


RESEARCH ARTICLE

# What is the Cow-Calf Economics of Genetic Panel Scores for Feedlot Traits?

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## Abstract

Past research has only studied genetic panel scores and feedlot performance. This research combines impacts of genetic panel scores on a cow-calf operation with previously estimated feedlot impacts to evaluate the potential for misaligned economic incentives in the beef industry. Calves that were higher genetic scores for two carcass traits, marbling and tenderness, had lower weaning weights and lower net returns. Correlations between genetic traits and cow size were small and mostly insignificant. The sum of the effects on feedlot and cow-calf sectors of a one-unit higher panel score totaled \$-2.83 per cow year for marbling and \$-4.93 per cow year for tenderness.

**Keywords:** Birth weight; budgets; cattle; cow-calf genetics; Igenity panel scores; weaning weight

**JEL classifications:** C20; O30; Q19

## Introduction

Previous research found that genetic profiles help predict key cattle growth traits in bull (Vestal et al., 2013), feeder (DeVuyst et al., 2011), and live cattle selection (Holt, 2010; Thompson et al., 2014), but there has been little research on the relationship between genotypic panel scores and economically relevant cow-calf production variables. Further, traits that are desirable in feedlot cattle production are potentially deleterious for cow-calf operations. For example, increased cow weights may not correlate with increased cow-calf profitability (Bir et al., 2018; Feuz, Russell, and Feuz, 2021). The goal here is to determine the net value of these genetic traits in the cow-calf sector by estimating their effect on calf birth weight, weaning weight, and cow weight and then using these estimates to determine the effect on expected profit.

Genetic testing in beef cattle started with testing for the leptin gene in the 1990s, and the tests focused on single nucleotide polymorphisms (SNPs) that were associated with fat deposition (Fitzsimmons et al., 1998). The leptin gene predicted intramuscular and external carcass fat and showed promise to increase feedlot profitability for cattle priced on a grid. While the leptin gene had little to no effect on days on feed and thus there was little value to sorting cattle, it was important in feeder cattle selection with differences up to \$48 per head between the different SNPs (DeVuyst et al., 2007). Although genetic testing in cattle showed promise for increasing profitability (Mitchell et al., 2009), testing for the leptin gene in feedlot cattle was abandoned after a few years (Van Eenennaam and Drake, 2012). In recent years, tests for the leptin gene have been

replaced by genomic marker panels. These tests use dozens of SNPs for predicting desired outcomes (Thompson, 2018).

Thompson et al. (2014) found that using genetic marker panels for management decisions and sorting cattle resulted in values of around \$1 per head for each trait evaluated. Using panel scores to market cattle, however, resulted in a range of values from \$1 to \$13 per head depending on the structure of the grid (Thompson et al., 2016). The value of these tests, however, was not enough to offset the cost of testing (the Igenity Feeder profile was \$15 in 2022). In 2016, the Igenity Gold profile studied here cost \$40, but the cost of the comparable Igenity Beef Profile has since fallen to \$29 per test and now includes 17 panel scores instead of 13 (Neogen, 2022). Selecting cattle based on genomic marker panels is expected to yield more than using the panels for management decisions alone (Thompson et al., 2014). The expected value of selecting for a single trait was \$22, and the value associated with selecting for multiple traits was \$38 (Thompson et al., 2014). The differences in value between these genetic differences are high, especially in bull testing (Vestal et al., 2013). The incomplete adoption of marker panels in bull selection could be due to a market inefficiency due to asymmetric information (Maples et al., 2022), which causes cow-calf producers with better feedlot genetics to not be fully rewarded. Testing for genomic panel scores is now used mostly for breeding animals and even for breeding animals the use of panel scores is not common.

Results from hedonic pricing models show that cow-calf producers did not initially consider available genetic information when selecting or replacing herd bulls (Irsik et al., 2008). Rather than focusing on genetics, the price of a bull was highly dependent on breed, with preference toward Angus, age, and lower birth weights. Expected progeny differences (EPDs) are increasingly used in cattle selection, with Boyer et al. (2019), Vestal et al. (2013), and Tang et al. (2023) concluding that EPDs were statistically significant determinants of bull prices.

Cow-calf producers have shifted their production practices over the last few decades resulting in higher mature cow weights (Bir et al., 2018; Feuz, Russell, and Feuz, 2021). This shift in weights was due to a push to produce for feedlot profitability rather than cow-calf profitability (Bir et al., 2018). A concern is that traits that are positive for feedlots could be negative for cow-calf producers. Previous studies did not examine the effects of Igenity panel scores at the cow-calf producer level and only offer insight into the value of selecting for these traits at the feedlot level (DeVuyst et al., 2011; Thompson et al., 2014, 2016). This research aims to overcome these gaps and combine the impacts of genetic panel scores from a cow-calf operation with previously estimated impacts on feedlot operations to evaluate the potential for misaligned economic incentives in the beef industry.

Herds have shifted to a more feedlot-driven genetic composition with an emphasis on muscle, growth, and carcass quality in the last few decades (Bir et al., 2018; Smith, 2014). What traits, if any, are correlated with higher weaning weights, optimal cow weights, or increased producer profitability? Does the optimal selection of Igenity panel scores for the entire beef sector differ from those that benefit cow-calf operators? Genetic traits as measured by Igenity panel scores are readily available and producers as well as the whole cattle industry can benefit from knowing more about how best to use this information.

## Data collection

Hair follicle samples were taken from cows, steers, heifers, and bulls at weaning or purchase across four ranches in southern Oklahoma owned and operated by the Noble Research Institute (NRI). The NRI herds are managed by PhD animal scientists and are managed to demonstrate the optimal level of management. These samples were sent to Neogen to determine the Igenity genetic profile for each animal. Here, 13 Igenity panel scores are used including birth weight, calving ease direct, calving ease maternal, stayability, heifer pregnancy, docility, milk, residual feed intake, average daily gain, tenderness, marbling, ribeye area, and fat thickness. The Neogen profiles are on

**Table 1.** Calf summary statistics ( $n = 1,205$ )

Variable	Mean	SD	Minimum	Maximum
Birth weight (lb.)	77.4	14.4	34	134
Weaning weight (lb.)	523.4	88.9	247	805
Age (days)	216.7	21.9	151	285
<i>Igenity panel score</i>				
Average daily gain	6.28	1.50	1	10
Birth weight	4.51	1.37	1	10
Calving ease direct	6.14	1.38	2	10
Calving ease maternal	5.86	1.13	2	9
Docility	6.34	1.08	1	9
Fat thickness	6.18	1.36	1	10
Heifer pregnancy rate	7.14	1.00	4	10
Marbling	6.30	1.53	2	10
Milk	6.30	1.27	2	10
Residual feed intake	6.28	1.22	3	10
Ribeye area	4.92	1.16	2	9
Stayability	6.64	1.03	3	10
Tenderness	5.95	2.07	1	10

a scale of 1–10. The panel scores predict equal increments of the targeted trait. For example, each unit higher panel score for birth weight predicts a birth weight that is 1.3 lb. higher.

