Determinants of Hereford and Braford bull prices in certified auctions in Brazil

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Abstract

The intensification and competitiveness of beef cattle production have increased the importance of careful sire selection, as bulls exert a disproportionate influence on the genetic and economic performance of herds. In this context, this study analyzes the factors that determine the selling prices of Hereford and Braford bulls marketed at certified auctions in Brazil. Data from 1,046 bulls sold at 26 auctions held in 2023 and organized by the breed association were used. The empirical analysis was based on multiple regression models estimated using the backward method, with Model 4 adopted as the final specification due to its greater parsimony and statistical stability. The results indicate that price formation is mainly explained by observable productive characteristics, such as animal weight and age, as well as birth weight, which showed a negative effect associated with potential productive risks. Among non-productive factors, the dual brand—assigned to animals ranked among the top 30% in evaluation programs—and the presence of awards stand out, both exerting a positive and statistically significant impact on the final price. The findings suggest that simplified institutional signals of quality play a central role in bull valuation, whereas more complex genetic information remains underutilized in the decision-making process.

Keywords: beef cattle; bovine genetics; auctions; livestock markets.

Introduction

The intensification and competitiveness of beef cattle production on a global scale have been strongly driven by advances in genetic improvement, resulting in substantial productivity gains in the main beef-producing and exporting countries (Viana et al., 2024). In this context, bulls play a central role in the productive efficiency of livestock systems, as they generate a significantly larger number of offspring than cows and therefore exert a decisive influence on the genetic and economic performance of herds (Lopes et al., 2023). Consequently, the careful selection of sires represents a strategic decision for producers, with direct effects on productivity, profitability, and the sustainability of the activity (Boyer et al., 2019; Son et al., 2025).

Among taurine breeds, Hereford is one of the most traditional breeds in Brazilian beef production, especially in southern Brazil, where its productive performance, adaptability, and carcass quality have historically favored its adoption. More recently, the expansion of certified beef programs has reinforced the market value of British breeds by rewarding quality-related attributes and creating opportunities for product differentiation, a trend also observed for Aberdeen Angus cattle (Vaz et al., 2021). As a result, Hereford and Angus have become the main European breed groups in Brazilian beef cattle production, both in purebred systems and in crossbreeding schemes (Vaz et al., 2023).

While Hereford remains an important breed in purebred breeding systems, commercial beef production in southern Brazil has increasingly incorporated crossbreeding strategies aimed at combining meat quality with environmental adaptation. In this context, the Braford breed has gained prominence because it combines the carcass and productive attributes of Hereford cattle with the adaptability associated with Bos indicus genetics. As a composite breed, Braford benefits from heterozygosity and heterosis effects, which may enhance productive efficiency and resilience under extensive production conditions (Gregory & Cundiff, 1980; Arthur et al., 1999). These characteristics positively affect both cow–calf efficiency and the production of animals destined for slaughter, reinforcing the economic relevance of this breed within Brazilian livestock systems (Vaz et al., 2023). In this sense, the analysis of the bull market goes beyond the restricted interest of seedstock operations and buyers, assuming broader importance for the entire beef agroindustrial complex.

In recent years, studies focused on bull commercialization at auctions have gained prominence in the literature, seeking to identify the attributes valued by buyers and the mechanisms that influence price formation in this specific market (Zimmerman et al., 2012; Evangelista et al., 2019; Tang et al., 2020; Lopes et al., 2023; Gatti et al., 2024). Recent evidence indicates relevant differences in valuation across breeds and marketing periods, with Braford bulls presenting higher average prices compared to other breeds, especially at autumn auctions, while purebred animals tend to achieve lower values in spring sales (Vaz et al., 2023).

Despite these advances, comparative analyses of the factors determining the prices of Hereford and Braford bulls within the same institutional and market environment remain scarce. In this context, the objective of this study is to analyze the factors that determine the selling prices of Hereford and Braford bulls marketed through auctions certified by the breed association in Brazil.

Materials and Methods

The study was conducted based on data collected at bull auctions certified by the Brazilian Hereford and Braford Association (ABHB, 2023) in 2023. Data collection and analysis were carried out in two stages. The first stage consisted of collecting data from 26 accredited auctions, yielding production records for a total of 1,046 bulls marketed in Brazil. The final selling price of the bull and the variables collected at this stage are presented in Table 1.

Table 1 – Productive and non-productive variables collected for the observed bulls.

