–122.128	0.000
Traction	0.249	0.004	0.215	68.660	0.000
Air. Cond	0.116	0.006	0.068	18.629	0.000
Manufact 1	0.766	0.031	0.188	24.416	0.000
Manufact 2	0.895	0.034	0.154	26.452	0.000
Manufact 4	0.165	0.035	0.024	4.660	0.000
Manufact 5	0.965	0.030	0.340	31.986	0.000
Manufact 6	0.959	0.031	0.235	30.660	0.000
Manufact 7	1.001	0.030	0.386	33.306	0.000
Manufact 8	0.741	0.030	0.261	24.651	0.000
Manufact 9	1.391	0.030	0.486	46.200	0.000
Manufact 10	1.001	0.030	0.509	33.930	0.000
Manufact 11	1.291	0.046	0.108	28.041	0.000
Manufact 12	0.929	0.030	0.400	31.186	0.000
Manufact 13	0.965	0.031	0.243	31.054	0.000
Manufact 14	1.196	0.029	0.691	40.615	0.000
Manufact 15	0.787	0.031	0.253	25.704	0.000
Manufact 16	0.988	0.030	0.422	33.254	0.000
Manufact 17	1.027	0.031	0.273	33.124	0.000
Manufact 18	1.043	0.030	0.537	35.268	0.000
Manufact 19	0.881	0.032	0.197	27.481	0.000
Manufact 20	0.927	0.030	0.382	31.080	0.000
Manufact 21	0.835	0.029	0.441	28.381	0.000
Manufact 23	0.459	0.033	0.086	13.981	0.000
Manufact 24	0.400	0.031	0.111	13.040	0.000

Dependent variable: Ln V.

Summary of the model

R	R squared	Adjusted R squared	Typical error of estimation
0.948	0.898	0.898	0.18460

[1] The number of observations, 12,570, was very large and though the number of considered variables, 42, was also high, the number of freedom degrees is more than sufficient for the statistical tests to be trustworthy. The fact that 35 of the variables were dummy suggests there may have been a bias in colinearity and in the matrix calculations since many columns had zeros.

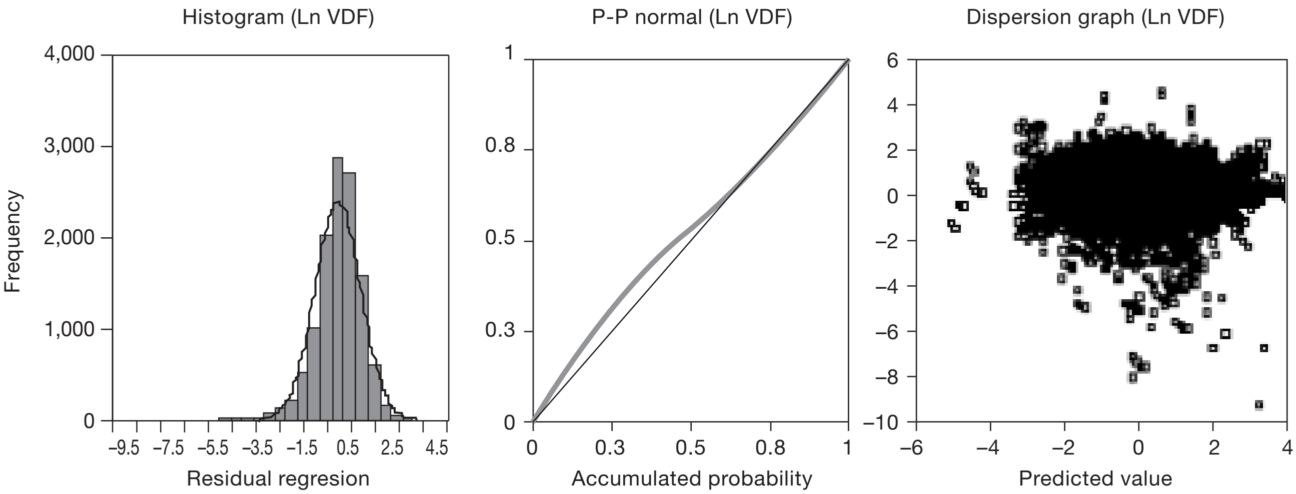

Figure 2. Histogram, P-P normal and dispersion graphs (residuals and predicted values).