Data were collected for 1,205 calves born and weaned on the NRI ranches during 2015 through 2020. Table 1 shows summary statistics for all calf events and panel scores. Data were collected for 1,544 cows, providing 10,156 cow weights. Cow data include mature cows, first-calf heifers, bred heifers, exposed heifers, and replacement heifers all over one year old. These weights were captured at the chute during pregnancy checks, breeding, veterinary applications, and weight checks from 2015 to 2020. There are more observations on cows since collection of data on calves. Table 2 reports the summary statistics of cow weights. Note that calf panel scores were used for the calves as compared to using dam panel scores because the calf panel scores were always available, while many of the dam scores were not. Using dam panel scores to measure the genetic effect on calves could have different results from this study, especially for the maternal traits. In particular, the dam's milk score would likely have provided more information about weaning weight than the calf's milk score.

The four cow/calf herds were located on four different ranches. The ranches are Oswalt Road Ranch (OR) located near the community of Oswalt, OK (33°59'24.5"N 97°15'16.1"W), D. Joyce Coffey Ranch (CR) located near the community of Marietta, OK (33°56'03.5"N 97°13'38.6"W), Pasture Research and Demonstration Farm (PRDF) located near the community of Ardmore, OK (34°13'06.6"N 97°12'14.4"W), and the Red River Research and Demonstration Farm (RRF) located near the community of Burneyville, OK (33°52'56.5"N 97°16'03.5"W). CR and OR are predominantly comprised of native prairie grass and PRDF and RRF have introduced bermudagrass pasture. Hay and protein cubes were fed in the winter months. Angus (*bos taurus*) cows were artificially inseminated following the 7-day CoSynch (Bridges et al., 2008) synchronization program. At CR and OR ranches, cattle were artificially inseminated with Angus

**Table 2.** Cow weight summary statistics ( $n = 10,156$ )

Variable	Mean	SD	Minimum	Maximum
Cow weight	1092	237.55	453	1804
Age (years)	3.77	2.87	1.0	14.9
<i>Igenity panel score</i>				
Average daily gain	6.21	1.40	2	10
Birth weight	4.17	1.30	1	9
Calving ease direct	6.48	1.30	2	10
Calving ease maternal	5.91	1.09	2	9
Docility	6.53	1.00	3	9
Fat thickness	6.32	1.24	2	10
Heifer pregnancy rate	7.31	0.98	4	10
Marbling	6.51	1.26	2	10
Milk	6.28	1.27	2	10
Residual feed intake	6.35	1.11	3	10
Ribeye area	4.53	1.19	1	8
Stayability	6.67	0.99	3	10
Tenderness	5.87	2.07	1	10

Note: Cows were weighed multiple times in each year. Replacement heifers included.

semen with Charolais bulls turned out within 24 hours upon insemination. At PRDF, Angus cows sired by Hereford bulls followed a natural 60-d breeding program.

Igenity panel scores predict future progeny performance in comparison to the progeny of other animals (Neogen, 2021). The panels include two to over 100 SNPs (DeVuyst et al., 2011), but the exact number is proprietary. Higher Igenity panel scores are not always better but indicate the animal has a higher genetic potential for that trait. Table 3 provides a description of each trait and its desired outcome. Igenity provides tables for the genetic effects of each score that allow producers to convert their panels into molecular breeding values (MBV's), so they can see their potential benefit to calf crop revenue, cull cow revenue, herd longevity, and less dystocia (difficult birth that is usually caused by the calf being too large). These molecular breeding values are in the units of the desired trait (i.e., the MBV's for the birth weight panel score are in pounds). The scores used at the time of this study were from the Igenity Gold index. That index is now grouped into the whole Igenity Beef Profile that has the 17 traits Igenity currently offers. Lastly, producers can put selection pressure on individual traits in their own index (Igenity, 2020).

### Econometric models

We estimated the impact of genetic panel scores, age, time of year, and sex on weaning weight, birth weight, and cow weight. Regression models included random effects, so we used restricted maximum likelihood using the MIXED Procedure in SAS (SAS Institute Inc., 2013). To determine the extent that two panel scores measure the same thing, we calculated Pearson bivariate correlation coefficients between Igenity genetic panel scores, weaning weight, and cow weight. If two panels had high correlation, one of the two panel score was omitted from the regression models.

**Table 3.** Descriptions and targeted outcomes of igenity panel scores

Trait	Description	Target <sup>a</sup>
<i>Maternal</i>		
Birth Weight	Variation in birth weight	Low
Calving ease direct	Percentage of unassisted births	High
Calving ease maternal	Probability a first calf heifer will calve unassisted	High
Stayability	Probability a cow remains productive in the herd until age 6	High
Heifer pregnancy rate	Heifer’s chance of conceiving over a normal breeding season	High
Docility	Animal’s genetic potential to be calm	High
Milk	Pounds of calf weaning weight affected by dam milk production	Medium
<i>Performance</i>		
Residual feed intake	Difference in animals’ daily consumption of feed to achieve the same level of gain	Low
Average daily gain	Pounds of gain per day post-weaning	High
<i>Carcass</i>		
Tenderness	Genetic potential for carcass tenderness measured by the Warner-Bratzler Shear Force test	High
Marbling	Indicates the degree of marbling in the ribeye at the 12th rib	High
Ribeye area	Estimates muscling in a beef carcass, measured in square inches of the rib eye at the 12th rib	High
Fat thickness	Depth of fat in inches over the rib eye muscle at the 12th rib	High

Source: Neogen (2021).

<sup>a</sup>The targeted direction is the direction that Igenity recommends selecting. The performance and carcass traits are targets for the feedlot sector, while the maternal traits are targets for the cow-calf sector.

Rebreeding success was not considered due to an inadequate number of observations (approximately 300 had sufficient information). Note that estimated equations are reduced form models. For example, birth weight is a known predictor of weaning weight, however, including birth weight in the weaning weight equation would not be a reduced form model. Weaning weight and birth weight equations use the genetic markers from the calf while the cow weight equation uses genetic markers from the cow.

Weaning weight is the main economic driver as it determines the quantity sold. The weaning weight relationship was modeled as

$$\begin{aligned}
 WeanWeight_{it} = & \beta_0^{WW} + \sum_{n=1}^{13} \beta_n^{WW} IBP_{itn} + \beta_{14}^{WW} Age_{it} + \beta_{15}^{WW} Age_{it}^2 \\
 & + \beta_{16}^{WW} Female_{it} + \tau_t^{WW} + \varepsilon_{it}^{WW}
 \end{aligned}
 \tag{1}$$

where  $WeanWeight_{it}$  is the calf weaning weight pounds for the  $i$ th animal in the  $t$ th year,  $Age_{it}$  is the calf’s age at weaning,  $Age_{it}^2$  is the calf’s age squared,  $IBP_{itn}$  is the Igenity genetic panel score for the  $n$ th panel (Igenity Gold had 13 panel scores),  $Female_{it}$  is a class variable that takes a value of one for females and zero for males, and year random effect  $\tau_t^{WW}$  and error term  $\varepsilon_{it}^{WW}$  for the weaning weight equation are assumed to be independent and normally distributed with a mean of zero and a constant variance. The square of age is included to capture a possibly nonlinear relationship.

