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ESTIMATING THE MARKET VALUE OF FARM TRACTORS IN CHILE: AN ECONOMETRIC APPROACH

ESTIMANDO EL VALOR DE MERCADO DE LOS TRACTORES AGRÍCOLAS EN CHILE: UNA APROXIMACIÓN ECONOMÉTRICA

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ABSTRACT

The aim of this study was to determine the main factors influencing the market price of agricultural tractors in Chile. A linear log model is used with data collected from ChileAutos, which is a website for vehicle sales, including 156 offers and 20 brands of new and used tractors. The results suggest that tractor price depends negatively on tractor age, increases at decreasing rates with tractor power and depends significantly on the manufacturer's brand.

Key words: tractor price, tractor power, tractor brand.

RESUMEN

El objetivo de este estudio fue determinar cuáles son los principales factores que explican el precio de mercado de un tractor agrícola en Chile. Se utiliza un modelo log lineal con datos recolectados del website ChileAutos, considerando 156 registros de oferta y 20 marcas de modelos de tractores nuevos y usados. Los resultados sugieren que el precio de mercado del tractor depende negativamente de los años de uso, crece a tasas decrecientes con la potencia del motor y depende en forma significativa de la marca del fabricante.

Palabras clave: precio de tractor, potencia de tractor, marca de tractor.

INTRODUCTION

Modern agriculture has become increasingly machinery intensive (Ghisellini et al., 2016; Canales et al., 2018). The introduction of intelligent machines and self-driving vehicles in agricultural operations has allowed for greater efficiency. However, fully exploiting these engineering advances requires a review of the management process for traditional agricultural machinery (Bochtis et al., 2014; and Nkakini and Etenero, 2019).

According to Ghadiryanfar et al. (2009) and Muñoz et al. (2011), the number of tractors can be considered an important indicator of investment in agriculture. The degree of rural capitalization can be evaluated by an index based on the number of tractors per surface unit, comparable between regions or countries. Thus, for example, the countries with the most tractors per 100 square

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kilometers of arable land are Slovenia, Japan, New Caledonia (French territory), Switzerland, Austria and Italy, with an average of 3,402 tractors for this group of countries. In Chile, this number only reaches 427 tractors (World Bank, 2018).

For some crops, machinery operating and ownership costs can represent more than half of crop production costs. Total machinery costs include repairs, maintenance, fuel, lubrication, insurance, interest and depreciation (Wu and Perry, 2004; Artuzo et al., 2015; Artuzo et al., 2018). An appropriate cost structure allows measuring, analyzing and monitoring such costs, which has implications on farm management and decision-making (Andrade et al., 2012; Abubakar et al., 2013).

Tractors are decisive in the profitability of most agricultural activities. As Velasco and González (2007) suggested, the factors that most influence the costs of operating a farm tractor are its intensity of use, repair and maintenance costs and age. One of the conclusions of their work is that the greater the market value of a tractor, the higher its operating costs.

Due to machinery depreciation, tractor functionality decreases with time and use. Given that the goal of agricultural companies is to maximize profits, replacement of a tractor is advisable at some point in its service life. However, the acquisition of a new tractor normally involves the sale of the old tractor and its market value depends on a set of physical and technical characteristics. Poblete (2010) concluded that the optimal replacement age for a tractor is 12 years (88 HP) and 13 years (73 HP), depending on the engine power.

Although several studies have estimated repair and maintenance costs of tractors and others agricultural machines, only a few studies have examined the relationship between tractor price and tractor power. Some studies on tractor costs include those conducted by Arias (2001), Guadalajara (2002) and Fenollosa and Guadalajara (2007) in Spain; Dumler et al. (2003) and Wu and Perry (2004) in the United States; Abubakar et al. (2013) and Obinna and Oluka (2016) and Ojo and Ayanwale (2019) in Nigeria; Dahab et al. (2016) in Sudan; Sopegno et al. (2016) in Italy; Paneque-Rondón (2017) in Venezuela; Théodore et al. (2017) in Gambia; and Galvão et al. (2018) in Brazil.

Guadalajara and Fenollosa (2010) used mathematical models to estimate mean market values of new and used agricultural tractors in Spain and Italy. Based on data collected from companies and the marketplace in both countries, their results show that the characteristics that most influence the market value of tractors are horsepower (+), traction (+) and age (-). Walley et al. (2007) and Sivakumar and Kaliyamoorthy (2014) showed that brand name is also important when considering the purchase of a tractor. Moreover, according to Cavallo et al. (2014), Walley et al. (2017) and Yezekyan et al. (2018), farmers appear to exhibit brand loyalty in the tractor market.