Variable	**Definition**	**Measurement**
Price	Final price of the bull at auction	R$
Breed	Breed of the bull	0=Hereford; 1=Braford
Age	Age of the bull at auction	Months
Weight	Weight of the bull at auction	kilograms
Scrotal circumference	Circumference of the bull's scrotum	Centimeters
Double brand	Number of official marks	0=One official brand; 1=Two official brands
Awards	Award-winning farm on cattle show during the year	0=No; 1 = Yes
Birth weight	Birth weight index of the bull compared to its generation	Index
Weaning weight	Weaning weight index of the bull compared to its generation	Index
Final index	Final index of the bull compared to its generation	Index

In the second stage, the data were analyzed using a multiple regression model, estimated according to Equation 1. Estimation was carried out using the Ordinary Least Squares (OLS) method, applying the Backward method (or backward elimination). The backward elimination technique was used to sequentially remove the least statistically significant variables until all remaining variables exhibited statistical significance ($p < 0.05$). This procedure contributes to the estimation of a more robust model by retaining only those variables that significantly explain the variation in the dependent variable. The Backward method has the advantage of reducing potential variable inclusion errors commonly associated with stepwise and forward selection procedures.

$$Price = \alpha + \beta_1 Breed + \beta_2 Age + \beta_3 Weight + \beta_4 Scrotal\ Circ. + \beta_5 Double\ Brand + \beta_6 Awards + \beta_7 Birth\ Weight + \beta_8 Weaning\ Weight + \beta_9 Final\ Index + \varepsilon \quad (1)$$

Multicollinearity occurs when two or more independent variables are highly correlated, which can inflate the standard errors of the estimated coefficients. To assess this phenomenon, the Variance Inflation Factor (VIF) was calculated for each variable. VIF values above 10 are indicative of multicollinearity problems.

Autocorrelation of the residuals, or serial dependence among the errors, may indicate that the observations are not independent. To investigate the presence of autocorrelation, the Durbin–Watson test was applied. Values close to 2 suggest the absence of autocorrelation, whereas values close to 0 or 4 indicate positive or negative autocorrelation, respectively.

The combination of these techniques enabled a robust analysis of the model, ensuring verification of the main regression assumptions and allowing for the identification of potential issues that could compromise the validity of the results obtained.

Statistical analyses for the estimation of regression parameters and for testing violations of basic assumptions (multicollinearity and residual autocorrelation) were performed using Python software (version 3.X), with the packages statsmodels, pandas, and matplotlib. The estimations were supported by computational tools for code verification and result validation.

Results

The results indicate consistent performance across the four estimated models, with coefficients of determination (R^2) ranging from 0.185 in the initial model to 0.181 in the final model (Table 2). Although the R^2 values are moderate, all models exhibited high overall statistical significance ($p < 0.001$), indicating relevant explanatory power in the context of bull price formation at auctions. The stability of the R^2 across specifications suggests that the successive exclusion of productive variables using the backward method did not substantially compromise the explanatory power of the model.

During the estimation process, scrotal circumference was the first variable to be excluded, followed by weaning weight and subsequently by breed, resulting in the final model (4) with no further exclusions. All models met the criteria for overall statistical significance, reinforcing the robustness of the results obtained.

Although the Durbin–Watson test is more commonly applied to time-series data, the value observed in the final model ($d = 1.40$) does not indicate relevant problems of residual autocorrelation and is considered acceptable in the context of cross-sectional data. Table 3 presents the estimated slope coefficients, their respective levels of statistical significance, and the Variance Inflation Factor (VIF) values, allowing for the individual assessment of the effects of the explanatory variables and the verification of the absence of relevant multicollinearity among them.

The interpretation of the results focuses on Model 4, considered the best-fitting specification among those estimated using the backward method, as it presents greater parsimony and statistical stability. In the final model, among the productive variables, animal weight at the time of sale exhibited a positive and highly significant coefficient ($p < 0.001$), indicating that increases in body weight are associated with consistent increases in the final price of bulls. In contrast, age showed a negative and statistically significant coefficient ($p < 0.001$), suggesting a price penalty for older animals at auctions, possibly related to expectations of shorter reproductive lifespan and lower economic returns.

Birth weight presented a negative and statistically significant coefficient ($p < 0.01$), indicating that animals with higher birth weights tend to achieve lower prices. This result may reflect buyers' concerns regarding calving ease, productive risks, and reproductive management. The final index, in turn, showed a positive and significant coefficient ($p < 0.05$), suggesting that synthetic indicators of productive performance positively influence price formation when evaluated jointly with other individual characteristics.

With respect to non-productive variables, the presence of awards showed a positive and statistically significant effect ($p < 0.05$), indicating that formal recognition of the selling seedstock operation functions as a relevant signal of quality, positively influencing buyers' willingness to pay. Similarly, the dual brand variable presented a positive and statistically significant coefficient ($p < 0.05$), indicating that bulls classified among the top 30% in their respective genetic evaluation programs achieve higher final prices at auctions. This result suggests

that the dual brand acts as a clear and objective signal of relative performance, reducing information asymmetry between sellers and buyers in the auction environment.

