# Economic Value of Brangus Cattle Traits in Argentina

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**Abstract**

Starting in the early 2000s, a boom in demand for agricultural commodities displaced cattle ranching out of the most productive areas of the Pampas' prairie. The crossbreeds between Angus and Hereford with Brahman, i.e., Brangus and Braford, have been successfully adopted across Argentina. However, little is known about the specific bulls' traits that drive the demand for genetic selection of cattle outside the Pampas. Obtaining the economic value of traits would help to identify the demand for adapting livestock production to different ecosystems while preserving the meat quality of Angus and Hereford cattle. We estimated hedonic price models using Brangus bull sales data from two cattle breeding ranches in the north of Cordoba province. We find that cattle ranchers prefer observed traits such as weight, coat color, and age, while genetic indicators such as Expected Progeny Differences (EPDs) have secondary importance. We argue that stronger preferences for read-coated bulls, as opposed to black-coated bulls, could be associated with the demand for reducing heat stress; the weak association between EPDs and prices may be related to unobservable variables such as ranchers' characteristics and that the value of genetics is implicit in the studs' reputation.

***Keywords***— Hedonic Pricing, Auctions, Technology Adoption, Climate adaptation
JEL Classification: Q12, Q13, Q16

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# 1 Introduction

Cattle adaptation to new environments is a possible pathway for increasing productivity and meat supply. In Argentina, changes in relative prices between agriculture and livestock pushed cattle ranching out from the core of the Pampean prairie to other regions of the country (Reca et al., 2010). The demand for adaptation in less productive areas, such as subtropical regions, created the economic opportunity to develop new synthetic breeds, like Brangus and Bradford. These breeds preserve the meat quality of Angus and Hereford bulls while improving the animals' ability to withstand heat stress, mainly by crossing these breeds with Brahman bulls. Estimating the value of bull characteristics will help ranchers make investment decisions in genetics.

While there is evidence of the adoption of crossbreeds, there is little to no information on the economic value of crossbreed traits in Argentina. Argentina's relevance in beef markets is two-fold. First, Argentina is a historical producer and exporter of beef. In 2022, Argentina was the sixth producer and fifth exporter country USDA (2023). Like other producing nations from the developing world, its modal production system relies predominantly on pastures rather than feedlots (Greenwood, 2021). The latter is relevant because there is potential for productivity and efficiency gains from introducing changes to genetics in harmony with sustainable production practices. Second, because of its location, Argentina has the ecosystems to adapt breeding options for mild and subtropical weather, with the potential of developing and exporting cattle genetics to different parts of the world.

This article aims to estimate the economic value of genetic and non-genetic traits for Brangus bulls in Argentina. Ranchers select bulls according to their preferences for traits. A trait is any characteristic of the animal that has an intrinsic value. They can be phenotypical, observed, such as the hide color or sex, or genotypical (estimated) based on the Expected Progeny Differences (EPDs). EPDs are measures of the genetic contribution of an animal to the set of genetic traits of its progeny. These indicators 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). For instance, a farmer looking to reduce birth complications would select a bull with a negative birth weight EPD. Incorporating that characteristic in the herd is intended to reduce the time of vigilance of calving cows.

We hypothesize that EPDs' economic value is affected by farmers' objectives and characteristics. The use of EPDs for bull selection is a new tool, and its value comes from improving precision for genetic information and investments. If EPDs are superior technology compared to bulls' visual aspect and own data, we should have observed widespread adoption; however, this is not the case. Foundational research in agricultural economics shows that technology is not a random process, and availability does not necessarily imply adoption (Hayami and Ruttan, 1985; Schultz, 1983; Sunding and Zilberman, 2001). At some point, top farmers adopt first, and other farmers are followers. Innovative farmers are less risk-averse and have lower adoption costs, giving genetic information relevance in bull selection. Traditional farmers' choices are based on a combination of visual inspection and phenotypical bull data. It takes more time than top farmers to adopt new tools. Hence, we should expect a coexistence of farmers with different levels of technology adoption.

We use a hedonic price model to estimate the value of EPD information. We follow the Ladd and Martin (1976) approach, which asserted that the value of an input can be decomposed into the value of each one of its characteristics. We employ cattle auction data of Brangus bulls' auctions from 2015 to 2022. Our dataset has bull sales price, their phenotypical attributes, and EPD information. Our results show that phenotypical traits are more relevant than EPDs as decision variables for cattle ranchers. We find that cattle ranchers prefer observed traits such as weight, scrotal circumference, and coat color, while EPDs have secondary importance after controlling by sire, stud, and pedigree. In general, EPDs seem less relevant for the price-setting process than phenotypical traits; however, they are more important by groups. Production and reproductive traits taken together are statistically significant. We argue that the preference for red-coated bulls is a response to adapting animals to subtropical climates. Conversely, the weak association between bulls' prices and EPDs may be related to a lack of information about the nature and uses of genetic traits.