into account due to their high correlation with horsepower; their inclusion would have generated an undesirable multicolinearity effect. The model allows some clear conclusions to be drawn: greater horsepower, four-wheel drive, and the presence of air-conditioning increases the price of used tractors, and age reduces it. When there is equality across these factors, the manufacturer affects the price; Avto tractors (Manufacturer 3) were the cheapest, and Fendt tractors (Manufacturer 9) the most expensive.

The value that a tractor can demand over its life since its fourth year is shown by expression [6].

$$\frac{V_{a_1}}{V_{a_2}} = \frac{e^{-0.048*a_1}+k}{e^{-0.048*a_2}+k} \quad ; \; V_{a_2} = V_{a_1} * e^{-0.048*(a_2-a_1)} \qquad [6]$$

Figure 3. Remaining value by year with respect to value in the fourth year.

Expression [6] can be used to estimate the percentage value of the tractor with respect to its value at 4 years. Figure 3 shows the change in the remaining value with respect to the value at 4 years.

To attempt to determine the change in a tractor's value over its entire life, information was collected on showroom prices[2]. This allowed the remaining value of a 4 year-old tractor to be determined as a percentage of its showroom price. Table 4 shows the percentages obtained (column 2) for tractors made by the seven main manufacturers. In the third column, the table shows the same for 29 year-old tractors calculated using equation [6]. Thus, a 4 year-old tractor maintains 56.16% of its showroom value, and 16.78% of this when it has reached the age of 29 years. In other words, during the first four years of a tractor's life, its value depreciates by 43.84%; during the following 25 years it falls by a further 39.38%.

Table 4. Average percentage of the remaining value compared with the new value (seven manufacturers)

Manufacturer	4 years old	29 years old
Lamborghini	56.46%	16.87%
Deutz	51.46%	15.38%
Case	46.39%	13.86%
John Deere	62.24%	18.60%
Same	47.12%	14.08%
Massey Ferguson	66.88%	19.99%
Landini	62.60%	18.71%
Average	*56.16%*	*16.78%*

[2] For new tractors, data was compiled from the MOMA web page.

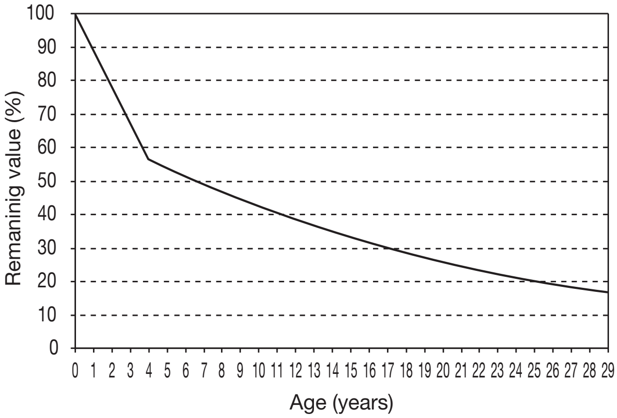

Figure 4. Remaining value by year.

Consequently, assuming an average value of 56.16% of the showroom price when a tractor is four years old, the original Figure 3 can be expanded to include the first four years of tractor life. Figure 4 shows the remaining value over the entire life span.

Models of depreciation by power group

Since horsepower was the variable that most influenced tractor value (explaining 47.73%), a model of depreciation by power group was sought (as undertaken by Perry *et al.,* 1990; Arias, 2001; Guadalajara, 2002) in order to invest the variable age with more influence, and to identify any differences in depreciation behaviour between tractors of different horsepower. Based on the work of Arias (2001), three groups of tractors were identified: small (≤ 60 hp, about 28.8% of all tractors considered), medium (60-90 hp; 41.8%) and large (> 90 hp; 29.35%). Table 5 shows the coefficients used in the depreciation model in each group.

