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RESEARCH ARTICLE

Economics of Smaller Aberdeen-Derived Beef Cows

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Abstract
We investigate differences in profitability of three Aberdeen-influenced breeds, Angus, Red Angus, and American Aberdeen. Using data from North Dakota, we measure differences in birth weights, calving intervals, weaning weights, cow weights, and profitability. Weaning weights differ between breeds, setting up a trade-off between lower feed costs for smaller cows and higher revenue for larger cows. American Aberdeen-influenced cows bred to Red Angus bulls have \$1–\$6 per acre higher returns than Angus or Red Angus-influenced cows. Aberdeen sires have the lowest returning calves.

Keywords: Aberdeen Angus; beef cattle; genetics; cow weight

1. Introduction
Numerous factors affect U.S. cow-calf profitability. Some factors are outside of the control of producers, such as prevailing market prices and weather. But others, such as breed and frame size, are controllable determinants of profitability. Of interest in this study are how differences in birth weights, calving interval, weaning weights, and feed expenses vary across Angus-, Red Angus-, and American Aberdeen-influenced cow herds and how those differences translate into profits. The three breeds derive from the same lineage but have developed under different selection pressures. In 1873, four Angus bulls were transported from Scotland to Kansas (American Angus Association, 2020). Over the next decade, 1,200 Angus cattle were imported to the Midwest, eventually becoming the American Angus breed (American Angus Association, 2020). Red Angus cattle was derived from Angus cattle but with red pigmentation due to a recessive gene (Oklahoma State University, 2015).

The origins of the Aberdeen breed date to 1974. An Angus herd at the Trangie (Australia) Research Center was separated into a "Lowline" herd, who had low yearling growth rates, and a "Highline" herd, who had high yearling growth rates (Barnett, 2020). After 15 years of researching the two herds, the "Lowline" herd stabilized at 30% smaller than the "Highline" herd (Barnett, 2020). "Lowline" cattle were imported into the U.S., becoming the American Aberdeen breed. Aberdeen cows are known for their calving ease, docility, low feed requirements, and higher stocking rates (Barnett, 2020).

While these three breeds have a common origin, selection pressures have changed genetics and phenotypes, including mature weight. This is relevant as mature beef cow weight has steadily increased in U.S. herds (Wiseman, Lalman, and DeVuyst, 2018), leading to increased weaning weights. However, Bir et al. (2018) found the marginal gains from heavier weaned calves from larger cows are offset by increased feed costs due largely to lower stocking rates, so larger cows had lower economic returns. Since the Aberdeen breed was selected for lighter cow weights, the results from Bir et al. (2018) suggest potential for higher cow-calf profits than their Angus and Red Angus cousins.

Calving interval, that is, the number of days between subsequent calving, also affects cow-calf profitability. A narrow calving window (<60–90 days) translates into more uniform calves and larger lot sizes at auction, potentially increasing returns. Ward, Ratcliff, and Lalman (2017) found that calves marketed in uniform lots of 10 head or more receive higher premiums than smaller non-uniform lots. Williams et al. (2012) found a lot selling one calf had prices $7.00/cwt less than a lot selling ten calves for identical weight and quality.

Ideally, a cow will produce one calf at the same time each year after being successfully bred during a breeding window. If a cow does not successfully rebreed in the allotted time, the producer must decide whether to transition her to a later breeding season, cull her, or retain her with delayed calving (Carpenter and Sprott, 2020). Cow-calf operations with tight calving intervals were more profitable (Amundson, 2020). Tight calving intervals lead to more uniform calves that better meet demand (Howard, 2013). Brown et al. (1954) concluded that calving intervals are influenced by calf's sire, nutrition, age, and the birth weight of the cow's previous calf. Titterington et al. (2017) reported dam breed and age and calving month significantly affect calving interval. According to Frazier et al. (1999), higher birth weight resulted in longer mature cow calving interval. Birth weight and weaning weight predicted calving interval but were affected by changes in growth traits (Frazier et al., 1999). Doren, Long, and Cartwright (1986) found "weaning weight of the previous calf was positively correlated with postpartum conception and calving interval."