Our results contribute to understanding the process of technology adoption in cattle production. We provide evidence that, while genetics tools and information are available, they are still not fully adopted. Our results indicate that there is still room for breeding programs to work on extension and education about new traits and breeds. Moreover, we generate evidence regarding the economic value of attributes of the Brangus breed, which has yet to be explored in the literature. Producers could benefit from obtaining information on animal genetic attributes to increase productivity per hectare, feed efficiency, and livestock quality. Likewise, the industry could benefit from cattle with genetic improvements resulting in better meat quality and quality that facilitates processing.

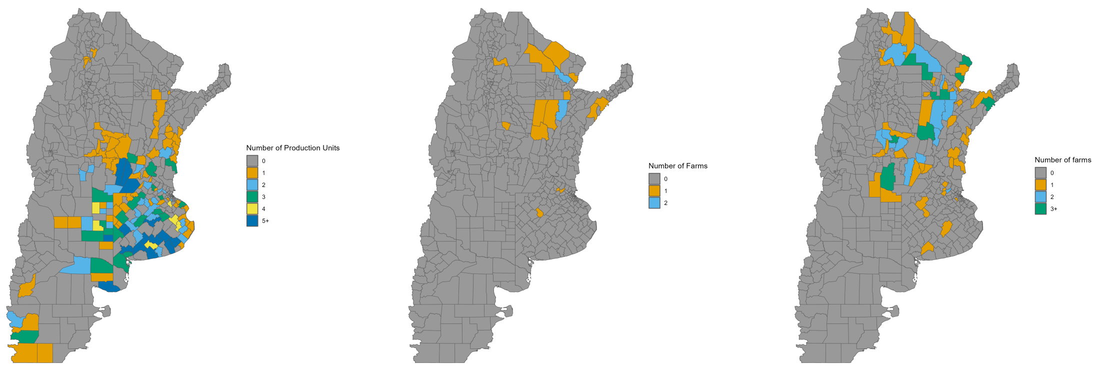
## 2 Beef Cattle Genetics Market in Argentina

### 2.1 Supply of Beef Cattle Genetics

The genetics supply is comprised of studs that develop genetics to sell service bulls and heifers, semen, and embryos to commercial ranches, the demand for genetics (Etcheverry, 2009). A series of factors influence beef supply; chiefly among them is the existence of diverse breeds. 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 grassland and pasture availability (Espasandín and Ducamp, 2004). Cattle breeders and feeders demand high-productivity bulls that increase the efficiency of their herds and sell their meat to domestic and foreign markets (Marcantonio, 2017).

Beef cattle genetics in Argentina have been historically based on European breeds such as Aberdeen Angus and Hereford. Because of the demand for adaptation, some studies have developed Brahman genetics. Ranches that breed Brahman bulls are mainly located in the northeastern region of Argentina, which observes subtropical conditions that are less suitable for Angus or Hereford. According to the 2018 National Agricultural Census, there are 788 bovine studs. Studs that keep bulls from these breeds are located mainly in the temperate Pampas region and constitute around 75% of the supply. Brahman studs constitute 2.4% of the total, but they are essential to improving the adaptability of Angus and Hereford breeds to subtropical climates.

The different climates strongly influence bovine genetics supply spatial distribution (Figure 1). Firms aim to breed pedigree animals adapted to the ecosystem where they are located. Ranchers in the area might be interested in buying bulls adapted to the productive environment. This is important because the bull will be responsible for 50% of the genetics of the future herd. If that herd receives traits that are not suitable, it may harm productivity and ranchers' future income. The two main crossbreeds are Brangus (Brahman × Angus), and Braford (Brahman *times* Hereford) expanded beef cattle production to new areas. Figure 2 shows examples of three different breeds and how much a Brangus bull resembles a mixture of its original breeds. Brangus and Braford breeds constitute 31% of stud farms in Argentina. The geographical distribution of both breeds shows they are in areas where Angus and Hereford bulls are not the first choices.