The most influential variable in all groups was age, followed by power and manufacturer in the case of the smaller tractors. The type of traction did not influence

Table 5. Econometric estimate of remaining value equation variables with respect to power groups

	Dependent variable: *Ln V*		
	Small tractors	**Medium tractors**	**Large tractors**
Constant	5.7127	5.2629	6.7270
Ln Power	0.6430	0.7915	0.5554
Age	–0.0410	–0.0455	–0.0583
Traction		0.2459	0.2883
Air. Cond		0.1291	0.1076
Manufacturer: Agria	0.9972	0.5046	
Manufacturer: Antonio Carraro	1.2262		
Manufacturer: Avto	0.2911	0.2939	–0.1432
Manufacturer: Belarus	1.1922	0.8927	0.7707
Manufacturer: Case Internacional	1.3463	0.9613	0.7583
Manufacturer: Deutz	1.1956	1.0253	0.7292
Manufacturer: Deutz-Fahr	0.7440	0.7326	0.5656
Manufacturer: Ebro	1.7066	1.3803	1.1211
Manufacturer: Fendt	1.1526	1.0088	0.8133
Manufacturer: Fiat			1.0755
Manufacturer: Fiatagri	0.9963	0.9700	0.6917
Manufacturer: Ford	1.0119	0.9381	0.8029
Manufacturer: Internacional	1.2645	1.2675	0.9848
Manufacturer: John Deere	1.0356	0.7944	0.4288
Manufacturer: Kubota	1.2028	1.0378	0.6864
Manufacturer: Lamborghini	1.2509	1.0057	0.7941
Manufacturer: Landini	1.0792	1.0541	0.7784
Manufacturer: Massey Ferguson	1.1204		
Manufacturer: Pasquali	1.0692	0.9284	0.7357
Manufacturer: Renault	1.0230	0.8477	0.5977
Manufacturer: Same	0.7131	0.2711	0.1600
Manufacturer: UTB	0.3735	0.4622	0.3545
Adj. R^2	*79.00%*	*86.60%*	*88.00%*

the value of the small tractors, nor did the presence of air-conditioning; the smallest tractors do not have sufficient power to run air-conditioning or four-wheel drive systems.

In the other two groups, the type of traction and the presence of air-conditioning were more influential on the price than the power of the machines themselves.

Thus, more powerful tractors suffer greater depreciation than those of the other groups; the coefficient of the age variable is greater. In fact, even though the mean age of tractors in the three groups was 16 years, the most common age for large tractors was 11 years, while the medium tractors had a mean age of 15 years and the small tractors a mean age of 23 years.

Starting with the coefficients for the variable «age» in each category (Table 5) and applying an expression equivalent to [2], the change in value of a tractor by power group from its fourth year is represented by:

— Small tractors: $V_{a_2} = V_{a_1} * e^{-0.041*(a_2-a_1)}$ [7]

— Medium tractors: $V_{a_2} = V_{a_1} * e^{-0.0455*(a_2-a_1)}$ [8]

— Large tractors: $V_{a_2} = V_{a_1} * e^{-0.0583*(a_2-a_1)}$ [9]

See Figure 5 for a graphical representation.

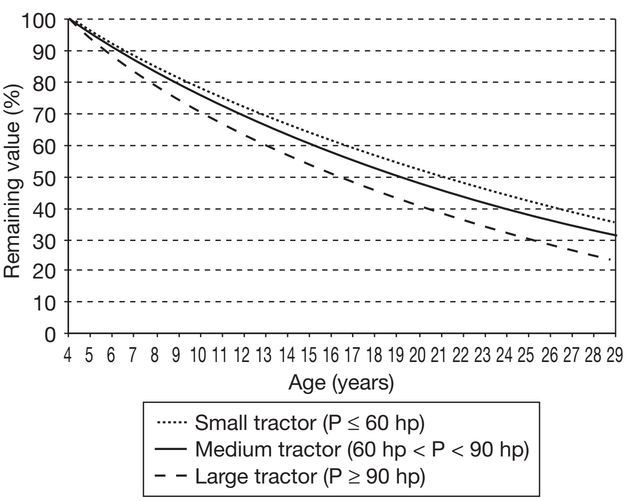

Figure 5. Remaining value by year for different tractors sizes with respect to value in the fourth year.