Lower birth weights are advantageous as they lead to lower problems with calving. An equation for calf birth weight was also estimated as

$$BirthWeight_{it} = \beta_0^{BW} + \sum_{n=1}^{13} \beta_n^{BW} IBP_{itn} + \beta_{14}^{WW} Female_{it} + \tau_t^{BW} + \varepsilon_{it}^{BW} \quad (2)$$

where  $BirthWeight_{it}$  is the calf birth weight in pounds. Year random effect  $\tau_t^{BW}$  and error term  $\varepsilon_{it}^{BW}$  are assumed to be independent and normally distributed with a mean of zero and a constant variance. The Igenity genetic panel scores represent the genetics of the calf.

As larger cows consume more forage, cow weight has an important influence on economic outcomes. The genetic relationship between cow weight and the panel scores is represented as

$$CowWeight_{it} = \beta_0^{CW} + \sum_{n=1}^{12} \beta_n^{CW} IBP_{itn} + \sum_{j=1}^{13} \beta_j^{CW} Age_{itj} + \sum_{k=1}^3 \beta_k^{CW} Q_{itk} + \mu_i^{CW} + \tau_t^{CW} + \varepsilon_{it}^{CW} \quad (3)$$

where  $CowWeight_{it}$  is the chute-recorded weight  $CW$  in pounds,  $Age_{it}$  is a class variable denoting cows at the  $j$ th age,  $Q_{itk}$  is a class variable to denote the  $k$ th quarter in which the cow was weighed, and individual cow random-effect  $\mu_i^{CW}$ , year random-effect  $\tau_t^{CW}$ , and error term  $\varepsilon_{it}^{CW}$  are all assumed to be independent and normally distributed with a mean of zero and a constant variance. The quarterly dummies capture seasonality in cow weights as the weights can vary due to pregnancy, nursing, and forage quality. No random effect was included for ranch since the information connecting the cow to the ranch was not available. Note that this is a repeated measures model and so the degrees of freedom associated with the genetic variables depends on the number of cows rather than the number of weights observed.

## Economic analysis

The economic analysis is based on the expected profit of a single, representative cow. This approach assumes the herd is equilibrium<sup>1</sup> and thus avoids the complexity of considering dynamics as in Boyer, Griffith, and DeLong (2021). It would not be a relevant approach if we wanted to consider large changes in genetics or if we wanted to consider multiple choice variables. First, an equation was specified to represent producer profit for a single, representative cow. The marginal values of the genetic panel scores are then the partial derivatives of the expected profit function. In cases where the function was nonlinear, a first-order Taylor series approximation was used to find the marginal revenue (or cost) associated with each panel score. These first-order derivatives include components for calf crop revenue, cull cow revenue, dystocia, variable cost, and feed cost. The marginal return of an additional unit of each panel score was calculated by summing the components. Sources of revenues and costs used in the analysis for a representative 1370-pound beef cow are reported in Table 4.

The expected profit for the representative cow combines calf crop revenue, cull cow revenue, and relevant costs associated with a cow-calf operation:

$$\pi = [(0.5WW_H \cdot P_H \cdot (1 - RPL) + 0.5WW_S \cdot P_S)(1 - \%Open) + (P_C \cdot \%Culled \cdot CW) - VariableCost - FeedCost(CW)]SD \quad (4)$$

<sup>1</sup>It is like an equilibrium displacement model. But, since there is no simultaneity, the calculations are simpler than those used in a typical supply/demand equilibrium displacement model (Brester et al., 2023; Lim, Gallardo, and Brady, 2023).

**Table 4.** Sources of revenues and costs used in the analysis for a representative 1370-pound beef cow

Sources of revenue used in the analysis:	Unit	Price (\$/unit)	Quantity (unit)	Revenue/ Cost (\$/head)
Weaned steers (90% birth rate; 100% of steers sold)	lbs	1.6747	546.74	412.03
Weaned heifers (90% birth rate; 23% of heifers sold)	lbs	1.6827	520.21	201.33
Cull cows (10% of herd)	lbs	0.7500	1370.00	102.75
Total gross revenue	\$	-	-	716.12
Variable costs used in the analysis:				
Veterinary/healthcare expenses	hd	42.00	1.00	42.00
Pasture rent (stocking rate at 4 acres/cow)	acres/hd	22.00	4.00	88.00
Hay (2.5% BW fed for 120 days)	lbs/hd	0.0375	4932.00	184.95
Range cubes (CP = 20%; 0.5% BW fed for 120 days)	lbs/hd	0.3250	822.00	267.15
Replacement heifer (replace 100% of heifer calves sold)	hd	500.00	0.23	115.00
Dystocia (1.1% of herd; loss of calves)	hd	1.68	533.50	9.86
Igenity panel score	hd	29.00	1.00	29.00
Interest on operating expenses	APR (%)	0.06	735.96	44.16
Total variable costs	\$	-	-	780.12
Gross margin	\$	-	-	-64.00

where:

$$RPL = 2 \cdot \frac{\%Culled}{1 - \%Open},$$

$$\%Culled = \%Open + \%Others,$$

$$\%Open = \%Base + \%Dystocia,$$

$$\%Dystocia = BW \cdot Rate,$$

$$Rate = 0.000125,$$

$$FeedCost(CW) = P_F CW^{0.75},$$

$$SD = aCW^{-0.75}, \text{ and}$$

$$SD(W = 1370) = 1$$

where  $\pi$  is the profit for the representative cow where  $WW_H$  is the heifer weaning weight in pounds,  $P_H$  is the heifer price per hundredweight,  $RPL$  represents the portion of heifers retained for replacement,  $WW_S$  is the steer weaning weight in pounds,  $P_S$  is the steer price per hundredweight,  $\%Open$  is the percent of the cow herd that did not calve (all percentages are used in decimal form so that 100% equals 1), culled for other medical issues, or had issues with dystocia,  $P_C$  is the cull cow price of lean cows,  $\%Culled$  is the portion of the cow herd that was culled,  $CW$  is the cow weight in pounds,  $VariableCost$  includes veterinary/health costs, the cost of the Igenity genetic panel scores, and the costs associated with replacing a cull cow with a replacement,  $SD$  is the stocking density divided by the acres needed to support a single representative cow (so  $SD = 1$  for the representative cow<sup>2</sup>),  $FeedCost(CW)$  is the total feed (forage, hay, and cubes) cost per

<sup>2</sup>Including  $SD$  lets the analysis be for the portion of a cow per four acres and prevents a bias toward larger cows.

pound of metabolic weight  $P_F$ , %Others is the percent of cows culled after producing a calf, %Base is the percent of cows culled related to age and failing to breed, %Dystocia is the percent of calves lost and cows culled due to calving issues and assumes a linear relationship with birth weight  $BW$  in pounds,  $Rate$  is the linear multiplier used to determine dystocia, and  $a$  is a constant. It is assumed the net energy for cow maintenance is a function of metabolic weight,  $CW^{0.75}$  (National Research Council, 1984). Cattle prices were calculated using LMIC (2021) data and assume an October 1 sale date as weaning in the data ranged from late August to late October, with most calves weaned in October. Expected values of equations (1)–(3) are then substituted into (4) for the corresponding variable: ( $WW_H = E(WeanWeight|Female = 1)$ ,  $WW_S = E(WeanWeight|Female = 0)$ ,  $BW = E(BirthWeight)$ , and  $CW = E(CowWeight)$ ).