Given previous research, it is possible, even likely, that genetic and phenotypic differences between Angus, Red Angus, and Aberdeen breeds differentially influence calving interval. Beef cows with recorded influence, that is percentage breed cows, from these three beef breeds are evaluated here. We hypothesize these cows differ in calving interval, weaning weights, revenues, and associated production costs. To determine the economic impact of genotypic and phenotypic differences between these breeds, we estimate models of birth weight, calving interval, and weaning weight. Feed costs, a critical component in economic returns, are approximated using a ration software tool. We then use these models to estimate expected biologic and economic returns by breed.

2. Bio-economic Model

It is assumed that the producer's objective is to maximize weighted average expected returns to fixed costs, labor, and management from cow-calf production by choosing sire and dam breeds. Mathematically,

$$\begin{aligned}\underset{D,S}{Max}\sum_{m=1}^{10}&[E[(Weaning\ Weight(D,S,Age\ at\ weaning(CI,D,S)] \times E[Price(Weaning\ Weight_m)]\\&+E(CullCowRevenue(D))-E[Cost(Cow\ weight_m, age_m, D)]) \times p(m) \times CC\%]/Acres\ per\ head(Cow\ \ weight_m)\end{aligned} \tag{1}$$

where D and S are dam and sire breeds, respectively, t is the age of the cow, CI is calving interval, $p(m)$ is the proportion of the cow herd of age m, and CC% is the percent calf crop. The model is normalized on acres required per head assuming pasture acres are fixed for a producer. Even though per head profits might be highest for a breed, higher forage requirements, and thus lower stocking rates, means fewer heavy-weight cows can be stocked on a given acreage. Total profits can then be higher for lighter-weight cows with lower per head profit but a higher stocking rate.

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To calculate weighted average profits, weaning weights were estimated for Angus- (AN), Red Angus- (AR), and Aberdeen-(LO[1]) influenced beef cows and bulls. Weaning weights were estimated functions of birth weights and calf age at weaning (among other variables), similar to Bir et al. (2018). Given the potential for calving interval to differ between sire and dam breeds, calving interval was also estimated and used to calculate calf weaning age on October 31, the assumed weaning date. Empirical model specifications for birth weight, calving interval, and weaning weights are discussed below.

2.1. Empirical Models

2.1.1. Calf Birth Weight Model

A model, modified from Bir et al. (2018), was used to estimate birth weight as a function of dam and sire breeds, dam's weight, age, and age squared, year of birth, and calf sex[2] and specified as:

$$\begin{aligned} CalfBirthWeight_{ist} = {} & \alpha_1 + \alpha_2 ADG_{i,t-1} + \alpha_3 CowBCSatWean_{i,t-1} + \alpha_4 CowWeightAtWean_{i,t-1} \\ & + \alpha_5 CowAge_{it} + \alpha_6 CowAge_{it}^2 + \alpha_7 AR_{it} + \alpha_8 LO_{it} \\ & + \alpha_9 C\_AR_{it} + \alpha_{10} C\_LO_{it} + \alpha_{11} C\_Unkwn \\ & + \alpha_{12} C\_UK_{it} + \alpha_{13} C\_Cont_{it} + \alpha_{14} CalfBirthYear_{it} \\ & + \alpha_{15} CalfSex_{it} + e_{it} + v_t + d_i + \rho_s \end{aligned} \tag{2}$$

where $CalfBirthWeight_{ist}$ denotes calf birth weight for dam i, sire s, and year t, α_1 denotes the intercept (base of Angus sire and Angus dam). $ADG_{i,t-1}$ denotes the average daily gain from the dam's previous calf during nursing. $CowBCSatWean_{i,t-1}$ denotes the dam's body condition score at her previous weaning. $CowWeightAtWean_{i,t-1}$ denotes the dam's weight at her previous weaning. $CowAge_{it}$ denotes the age of the dam and was estimated in quadratic form. AR_{it} denotes a Red Angus sire and LO_{it} is an Aberdeen sire. C_AR_{it} denotes a Red Angus dam, C_LO_{it} is an Aberdeen dam, C_UNKWN_{it} are the dams of unknown breeds, C_UK_{it} are dam breeds from the UK (other than AN, AR, and LO), and C_CONT_{it} are Continental dam breeds. $CalfBdateYear_{it}$ is the year that the calf was born. $CalfSex_{it}$ indicates calf sex ϵ\{Heifer, Bull\}. The error term, e_{it}, and random effects for year v_t, individual dams d_i, and individual sire ρ_s are assumed to be independent and normally distributed for dam i, sire s, and year t.