Finally, the Variance Inflation Factor (VIF) values in Model 4 remained below critical thresholds, indicating the absence of severe multicollinearity among the explanatory variables and reinforcing the statistical consistency of the estimates.

Table 2 – Overall significance of the estimated models (ANOVA), coefficient of determination (R-square), and variables excluded by the backward method.

Model	R-square	ANOVA		Excluded variable	Durbin-Watson
		F	p-value		
1	0.185	18.14	<0.001	Scrotal circ.	
2	0.184	20.32	<0.001	Weaning weight	
3	0.183	23.14	<0.001	Breed	
4	0.181	26.67	<0.001	-	1.40

Table 3 – Slope coefficients, individual significance, and multicollinearity test (VIF) of the models estimated using the backward method.

Model	Variables	Coefficients	t-statistic	p-value	VIF
1	Intercept	-9,163.08	-1.695	0.090	
	Breed (0=Hereford; 1 =Braford)	1,636.85	1.386	0.166	1.045
	Age	-335.17	-4.313	<0.001	1.762
	Weight	40.50	8.006	<0.001	1.980
	Scrotal circumference	121.99	0.873	0.383	1.375
	Double brand (0=No; 1=Yes)	1,730.18	1.931	0.054	1.613
	Awards (0=No; 1=Yes)	2,090.53	2.373	0.018	1.130
	Birth weight	-2,467.01	-3.279	0.001	1.170
	Weaning weight	562.34	0.952	0.341	3.191
	Final index	662.46	1.019	0.308	3.768
2	Intercept	-5,340.674	-1.685	0.093	
	Breed (0=Hereford; 1 =Braford)	1,652.04	1.399	0.162	1.045
	Age	-331.68	-4.274	<0.001	1.758
	Weight	41.80	8.648	<0.001	1.809
	Double brand (0=No; 1=Yes)	1,797.95	2.014	0.044	1.601
	Awards (0=No; 1=Yes)	2097.90	2.381	0.018	1.130
	Birth weight	-2,418.08	-3.223	0.001	1.163
	Weaning weight	481.10	0.825	0.410	3.112
	Final index	778.01	1.223	0.222	3.612
3	Intercept	-5,175.88	-1.636	0.102	
	Breed (0=Hereford; 1 =Braford)	1,567.85	1.333	0.183	1.037
	Age	-336.57	-4.351	<0.001	1.747
	Weight	41.89	8.671	<0.001	1.808
	Double brand (0=No; 1=Yes)	1813.41	2.032	0.042	1.600
	Awards (0=No; 1=Yes)	2,009.57	2.299	0.022	1.114
	Birth weight	-2,296.28	2.652	0.002	1.118
	Final index	1,159.32	-3.123	0.008	1.706
4	Intercept	-3,438.36	-1.192	0.234	
	Age	-351.50	-4.590	<0.001	1.711
	Weight	42.10	8.715	<0.001	1.806
	Double brand (0=No; 1=Yes)	1,776.80	1.991	0.047	1.598
	Awards (0=No; 1=Yes)	1,923.88	2.205	0.028	1.108
	Birth weight	-2,281.19	2.596	0.002	1.118
	Final index	1,134.19	-3.101	0.010	1.702

With respect to non-productive variables, the presence of awards showed a positive and statistically significant effect ($p < 0.05$), indicating that formal recognition of the selling seedstock operation functions as a relevant signal of quality, positively influencing buyers' willingness to pay. Similarly, the dual brand variable presented a positive and statistically significant coefficient ($p < 0.05$), indicating that bulls classified among the top 30% in their respective genetic evaluation programs achieve higher final prices at auctions. This result suggests that the dual brand acts as a clear and objective signal of relative performance, reducing information asymmetry between sellers and buyers in the auction environment.

Finally, the Variance Inflation Factor (VIF) values in Model 4 remained below critical thresholds, indicating the absence of severe multicollinearity among the explanatory variables and reinforcing the statistical consistency of the estimates.

Discussion

The results of Model 4 indicate that bull price formation at auctions is explained by a limited set of observable productive variables and institutional quality signals, whereas more technical genetic attributes exert a reduced influence in the analyzed context. This pattern is consistent with studies conducted in Brazil, which highlight the predominance of simple visual and productive criteria in buyers' decision-making processes (Evangelista et al., 2019; Lopes et al., 2023).