The model proposed by Sopegno et al. (2016) shows that operating cost predictions for complex cultivation systems can be obtained where manpower and agricultural machinery are shared among the various operations for each individual crop. Dahab et al. (2016) and Théodore et al. (2017) have described that the accumulated repair and maintenance costs, as a percentage of the agricultural tractor purchase price, increased with the age and working hours of the tractor. This means that, indirectly, tractor market value continues to decrease as tractor age increases. Dumler et al. (2003) and Wu and Perry (2004) evaluated different depreciation methods to determine farm equipment and tractor values, which depend on age, intensity of use and brand.

The main aim of this work was to analyze factors that affect farm tractor price. Unlike most previous studies, a hedonic regression approach is used in order to estimate the impact that various factors or attributes have on the price. This work can be useful in two respects: first, it provides more precise market information for farm decision making, and second, this information can be also used for tax-related considerations in public policy making.

MATERIALS AND METHODS

Data for this study were collected between May 17 and June 30, 2017, from ChileAutos (https://www.chileautos.cl/), a website for vehicle sales. The sample is composed of 156 listings of new and used tractor models in Chile, including John Deere ® (30.1%), Massey Ferguson ® (15.4%), New Holland ® (12.2%), Ford ® (6.4%), Landini ® (6.4%), Same ® (5.1%), Case ® (3.2%) and Kubota ® (2.6%). Thus, the database included a total of 156 observations, 20 brands, with an average offer price of US$23,744 (SD = 16,952), average age of 15 years (SD = 11.1) and an average brand value of US$211 per HP (SD = 114.2).

The variables included in the model were limited by the availability of data. The following variables were considered: offer price, model and brand, year of manufacture of the tractor and power, measured in HP. Most of these variables, or other variables generated from them, have been used in previous estimations (Arias, 2001; Guadalajara, 2002; Fenollosa and Guadalajara,

2007) and, therefore, can be considered explanatory variables in this study.

A continuous linear model (CLM) was used for the estimations. The CLM takes the form:

$$E(Y_i) = \mu_i \qquad i = 1, \ldots n \tag{1}$$

where the dependent variable, Y_i or random variable, is an independent normal variable, with mean μ_i and constant variance σ^2. As before in matrix notation, Equation (1) was re-written as:

$$E(Y) = \mu = X\beta \tag{2}$$

where μ is x 1, X is n x k, β is k x 1 and k is the number of unknown parameters including the intercept.

First, the CLM requires a dependent variable with a normal distribution. Second, the relationship between the dependent and independent variables must be linear in nature. Third, the variance of errors is necessarily the same across all levels of the independent variables. The generated model considered the assumptions of normality, homoscedasticity and linearity. Fulfillment of the three assumptions was verified by analysis of the residuals. Following Rosen (1974), we assume a hedonic price function with a general form:

$$p_i = p_i(x_i, \beta) + \mu_i \tag{3}$$

In Equation (3) p_i represents the price of tractor i (in dollars) as a function of its vector of attributes, x_i. The hedonic pricing approach assumes that the price of a tractor is equal to the sum of the prices of its attributes or characteristics. In our model, the attributes included are age, power and brand. More specifically:

$$\ln p_i = \alpha_0 + \beta_1 x_1 + \beta_2 x_2 + \beta_3 x_2^2 + \gamma_1 D_1 + \delta_1 x_1 D_1 \tag{4}$$

The model of Equation (4) is called log-linear, or simply log-lin. In this model, there are two continuous variables: x_1 = age of the tractor (in years) and x_2 = power (in HP). A dummy variable, D_1, which takes the values 1 for "more expensive brands" (tractors with a price/power ratio above the median) and 0 for *"cheaper brands"* (tractors with a price/power ratio below the median), was also included. The interaction variable was $X_1 D_1$, which corresponds to a moderating effect variable between age and brand.

In the estimation of the final model, different specifications were tested for the brand grouping, such as 10th and 20th percentiles, but they were not statistically significant. Once the final model was obtained, the fulfillment of the normality assumptions, homoscedasticity and linearity was verified by analysis of the residuals.