A proposed classification of tractors by power group; effect on depreciation

The above grouping of tractors by horsepower is that most commonly used. However, in terms of tractor depreciation, this may not be the most adequate. Figure 5, for example, shows the depreciation curves of small and medium tractors to be very similar. Cluster analysis was therefore used to obtain a different power classification[3] that worked better with the depreciation model. Table 6 shows the results obtained with the central values for each cluster and the number of observations. The resultant classification was: small tractors (13-79 hp), medium tractors (80-133 hp), and large tractors (134-263 hp). According to this new classification, the number of small tractors represented 62.66% of the total observations, medium tractors 31.52%, and large tractors 5.82%. Econometric models were obtained for each of these new tractor group (Table 7).

In general, with the new cluster classification the model better reflected the influence of horsepower on the change in market value. In small tractors, traction became a more important variable since, under the new rating, these have more power and therefore more chances of having four-wheel drive. This classification is similar to that used by Cross and Perry (1996) (< 80, 80-150, > 150 hp) and Wu and Perry (2004) (< 80, 81-120, 121-145, > 145 hp).

With respect to medium tractors, a number of variables, such as air conditioning, were no longer important. With respect to the larger tractors, the variables important in their depreciation remained the same.

The coefficient of the variable age did not vary in the new group of small tractors (–0.041), but it increased in the corresponding groups of medium (–0.0569 instead of –0.0455) and large tractors (–0.0687 instead

Table 6. Cluster analysis for defining the three horsepower groups

	Centre conglomerate groups		
	1	2	3
Power	100	167	59
Number of observations in each group	3,963	731	7,876

[3] A further cluster classification was obtained with four groups: small tractors (≤ 57 hp), medium tractors (> 7 to ≤ 87 hp), large tractors (> 87 to < 138 hp), and extra large tractors (≥ 138 hp). However, this did not provide any advantage over the use of three groups.

Table 7. Econometric estimate of remaining value equation variables by cluster analysis-defined horsepower groups

	Dependent variable: *Ln V*		
	Small tractors	**Medium tractors**	**Large tractors**
Constant	5.1394	10.2678	5.7399
Ln. Power	0.7911		0.7805
Age	–0.0410	–0.0569	–0.0687
Traction	0.2473	0.2859	0.3464
Air. cond			0.2462
Manufacturer: Agria	0.8497		
Manufacturer: Antonio Carraro	1.0159		
Manufacturer: Avto	0.2390		–0.2362
Manufacturer: Belarus	0.9921	–0.1823	0.7548
Manufacturer: Case Internacional	0.9808	–0.1689	0.6262
Manufacturer: Deutz	1.0863	–0.2431	0.4226
Manufacturer: Deutz–Fahr	0.7252	–0.3759	0.4492
Manufacturer: Ebro	1.4678	0.1574	1.0494
Manufacturer: Fendt	1.0694	–0.2142	0.7789
Manufacturer: Fiat			0.7377
Manufacturer: Fiatagri	1.0248	–0.3340	0.4972
Manufacturer: Ford	0.9793	–0.1886	0.8647
Manufacturer: Internacional	1.2503		0.8154
Manufacturer: John Deere	0.8947	–0.5341	0.2059
Manufacturer: Kubota	1.0562	–0.2281	0.3761
Manufacturer: Lamborghini	1.0968	–0.1984	
Manufacturer: Landini	1.0873	–0.1192	0.4751
Manufacturer: Massey Ferguson	0.9768		
Manufacturer: Pasquali	0.9979	–0.3362	0.6932
Manufacturer: Renault	0.8866	–0.4047	0.3271
Manufacturer: Same	0.5493	–1.0346	
Manufacturer: UTB	0.4011	–0.7242	0.4739
Adj. R^2	*86.98%*	*84.22%*	*93.46%*