(a) Angus (b) Brahman (c) Brangus

Figure 1. Spatial distribution of farms by breed

**Note**: Author's calculations from 2018 National Agricultural Census data.

(a) Angus bull[1] (b) Brahman[2] (c) Brangus[3]

Figure 2. Typical visual characteristics of all three breeds

## 2.2 Demand for Cattle Genetics

The demand for cattle genetics comes from cattle farmers who purchase bulls for crossbreeding and trait selection. Crossbreeding is a response to long-term demand trends from cattle farmers, and its main objective is to take advantage of heterosis, an increase in the performance of hybrids over that of purebreds caused by specific gene combinations (Bourdon, 2000, p. 29). 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

[1] https://domesticanimalbreeds.com/angus-cattle-breed-everything-you-need-to-know/

[2] https://brcutrer.com/health-and-wellness-with-brahman-cattle/

[3] https://www.bovine-elite.com/shop/beef-semen-sales-registered/brangus-black/mr-new-blood-50h/

traits are stable, breeders could use them in a genetic plan to select attributes they want to improve in their herd. For instance, Brangus has received increased attention in Argentina because of its adaptation to different climates. The Brangus herd book, which approximates the breed presence in the national herd, shows an increase of 5.9% on average in the number of calves under the Brangus genetic evaluation in the last 20 years (Figure 3).

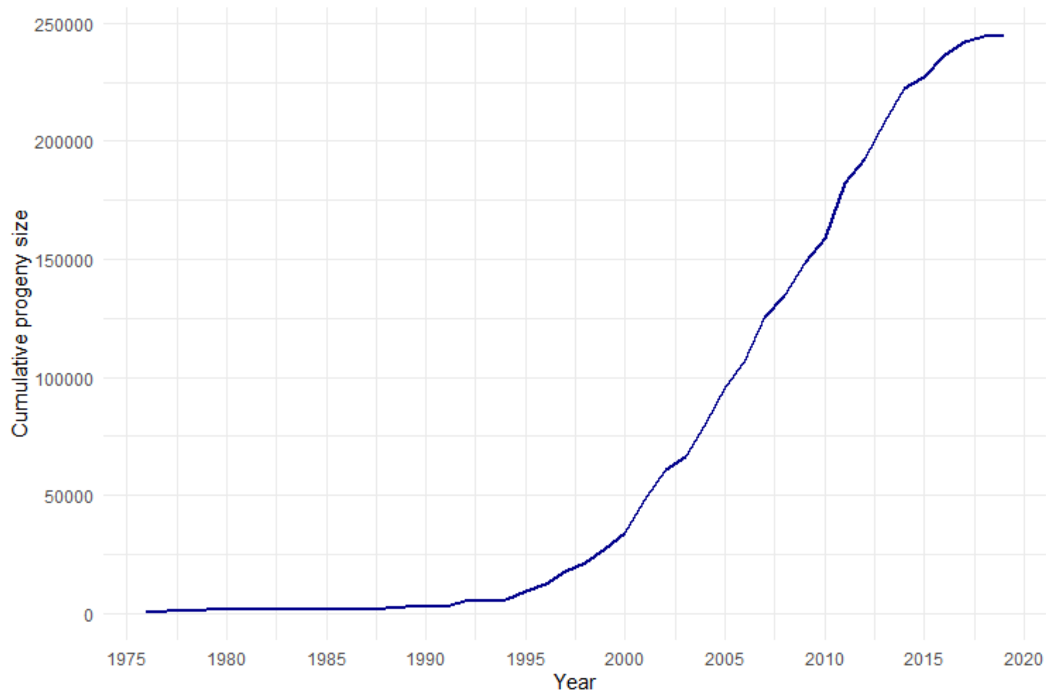



Figure 3. Number of calves by bulls' birth year present in the Brangus herd book

In Argentina, cattle studs sell bulls through auctions or direct sales to commercial ranches. Breeders' Associations sponsor the auctions to signal the quality of bulls. Further, two types of bull are sold on whether they have complete or incomplete genetic data. Those with complete ancestry and pedigree data are purebred animals registered in the breed registry of the corresponding association. The main buyers of purebred bulls are other studs interested in reproducing them and offering more bulls for commercial ranches. The other type of bull offered in sponsored auctions are animals with incomplete data that have passed a visual inspection and gene testing; these are marketed as pure controlled animals. These bulls are generally cheaper than purebred animals and the primary alternative for cow-calf operators interested in investing in genetics.