In this model, the percentage impact on the dependent variable can be defined as the percentage variation of the price attributed to the variation of a unit in an explanatory variable (Troncoso et al., 2012). This is:

$$\Delta p_i\% = \frac{\Delta p_i}{p_i} = 100\left(\frac{\partial p_i}{\partial x_i}\right) = 100\, \beta_i \tag{5}$$

Where the coefficient of a continuous explanatory variable is a derivative and, therefore, it can be interpreted as a percentage change in the dependent variable caused by a small change in the independent variable. Thus, the percent impact values of the variables age and power were estimated as 100 β_i; in this case β_p is a semi-elasticity of price-age and price-power, respectively. Nevertheless, in order to estimate the percent impact of the binary variable, and in accordance with Troncoso et al. (2012), the following consistent estimator was used for $g(Y_q)$, where $g(Y_q) = e^{Y_q}$:

$$\Delta p_i\% = \frac{\Delta p_i}{p_i} = 100\left[\exp\left(\gamma_q - 0.5 var(\gamma_q)\right) - 1\right] \tag{6}$$

Equation (6) is a suitable interpretation of the coefficient of a dummy variable, particularly in the case of small samples (Giles, 1982; Halvorsen and Palmquist, 1980). In this study, the dummy variable is the tractor brand.

As indicators of goodness of fit of the model, the adjusted R^2 statistic and the likelihood ratio chi-square (X^2) were used.

RESULTS AND DISCUSSION

The characteristics of the sample are presented in Table 1. This included 156 tractors with a mean price of US$ 23,744 (US$ 1 = $CL 750), mean age of 15.02 years and mean power of 102 HP.

Table 2 shows the results of the log-linear regression analysis where the natural logarithm of tractor price (In p_i) is the dependent variable. The signs of the coefficients show the direction of the relation of each independent variable (tractor power, age and brand) with the dependent variable. The results of this study show that the tractor price increases with tractor power but at a decreasing rate. Our results also show that the price depends negatively on tractor age and significantly on the manufacturer's brand. Older tractors are associated with a lower price. However, the negative sign of the age variable squared is not statistically significant. This suggests tractor price decreases less as it gets older,

Table 1. Characteristics of the sample (US$ 1 = CL $ 750)

	Total sample	Cheap brands	Expensive brands
Observations (N°)	156	78	78
Observations (%)	100	50	50
Tractor price (US$)	23,744	14,439	33,049
Age (years)	15.02	21.12	8.92
Power (HP)	102	95	110
(ln) Tractor price	9.83	9.41	10.24
(ln) Age	2.37	2.90	1.83
(ln) Power	4.52	4.49	4.55

Data was collected from "Chile Autos" (https://www.chileautos.cl), a Chilean website for vehicle sales. The sample is composed of 156 listings of new and used tractor models. The characteristics of each tractor include price (measured in US dollars), age (measured in years) and power (measured in horsepower). The tractor power is normally expressed in kilowatts (kW) or horsepower (HP): 1 kW = 1.34 HP.

Table 2. Factors affecting the price of farm tractors in Chile.

	Beta	SD	Student's t	Sig.
Constant	8.30128	0.13523	61.38721	***
Age	-0.02543	0.00318	-8.00193	***
Power	0.02203	0.00197	11.18306	***
Power squared	-0.00005	0.00001	-4.95549	***
Brand	0.25912	0.09369	2.76576	***
Age x Brand	0.01552	0.00570	2.72421	***
Observations			156	
F			166.275***	
R-squared			0.847	
Adjusted R-square			0.842	
Likelihood ratio chi-square			293.018***	
Durbin-Watson			1.74	
Condition index			23.77	

The dependent variable is Price (measured in US dollars). The independent variables are Age (measured in years), Power (measured in HP); Brand (a dummy variable that takes the value one for tractors with a price/power ratio above the median) and zero otherwise; and Age x Brand (an interaction term between the variables Age and Brand).
*** = Significant at the 1% level ($p < 0.01$) based on t-statistics.

which is consistent with other results reported in previous studies (for example, Guadalajara and Fenollosa, 2010; Dahab et al., 2016 or Theodore et al., 2017). Following Guadalajara (2002), this study includes "brand" as a dummy variable. Differences in tractor prices are statically evident between different tractor brands. For two tractors of the same age, the price of the tractor with the more expensive brand is 25.9% higher than the price of the tractor with the cheaper brand. The variables included in the model explain 84.2% of the variance of the dependent variable according to the adjusted R^2 statistic (adjusted R^2 = 84.2). The model as a whole was significant at $p < 0.01$ according to the likelihood ratio chi-square (X^2 = 293.018).

