Economic Value of Expected Progeny Differences (EPDs) of Angus cattle in Argentina

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Abstract

We use data from two distinct sources, Brangus bull sales and Angus semen sales, to estimate hedonic pricing models that establish which traits (observed or genetic) are valued most to set the selling price of a bull. Cattle ranching has been displaced from the Pampas into hotter and drier areas of Northeastern Argentina due to rising land prices. Consequently, several crossbreeds have been introduced to preserve the meat quality of Angus and Hereford bulls while improving the animal's ability to withstand heat stress, mainly by crossing these breeds with Brahman bulls. We find that cattle ranchers prefer observed traits such as weight, coat color, and age, while EPDs have secondary importance after controlling by sire, company, and transaction date. The preference for read-coated bulls is a response to adapting animals to subtropical climates; on the other hand, we argue that the lack of response of price to EPDs may be related to a lack of information about the nature and uses of genetic traits.

Keywords— Hedonic Pricing, Climate Change, Crossbreeding

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1 Introduction

Argentinean cattle ranchers are incentivized to produce larger amounts of beef at increasing quality to compete in the World food markets. In this case, its relevance comes from the fact that it is a historically large beef producer and exporter country. In 2022, Argentina was the sixth largest producer and the fifth largest exporter (USDA, 2023). Argentina's model beef production system consists of grass pastures with feedlots comprising only 28% of the total (Greenwood, 2021). This implies the potential to increase productivity and efficiency through genetic improvement and sustainable production practices without necessarily switching to feedlot production.

Increases in the relative price of land fueled by higher demand for soybeans, mainly from China, and by higher yields due to genetically engineered soybean varieties livestock grazing has been displaced out of the temperate Pampas region (Bustos et al., 2016). This, in turn, fueled the demand for cattle better adapted to drier subtropical weather due to market preference for beef from grass-fed cows.

Demand for new traits drives technological innovations such as crossbreeding and selection; they can be phenotypical, that is, observed, such as the hide color or the sex of genotypical (estimated) based on the Expected Progeny Differences, a measure of the genetic contribution of an animal to the set of genetic traits of its progeny. EPDs are objective measures of an animal controlling for observed traits and the animal's pedigree. EPDs provide helpful information regarding a bull's likelihood to father calves with superior attributes relative to its ancestors. Examples of EPDs are birth weight, weaning weight, and scrotal circumference (Dhuyvetter et al., 2005; Mitchell et al., 2018).

Cattle ranchers also use EPDs to decide which herd traits to select to adapt to production conditions. For example, the demand for specific cattle traits is associated with breeds that exhibit better feed efficiency where food is scarce or under adverse climates (Burrow, 2012). Concerning climate change, animal breeders usually prefer animals with lighter hide colors, such as Red Angus, or new breeds that can adapt better to tropical conditions, such as the Zebu or Nellore breeds in Brazil.

This article estimates the economic value of genetic and non-genetic traits for Angus and Brangus breeds from Argentina. We use the Ladd and Martin (1976) hedonic model, which asserts that the value of an input can be decomposed into the value of each one of its characteristics (Carvalho et al. (2022), for example, follows a similar methodology.) We employ two data sources; for semen sales, we use sire summaries of all Angus bulls offered in 2022. These summaries contain information on a bull's EPDs, the price of a straw of semen, and other characteristics such as the name of the sire and dam and a picture of the animal. Our second data source is cattle auctions of Brangus bulls from a ranch that took place in Córdoba from August each year from 2015 to 2022. It must be noted that the prices charged in the first case are bid prices, that is, the price posted in the sire summary, which may not coincide with the actual price paid but constitutes a reasonable approximation[1]. On the other hand, in the case of cattle auctions for Brangus bulls, the recorded price is the actual price paid by the buyer. Also, a bull is a capital investment; a buyer acquires a stream of profits from such an animal.

Figure 1 shows examples of three different breeds and how much a Brangus bull resembles a mixture of its original breeds.

Figure 1. Aberdeen Angus, Brahman, and Brangus bulls

This article shows how information about genetic traits can help cattle ranchers increase productivity per animal through higher feed efficiency and better health by selecting the best animals (i.e. those with higher trait levels). Finally, higher beef quality can lower processing costs and, thus, increase the performance of the beef industry as a whole.

The remainder of the paper proceeds as follows. Section 2 provides background on the supply and demand for animal characteristics. Next, in section 5, we describe the data in greater detail and then present our empirical results. Finally, Section 6 concludes.