The panel scores appear in the profit function through the three weight equations. The derivatives are then taken via the chain rule and then evaluated at sample means.

The first step in calculating marginal revenues is to derive marginal revenue for an additional pound of calf revenue, including a price slide (Brorsen et al., 2001). The derivative of revenue (weight times price) is

$$MR = \frac{\partial Revenue}{\partial WW} = Slide \cdot WW + Price \tag{5}$$

where  $MR$  is the marginal revenue of an extra pound of gain,  $Slide = \left(\frac{\partial P}{\partial WW}\right)$  is the price slide associated with a higher weaning weight,  $WW$  is the calf weaning weight, and  $Price$  is the calf price per pound. Marginal revenue is calculated separately for heifers and steers as defined in equation (4) using their respective prices.

The first-order partial derivative was taken from the profit function in (4) with respect to  $IBP_i$  via the chain rule for the  $i$ th calf panel score  $\left(\frac{\partial \pi}{\partial IBP_i^{Calf}}\right)$  to find the marginal values associated with each calf panel score. The marginal values associated with each calf panel score were used to find the marginal return associated with an additional unit of each panel score. The marginal returns associated with each calf panel score are broken down into individual components to understand the individual effect of each panel score on calf crop revenue and dystocia. This is represented as

$$\frac{\partial \pi}{\partial IBP_i^{Calf}} = \left(\frac{\partial \pi}{\partial WW} \cdot \frac{\partial WW}{\partial IBP_i^{Calf}} \cdot MR\right) + \left(\frac{\partial \pi}{\partial DYS} \cdot \frac{\partial DYS}{\partial BW} \cdot \frac{\partial BW}{\partial IBP_i^{Calf}} \cdot P_A\right) \tag{6}$$

where  $\left(\frac{\partial \pi}{\partial WW} \cdot \frac{\partial WW}{\partial IBP_i^{Calf}} \cdot MR\right)$  is the marginal return associated with an additional unit of Igenity panel score  $i$  for calf crop revenue and  $\left(\frac{\partial \pi}{\partial DYS} \cdot \frac{\partial DYS}{\partial BW} \cdot \frac{\partial BW}{\partial IBP_i^{Calf}} \cdot P_A\right)$  is the marginal return associated with an additional unit of each Igenity panel score for dystocia cost where  $P_A$  is the price of the heifer, steer, or cow. The calf panels are only used to evaluate these two components of a cow-calf operation assuming that stocking density is equal to one.

The first-order partial derivative was taken via the chain rule of the profit function with respect to  $IBP_i$  for the  $i$ th cow panel score  $\left(\frac{\partial \pi}{\partial IBP_i^{Cow}}\right)$  to find the marginal return associated with each cow panel score. The marginal returns associated with each cow panel score are the sum of individual components of cull cow revenue, feed cost, and stocking density. This is represented as

$$\begin{aligned} \frac{\partial \pi}{\partial IBP_i^{Cow}} &= \left(\frac{\partial \pi}{\partial CW} \cdot \frac{\partial CW}{\partial IBP_i^{Cow}} \cdot P_C\right) + \left(\frac{\partial \pi}{\partial Feedcost} \cdot \frac{\partial Feedcost}{\partial CW} \cdot \frac{\partial CW}{\partial IBP_i^{Cow}} \cdot P_F\right) \\ &+ \left(\frac{\partial \pi}{\partial SD} \cdot \frac{\partial SD}{\partial CW} \cdot \frac{\partial CW}{\partial IBP_i^{Cow}} \cdot P_C\right) \times \pi \end{aligned} \tag{7}$$



where  $\left(\frac{\partial\pi}{\partial CW} \cdot \frac{\partial CW}{\partial IBP_i^{COW}} \cdot P_C\right)$  is the marginal return of an additional unit of Igenity panel score  $i$  for cull cow revenue,  $\left(\frac{\partial\pi}{\partial Feedcost} \cdot \frac{\partial Feedcost}{\partial CW} \cdot \frac{\partial CW}{\partial IBP_i^{COW}} \cdot P_F\right)$  is the marginal cost associated with an additional unit of each Igenity panel score for feed cost, and  $\left(\frac{\partial\pi}{\partial SD} \cdot \frac{\partial SD}{\partial CW} \cdot \frac{\partial CW}{\partial IBP_i^{COW}} \cdot P_C\right)$  is marginal return (cost) from an additional unit of each Igenity panel score for a change in stocking density. Assuming that stocking density equals one for cull cow revenue and feed cost, the cost of an increase in cow weight was reflected through a reduced stocking density.

Since these are largely closed herds, changing the calf genetics would eventually change the cow genetics. As Tables 1 and 2 show, average genetic panel scores for cows and calves were similar. Thus, the effect of changing the genetics must be the sum of the effects of calf and cow panel scores. So, equations (6) and (7) are summed to determine the marginal return for each additional unit of the panels for the whole cow-calf operation. This is represented as

$$\frac{\partial\pi}{\partial IBP_i} = \frac{\partial\pi}{\partial IBP_i^{Calf}} + \frac{\partial\pi}{\partial IBP_i^{Cow}} \tag{8}$$

When expanded, equation (8) can be represented as

$$\begin{aligned} \frac{\partial\pi}{\partial IBP_i} = & ((0.5\beta_i^{WW}MR_H(1 - RPL)) + (0.5\beta_i^{WW}MR_S))(1 - \%Open) + (\beta_i^{CW}P_C \cdot \%Culled) \\ & + [ -((1.5WW_H \cdot P_H) + (0.5WW_S \cdot P_S)) + (CW \cdot P_C) - VariableCost] \cdot \beta_i^{BW}Rate \\ & + (0.75\beta_i^{CW} \cdot P_F \cdot CW^{-0.25})SD + (-0.75\beta_i^{CW} \cdot a \cdot CW^{-1.75} \cdot CW \cdot P_C \cdot \%Culled) \end{aligned} \tag{9}$$

where  $\beta_i^{WW}$  is the marginal value for Igenity panel score  $i$  from equation (1): the weaning weight equation,  $MR_H$  is the marginal revenue of an extra pound of weaning weight for heifers,  $MR_S$  is the marginal revenue of an extra pound of weaning weight for steers,  $\beta_i^{BW}$  is the regression coefficient from equation (2) for birth weight, and  $\beta_i^{CW}$  is the regression coefficient from equation (3) for cow weight.