2.1.2. Calving Interval Model

Calving interval was specified as:

$$\begin{aligned} LnCalvingInterval_{ist} = {} & \beta_1 + \beta_2 BirthWeightRatio_{i,t-1} + \beta_3 ADG_{i,t-1} + \beta_4 CowBCSatWean_{i,t-1} \\ & + \beta_5 CowWeightAtWean_{i,t-1} + \beta_6 CowAge_{it} + \beta_7 CowAge_{it}^2 + \beta_8 AR_{it} + \beta_9 LO_{it} \\ & + \beta_{10} C\_AR_{it} + \beta_{11} C\_LO_{it} + \beta_{12} C\_Unkwn + \beta_{13} C\_UK_{it} + \beta_{14} C\_Cont_{it} \\ & + \beta_{15} CalfBirthYear_{it} + \beta_{16} CalfSex_{it} + \varphi_{ist} + r_t + \tau_i + \chi_s \end{aligned} \tag{3}$$

where $LnCalvingInterval_{ist}$ denotes the natural logarithm of the number of days between each calving for dam i and year t. β_1 denotes the intercept for an Angus sire and Angus dam.

[1]The uniform breed code now denotes American Aberdeen as "AA," but "LO" is also listed.

[2]We are unable to use milk EPDs in our models as (1) the cows in the study are not purebred but influenced and (2) the Aberdeen Angus Breed has not developed EPDs for their breed.

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$BirthWeightRatio_{i,t-1}$ is lagged birth weight[3] divided by dam weight at weaning from the previous year. The error term φ_{it} and random effects for dam τ_i, sire χ_s, and year r_t are assumed to be independent and normally distributed.

2.1.3. Weaning Weight and Dam Weight Models

A model also modified from Bir et al. (2018) was used to estimate weaning weight as follows:

$$\begin{aligned} CalfWeaningWeight_{ist} = {} & \delta_1 + \delta_2 AR_{it} + \delta_3 LO_{it} + \delta_4 CalfBirthWeight_{it} + \delta_5 AgeAtWean_{it} \\ & + \delta_6 CowBCSatWean_{i,t-1} + \delta_7 CowWeightAtWean_{i,t-1} + \delta_8 CowAge_{it} \\ & + \delta_9 CowAge_{it}^2 + \delta_{10} C\_AR_{it} + \delta_{11} C\_LO_{it} + \delta_{12} C\_Unkwn_{it} + \delta_{13} C\_UK_{it} \\ & + \delta_{14} C\_Cont_{it} + \delta_{15} CalfBirthYear_{it} + \delta_{16} CalfSex_{it} + u_{it} + w_t + \phi_i + \eta_s \end{aligned} \tag{4}$$

where $CalfWeaningWeight_{ist}$ denotes calf weaning weight for a calf from dam i, sire s, and year t, δ_1 denotes the intercept for an Angus sire and Angus dam. The error term u_{it} and random effects for dam φ_i, sire η_s, and year w_t are assumed to be independent and normally distributed. For each breed, dam weight at age two through ten was estimated as

$$CowWeightAtWean_{it} = \theta_1 + \sum_{n=2}^{4} \theta_i CowBreed_{it} + \theta_5 CowAge_{it} + \theta_6 CowAge_{it}^2 + \gamma_{it} + \omega_i \tag{5}$$

where ω_i is random effect by cow. These cow weights were used to simulate calf birth weight, calving interval, and calf weaning weight.