The results in Table 2 also indicate a significant and negative relation between tractor price and tractor age (β = -0.025, $p < 0.01$). They show that age represents the effects of deterioration and obsolescence on tractor price. The positive relation between tractor price and tractor horsepower (β = 0.022, $p < 0.01$) and the negative quadratic relationship between the same two variables (β = -0.00005, $p < 0.01$) indicate that tractor price grows at a decreasing rate with tractor horsepower.

The significant relation between tractor price and tractor brand (β = 0.259, $p < 0.01$) shows that brand names influence tractor purchase decisions. In fact, the change in brand (from a cheap to an expensive brand) produces an increase in the effect that age has on tractor price. For example, the effect that one additional year has on tractor price is 1.6% greater for the expensive brands than for the cheap brands. These results are consistent with those reported in the literature (Dumler et al., 2003; Wu and Perry, 2004; Walley et al., 2007; Cavallo et al., 2014; Sivakumar and Kaliyamoorthy, 2014; Yezekyan et al., 2018). According to Dumler et al. (2003) and Walley et al. (2017), tractor age and brand name are the most important factors impacting the purchase decision for agricultural tractors.

From the data in Table 2, the model for relatively more expensive brands may be stated as:

$$E(\ln p / X_1, X_2, X_2^2, D_1 = 1) \quad \underset{(0.13523)}{8.30128} - \underset{(0.00318)}{0.02543X_1} + \underset{(0.00197)}{0.02203X_2} - \underset{(0.00001)}{0.00005X_2^2} + \underset{(0.09369)}{0.25912D_1} + \underset{(0.00570)}{0.01552X_1D_1} \quad (7)$$

The model for relatively cheaper brands may be stated as:

$$E(\ln p / X_1, X_2, X_2^2, D_1 = 0) \quad \underset{(0.13523)}{8.30128} - \underset{(0.00318)}{0.02543X_1} + \underset{(0.00197)}{0.02203X_2} - \underset{(0.00001)}{0.00005X_2^2} \quad (8)$$

As indicated in equations (7) and (8), the independent term is the same for high and low price brands, but the slope is steeper for high price than for low price brands because $\delta_1 = 0.016$ is positive. Therefore, the tractor market value for every additional year of age depends on the brand.

The results of the semi-elasticities, elasticities and percent impact of the variables included in the model are presented in Table 3. The semi-elasticities suggest that an additional year of age for the tractor results into a reduction of 2.54% of its market value, whereas each HP of additional power implies an increase of 2.20% in the market value of the tractor. The analysis of the elasticities indicates that tractor price is inelastic to age ($\eta_{p,e} = -0.38$) and elastic to power ($\eta_{p,p} = 2.25$). The results also show that the most expensive brands are 25.9% more expensive than the cheapest brands for a tractor with the same age.

The numbers in Table 3 also show that the interaction between tractor age and brand is statistically significant. The change in market value of the tractor for an additional year of age is greater for high price than for low price tractors.

Although these results are interesting, there are some limitations to this study. In Chile, there are different ways to buy or sell a new or second hand tractor; there are companies such as Salfa, Sigdotek and Machinio Chile, and also websites such as ChileAutos, MercadoLibre, MarketBook, Yapo, Vivastreet, Mitula and Mercado Vial. The data used in this study come from ChileAutos. In this sense, a representativeness bias of the sample may constitute a limitation of this study. On the other hand, another limitation is a possible omitted variable bias, which occurs when a regression model leaves out relevant independent variables that interact with the included variables. We do not have information on other characteristics that can affect tractor price such as traction capacity, hours of use, type of cab (fully enclosed cab or open station), among others.

Table 3. Semi-elasticities, elasticities and percent impact estimations.

	Semi-elasticity (marginal effect)	Elasticity	Percent impact
Age	-2.54	-0.38	
Power	2.20	2.25	
Brand			25.91
Age x Brand			1.56

The dependent variable is Price (measured in US dollars and expressed in natural logarithm). The independent variables are: Age (measured in years), Power (measured in HP), Brand (variable that takes the value one for tractors with a price/power ratio above the median) and zero otherwise, and Age x Brand (an interaction term between the variables Age and Brand).

CONCLUSIONS

The central focus of this study was to identify the variables that influence the price of farm tractors in order to estimate the impact on the price. Based on a log-linear model and using a data set from Chile, the main results of this study suggest that tractor price depends negatively on tractor age, increases at decreasing rates with tractor power and depends significantly on the manufacturer's brand. These results provide more precise market information for the agribusiness decision making and for fiscal-related considerations in public policy making.

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