Holding dystocia and stocking density constant, the marginal effect of the calf Igenity panel scores on calf crop revenue is

$$\frac{\partial\pi}{\partial(WW \cdot P)} \frac{\partial(WW \cdot P)}{\partial IBP_i} = \left[ \left( \frac{\partial(WW_H P_H)}{\partial IBP_i} (1 - RPL)0.5 \right) + \left( \frac{\partial(WW_S P_S)}{\partial IBP_i} \cdot 0.5 \right) \right] (1 - \%Open) \tag{10}$$

Holding dystocia and stocking density constant, the marginal effect of the cow Igenity panel scores on cull cow revenue is

$$\frac{\partial\pi}{\partial CW} \frac{\partial CW}{\partial IBP_i} = (\beta_i^{CW} \cdot P_C \cdot \%Culled) - (\beta_i^{CW} \cdot FeedCost_C) \tag{11}$$

where cow price is expressed in dollars per pound. Cull cow prices differ little by weight (Peel and Doye, 2017), so a price slide is not used for cows.

Higher birth weights are usually associated with lower calving ease, a higher rate of dystocia, and higher weaning weights (Berger et al., 1992). To find the effect of the calf Igenity panel scores on birth weight and dystocia, the profit function is differentiated with respect to the calf Igenity panel scores. This equation is represented as

$$\frac{\partial \pi}{\partial DYS} \frac{\partial DYS}{\partial BW} \frac{\partial BW}{\partial IBP_i} = \left[ -((1.5WW_H \cdot P_H) + (0.5WW_S \cdot P_S)) \right. \\ \left. + (CW \cdot P_C) - VariableCost \right] \cdot \beta_i^{BW} \cdot Rate \cdot SD. \quad (12)$$

Increased dystocia affects all revenue streams since it results in a larger percent of heifers retained for replacement, fewer steers and heifers sold due to death loss, and increases cull cow revenue due to an increase in cows culled. It also imposes an extra feed cost from retaining another heifer, potentially lower weaning weights, and a loss in productivity from culling an extra cow. The Noble Research Institute herds have a low rate of dystocia due to the herd being selected for maternal traits, so the rate of dystocia for an 85-pound calf is assumed to be 1.11%.

Feed cost is expected to change with cow weight and a change in the cow Igenity panel scores. Since feed cost is based on metabolic weight, the derivative is

$$\frac{\partial \pi}{\partial Feedcost} \frac{\partial Feedcost}{\partial CW} \frac{\partial CW}{\partial IBP_i} = (0.75\beta_i^{CW} \cdot P_F \cdot CW^{-0.25}). \quad (13)$$

Feed costs were calculated for the representative cow using the CowCulator software (Lalman, Gross, and Beck, 2020). This research assumes a rental rate of bermudagrass at \$22/acre (Sahs, 2021), a 75% utilization rate of introduced bermudagrass, and four acres of bermudagrass required per representative cow. Hay consumption is assumed to have an 80% utilization rate and a price of \$75/ton (\$0.0375/lb) (Doye and Lalman, 2011). Protein cubes with crude protein equal to 20% are used and are composed of 65% wheat middlings, 30% cottonseed meal, and 3% molasses (Bir et al., 2018). A cube price of \$650/ton (\$0.325/lb) was obtained from Tractor Supply Co. (2022). Total feed cost was calculated by multiplying pounds of forage, hay, and cubes used by their utilization rates and price and dividing the result by cow metabolic weight to obtain feed cost per metabolic pound.

As cows get larger, stocking density will decrease. The effect of genetics on stocking density only comes through the cow weight equation:

$$\frac{\partial \pi}{\partial SD} \frac{\partial SD}{\partial CW} \frac{\partial CW}{\partial IBP_i} = -0.75\beta_i^{CW} \cdot a \cdot CW^{-1.75} \cdot CW \cdot P_C \cdot \%Culled \quad (14)$$

## Results and discussion

Pearson bivariate correlation coefficients were estimated for the Igenity panel scores of the calves<sup>3</sup> to determine the similarity of the panel scores (Table 5). Similar to DeVuyst et al. (2011), only a couple pairs of panel scores had high correlation. The collinearity among these scores is likely due to the scores using the same or similar SNPs (DeVuyst et al., 2011). The two with the highest correlation are the Igenity Birth Weight Score and the Igenity Calving Ease Direct Score with a value of  $-0.82$ . The Igenity Calving Ease Direct Score was omitted from the regression models since it was measuring roughly the same effects as the Birth Weight Score.

The correlations between panel scores and the phenotypic variables, weaning weight, birth weight, and cow weight (Table 6) all show that more variation is unexplained than explained by the panels. The highest correlations between the selected weights and the panel scores is the Igenity Marbling Score with a correlation coefficient of  $-0.41$  for birth weight. That relationship is likely due to high marbling Angus bulls being selected for maternal traits and thus low birth

<sup>3</sup>The correlation matrix using the cow panel scores is similar and is available in Garrison (2022, p. 50, Table II-5).

**Table 5.** Pearson correlation coefficients between igenity panel scores, calves. ( $n = 1,205$ )

Igenity Panel Score	ADG	BW	CED	CEM	DOC	FAT	HPR	MAR	MIL	RFI	REA	STA
ADG <sup>a</sup>	1.00											
BW <sup>b</sup>	-0.06*	1.00										
CED <sup>c</sup>	0.19*	-0.82*	1.00									
CEM <sup>d</sup>	0.04	-0.34*	0.38*	1.00								
DOC <sup>e</sup>	0.13*	-0.13*	0.15*	0.02	1.00							
FAT <sup>f</sup>	0.24*	-0.43*	0.46*	0.19*	0.20*	1.00						
HPR <sup>g</sup>	0.17*	-0.22*	0.27*	0.05*	0.12*	0.21*	1.00					
MAR <sup>h</sup>	0.45*	-0.47*	0.47*	0.14*	0.09*	0.51*	0.30*	1.00				
MIL <sup>i</sup>	0.14*	-0.23*	0.25*	0.29*	0.08*	0.19*	0.14*	0.14*	1.00			
RFI <sup>j</sup>	0.26*	-0.23*	0.27*	-0.06*	0.16*	0.33*	0.16*	0.38*	0.08*	1.00		
REA <sup>k</sup>	0.20*	0.21*	-0.12*	-0.01	0.10*	-0.19*	0.04	-0.13*	0.03	0.00	1.00	
STA <sup>l</sup>	0.21*	-0.27*	0.29*	0.05	0.06*	0.30*	0.21*	0.29*	0.06*	0.18*	-0.12*	1.00
TEN <sup>m</sup>	0.13*	-0.04	0.08*	-0.01	0.11*	0.19*	0.06*	0.21*	0.09*	0.31*	0.03	0.08*

Notes: Single asterisks denote significance at the 5% level.