2.1.4. Simulated Returns

To compute revenue by dam and sire breed, birth weight, calving interval, and weaning weight models were calculated using equations (2)–(5) using mean values of right-hand-side variables for each breed and dam age. Nine combinations of dam and sire breeds were included in the calculations. First, cow weights were simulated using equation(5). Second, bull and heifer birth weights were simulated using the regression results from equation(2) and cow weights from (5). Third, using the calculated cow weights and birth weights, calving intervals were calculated using equation(3). Last, using prior simulated values, weaning weights by dam and sire breeds for steer and heifer calves were calculated using equation(4). These results, along with 2010–2019 calf price[4] data from Oklahoma auctions (Livestock Marketing Information Center, 2020), were used to calculate heifer and steer revenues by year, cow age, dam breed, and sire breed. The number of heifers sold was adjusted to account for heifers retained as replacements for culled cows. Using cow weights for each breed and age and the percent of cows culled by age (taken from Azzam et al., 1990), expected cull cow revenue was computed and included in annual revenue.

An age distribution of cows, taken from Azzam et al. (1990) as modified by Bir et al. (2018), was used to weight the distribution of calf weaning weights and revenues based on dam age. Revenues were then averaged across the 10 years. Based on the culling model, 19 heifers were retained annually for 100-head breeding herd. We assumed 85% of the retained heifers breed with the balance culled as feeder heifers[5].

[3]Lagged values, such as lagged birth weight and lagged ADG, are taken from a dam's previous calf as these prior outcomes are hypothesized to influence subsequent calving interval.

[4]Linear interpolation was used to approximate prices for each weaning weight.

[5]This is a conservative assumption as many heifers are bred after the desired window and are sold as bred heifers.

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3. Data

Data on cows, bulls, calves, and calving season were collected from North Dakota State University's Dickenson Research Extension Center (DREC) research herd. In the 1990s, DREC started discussing the benefits of small cows versus large cows and began breeding larger heifers to several breeds, including Angus, Red Angus, and Aberdeen bulls. DREC's research focused on comparing breed efficiency. Data were collected from 2001 to 2018 and consisted of 1,204 observations from primarily spring-calving cows[6] with lineage from each of the three Angus-derived breeds and other beef breeds. Data included sire of dam breed, dam birth date, sire breed, calf birth date, calf sex, calf birth weight, calf weaning date, calf weaning weight, dam weight at weaning, and dam body condition score. Summary statistics for the data are shown in Table 1. As average daily gains of nursing calves are critically important in determining weaning weights, these are reported in Table 2.

Feeder calf and cull cow prices from North Dakota (LMIC, 2020) and the age distribution model were used to calculate weaned calf, cull feeder heifer, and cull cow revenues. Pasture, hay, and protein supplementation requirements were calculated using CowCulator[7] (Lalman and Gill, 2013). The feed requirement calculations are based on cow weight, stage of gestation/lactation, body condition score, and target body condition score.[8] Given the climate in western North Dakota, cows were assumed to graze smooth brome grass pastures for 7 months and fed hay for the remaining 5 months each year. Protein in the form of 20% range cubes was used to supplement protein as required. Rations were computed for each breed by cow age and month of the year, resulting in 360 rations. Annual requirements for pasture, hay, and protein were computed by summing across months by age and breed.

Smooth brome grass pasture yields varied from 1500–2700 pounds per acre (Manske, 2018). Using a pasture utilization rate of 25% (Meehan et al., 2018), acres of pasture were computed for each breed and cow age by month under each of the grass yields. Acreage requirements were then multiplied by the age distribution model to generate a weighted average acreage requirement by dam breed, that is, acres of pasture per cow. Pasture utilization rates were then varied from 25% to 50% to assess the sensitivity of the model to this parameter.

Hay was assumed fed from October through March with an 80% utilization rate (Sexten et al., 2021). Dividing the annual hay requirement by 0.8 generated annual hay purchases for each breed and age. Then, the distributions of hay purchases were weighted by the age distribution and summed to generate the weighted average hay purchased, that is, pounds of hay fed per cow. Pounds of protein (20% range cubes) fed were similarly computed, assuming a 100% utilization rate. USDA National Agriculture Statistics data were used for North Dakota pasture lease rates and hay prices (USDA, 2019). Protein (20% range cube) prices were from Stillwater Milling Company (2020). Per head cow fixed and variable costs were taken from Doye and Lalman (2011) based on cow weight. Percent calf crop was set at 85% (UNL, 2015).