2 Background

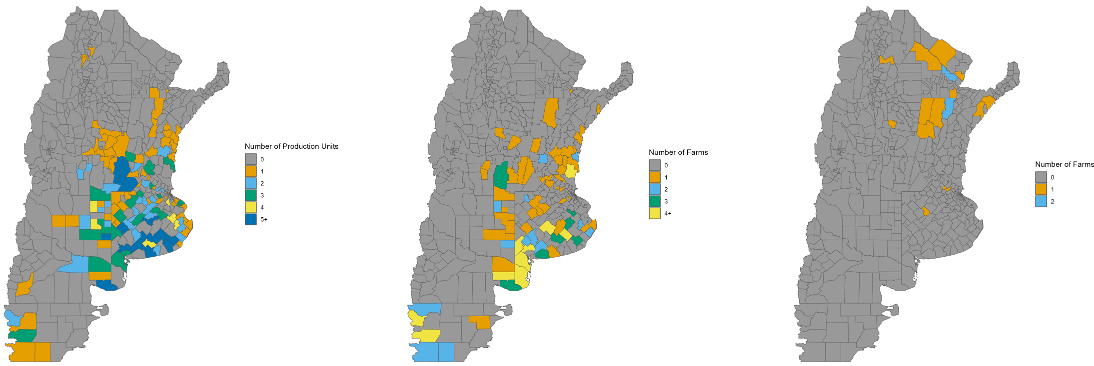
2.1 Cattle Genetics market overview

Crossbreeding is a method for increasing the productivity of cattle genetics, which constitutes a climate-induced innovation by the demand for beef and other factors, such as pasture land availability. Bovine genetics can be marketed as frozen bull semen or service bulls.[2] Bull semen is sold through Artificial Insemination (AI) centers, while Breed Associations carry out bull sales by auctioning their bulls.

Bovine genetics supply is influenced by breeds' geographic distribution (Figure 2). According to the 2018 National Agricultural Census, there are 788 bovine stud farms. Stud farms aim to breed pedigree animals adapted to different climates. Beef cattle in Argentina are from European breeds such as Aberdeen Angus or Hereford. Ranches that keep bulls from these breeds are located mainly in the temperate Pampas region and constitute around 75% of the total number of farms.

[1]One instance where both prices may differ is when genetics companies offer bulk discounts when ranchers buy semen from more bulls from the same company.

[2]Cattle can also be sold as embryos for in-vitro fertilization. Still, it is economically indistinguishable from buying a newly-born bull, except that embryos can be male or female.

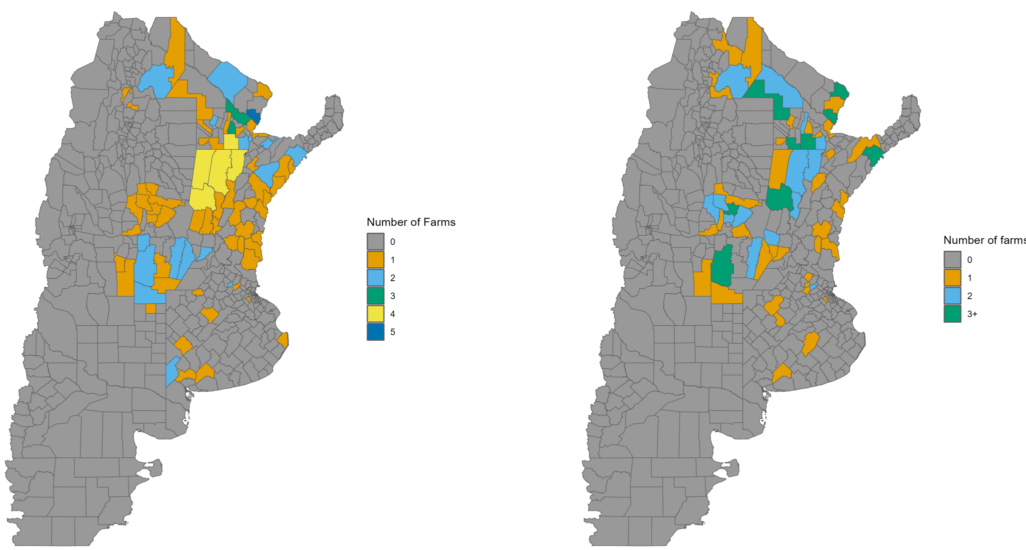


(a) Angus (b) Hereford (c) Brahman

Figure 2. Spatial distribution of farms by breed

Note: Author's calculations from National Agricultural Census data.

On the other hand, ranches that breed Brahman bulls are located in the northeastern region, a much hotter and drier area, which is the climate to which this breed has adapted since it originated from Northern India. Brahman ranches constitute 2.4% of the total, but they are essential to understanding and improving the adaptability of Angus and Hereford breeds to subtropical climates.