Conditional to having or choosing a breed for the herd, farmers would select the bulls according to their preferences. Service bulls are the most common option for commercial

[3]Source: Own calculations based on the 2023 Brangus Association herd book. Available at: https://brangus.org.ar/programa-erbra/

ranchers interested in investing in genetic improvement. Several attributes matter in selecting the best bull. We can divide these aspects into (i) visual characteristics that describe bulls' breeding ability associated with their biological type and age; (ii) phenotypical traits are observed characteristics of bulls that are generally associated with their productive and reproductive abilities; and (iii) genetic traits which are objective measurements performed on pedigree cattle with genomic tests to determine their ability to pass certain traits to future generations.

Genetic traits are called Expected Progeny Differences (EPD) 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 (Bourdon, 2000). The intuition behind these estimations is that after controlling for all possible environmental factors that affect the characteristics of an animal, we end up with a portion of the variation in the value of each trait that can only be attributed to the inheritance of the animal's parents. 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. Examples of EPDs match phenotypical data of the bull, such as birth weight, weaning weight, and scrotal circumference, or meat carcass attributes, such as ribeye area (Dhuyvetter et al., 2005; Mitchell et al., 2018). For instance, selecting bulls with a negative birth weight EPD increases the probability of having lower birth weight in calves, which could facilitate births and reduce costs for farmers. Further, its correlation with a high EPD weaning weight would increase the chances of increasing calves' weight-gaining productivity.

# 3 Theoretical Framework

## 3.1 Hedonic pricing model

We introduce the hedonic pricing model, suitable for estimating the demand for cattle traits as an input of the commercial ranchers' production function. The hedonic pricing model 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 on its set of characteristics; consequently, the value of such characteristics can be estimated using a linear regression of the price on their quantities. Dhuyvetter and Schroeder (2000) 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:

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

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

The literature on hedonic pricing has looked at the market value of cattle traits. (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. In dairy markets, Richards and Jeffrey (1996) elucidate the impact of production and health traits on the price of bulls' semen. 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 uses data from cattle associations or auctions in different places in North America. Walburger (2002) showed that the most critical 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. For instance, Boyer et al. (2020) studied which factors affect the price of bred heifer prices, particularly months of pregnancy, lot size, heifer price, and timing of purchase affect their price: the authors also found that the effect of lot size is non-linear on the logarithm of bred heifer price.

Another strand of literature has investigated the demand side of cattle markets using surveys or choice experiments. 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 one 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 ease and temperament, while feeders prefer animals with higher slaughter weight and feed efficiency.

Recently, attention has shifted toward evaluating the impact of 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. Video auctions 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) show 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.

## 3.2 Input Characteristics Model

To model the demand for cattle traits, we use 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 $\omega_{ji}$ 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, $\tau_j$.

### 3.3 Empirical Specification

We estimate the input characteristics hedonic model for identifying where the price of a bull $i$ in year $t$ can be described as:

$$log(price_{it}) = \mathbf{X}_{it}\gamma + \mathbf{Z}_{it}\beta + D_i\gamma + \sigma_i + \rho_t + \varepsilon_{it} \tag{6}$$

Where $price_{it}$ is the price of the bull, $\mathbf{X}_{it}$ is a set of phenotypical traits, $\mathbf{Z}_{it}$ is a vector of genetic traits. In our model, $\mathbf{X}_{it}$ includes the animal's weight, age, or color, which indicates the bull's condition and characteristics. The second group of variables, genetic traits ($\mathbf{Z}_{it}$), 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 data represent the potential of the bull to pass features to its progeny. Since EPD values do not observe significant variation within a stud and are strongly correlated, we include them as dummy variables that take a value of 1 if the EPD is above the median and 0 otherwise. In addition, we incorporate a vector of dummy variables to control differences in stud characteristics ($stud_i$) and the genetic quality of the bulls ($PP_i$). Specifically, the latter takes a value of 1 if the bull is Pure Pedigree (PP) and 0 if it is a Pure Controlled (PC) bull. Lastly, to control potential differences in auctions by year, we include a set of fixed effects, including sire ($\sigma_i$) fixed effects, and year ($\rho_t$) fixed effects, and, $\varepsilon_{it}$ is the error term[4]

## 4 Data

Our data consists of a list of bulls sold in auctions in August of every year from two studs in the Northwestern districts of Córdoba, Argentina. One has records from 2015 to 2022, while the other goes from 2018 to 2022. Both studs have more than 20 years of auctioning bulls and heifers to ranchers from the northwest of that province. They sell Brangus bulls suitable for

[4] See Appendix A for more details.

ranchers in the region, but also for ranches in the northern provinces of Argentina, Paraguay, and south of Brazil.