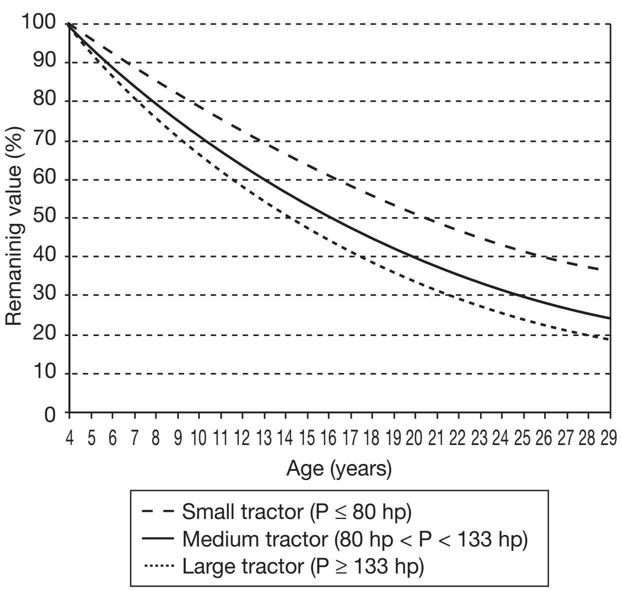

Figure 6. Remaining value by year for cluster analysis-defined tractor sizes with respect to value in the fourth year.

of –0.0583). Thus, the new classification obtained greater differences in depreciation.

Analogously, using these coefficients and applying expression [2], the change in value with age for each power group is represented by:

— Small tractors (P < 80 hp):

$$V_{a_2} = V_{a_1} * e^{-0.041*(a_2 - a_1)} \qquad [10]$$

— Medium tractors (80 hp ≤ P ≤ 133 hp):

$$V_{a_2} = V_{a_1} * e^{-0.0569*(a_2 - a_1)} \qquad [11]$$

— Large tractors (P > 133 hp):

$$V_{a_2} = V_{a_1} * e^{-0.0687*(a_2 - a_1)} \qquad [12]$$

See Figure 6 for a graphical representation.

Conclusions

The following conclusions can be drawn:

1. Tractors are the most commonly used agricultural machinery in Spain, both in terms of present numbers and the increase in their numbers over recent years. Following the second hand tractor market is therefore very important. Tractors over 20 years of age accounted for more than 40% of all title changes in 2003; this gives an impression of the obsolete nature of Spain's tractors.

2. The *Plan Renove* promoted by the Spanish government in 2005 (supported by ANSEMAT), and the introduction of the IAS system justify the need to establish methods that can more accurately determine the depreciation of the country's tractors.

3. With respect to the valuation of used agricultural machinery, the Anglo-Saxon school is more developed; in Spain, studies in this area have been scarce. This may be related to the amount of data available in each country; in the USA, information is abundant and easy to access. This justifies the use of econometric methods to determine machinery values. In Spain, however, MOMA purchase and sale price information is published only in a paper format, and only a few internet sites with information in this area exist.

4. All of the models for estimating the remaining value of tractors are of the linear-logarithmic type.

5. Based on the general model for used tractors in Spain, power alone accounts for nearly 50% of a machine's value. Power and age together explain some 73.4%; if the traction type, the existence of air-conditioning and the manufacturer are taken into account, some 90% is explained.

6. A general empirical model for calculating the depreciation of used tractors is proposed. This is a linear-logarithmic model (decreasing type) with a coefficient of –0.048 for the variable age. It is valid for use with tractors between the ages of 4 and 29 years. The change in value over the first four years is uncertain, but in general, a 4 year-old tractor keeps 56.16% of its showroom value, and 16.78% at 29 years. Further, more detailed studies analysing depreciation in the first four years of a tractor's life are required.