4. Results and Discussion

4.1. Regression Results

Calf birth weight, calving interval, and calf weaning weight models were estimated using PROC MIXED in SAS Enterprise Guide 9.4 (SAS Institute Inc., 2012). Results for the four models are discussed below.

[6]Calving date varied by year with bull turn-out dates but mostly February through June. March and April were peak calving months in the data.

[7]CowCulator uses Nutrient Requirements for Beef Cattle (National Academies of Sciences, Engineering and Medicine, 2016) equations for beef cow nutritional requirements.

[8]There may be differences in nutritional requirements for Aberdeen-influenced beef cows. Research is not available to indicate their nutritional demands vary from other Angus-derived breeds.

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Table 1. Summary statistics (n = 1204)

Item	Mean	SD	Minimum	Maximum
Calf Birth Weight (lb)	76.9	14.0	25.0	140.0
Lagged Calving Interval (days)	370.6	0.09	x309.0	784.0
Calf Weaning Weight (lb)	499.6	92.8	170.0	776.0
Calf Age at Weaning (days)	205	23.89	127	253
Lagged Calf Birth Weight Divided by Cow's Weight at Weaning	0.06	0.02	0.02	0.7
Lagged Average Daily Gain (lb/day)	1.0	0.18	0.5	1.6
Lagged Cow Body Condition Score at Weaning	5.5	1.1	0	8.0
Lagged Cow weight at Weaning	1236.6	212.8	704.0	1920.0
Dam Weight at Weaning (lb)	1236.6	212.8	704.0	1920.0
Dam Age at Weaning (years_	4.6	2.2	2.0	14.0
Cow Age at Calving (years)	3.8	2.1	1.0	13.2
Cow Age at Calving Squared (years)	18.9	22.9	1.0	173.4
Angus Sire (n)	187	–	–	–
Red Angus Sire (n)	655	–	–	–
American Aberdeen Sire (n)	362	–	–	–
Angus-influenced Dam (n)	166	–	–	–
Red Angus-influenced Dam (n)	341	–	–	–
American Aberdeen-influenced Dam (n)	277	–	–	–
Unknown Dam (n)	271	–	–	–
Other British Dam (n)	20	–	–	–
Continental Dam (n)	129	–	–	–
Calf Birth Year	–	–	2003	2018
Heifer calf (n)	634	–	–	–
Bull calf (n)	570	–	–	–

Table 2. Average daily gain (lb/day) for nursing calves[a]

		Sire Breed		
Dam Breed	Calf Sex	AN	AR	LO
AN	Bull	2.77	2.61	2.28
	Heifer	2.50	2.44	1.96
AR	Bull	2.70	2.55	2.20
	Heifer	2.46	2.31	1.96
LO	Bull	2.14	2.23	1.92
	Heifer	2.12	2.06	1.84

[a]ADG was calculated from birth to weaning using the DREC data set.
AN = Angus-influenced; AR = Red Angus-influenced; LO = America Aberdeen-influenced.

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Table 3. Regression results for birth weight (lb), natural log calving interval (days), and weaning weight (lb)