We used the price and their phenotypical and EPD information for each bull. The phenotypical variables available are coat color, which takes a value of one if it is red, 0 if it is black, weight of the bull in kilograms, scrotal circumference in centimeters, and age in years. The estimated genetic data contains two indicators: productive and reproductive EPDs. The first group indicates the potential growth attributes to be passed to the calves of the bull, which includes birth, weaning, and final weight progeny potential. The second group indicates the ability of the bull to transmit reproductive features, and it contains the scrotal circumference and maternal aptitude of heifers. The scrotal circumference EPD is associated with improving male progeny fertility and early precocity in female progeny. Maternal EPD indicates the potential for producing more kilograms at weaning because of cows' milk production.

Table 1 presents summary statistics for 723 Brangus bulls auctioned from 2015 to 2022 and a comparison with the EPDs of the base population of the Brangus herd book[5]. Descriptive statistics show that the weight of the bulls is 750 kilograms, they are 2.2 years old, and the scrotal circumference is 39 centimeters. In our sample, 33% of the bulls have a red coat, while the remaining animals are black Brangus. We use the EPD herd book averages to show whether auctioned bulls are representative of the national supply of Brangus genetics. We can interpret EPDs as deviations from the herd book-based population. Specifically, these bulls give calves with birth weights about the breed's average (+0.08). Calves may gain 9 kilograms on average at the weaning stage, while the final adult weight would be 19.9 kilograms on average. The reproductive EPDs show that bulls have good qualities regarding scrotal circumference (+0.02 cm) and weaning weight gains because of milk production from the maternal EPD (+0.51 kg). On average, auctioned bulls have birth weight EPDs (+0.23) above the national average (+0.13).

[5]The herd book dataset has the EPD for all the registered bulls of the breed in Argentina; however, the dataset has no prices.

| | Herd book average | Mean | SD | Min | Max |
|---|---|---|---|---|---|
| Bull Price (USD) | | 3029.75 | 1193.52 | 1274.36 | 10590.06 |
| Weight (kg) | | 750.04 | 86.92 | 557.00 | 1035.00 |
| Scrotal Circumference (cm) | | 39.31 | 2.33 | 34.00 | 48.00 |
| Age (years) | | 2.24 | 0.37 | 1.65 | 3.34 |
| Color (= 1 if red, = 0 if black) | | 0.33 | 0.47 | 0 | 1 |
| Birth Weight (EPD) | 0.13 | 0.21 | 0.85 | −3.19 | 3.25 |
| Weaning Weight (EPD) | 8.20 | 9.54 | 3.93 | −2.76 | 24.59 |
| Final Weight (EPD) | 17.59 | 19.93 | 7.26 | −2.78 | 49.34 |
| Scrotal Circumference (EPD) | 0.91 | 0.93 | 0.60 | −0.91 | 3.97 |
| Maternal (EPD) | 2.85 | 3.36 | 1.59 | −4.13 | 9.02 |
| $Stud_i$ (=1, if stud 2) | | 0.50 | 0.50 | 0.00 | 1.00 |
| $PP_i$ (=1, if Purebred) | | 0.86 | 0.34 | 0.00 | 1.00 |
| Observations | | 723 | | | |

Note: Brangus population averages are extracted from the 2022 herd book.
Available at: https://brangus.org.ar/programa-erbra

Table 1. Descriptive Statistics

## 5 Results

This section presents the results from a hedonic pricing analysis of Brangus bull characteristics. Table 2 shows the coefficients from the hedonic regressions; we use four specifications with varying numbers of predictors. From columns (1) to (5), we add the dummies for studs, purebred year, and sire fixed effects. All the estimations have standard deviations robust to heteroskedasticity. We show the $R^2$ and the adjusted $R^2$[6]. Column (5) is the complete and preferred specification because it has the highest $R^2$.

We find that coefficient estimates associated with bulls' traits are not significantly affected by the incorporation of fixed effects. There is a positive effect of weight, scrotal circumference, and coat color on prices that remain statistically significant after incorporating fixed effects. An additional kilogram increases bulls' price by 0.1%. The age coefficient implies that an additional year implies 10% lower prices per bull. An extra centimeter of scrotal circumference implies 2.2% higher prices. Lastly, having a red coat implies 11% higher prices than a black Brangus bull. This shows that phenotypical characteristics are associated with

[6] We show the correlation matrix between explanatory variables and the Variance Inflation Factor from our estimates in Appendix A

bull prices individually.