(a) Braford (b) Brangus

Figure 3. Spatial distribution of Braford and Brangus ranches

Note: Author's calculations from National Agricultural Census data.

The cattle genetics supply can be expanded to new regions through crossbreeding; Figure 3 shows the spatial distribution of two hybrid breeds: Brangus (Brahman $\times$ Angus) and Braford (Brahman $\times$ Hereford), that constitute 31% of total ranches in Argentina. The geographical distribution of both breeds shows that they are likely to be located in areas where Angus and Hereford bulls are not the first choice of breeds.

Breed	**Number of Farms**
Aberdeen Angus	434
Hereford	140
Braford	117
Brangus	107
Holstein	21
Shorthorn	19
Brahman	18
Limousin	8
Fleckvieh/Simmental	4
Criolla	3
Jersey	3
Brown Swiss	1
Others/Uncategorized	51

Table 1. Number of farms by breed

Note: a farm may keep animals from more than one breed

The demand for cattle genetics comes from cattle farmers who demand genetics through crossbreeding or trait selection. Crossbreeding is a response to long-term demand trends from cattle farmers, and its main objective is to take advantage of **heterosis** (Bourdon, 2000, p. 29), an increase in the performance of hybrids over that of purebreds caused by certain gene combinations. In the case of Brangus animals, they have better survivability in hotter climates than Angus and can gain weight at a faster rate than Brahman bulls. Crossbreeding takes several generations; for example, Brangus and Braford crossbreeds require around ten years to stabilize their phenotypic and genotypic traits due to small initial herd numbers. Once traits are stable, breeders can select these attributes to maximize profits.

3 Hedonic pricing

The most important building block of our analysis is the hedonic pricing model, which asserts that the price of a good or service (livestock genetics in this case) is a function of its intrinsic characteristics (Rosen, 1974). Similarly, the Input Characteristics Model developed by Ladd and Martin (1976) is the theoretical basis for adapting the hedonic pricing framework to input demands. According to this model, the price paid for a unit of the input depends (linearly) on its set of characteristics; consequently, the value of such characteristics can be estimated using a linear regression of the price on their quantities.

Schroeder et al. (1988) adapted this framework to the particular case of feeder cattle pricing, similar to our case, where the price of any lot of cattle depends on the attributes of the animal, which can be observed (weight, age, color, or breed) or estimated (such as the Expected Progeny Differences or selection indexes), as well as market factors such as expectations about input prices, interest rates or beef prices.

In other words, the price of a bull i at time t on market h is the n:

$$r_{it} = f(X_{it}, Z_{ht}) \tag{1}$$

X_{it} are the animal's characteristics and Z_{ht} are the factors affecting market h.

Dhuyvetter et al. (1996) is the first article that includes estimated and observed genetic traits in the pricing equation and additional variables such as the presence of a picture in the bull catalog, sale location, and percentage of semen rights kept by the seller. The authors find that all variables related to the animal's weight are significant (birth weight, weaning weight, and weight EPD), as well as those related to the visual aspect of the animal (color, polled, muscling, and conformation). Concerning market factors, sale location, picture in the catalog, order of sale, and location have significant effects on the price of the animal.

Jones et al. (2008) improve on earlier articles by expanding the set of EPDs and market factors; the most important finding is that weight EPD had a higher value than the observed weight in their sample and predictors of carcass quality. This article also incorporates pedigree into the analysis using sire fixed effects and marketing factors such as order of sale, picture of the animal, and season.

Walburger (2002) shows that the most important traits for Canadian breeders are sale weight, birth weight, scrotal circumference, ribeye area, and weight gain; that is, production and reproductive traits, but the former have increasing importance.

These findings are replicated in other segments of the market, Boyer et al. (2020), studies which factors affect the price of bred heifer prices, particularly months pregnant, lot size, heifer price, and timing of purchase affect their price; the authors also find that the effect of lot size is non-linear on the logarithm of bred heifer price.

Another strand of the literature has focused on dairy bulls (mainly Holstein, but also Jersey and Guernsey), for example, Richards and Jeffrey (1996), who elucidate the impact of production and health traits on the price of bulls' semen[3]. This article finds that production traits (milk yield, protein, and fat content), general conformation (also called "type"), body capacity, and bull popularity significantly impact the animal's price.