Variable[a]	Birth Weight (SE)	Ln Calving Interval (SE)	Weaning Weight (SE)
Intercept	55.1 (3.85)***	5.9 (0.04)***	−298.9 (27.14)***
Calf birth weight	–	–	2.3 (0.12)***
Calf age at weaning			2.5 (0.09)***
Lagged calf birth weight divided by cow's weight at weaning	–	0.7 (0.26)***	–
Lagged average daily gain	−0.9 (0.99)	−0.02 (0.01)*	–
Lagged cow body condition score at weaning	−0.4 (0.32)	2.4e-3 (2.5e-3)	−3.9 (1.61)*
Lagged cow weight at weaning	6.0e-3 (2.0e-3)***	2.4e-5 (1.8e-5)	0.08 (0.01)***
Cow age at calving years	8.2 (0.77)***	−8.4e-3 (5.5e-3)	30.2 (3.37)***
Cow age at calving years squared	−0.6 (0.06)***	6.2e-4 (4.7e-4)	−2.4 (0.27)***
Red angus sire	1.7 (1.90)	−1.6e-3 (9.6e-3)	−15.2 (6.70)*
America Aberdeen sire	−5.0 (2.3)*	−0.01 (0.01)	−56.82 (8.01)***
Red angus dam[b]	−0.2 (0.88)	6.7e-3 (5.0e-3)	6.2 (3.92)
American Aberdeen dam	−9.4 (0.88)***	5.9e-1 (5.7e-3)	−23.2 (4.68)***
Unknown dam	−0.4 (1.21)	−1.8e-3 (7.88e-3)	−1.6 (5.31)
Other British dam	−0.8 (0.85)	−9.7e-4 (5.0e-3)	−1.1 (3.78)
Continental dam	2.3 (1.1)*	5.5e-3 (7.1e-3)	3.2 (4.83)
Heifer	−6.2 (0.60)***	–	−26.9 (2.52)***
n	1198	765	1198
−2 Log Likelihood	9010.5	−1817.0	12,353.5
Covariance Calf sire	16.7	0.0002	149.8
Covariance Calf dam	25.7	0	615.2
Covariance Birth year	9.3	0.003	620.5
Residual variance	82.3	0.003	1314.3

[a]Fixed effects for year omitted for brevity.
[b]Dam breeds are Angus influence (base), Red Angus-influenced, and American Aberdeen-influenced.
$^{*}P \leq 0.05$; $^{**}P \leq 0.01$; $^{***}P \leq 0.001$.

4.1.1. Birth Weight

The coefficient estimates, standard errors, and level of significance for the calf birth weight model are shown in Table 3. The coefficient for cow weight at previous weaning ($CowWeightAtWean_{i,t-1}$) is positive and statistically significant, implying larger cows birthed heavier calves. The coefficient for cow age ($CowAge$) is positive and statistically significant, and the coefficient for cow age squared ($CowAge^2$) is negative and statistically significant. Taken together, birth weight increased in cow age up to age six and then declined. Of the sire breeds, only the Aberdeen coefficient (LO) is statistically significant, decreasing birth weight by 5.0 pounds relative to Angus sires. The Aberdeen-influenced dam coefficient (C_LO) is also negative and statistically significant, decreasing birth weight by 9.4 pounds relative to Angus-influenced dams. Heifer calves were 6.2 pounds lighter than bull calves.

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Table 4. Regression results for dam weight (lb) at weaning by breed and age (n = 1,203)

Variable[a]	Estimate
Intercept	909.7 (25.92)***
Red Angus	7.8 (16.03)
American Aberdeen	−240.8 (14.70)***
Age	134.4 (4.54)***
Age squared	−7.76 (0.39)***
−2 Log Likelihood	14,371.7
Covariance Calf dam	18,924.0
Covariance Birth year	1932.9
Residual variance	3548.9

[a]Angus-influenced dam base. Other breeds omitted for brevity.
*$P \leq 0.05$; **$P \leq 0.01$; ***$P \leq 0.001$.

4.1.2. Calving Interval

The coefficient estimates for the natural logarithm of calving interval (*LnCalvingInterval*) model are also shown in Table 3. The coefficient for calf birth weight divided by cow's weight at weaning of previous calf ($BirthWeightRatio_{i,t-1}$) was positive and significant at $P \leq 0.001$. Heavy calves relative to dam weight increased the following calving interval similar to the findings of Frazier et al. (1999). This may be due to increased nutritional demands during pregnancy delaying breeding and/or increased damage to the reproductive tract during calving. Average daily gain of the previous calf (ADG_{t-1}) is negative and significant at the $P \leq 0.05$ level. Frazier et al. (1999) also reported that calving interval decreased as weaning weight increased. This may be due to higher metabolic efficiency of the dam leading to both higher ADG of her calves and shorter calving interval.