In columns (2) to (5), the addition of fixed effects affects the statistical significance of the EPD. Results show that these attributes are sensitive. Specifically, an above-the-median birth weight EPD is associated with a bull price 4% lower than bulls with EPD values below the median. The negative association in this case is expected because a higher-than-average birth weight increases birth problems for ranchers. A higher weaning weight EPD is expected to be positively associated with price because cow-calf operators want to obtain heavy calves. The weaning weight EPD median coefficient shows that bulls with these values have 6% higher prices than bulls below the median. Genetic traits related to reproduction are statistically significant and imply a price 5% higher than below-the-median bulls, respectively (scrotal circumference and maternal EPDs).

| | *Dependent variable:* | | | | |
|---|---|---|---|---|---|
| | log(*price*) | | | | |
| | (1) | (2) | (3) | (4) | (5) |
| Weight (kg) | 0.001*** | 0.001*** | 0.001*** | 0.001*** | 0.001*** |
| | (0.000) | (0.000) | (0.000) | (0.000) | (0.000) |
| Scrotal circumference (cm) | 0.033*** | 0.033*** | 0.029*** | 0.025*** | 0.022*** |
| | (0.006) | (0.006) | (0.005) | (0.005) | (0.006) |
| Age (years) | −0.102** | −0.119*** | −0.121*** | −0.146*** | −0.105** |
| | (0.040) | (0.040) | (0.038) | (0.043) | (0.044) |
| Color (=1 if red) | 0.171*** | 0.133*** | 0.185*** | 0.174*** | 0.110*** |
| | (0.023) | (0.023) | (0.021) | (0.021) | (0.039) |
| Birth weight EPD | −0.075*** | −0.076*** | −0.056*** | −0.052** | −0.040* |
| (= 1 if above median) | (0.024) | (0.023) | (0.021) | (0.021) | (0.022) |
| Weaning weight EPD | 0.061** | 0.068*** | 0.055** | 0.059*** | 0.055** |
| (= 1 if above median) | (0.027) | (0.025) | (0.023) | (0.022) | (0.025) |
| Final weight EPD | 0.008 | −0.008 | −0.006 | −0.013 | −0.010 |
| (= 1 if above median) | (0.028) | (0.026) | (0.023) | (0.023) | (0.026) |
| Scrotal circumference EPD | −0.055** | −0.070*** | −0.032 | −0.026 | −0.038 |
| (= 1 if above median) | (0.024) | (0.023) | (0.020) | (0.021) | (0.023) |
| Maternal EPD | 0.123*** | 0.091*** | 0.058*** | 0.044** | 0.031 |
| (= 1 if above median) | (0.021) | (0.021) | (0.020) | (0.020) | (0.025) |
| $Stud_i$ | | 0.153*** | 0.047* | 0.028 | 0.037 |
| | | (0.022) | (0.025) | (0.026) | (0.055) |
| $PP_i$ | | | 0.116*** | 0.110*** | 0.084** |
| | | | (0.027) | (0.023) | (0.041) |
| Lot order FE | | | | X | X |
| Sire FE | | | | | X |
| Observations | 723 | 723 | 723 | 723 | 723 |
| $R^2$ | 0.288 | 0.336 | 0.348 | 0.495 | 0.631 |
| Adjusted $R^2$ | 0.279 | 0.326 | 0.338 | 0.482 | 0.535 |
| *Note:* | *p<0.1; **p<0.05; ***p<0.01 | | | | |

Table 2. Brangus bulls price analysis

Joint F tests show that while some traits might not be significant individually, they are relevant by group. Table 4 presents hypotheses testing to assess whether groups of traits are statistically significant using the estimates in column 5 from Table 2. This test is performed to verify whether the attributes have a joint association with prices. The results show that the coefficients related to phenotypical traits and EPDs are statistically significant by group at different p values.

| | **F-Stat** | **p-value** | **Result** |
|---|---|---|---|
| Phenotypical traits | 39.54 | 0.00 | Significant at 1% |
| Production EPDs | 2.22 | 0.08 | Significant at 10% |
| Reproductive EPDs | 3.85 | 0.02 | Significant at 5% |
| All EPDs | 2.61 | 0.02 | Significant at 5% |

Table 3. F-test by groups of coefficients

## 6 Discussion

Our results suggest different levels of analysis regarding the value of genetic traits. First, one feature of our analysis is that phenotypical traits are more relevant as decision variables than genetic traits for purchasing a bull. When taken individually, EPDs are generally less relevant for the price-setting process than phenotypical traits. The latter could be due to three reasons. First, the co-existence of ranchers interested only in phenotypical attributes and those looking at both traits. Second, the variability of EPD values is small, i.e., often estimated with low precision, which may mask the fact that the value of genetics may come from the stud's reputation and not from specific traits. Third, there are different types of buyers, characteristics, and objectives, which we do not have available in our data.