<sup>a</sup>Average Daily Gain, <sup>b</sup>Birth Weight, <sup>c</sup>Calving Ease Direct, <sup>d</sup>Calving Ease Maternal, <sup>e</sup>Dolcility, <sup>f</sup>Fat Thickness,

<sup>g</sup>Heifer Pregnancy Rate, <sup>h</sup>Marbling, <sup>i</sup>Milk, <sup>j</sup>Residual Feed Intake, <sup>k</sup>Ribeye Area, <sup>l</sup>Stayability, <sup>m</sup>Tenderness.

**Table 6.** Pearson correlation coefficients between weights, igenity panel scores

Igenity panel score	Weight		
	BW	WW	CW
Average daily gain	−0.23***	−0.16***	−0.16*
Birth weight	0.35***	0.21***	−0.12*
Calving ease direct	−0.37***	−0.19***	0.03
Calving ease maternal	−0.13***	0.00	0.04
Docility	−0.10***	−0.08***	−0.04
Fat thickness	−0.28***	−0.22***	−0.04
Heifer pregnancy rate	−0.16***	−0.13***	0.01
Marbling	−0.41***	−0.30***	−0.04
Milk	−0.05*	−0.09***	0.05*
Residual feed intake	−0.27***	−0.30***	−0.12*
Ribeye area	0.09***	0.11***	−0.21*
Stayability	−0.19***	−0.14***	0.01
Tenderness	−0.16***	−0.25***	−0.03

Notes: Single, double, and triple asterisks (\*, \*\*, \*\*\*) indicate significance at the 10, 5%, and 1% level.

weights, while Hereford and Charolais bulls would have less marbling and were selected for terminal performance with less consideration of calving ease. Cow weight has a lower correlation with genetic panel scores than the other weights because cow weights vary substantially by age.

Table 7 shows the estimated regressions for birth, weaning, and cow weights equations. Outliers in the data were investigated using Cook's Distance (Cook, 1977) with values over 0.01 being identified as potential outliers. Most outliers in terms of weight were attributed to Hereford and Charolais breeds rather than predominately Angus breeds.<sup>4</sup> As a result, these outliers were included since they represent some unmeasured genetics.

Calf Igenity scores that were significant predictors of weaning weight include average daily gain, birth weight, docility, marbling, residual feed intake, ribeye area, stayability, and tenderness (Table 7). Only residual feed intake and ribeye are in the desired direction reflected in Table 3. For the other independent variables, the effect on weaning weight is counter to the desired effects on other traits. For example, higher marbling is a desirable carcass trait, yet it led to lower weaning weights. The negative coefficient on average daily gain was unexpected. Average daily gain in the feedlot was hypothesized to have a positive relationship with weaning weight because a higher genetic potential for gain should yield a higher weaning weight. The birth weight score was positive, consistent with Bir et al. (2018).

Calf Igenity panel scores that were significant predictors of birth weight<sup>5</sup> include average daily gain, birth weight, marbling, milk, residual feed intake, ribeye area, and tenderness (Table 7). Average daily gain, marbling, residual feed intake, and tenderness calf panels had negative

<sup>4</sup>Models were also estimated with breed dummy variables and results were qualitatively similar.

<sup>5</sup>Multiple comparisons are a potential concern in this analysis. Bonferroni corrected *p*-values (Napierala, 2012) are the most conservative test in this case and can be obtained by dividing the critical value by twelve, which would make the critical value 0.004. Using the Bonferroni correction does not change the significance of most of the panel scores in the birth weight and weaning weight equations including average daily gain, marbling, residual feed intake, ribeye area, and tenderness (Napierala, 2012).

**Table 7.** Regression results for cow weight, birth weight, and weaning weight prediction equations (lbs)

Variable	Equation		
	CW	BW	WW
Constant	1474.27***	96.31***	-288.02
<i>Igenity Panel Scores*</i>			
Average daily gain	3.34	-1.42***	-4.73***
Birth weight	6.15**	2.67***	4.93***
Calving ease maternal	0.46	-0.30	2.63
Docility	-0.60	-0.23	-3.44*
Fat thickness	-3.20	0.12	-1.51
Heifer pregnancy	1.22	-0.59	-0.17
Marbling	-4.20	-1.34***	-5.76***
Milk	4.04	0.82***	1.74
Residual feed intake	-9.05***	-0.96***	-7.07***
Ribeye area	-1.83	0.81**	6.35***
Stayability	0.15	-0.48	-3.87*
Tenderness	-2.72**	-0.53***	-4.57***
Heifer calf		-6.97***	-20.45***
Age at weaning			6.96***
Age at weaning <sup>2</sup>			-0.01***
<i>Cow age</i>			
Age 1	-546.64***		
Age 2	-375.88***		
Age 3	-285.14***		
Age 4	-178.08***		
Age 5	-111.61***		
Age 6	-58.41***		
Age 7	-30.50*		
Age 8	-22.80		
Age 9	-39.36*		
Age 10	-53.29**		
Age 11	-160.16***		
Age 12	-99.03***		
Age 13	-79.22***		
Quarter 1	-68.39***		
Quarter 2	-54.78***		
Quarter 3	4.92		

Notes: Single, double, and triple asterisks (\*, \*\*, \*\*\*) indicate significance at the 10, 5, and 1% level. Dependent variables in the three equations are cow weight (CW), birth weight (BW), and weaning weight (WW).

\*The Igenity Gold profile provided scores 1-10 for 13 traits. The Igenity Calving Ease Direct score was dropped due to multicollinearity issues.

**Table 8.** Marginal returns of an additional unit of each panel score (\$/unit/cow/year)

Igenity Panel Score	Calf Crop	Dystocia	Cow	Feed Cost	Cow-Calf	Feedlot <sup>a</sup>	Beef Sector
Average daily gain	-5.43	0.24	0.25	-0.11	-5.23	0.54	-4.69
Birth weight	5.66	-0.45	0.46	-0.20	5.12		
Calving ease direct	3.02	0.05	0.03	-0.01	3.06		
Docility	-3.95	0.04	0.05	0.02	-3.90		
Fat thickness	-1.73	-0.02	-0.24	0.10	-1.70		
Heifer pregnancy rate	-0.19	0.10	0.09	-0.04	-0.11		
Marbling	-6.61	0.23	-0.32	0.14	-6.32	3.52	-2.80
Milk	1.99	-0.14	0.30	-0.13	1.80		
Residual feed intake	-8.11	0.16	-0.68	0.29	-7.82		
Ribeye area	7.28	-0.14	-0.14	0.06	7.17	-2.81	4.36
Stayability	-4.44	0.08	0.01	-0.00	-4.36		
Tenderness	-5.24	0.09	-0.20	0.09	-5.12	0.19	-4.93

Notes: Values reported indicate a unit change within each panel score. The units are dollars per representative cow. Since the representative cow uses four acres of Bermudagrass, the units can also be interpreted as dollars per four acres of Bermudagrass.