The literature survey thus far uses supply data from cattle associations or auctions in different places in North America. Still, other articles investigate the demand side of cattle markets using surveys or choice experiments where researchers can obtain a set of stared preferences. Sy et al. (1997) ran a survey from different segments of the market (purebred breeders, commercial cow-calf producers, and cattle feeders). Each segment prefers a set of traits over another due to its distinct profit maximization objectives. Purebred breeders place more weight on milking ability and weaning weight, cow-calf operators value calving

[3]Because of the nature of dairy farming, it is more common to sell a bull's semen instead of the animal itself (it is not profitable to keep a bull on the herd for a long time)

ease and temperament, while feeders prefer animals with higher slaughter weight and feed efficiency.

Recently, attention has shifted toward video cattle auctions, such as the *Superior Livestock Auction* (Zimmerman et al., 2012), which allows buyers from different locations to participate in the auction via the internet and created a demand for specific management practices such as age and source verification, vaccination protocol compliance, and weight variation certification. Similarly Martinez et al. (2021) shows that feeder cattle were sold at a premium if the animal has been tested for bovine diarrhea virus but also finds a significant impact of corn future prices on the valuation of animals. This set of articles relies on observed traits, not EPDs, and also does not control for the animal's pedigree, only for the region of origin; however, a significant effect is found on the lot size and weight of the bull, both with a quadratic term.

4 Theoretical Framework

4.1 Input Characteristics Model

The Input Characteristics Model from Ladd and Martin (1976) is a neoclassical firm model that assumes the existence of n inputs used to manufacture one unit of a good q that is sold at a price p, let r_i be the price of a unit of the input, which requires a fixed amount of a characteristic, such that ω_{ji} is the amount of characteristic j required to produce one unit of input i, then:

$$\omega_{j.} = \sum_{i=1}^{n} \omega_{ji} x_i \tag{2}$$

The production function depends, in turn, on the entire set of characteristics, such that:

$$q = F(\omega_{1.}, z_{2.}, \ldots, \omega_{m.}) = F\left(\sum_{i=1}^{n} \omega_{1i} x_i, \sum_{i=1}^{n} \omega_{2i} x_i, \ldots, \sum_{i=1}^{n} \omega_{mi} x_i\right) \tag{3}$$

The profit function can be written as:

$$\pi = pF(\omega_{1.}, \omega_{2.}, \ldots, \omega_{m.}) - \sum_{i=1}^{n} r_i x_i \tag{4}$$

The first-order conditions for $i = 1, \ldots, n$ are:

$$\begin{aligned} \frac{\partial \pi}{\partial x_i} &= p \sum_{j=1}^{m} \frac{\partial F}{\partial \omega_{j.}} \frac{\partial \omega_{j.}}{\partial x_i} - r_i = 0 \\ &= p \sum_{j=1}^{m} \frac{\partial F}{\partial \omega_{j.}} \omega_{ji} - r_i = 0 \end{aligned}$$

Solving for r_i, we get:

$$r_i = p \sum_{j=1}^{m} \frac{\partial F}{\partial \omega_{j.}} \omega_{ji} = \sum_{j=1}^{m} \tau_j \omega_{ji} \tag{5}$$

Then, the price of input i is a linear function of the number of characteristics weighted by the value of their marginal product, τ_j.

For the bull sales, the same model holds, but with a small correction, r_i measures the value of the bull over the rancher's investment horizon:

$$r_i = \frac{1}{\rho} \sum_{j=1}^{m} \left(\frac{\partial F}{\partial \omega_{j.}} + \frac{dv}{dt} \right) \omega_{ji} = \frac{1}{\rho} \sum_{j=1}^{m} \tilde{\tau}_j \omega_{ji} \tag{6}$$

Where ρ is the interest rate and $\frac{dv}{dt}$ is the rate of change of the net present value of the bull (Richards and Jeffrey, 1996).

4.2 Empirical Specification

In the context of beef cattle markets, the characteristics described in subsection 4.1 can be classified into two kinds; first, observable characteristics, defined as any trait that can be measured easily and straightforwardly, such as weight, age or color of the animal; and, second, genetic traits, that are statistical estimations calculated from the performance information of an animal relative to its relatives, past and present, controlling for pedigree, age, breed, season, and environmental factors.

These traits are called **Expected Progeny Differences (EPD)** (Bourdon, 2000), and are the genetic value of an animal as a parent, the value of an animal's genotype due to independent and transmittable gene effects. The intuition is that EPDs measure the expected contribution of a bull to his offspring independent of environmental effects. These values are calculated using large-scale genetic evaluations that breed associations typically carry out periodically; results from these evaluations are reported in the **sire summary**, a list of animal traits relative to the average sellers use to market the bull.