The first reason is related to investments in human capital. More sophisticated ranchers may emphasize reading EPDs before making decisions, while others may only look at visual characteristics and the bull's behavioral data. The more dimensions or traits to look at before choosing bulls, the more investment in human capital is required. For instance, buying a bull with the potential of reducing the average weight of calves may come with correlations with other genetic traits that may express themselves in calves. For instance, a bull with birth weight EPD lower than the average could come with low weaning weight EPD. The investment might be affected negatively if the rancher had good weaning weight. Hence, buying bulls requires understanding complex genetic correlations.

Further, EPD traits do not vary significantly within studs, and their low precision could affect their value. The value of traits looks relatively small because the demand is conditional on the studs' reputation. It is reasonable to think that farmers understand that studs have good-quality bulls. Conditional to the decision to participate in the auction, farmers would look at phenotypical and visual attributes because they already know that these studs have good genetics. Smith et al. (2023) studied Genomically-Enhanced EPDs (GE-EPDS), traits estimated using genomic tests on newborn calves, pedigree, and performance data to increase the accuracy of regular EPDs. They observe that all "traditional" EPDs positively and significantly affect the willingness to pay for genetic traits[7]. In contrast, GE-EPDs do not appear to convey any additional value. The authors argue that this result results from buyers deciding first on a specific value for certain EPDs to choose bulls. A possible explanation is that there is a lack of information on interpreting the accuracy of EPDs while such values are reported as necessary for ranchers' decision-making process.

Several articles have dealt with the limited statistical significance of EPD valuations on bull prices, at least in the American context. Boyer et al. (2019) used panel data of bull auction sales and EPDs from Tennessee and found that producers value traits directly related to their profits. Specifically, calving ease and a measure of projected growth, i.e., weaning weight EPD minus birth weight EPD, have a positive and significant effect on the bull's price. However, the bulk of the impact on prices is explained by two observed traits: average daily gain and frame score.

Tang et al. (2020) showed evidence of grid pricing allowing for EPDs to signal the quality of a bull, but it is not conclusive since the sign of such changes is not monotonic across the period. The authors examine bull buyers' marginal valuations of bull attributes over time as a response to grid pricing, a pricing scheme where a bull's base price is subject to premiums or discounts for carcasses above and below a base or standard set of quality specifications. If buyers become more familiar with EPDs for specific traits, their valuations must increase accordingly. They show that birth weight EPD is the only trait systematically significant across periods (but with a negative coefficient). At the same time, maternal milk EPD is substantial mostly in the latter years, while marbling and ribeye area are primarily insignificant, particularly for latter periods.

Similarly, Thompson et al. (2022) looked at the determinants of bulls' prices in traditional vs. genomic EPDs and observed characteristics with auction data. The influence of genomic traits is measured through an interaction term. In this data set, authors find a similar result: genomic-enhanced EPDs do not significantly affect the price beyond that of traditional EPDs. Moreover, only birth weight and ribeye area EPDs are found to have a statistically significant effect on the price of a bull. Also, the genomic-enhanced weaned calf value is statistically significant. The authors find that observed traits such as weight, age, scrotal circumference,

[7] Calving ease, weaning weight, docility, milk, mature and carcass weight, ribeye area, and weaned calf value.

and intramuscular fat explain most of the variation in bull prices.

The demand for traits is related to ranchers' characteristics, which is a data limitation of our study. We cannot separate between breeding, cow-calf operators, or feeder cattle ranchers. The three types of buyers might have different preferences. For instance, while a cow-calf might be interested in low birth weight to reduce costs, feeder cattle ranchers might look at attributes related to rapid weight gain. We do not have demographic and production characteristics that might affect the demand for EPDs. With that data, we could further investigate and better understand the effect of farmer types and their preferences concerning genetic investment decisions.

## 7 Conclusion

In this paper, we investigate the determinants of Brangus bull prices in auctions from Northwestern Córdoba to determine which attributes are more highly valued by cattle ranchers. Understanding these relationships would help to know the potential for breeding and trait selection in areas where production conditions are arid or semi-arid. Moreover, it can increase beef production by incorporating new lands into production and productivity through technical efficiency. 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 daughters inherit. For beef cattle, these traits are expressed in both sexes, so a visual evaluation of the bull may provide a sufficient evaluation of its characteristics.