<sup>a</sup>The feedlot values are from Thompson et al., (2018).

relationships with birth weight. These panel scores related to feedlot and carcass performance were hypothesized to have little to no relationship with birth weight. Calving ease was not significant, which means that it added no information beyond what was already included in the birth weight panel score. Positive relationships include birth weight score, ribeye area, and milk. As expected, when the birth weight score increases, birth weight also increases. The Ribeye area panel, a measure of genetic potential for ribeye area at the 12<sup>th</sup> rib (Igenity, 2020), was also a significant predictor of birth weight.

The relationships between cow weight and the cow panel scores are mostly insignificant except for birth weight ( $p < 0.05$ ), residual feed intake ( $p < 0.01$ ), and tenderness scores ( $p < 0.01$ ). The birth weight panel score had a positive effect on all three weights.

Age at weaning and the quadratic transformation of age at weaning were both significant predictors ( $p < 0.01$ ) of weaning weight. The quadratic term for age has a negative relationship with weaning weight and shows that weaning weight increases with age at a decreasing rate. Heifer calves were significantly ( $p < 0.01$ ) lighter at birth (about seven pounds) and weaning (about 20.5 pounds) than male calves.

### Economics

Marginal values associated with each trait were estimated across four components of cow-calf production, including calf revenue, losses from dystocia, cull cow revenue, and associated costs of production. Table 8 shows the marginal returns associated with each aspect of production. Every trait except for birth weight, calving ease direct, and ribeye area had a negative marginal revenue. The highest negative marginal values were associated with residual feed intake, -\$7.82, marbling, -\$6.32, average daily gain, -\$5.23, and tenderness, -\$5.12. Residual feed intake was hypothesized to have a negative impact on revenue as an animal with a higher score is expected to produce progeny that consume more feed for the same daily gain (Igenity, 2020). However, it was unexpected for average daily gain to have a negative impact on revenue. A higher score was expected to be associated with a higher rate of gain over the same period although the MBV's are

quite small with an expected 0.02-pound difference for each associated with the carcass index and so not expected to have much of a relationship with calf crop revenue. However, since they were estimated to reduce weaning weight, they also had a large negative effect on cow-calf marginal revenue. A one-unit increase in marbling panel scores reduced marginal revenue by \$6.61 per cow and residual feed intake by \$8.11 and similar amounts for cow-calf returns. Given budgeted cow-calf returns were negative (−\$64 per cow), changing the genetics contributing to these two panels could reduce losses by 10% or more for just a one-unit change in these panel scores.

The highest positive impact on cow-calf returns for a unit change in scores was ribeye area, \$7.17/head, and birth weight, \$5.12/head. The ribeye area score has a large positive relationship with weaning weight. The birth weight score positively affected revenue because higher weaning weights from a higher birth weight score was more important than the adverse effect on dystocia rates.

The marginal effect of dystocia is included in the total value of each trait, although its initial impact is quite low. As stated earlier, the rate of dystocia for an 85-pound calf is assumed to be 1.11%. Vet cost was assumed to be \$42/head, and the other variable costs associated with losing a calf were assumed to be \$500. The largest improvement (\$/head) in dystocia cost is only \$0.24/head, and largest negative effect was only −\$0.45/head. These effects are not economically significant. At this low rate of dystocia, this herd could increase net revenue with slightly higher birth weight scores. Marginal changes to genetics will have negligible impacts on feed cost with values ranging from −\$0.20/head for a one-unit change in birth weight score to \$0.29/head for a one unit change in residual feed intake score.

Average daily gain score adversely impacted cow-calf returns by over \$5 per head for a one-unit increase in the panel score. Most of that decrease was due to depressing calf crop value through weaning weight.

These numbers might seem quite small for a cow-calf producer, but they could make quite a difference in sire selection. Assuming a single bull sires 25 calves a year for four years, multiple-unit changes in these calf and cow panel scores could result in thousands of dollars lost or gained. For example, a three-unit change in the average daily gain score would reduce returns by \$1,629, and a three-unit change in the ribeye area score would improve returns by \$2,184. Since bull genetics will directly affect calf panel scores, multiple-unit changes in genetic panel scores can justify substantial differences in bull prices.

Lastly, molecular breeding values for feedlot selection, taken from Thompson et al. (2014), were evaluated against the same traits' effect on cow-calf revenue. The only traits that were the same between the two studies were average daily gain, marbling, ribeye area, and tenderness. The return (\$/head) associated with molecular breeding values was reported in the units of each individual MBV. After adjusting for the scale difference between the MBV's and the Igenity panel scores, the resulting effects on feedlot profit were average daily gain, \$0.54, marbling, \$3.52, stayability, −\$2.81, and tenderness, \$0.19 (Table 8). Each of these traits has the opposite effect on feedlot profit as on cow-calf returns. The impact on the cow-calf returns was larger than on feedlot returns. These results have significant implications for the beef sector. Continued improvements in two terminal traits (ADG and marbling) and one consumer trait (tenderness) are not justifiable from a system perspective.<sup>6</sup> Alternatively, ribeye area panel score improved cow-calf returns but adversely impact feedlot returns.

### **Sensitivity analysis**

Given reduced-form equations were used to predict weaning, cow, and birth weights, further modeling was used to explore the effects of the Igenity panel scores with additional exogenous

<sup>6</sup>Admittedly, we did not evaluate the impact on consumers from each of these traits. There are possibly gains at the retail level from marbling and tenderness that are not included in our analyses.

**Table 9.** Regression results for weaning weight sensitivity analysis (*lbs*)

Variable	Equation		
	WW-PB <sup>a</sup>	WW-BW <sup>b</sup>	WW-AGE <sup>c</sup>
Constant	-291.26	-593.24***	737.39
<i>Igenity Panel Scores*</i>			
Average daily gain	-4.46***	-2.15	-4.82***
Birth weight	4.46**	-1.73	4.98***
Calving ease maternal	3.63*	3.44**	2.76
Docility	-2.90	-2.71	-3.45*
Fat thickness	-1.34	-1.97	-1.40
Heifer pregnancy	0.24	1.22	-0.11
Marbling	-5.13***	-2.46	-5.81***
Milk	1.62	0.56	1.85
Residual feed intake	-7.19***	-4.19**	-7.11***
Ribeye area	6.56***	4.10**	6.40***
Stayability	-4.03**	-3.15*	-4.05*
Tenderness	-4.27***	-3.18***	-4.55***
Female	-21.63***	-3.57	-20.25***
Age at weaning	6.87***	7.10***	-7.67
Age at weaning <sup>2</sup>	-0.01***	-0.01***	-0.06
Age at weaning <sup>3</sup>	-	-	-0.0001
Angus	-28.55***	-	-
Angus cross	18.32	-	-
Birth weight	-	2.67***	-