7. Using the new power groups obtained from cluster analysis —small tractors (< 80 hp), medium tractors (80-133 hp) and large tractors (> 133 hp)— better reflects the influence of horsepower on the change in market value. In both the traditional and cluster analysis-derived groupings, tractors of larger size are those that depreciate in value most quickly.

References

ARIAS P., 2001. Análisis temporal de las ventas y estimación del valor residual de tractores en España. Rev Esp Estud Agrosoc Pesq 192, 195-222. [In Spanish].

ASAE STANDARDS, 1996. Standards engineering practices data. 43rd ed. 235 pp.

AUDSLEY E., WHEELER J., 1978. The annual cost of machinery calculated using actual cash. J Agr Engng Res 23, 189-201.

BOX G.E., COX D.R., 1964. An analysis of transformations. J Royal Statist Soc, Series B 26(2), 211-243.

COOPER D.N., 1994. Net investment in agricultural tractors. J Agr Econ 45(3), 339-350.

CROSS T.L., PERRY G.M., 1995. Depreciation patterns for agricultural machinery. Am J Agr Econ 77, 194-204.

CROSS T.L., PERRY G.M., 1996. Remaining value functions for farm equipment. Appl Eng Agr 12(5), 547-553.

DUMLER T.J., BURTON R.O., KASTENS T.L., 2003. Predicting farm tractor values through alternative depreciation methods. Rev Agr Econ 25(2), 506-522.

FENOLLOSA M.L., 2006. Modelos de valoración de tractores agrícolas y cosechadoras, nuevos y usados en España e Italia, mediante técnicas econométricas. Tesis Doctoral. Univ Politécnica, Valencia, Spain. [In Spanish].

FRANK L., 2003. Coefficients of repair and maintenance costs for axial and transverse combine harvesters in Argentina. Span J Agric Res 3, 81-98.

GUADALAJARA N., 2002. Valoración de tractores agrícolas mediante métodos econométricos. Su aplicación en España e Italia. Rev Esp Estud Agrosoc Pesq 196, 67-94. [In Spanish].

HANSEN L., LEE H., 1991. Estimating farm tractor depreciation: tax implications. Can J Agr Econ 39, 463-479.

LEATHAM D.J., BAKER T.G., 1981. Empirical estimates of the effects of inflation on salvage values, cost and optimal replacement of tractors and combines. N C J Agr Econ 3(2), 109-117.

MAPA, 1996. Análisis del parque nacional de tractores agrícolas. Ministerio de Agricultura, Pesca y Alimentación, Madrid. 31 March, 1996. [In Spanish].

MCNEILL R.C., 1979. Depreciation of farm tractors in British Columbia. Can J Agr Econ 27, 53-8.

MOMA (1998 to 2003). Guía MOMA, Catálogo y estadísticas de precios de maquinaria agrícola usada. Nº 6-7, MOMA Editorial, S.L. [In Spanish].

MUSSER W.N., TEW B.V., WHITE F.C., 1986. Choice of depreciation methods for farm firms. Am J Agr Econ 4, 980-989.

PEACOCK D.L., BRAKE J.R., 1970. What is used farm machinery worth? Michigan State University. Agr Exp Sta, Res Rep 109.

PEÑA D., 2002. Análisis de datos multivariantes. McGraw-Hill, Madrid. [In Spanish].

PERRY G.M., BAYANER A., NIXON C.J., 1990. The effect of usage and size on tractor depreciation. Am J Agr Econ 72(2), 317-325.

REID D.W., BRADFORD G.L., 1983. On optimal replacement of farm tractors. Am J Agr Econ 65(2), 326-331.

UNTERSCHULTZ J., MUMEY G., 1996. Reducing investment risk in tractors and cabins with improved terminal asset value forecast. Can J Agr Econ 44(3), 295-309.

WEERSINK A., STAUBER S., 1988. Optimal replacement interval and depreciation method for a grain combine. W J Agr Econ 13(1), 18-28.

WU J., PERRY M., 2004. Estimating farm equipment depreciation: which functional form is best? Am J Agr Econ 86, 483-491.