Following Pinto et al. (2023), the price of a bull can be decomposed into three kinds of determinants:

1. **Physical traits**: directly observed traits
2. **Genetic traits**: Expected Progeny Differences of the animal's characteristics.
3. **Market determinants**: factors that affect the price not related to the animal's characteristics, such as the firm that markets the bull, the sire (father) of the bull, and the transaction date.

Then the price of a bull i in year t can be described as:

$$\log(r_{it}) = Z_{it}\beta + X_{it}\gamma + M_{it}\delta + \varepsilon_{it} \tag{7}$$

Where r_{it} is the price of the bull, Z_{it} are the genetic traits, X_{it} are observable, and M_{it} are the set of market factors, ε_{it} is the error term.

In our specification, market factors include ranch (τ_i), sire (σ_i), and year (ξ_t) fixed effects; for the auction model and an insemination center fixed effect (δ_i) for the semen sales model. Therefore, the regression models are:

$$\begin{aligned} \log(r_i) &= Z_i\beta + X_i\gamma + \delta_i + \varepsilon_i & (8)\\ \log(r_{it}) &= Z_{it}\beta + X_{it}\gamma + \tau_i + \sigma_i + \xi_t + \varepsilon_{it} & (9) \end{aligned}$$

5 Data and Results

5.1 Angus bull semen sales

Our data comes from the sire catalogs of five artificial insemination centers specializing in Aberdeen Angus bulls. We then use only the subset of animals born in Argentina (121 out of 190 bulls), so their EPDs represent the Argentine herd.

Variable	**Group**
Price (in USD) per 50ml straw	Outcome
Color dummy (= 1 if Red Angus) Birth weight (kg) Weaning weight (kg) Weight at 24 months Scrotal circumference (cm) Age in years	Observed characteristics
Gestation length EPD Birth weight EPD Weaning weight EPD Adult weight EPD Scrotal circumference EPD	Production traits
Height EPD Milk EPD	Calving traits
Ribeye area EPD Hip fat thickness EPD Dorsal fat thickness EPD Intramuscular fat EPD Retailer cuts EPD	Carcass

Table 2. Variable descriptions (Angus)

Table 2 shows the variables included in the analysis, their definition, and their grouping. We use smen prices in US dollars using the average exchange rate with the Argentine peso for

October 2022, when samples were sold. The first group of variables is the set of observable traits; this information is also contained in the sire summary, along with a picture of the bull. The second group of variables is the Expected Progeny Differences, grouped into production, reproduction, and carcass yield.

Statistic	Mean	St. Dev.
Price (USD)	3.10	1.23
Gestation length EPD	−0.28	0.73
Birth weight EPD	−0.36	1.01
Weaning weight EPD	6.62	4.79
Milk EPD	1.69	2.68
Adult weight EPD	21.10	13.70
Scrotal circumference EPD	1.21	0.49
Height EPD	1.55	0.90
Ribeye area EPD	1.71	2.49
Hip fat EPD	0.30	0.34
Dorsal fat thickness EPD	0.74	0.97
Intramuscular fat EPD	0.002	0.06
Retailer cuts EPD	−0.11	0.62
Red Angus	0.48	0.50
Birth weight (kg)	33.80	4.82
Weaning weight (kg)	281.00	54.10
Weight at 24 months (kg)	863.00	124.00
Scrotal circumference (cm)	41.80	1.84
Age	5.61	2.37

Table 3. Descriptive Statistics (Angus bulls)

Table 3 shows the summary statistics for 121 bulls from 5 artificial insemination centers. The average price per straw is 3.1 USD, and almost half of the sample consists of Red Angus bulls. All weight measures are within the standard values for their breed, but their EPDs show that, on average, animals transmit low birth and weaning weight. On the other hand, these bulls show a better maternal aptitude than the average for their breed and better beef quality. A surprising result is that we expect the progeny from these bulls to express 14% lower retailer cuts than the breed average.