Notes: Single, double, and triple asterisks (\*, \*\*, \*\*\*) indicate significance at the 10, 5, and 1% level. Weaning weight equations with the addition of: <sup>a</sup>Primary breed (PB), <sup>b</sup>birth weight (BW), and <sup>c</sup>age at weaning<sup>3</sup> (AGE) are added to the original weaning weight equation to test the assumption of a reduced form model *ceteris paribus*.

variables in the model. Three additional equations were estimated for weaning weight that include a cubic effect for age, a class variable for primary breed, and calf birth weight. Table 9 shows the results of each of these equations. Primary breed includes Angus, Angus cross, and unknown breeds. Angus cross calves were sired by the Charolais cleanup bulls or part of the Hereford breeding program. Primary breed was hypothesized to partially mitigate the effects of the calf Igenity panel scores due to the genetic power of breed, however, that was not the case. Eight of the twelve calf panel scores were significant at the 10% level, and signs were unchanged for the panel scores. Angus was a significant predictor of weaning weight ( $p < 0.01$ ) and resulted in a 29-pound decrease in weaning weight. The measure of genetics used by Worley et al. (2021) considered breed as their sole measure of genetics. The results in Table 9 suggest that there is considerable information in the genetic panel scores beyond breed. Future research with much larger datasets might be able to consider the possibility of genetic effects varying by breed.

Birth weight also significantly impacted weaning weight ( $p < 0.01$ ). In this equation, five panel scores were significant with the sign changed for the birth weight score. The birth weight score became insignificant as actual birth weight appears to be a superior measure than the panel score in terms of predicting weaning weight. The other panel scores did not change their sign from the



**Table 10.** Sensitivity analysis of increased dystocia on marginal returns

Igenity panel score	Calf crop	Dystocia	Cow	Feed cost	Cow-calf	Feedlot	Beef sector
Average daily gain	(4.66)	2.58	0.25	(0.11)	(2.13)	0.54	(1.59)
Birth weight	4.86	(4.86)	0.46	(0.20)	(0.09)		
Calving ease direct	2.59	0.55	0.03	(0.01)	3.14		
Docility	(3.39)	0.41	(0.05)	0.02	(2.98)		
Fat thickness	(1.48)	(0.22)	(0.24)	0.10	(1.66)		
Heifer pregnancy rate	(0.17)	1.08	0.09	(0.04)	0.90		
Marbling	(5.68)	2.44	(0.32)	0.14	(3.18)	3.52	0.34
Milk	1.71	(1.50)	0.30	(0.13)	0.16		
Residual feed intake	(6.97)	1.75	(0.68)	0.29	(5.09)		
Ribeye area	6.26	(1.47)	(0.14)	0.06	4.82	(2.81)	2.01
Stayability	(3.81)	0.88	0.01	(0.00)	(2.94)		
Tenderness	(4.50)	0.96	(0.20)	0.09	(3.51)	0.19	(3.32)

original weaning weight equation, although the production and carcass traits had a much smaller effect on weaning weight.

The last weaning weight equation evaluated includes the cubic term for age. This model included eight significant panel scores and signs unchanged. So, the addition of other exogenous variables to the model did not impact the marginal revenues. Average daily gain, marbling, residual feed intake, and tenderness were still significant negative predictors of weaning weight, reducing cow-calf revenue.

The rate of dystocia could be higher for some producers, so the breakeven rate of dystocia was calculated at which the added value from the calf birth weight score was equal to the cost associated with dystocia. Table 10 shows the resulting effects of the calf Igenity panel scores on dystocia. Using an average birth weight of 85 pounds, the marginal revenue of \$4.86 from the change in birth weight score was set equal to the marginal cost of the dystocia equation. Solving for the dystocia rate yields a 12% ( $= BW \times 0.00135$ ), meaning a dystocia rate of 12% ( $85 \times 0.00135$ ) is required to offset the loss from a lower weaning weight. This is a very high rate of dystocia, although it is not impossible with heavier birth weights.

As feed cost uses metabolic cow weight, a change in feed cost was also considered. Sensitivity analysis on feed cost shows only changes of a few cents per each unit change in panel score and so are not presented here. This is because the panel scores have little influence on cow weight.

## Conclusion

Thompson et al., (2014, 2016) found that Igenity scores focused on production and carcass traits had positive relationships with feedlot performance. Our results show average daily gain, residual feed intake, and marbling had negative relationships with birth and weaning weights and cow-calf returns. While lower birth weights and increased calving ease are generally positive for cow-calf producers, the lower weaning weights reduce returns.

Cow-calf producer marginal returns drop sharply for an additional unit of residual feed intake, average daily gain, marbling, and tenderness scores. These scores have a negative net effect when compared to the average daily gain, marbling, and tenderness feedlot molecular breeding values for selection and indicating net negative gains to the sector. Our results suggest, as has been

hypothesized, that the U.S. beef sector has put too much emphasis on terminal traits without fully evaluating the impact on cow-calf producers. Given the significance and net negative effect of the panel scores to producers using the cattle in this study, producing for traits on feedlot and carcass traits is harmful when system-wide impacts are assessed.

One caution is that this is the first study of genetic panel scores and cow-calf productivity. While the study is from four ranches, the herds were managed similarly under a similar climate. Many had similar genetics although some were purchased from different breeders. Before widespread recommendations from our study can be made, the study needs to be replicated for a wider range of genetics and environments.

**Author contribution.** Conceptualization, G.L.G., B.W.B. and J.T.B.; Data Curation, J.T.B., A.B., E.M.W.; Formal Analysis, G.L.G., B.W.B., J.T.B., E.A.D., E.M.W.; Writing—Original Draft, G.L.G.; Writing—Review and Editing, B.W.B., J.T.B., E.A.D., G.L.G.; Software A.B.; Project administration, B.W.B. and J.T.B.; Funding Acquisition, B.W.B and J.T.B.

**Funding statement.** The data collection was funded by the Noble Research Institute, LLC (NRI), Ardmore, Oklahoma. Garrison was funded by a memorandum of understanding with NRI. Brorsen receives funding from the Oklahoma Agricultural Experiment Station and National Institute of Food and Agriculture Hatch Project OKL03170 as well as the A.J. and Susan Jacques chair. The data collection was begun while Biermacher and Whitley were employees of NRI.

**Data availability statement.** The data are owned by NRI. The authors are willing to assist others in gaining the same restricted access that the authors were granted.

**Competing interests.** The authors declare no competing interests.

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Cite this article: Garrison, G.L., B.W. Brorsen, J.T. Biermacher, E.A. DeVuyst, A. Bancroft, and E.M. Whitley (2023). "What is the Cow-Calf Economics of Genetic Panel Scores for Feedlot Traits?" *Journal of Agricultural and Applied Economics* 55, 651–669. <https://doi.org/10.1017/aae.2023.35>