Coat color stands out among the set of observable traits; we argue that the demand for coat color could be associated with adapting to hotter and dryer climates in northern Argentina. Due to the competition for land with agricultural commodities, cattle have been adapted to these areas. However, from our results, we see that productive traits have heterogeneous demand, indicating that unobservable characteristics of the demand might be affecting the results.

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. Generating primary data would help us identify whether genetic trait information increases ranchers' willingness to pay and their perceptions about them.

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# 8 Appendix. Supplementary Analysis

Table 4 shows the correlation coefficients for the bulls' traits variables. The correlation matrix shows only two correlations above 0.5: i) median weaning weight EPD and median final weight EPD, and ii) weight and age.

| Variables | Weight | SC | Age | Red coat | Median BW EPD | Median WW EPD | Median FW EPD | Median SC EPD | Median Maternal EPD |
|---|---|---|---|---|---|---|---|---|---|
| Weight | 1.000 | | | | | | | | |
| SC | 0.396 | 1.000 | | | | | | | |
| Age | 0.624 | 0.265 | 1.000 | | | | | | |
| Red coat | -0.036 | -0.042 | -0.083 | 1.000 | | | | | |
| Median BW EPD | 0.175 | 0.130 | 0.010 | 0.107 | 1.000 | | | | |
| Median WW EPD | 0.169 | 0.217 | -0.037 | -0.037 | 0.397 | 1.000 | | | |
| Median FW EPD | 0.211 | 0.205 | -0.053 | -0.089 | 0.367 | 0.638 | 1.000 | | |
| Median SC EPD | 0.024 | 0.413 | -0.145 | 0.002 | 0.101 | 0.250 | 0.303 | 1.000 | |
| Median Maternal EPD | 0.002 | -0.004 | -0.003 | 0.122 | 0.018 | -0.104 | -0.018 | 0.048 | 1.000 |

Table 4. Correlations coefficients between explanatory variables

We checked for multicollinearity using the Variance Inflation Factor (VIF). Table A2 shows variance inflation factors for all variables in all five models. Goldberger (1991)shows that the standard error of any given coefficient j can be written as:

$$\hat{\beta}_j = \frac{1}{1 - R_j^2} \frac{s^2}{(n-1)Var_j}$$

Where $Var_j$ is the sample variance of variable $j$ and $R_j^2$ is the r-squared coefficient from a regression of $j$ against all other regressors included in the model, hence $1/(1 - R_j^2)$ is the variance inflation factor of regressor $j$. The higher the variance of $j$ explained by all other variables, the higher the VIF; these are the values reported in columns (1) to (5). For fixed effects, this value is the Generalized Variance Inflation factor (GVIF), equal to the average VIF for all levels corrected by the degrees of freedom:

$$GVIF = VIF^{1/2 \times df}$$

The rule of thumb is generally a VIF above 10, which could indicate strong multicollinearity. The average of all our estimates ranges between 1 and 3.7.

| **Variance Inflation Factors** | **(1)** | **(2)** | **(3)** | **(4)** | **(5)** |
|---|---|---|---|---|---|
| Weight | 1.97 | 1.97 | 1.97 | 1.47 | 1.69 |
| Scrotal circumference | 1.51 | 1.51 | 1.51 | 1.24 | 1.41 |
| Age | 1.83 | 1.84 | 1.84 | 1.38 | 1.64 |
| Color | 1.06 | 1.12 | 1.13 | 1.11 | 1.92 |
| Birth Weight EPD | 1.26 | 1.26 | 1.27 | 1.14 | 1.37 |
| Weaning weight EPD | 1.83 | 1.84 | 1.85 | 1.38 | 1.60 |
| Final weight EPD | 1.89 | 1.90 | 1.93 | 1.41 | 1.63 |
| Scrotal circ. EPD | 1.40 | 1.41 | 1.43 | 1.21 | 1.41 |
| Maternal EPD | 1.04 | 1.09 | 1.11 | 1.10 | 1.41 |
| Stud FE | | 1.15 | 1.18 | 1.30 | 3.64 |
| PP FE | | | 1.14 | 1.08 | 1.82 |
| Year FE | | | | 1.05 | 1.40 |
| Sire FE | | | | | 1.04 |

Table 5. Variance Inflation Factors from the estimated models