	Dependent variable:			
	log(price)			
	(1)	(2)	(3)	(4)
Birth weight in kg	−0.011**	−0.007	−0.006	−0.004
	(0.005)	(0.006)	(0.006)	(0.006)
Weaning weight in kg	0.001**	0.001**	0.001***	0.002***
	(0.0005)	(0.0005)	(0.0005)	(0.0005)
Weight after 24 months in kg	0.0001	0.0001	0.0002	0.0001
	(0.0002)	(0.0002)	(0.0003)	(0.0002)
Scrotal circumference in cm	0.014	0.016	0.015	0.016
	(0.012)	(0.012)	(0.013)	(0.013)
Age in years	0.016*	0.015	0.013	0.012
	(0.010)	(0.010)	(0.011)	(0.011)
Coat (=1 if red)	0.117***	0.115**	0.118**	0.164***
	(0.043)	(0.044)	(0.046)	(0.049)
Gestation length in days		−0.010	−0.008	0.013
		(0.031)	(0.031)	(0.031)
Birth weight EPD		−0.036	−0.037	−0.036
		(0.029)	(0.030)	(0.029)
Weaning weight EPD		0.005	0.006	0.005
		(0.011)	(0.012)	(0.011)
Final weight EPD		−0.002	−0.002	−0.001
		(0.004)	(0.004)	(0.004)
Scrotal circumference EPD			0.018	0.008
			(0.051)	(0.050)
Height EPD			−0.043	−0.053*
			(0.030)	(0.029)
Milk EPD			−0.009	−0.009
			(0.009)	(0.009)
Ribeye Area EPD				0.029***
				(0.010)
Hip fat thickness EPD				−0.197*
				(0.118)
Back fat thickness EPD				−0.022
				(0.033)
Intramuscular fat EPD				−0.592
				(0.360)
% Retailer cuts EPD				−0.143***
				(0.054)
AI Center FE	x	x	x	x
Observations	121	121	121	121
R^2	0.167	0.184	0.207	0.303
Adjusted R^2	0.100	0.085	0.085	0.155
Residual Std. Error	0.225 (df = 111)	0.227 (df = 107)	0.227 (df = 104)	0.218 (df = 99)
Note:				*p<0.1; **p<0.05; ***p<0.01

Table 4. Angus bulls price analysis

Estimated coefficients from the hedonic pricing equation are shown in Table 4; we show four specifications, each incorporating EPDs per group to evaluate the model's sensibility to include further information. These coefficients can be understood as the marginal contribution of each trait to the price of an Aberdeen Angus semen straw. The signs of coefficients behave as expected (positive for productivity-enhancing traits, negative for deleterious traits), but most are not statistically significant. Interestingly, red-coated Angus bulls have a 16.4% higher price than black Angus. Similarly, animals with larger ribeye are EPD have a 2.9% higher price.

	F-Stat		**p-value**	**Result**
Production EPDs	0.69	$(5, 104)$	0.64	Not significant
Calving EPDs	2.13	$(2, 101)$	0.12	Not significant
Carcass EPDs	3.01	$(4, 103)$	0.02	Significant (5%)

Table 5. Hypothesis tests on coefficient groups

In Table 5, we show the coefficient tests per group of variables to test for joint significance of EPDs in column (4) of Table 4, we have that only carcass EPDs are jointly significant, due to the importance of the ribeye area and percent retailer cuts EPDs.

5.2 Brangus bull sales

This section presents the results from a hedonic pricing analysis of Brangus bull characteristics. Our data comes from a stud farm from the Córdoba province and consists of a list of bulls sold in auctions from August of every year from 2015 to 2022. However, we have to remove data for 2015 from the analysis due to a lack of data on coat color; the data is similar to that from Angus Semen because it includes data from EPDs and phenotypical traits.

Definition	**Group**
Price of bull (USD)	Outcome
Color (= 1 if Red Brangus) Birth weight (kg) Final weight (kg) Scrotal circumference (cm) Age (years)	Observed characteristics
Birth weight EPD Weaning weight EPD Final weight EPD Scrotal circumference EPD	Production EPDs
Height EPD Milk EPD	Reproductive EPDs

Table 6. Variable descriptions (Brangus)

Table 6 presents the variables used in the regression and their definition; it also includes the group to which they belong. For the sample of Brangus animals, we do not have a measure of their EPDs related to beef quality for years before 2022, so we dropped them from the analysis.

Statistic	Mean	St. Dev.
Price (USD)	3,279.00	1,198.00
Birth weight EPD	−0.06	0.98
Weaning weight EPD	0.02	1.00
Calving EPD	−0.24	0.96
Milk EPD	−0.16	0.92
Adult weight EPD	0.09	0.99
Scrotal circumference EPD	−0.01	0.96
Scrotal circumference (cm)	39.60	2.39
Age	6.69	2.01
Birth weight (kg)	36.50	4.94
Weaning weight (kg)	756.00	75.80

Table 7. Descriptive Statistics (Black Brangus bulls)

Statistic	Mean	St. Dev.
Price (USD)	3,642.00	1,566.00
Birth weight EPD	0.26	0.86
Weaning weight EPD	0.05	0.86
Calving EPD	−0.08	0.79
Milk EPD	−0.01	0.95
Adult weight EPD	0.04	0.87
Scrotal circumference EPD	0.17	1.00
Scrotal circumference (cm)	39.40	2.09
Age	5.59	1.77
Birth weight (kg)	35.80	4.87
Weaning weight (kg)	752.00	83.10

Table 8. Descriptive Statistics (Red Brangus bulls)

Tables 7 and 8 present summary statistics for 165 black Brangus and 134 red Brangus bulls auctioned from 2016 to 2022. The average price is 3,279 USD per black animal and 3,642 USD per red animal. The average weight is above the breed average, and their EPDs show that these animals have higher than average birth and adult weight and better calving aptitude.