Among the productive variables, animal weight at the time of sale showed a positive and highly significant impact on price, a result widely documented in the literature. Lopes et al. (2023) emphasize that body weight is strongly associated with perceptions of quality and performance, regardless of the final price achieved. Similar evidence has been observed in the United States, where producers are encouraged to offer heavier, more mature, and faster-growing bulls, provided that they sire lighter calves at birth (Boyer et al., 2019).

Animal age exhibited a negative effect on price, indicating a penalty for older bulls, possibly related to expectations of reduced reproductive lifespan. In North American markets, Joseph et al. (2024) also found that buyers closely evaluate bulls' growth capacity and body weight at the time of sale, jointly considering traits associated with productive and reproductive efficiency.

The negative coefficient associated with birth weight suggests that buyers avoid bulls potentially linked to higher risks of dystocia, even when these animals exhibit good subsequent productive performance. Similar results were observed in simulated auctions in the United States, where calving ease ranked among the most relevant criteria for sire selection (Culbertson et al., 2024).

Regarding non-productive variables, the dual brand—assigned to animals ranked among the top 30% in evaluation programs—showed a positive and significant effect on the final price. This finding indicates that the dual brand functions as a simplified institutional signal of relative performance, reducing information asymmetry in the auction environment. International evidence suggests that simplifying genetic information into aggregated indices facilitates buyers' decision-making, even when more detailed technical indicators are available (Smith et al., 2021).

Complementarily, the presence of awards also contributed positively to bull valuation, reinforcing the role of formal recognition mechanisms in price formation. International studies indicate that awards and rankings function as important quality signals, particularly in contexts characterized by high heterogeneity among buyers (Funes-Leal, 2024).

The lack of statistical significance for variables such as breed and more complex genetic indicators in the final model suggests that, once observable productive characteristics and institutional quality signals are controlled for, these attributes do not exert additional robust influence on prices. This result is consistent with evidence pointing to heterogeneity in buyer profiles and limited use of expected progeny differences (EPDs) in decision-making, both in Brazil and in other countries (Ingram et al., 2023; Gatti et al., 2024). In the present study, this "detailed" or "more complex" genetic information refers specifically to the individual outputs of the breed-association genetic evaluation programs—namely the expected progeny differences (EPDs) and their component indices, such as the weaning weight index, together with scrotal circumference as a fertility-related genetic indicator—rather than the single aggregate signal conveyed by the dual brand. These disaggregated indicators were either eliminated by the backward procedure (scrotal circumference and the weaning weight index) or did not exert a robust additional effect on price once the observable productive traits (weight and age) and the aggregate institutional signals were accounted for.

Long-term studies indicate that this behavior may change as producers become more professionalized and more integrated into demanding markets. In Angus auctions in the United States, Tang et al. (2020) and Thompson et al. (2022) observed gradual changes in demand for genetic information, with increasing interest in carcass traits and daughters' milk production, although visual and productive attributes continue to play a central role.

In summary, the results of Model 4 indicate that bull pricing at auctions reflects a combination of immediate productive performance and simplified institutional quality signals, while more detailed genetic

information remains underutilized in the decision-making process. This finding underscores the importance of communication and certification strategies aligned with buyers' profiles.

Conclusions

The results of this study indicate that price formation of bulls at certified auctions is mainly explained by directly observable productive characteristics, such as animal weight and age, combined with simplified institutional quality signals. Model 4, adopted as the final specification, shows that attributes associated with immediate performance and the reduction of productive risks exert a stronger influence on buyers' willingness to pay than more complex genetic indicators.

Among non-productive factors, the dual brand—assigned to animals ranked among the top 30% in evaluation programs—and the presence of awards stand out, both exhibiting positive and statistically significant effects on the final price. These results indicate that formal certification and recognition mechanisms act as important quality signals in the auction environment, contributing to the reduction of information asymmetry and influencing buyers' behavior even after controlling for individual productive characteristics.

Taken together, the findings suggest that, in the analyzed context, detailed genetic information remains underutilized in the decision-making process, while easily interpretable institutional signals play a central role in the valuation of breeding bulls. These results reinforce the importance of communication, certification, and auction organization strategies aligned with buyers' profiles, and point to the potential for diffusion policies aimed at expanding the efficient use of genetic information in beef cattle production. In particular, the genetic information that these results suggest should be considered more systematically at the moment of bull purchase comprises the expected progeny differences (EPDs) and selection indices provided by the breed-association evaluation programs—especially birth weight (as an indicator of calving ease), weaning and post-weaning (yearling) growth, and scrotal circumference (associated with fertility and earlier puberty in daughters), as well as carcass and maternal (milk) traits where these are available—rather than reliance on the aggregate dual-brand classification alone.

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