	Dependent variable:			
	log(price)			
	(1)	(2)	(3)	(4)
Birth weight	−0.011***	−0.007**	−0.003	−0.004
	(0.003)	(0.004)	(0.006)	(0.007)
Adult Weight	0.002***	0.001***	0.001***	0.001**
	(0.0002)	(0.0003)	(0.0003)	(0.0003)
Scrotal circumference	0.033***	0.025***	0.023**	0.024**
	(0.007)	(0.008)	(0.010)	(0.012)
Age	−0.174***	−0.173***	−0.161***	−0.115**
	(0.040)	(0.045)	(0.047)	(0.055)
Coat (=1 if red)	0.250***	0.214***	0.211***	0.126
	(0.033)	(0.036)	(0.039)	(0.091)
Birth weight EPD			−0.043	−0.008
			(0.033)	(0.045)
Weaning weight EPD			−5.640	−13.600*
			(7.450)	(8.190)
Final weight EPD			−0.004	−0.029
			(0.033)	(0.044)
Scrotal circumference EPD			−0.003	−0.002
			(0.026)	(0.033)
Maternal EPD			−4.860	−11.700*
			(6.410)	(7.050)
Milk EPD			6.390	15.300*
			(8.380)	(9.230)
Year FE	x	x	x	x
Ranch FE		x	x	x
Sire FE				x
Observations	299	299	299	299
R^2	0.471	0.619	0.626	0.778
Adjusted R^2	0.451	0.495	0.491	0.561
Residual Std. Error	0.257 (df = 287)	0.246 (df = 225)	0.248 (df = 219)	0.230 (df = 151)
Note:				*p<0.1; **p<0.05; ***p<0.01

Table 9. Brangus bulls price analysis

Table 9 presents the coefficients from the hedonic regressions; we use four specifications again, with varying numbers of predictors. From columns (1) to (4), we add a set of year, sire, and ranch fixed effects. Column (4) is the full specification; coefficients signs have the expected signs (similar to those of Angus bulls). Genetic traits related to reproduction are statistically significant (maternal, milk, and weaning weight). There is no effect of coat color on prices; on the other hand, age is significant, and an additional year implies 11.5% lower prices per bull. An additional centimeter of scrotal circumference implies 2.4% higher prices.

6 Conclusion

Phenotypical traits are more relevant as decision variables for cattle ranchers. In general, EPDs are little or insignificant for the price-setting process. This can be attributed to two reasons; one is that we do not know the volume of transactions per bull, which would enable us to ascertain which animals are the most popular; the other reason is that the value of information may be correlated to unobserved variables, that is, demographic and other characteristics of ranchers. Suppose we can capture demographic characteristics related to the production and knowledge of EPDs and how to use them. In that case, we can better understand the effect of farmer types and their preferences concerning investment decisions in genetics.

We used two data sets to determine which genetic attributes are more highly valued by cattle ranchers when deciding which bulls to buy. Our results show that observed traits have a statistically significant effect on the price of an animal, while Expected Progeny Differences mostly do not.

One possible interpretation of this result is that ranchers are still unfamiliar with EPDs and do not use them to base their breeding decisions. Similarly, it may also be the case that genetic traits are not as relevant for beef cattle as they are for dairy cattle; in the dairy industry, all relevant production traits are expressed in females only, and an estimation of the transmitting ability of such traits is needed to determine which traits will the bull's daughter's inherit. For beef cattle, these traits are expressed in both sexes, so a visual evaluation of the bull may provide a sufficient evaluation of his characteristics.

Coat color stands out among the set of observable traits; we argue that this is a consequence of breeding for adaptation to hotter and dryer climates from Northeastern Argentina, where cattle ranching has been displaced due to competition for land with soybeans.

A follow-up of this study will consist of a choice experiment with cattle ranchers to determine whether additional information about EPDs would change their decision when deciding which animal to buy. This experiment will also survey individuals about their knowledge of genetic traits and how to use them.

References

Bourdon, R.M., *Understanding Animal Breeding*, Prentice Hall, 2000.

Boyer, Christopher, Kenneth Burdine, and Kevin Laurent, "Factors influencing bred beef heifer sale prices in a sequential auction," *Applied Animal Science*, 2020, *36* (5), 754–759.

Burrow, H.M., "Importance of adaptation and genotype × environment interactions in tropical beef breeding systems," *Animal*, 2012, *6* (5), 729–740.

Bustos, Paula, Bruno Caprettini, and Jacopo Ponticelli, "Agricultural Productivity and Structural Transformation: Evidence from Brazil," *American Economic Review*, June 2016, *106* (6), 1320–65.

Carvalho, Glauco Rodrigues, Weslem Rodrigues Faria, Vinícius Pimenta Delgado Ribeiro Nardy, and Admir Antonio Betarelli Junior, "Hedonic pricing analysis for semen of dairy bulls in Brazil," *PLOS ONE*, 04 2022, *17* (4), 1–17.

Dhuyvetter, Kevin C., R. Jones, T. Turner, and T. Marsh, "Economic values associated with expected progeny differences (EPD) for angus bulls at auction," Technical Report, Kansas Agricultural Experiment Station Research Reports 2005.

_ , Ted C. Schroeder, Danny D. Simms, Ronald P. Bolze, and Jeremy Geske, "Determinants of Purebred Beef Bull Price Differentials," *Journal of Agricultural and Resource Economics*, 1996, *21* (2), 396–410.

Greenwood, Paul L., "Review: An overview of beef production from pasture and feedlot globally, as demand for beef and the need for sustainable practices increase," *Animal*, 2021, *15*, 100295. Sustainable livestock systems for high-producing animals.

Jones, Rodney D., Tyler Turner, Kevin Dhuyvetter, and Thomas Marsh, "Estimating the Economic Value of Specific Characteristics Associated with Angus Bulls Sold at Auction," *Journal of Agricultural and Applied Economics*, 2008, *40* (1), 45528.

Ladd, George W. and Marvin B. Martin, "Prices and Demands for Input Characteristics," *American Journal of Agricultural Economics*, 1976, *58* (1), 21–30.

Martinez, Charles C., Christopher N. Boyer, and Kenneth H. Burdine, "Price Determinants for Feeder Cattle in Tennessee," *Journal of Agricultural and Applied Economics*, 2021, *53* (4), 552–562.

Mitchell, James L., Derrell S. Peel, and B. Wade Brorsen, "Price Determinants of Bred Cows," *Journal of Agricultural and Applied Economics*, 2018, *50* (1), 64–80.

Pinto, Allan F., Brittney K. Goodrich, William Kelley, and Max Runge, "Price determinants of bred heifers: Do reputations matter?," *Canadian Journal of Agricultural Economics/Revue canadienne d'agroeconomie*, 2023, *71* (1), 5–23.

Richards, Timothy J. and Scott R. Jeffrey, "Establishing Indices of Genetic Merit Using Hedonic Pricing: An Application to Dairy Bulls in Alberta," *Canadian Journal of Agricultural Economics/Revue canadienne d'agroeconomie*, 1996, *44* (3), 251–264.

Rosen, Sherwin, "Hedonic Prices and Implicit Markets: Product Differentiation in Pure Competition," *Journal of Political Economy*, 1974, *82* (1), 34–55.

Schroeder, Ted, James Mintert, Frank Brazle, and Orlen Grunewald, "Factors Affecting Feeder Cattle Price Differentials," *Western Journal of Agricultural Economics*, 1988, *13* (1), 71–81.

Sy, Hamath A., Merle D. Faminow, Gary V. Johnson, and Gary Crow, "Estimating the Values of Cattle Characteristics Using an Ordered Probit Model," *American Journal of Agricultural Economics*, 1997, *79* (2), 463–476.

USDA, "Production, Supply and Distribution (PSD) data," https://apps.fas.usda.gov/psdonline/app/index.html#/app/home 2023. Accessed: 2023-02-10.

Walburger, Allan M., "Estimating the Implicit Prices of Beef Cattle Attributes: A Case from Alberta," *Canadian Journal of Agricultural Economics/Revue canadienne d'agroeconomie*, 2002, *50* (2), 135–149.

Zimmerman, Lance C., Ted C. Schroeder, Kevin C. Dhuyvetter, K. C. Olson, Gerald L. Stokka, J. T. Seeger, and D. M. Grotelueschen, "The Effect of Value-Added Management on Calf Prices at Superior Livestock Auction Video Markets," *Journal of Agricultural and Resource Economics*, 2012, *37* (1), 128–143.