4.1.3. Calf Weaning Weight

The coefficient estimates for the calf weaning weight model (*CalfWeaningWeight*) are shown in Table 3. The coefficient for calf birth weight (*CalfBirthWeight*) was positive and statistically significant. Heavier calves at birth are heavier at weaning, with each pound of birth weight adding 2.3 pounds of weaning weight. The coefficient for cow body condition score (BCS) at the previous calf weaning ($CowBCSatWean_{t-1}$) was negative and statistically significant. This result seems counter intuitive but may be related to lower milk production. Cows producing less milk may be better able to maintain BCS but wean lighter calves. The coefficient for cow weight at weaning (*CowWeightAtWean*) was positive and statistically significant, meaning heavier cows wean heavier calves. The coefficient for cow age (*AgeAtCalving*) was positive and statistically significant. The coefficient for cow age squared ($CowAge^2$) is negative and statistically significant. Combined these two coefficients indicate that cows weaned their heaviest calves at age six or seven. Both of the two reported sire breeds were statistically significant. At weaning, Red Angus-sired calves were 15.2 pounds lighter at weaning and Aberdeen-sired calves were 56.8 pounds lighter on average, than Angus-sired calves. Calf sex coefficient (*CalfSex*) was negative and statistically significant, indicating heifer weaning weight was 26.9 pounds lighter than steer weaning weight.

4.1.4. Dam Weight at Weaning

Table 4 provides the regression results for dam weight at weaning (equation 5) by breed and age. Coefficients for cattle breeds were negative and statistically significant when compared to the base

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Table 5. Simulated steer and heifer calf birth weight (lb)

Dam										
Sire		Angus			Red Angus			Aberdeen		
Cow Age	Calf Sex	AN	AR	LO	AN	AR	LO	AN	AR	LO
2	Bull	79	79	69	81	81	70	74	74	64
	Heifer	73	73	62	75	75	64	68	68	58
3	Bull	85	85	74	87	87	76	80	80	70
	Heifer	79	79	68	81	81	70	74	74	63
4	Bull	90	90	79	91	91	81	85	85	74
	Heifer	84	84	73	85	85	75	79	79	68
5	Bull	93	93	82	95	95	84	88	88	77
	Heifer	87	87	76	89	89	78	82	82	71
6	Bull	95	95	84	97	97	86	90	90	79
	Heifer	89	89	78	91	91	80	84	84	73
7	Bull	96	96	85	97	97	87	91	91	80
	Heifer	89	89	79	91	91	81	85	85	74
8	Bull	95	95	84	97	97	86	90	90	80
	Heifer	89	89	78	91	91	80	84	84	73
9	Bull	93	93	83	95	95	84	88	88	78
	Heifer	87	87	76	89	89	78	82	82	72
10	Bull	90	90	79	92	92	81	85	85	75
	Heifer	84	84	73	86	86	75	79	79	68

AN = Angus-influenced; AR = Red Angus-influenced; LO = American Aberdeen-influenced.

dam breed, Angus-influenced. The coefficient for dam age was positive and statistically significant, while the coefficient for dam age squared was negative and statistically significant. This implies that dam weight at weaning increases up to about age ten and then declines; however, most cows are culled at or before age ten. These regression results were used to simulate dam weights for each breed from ages two through ten.

4.1.5. Simulation Results

Using the regression estimates from the birth weight equation(2) and dam weights (5), birth weights were simulated. Average daily gain varied depending on sire and dam breeds (see Table 2). Body condition score was held at 5.5 at calving and 5.0 at weaning (OSU, 2021). Other variables were held at breed mean values. Table 5 reports the simulated birth weights by dam and sire breed and age of dam. As expected, younger cows birth lighter calves, calf birth weight peaks at cow age 6–7. For an Angus dam and Angus sire, bull calf birth weights range from 79 to 96 pounds as the dam age increases from two to six, and heifer birthweights range from 73 to 89 pounds. For a Red Angus dam and Red Angus sire, bull calf birthweights range from 81 to 97 pounds, and heifer birth weights range from 75 to 91 pounds. For an Aberdeen-influenced dam and Aberdeen sire, bull calf birth weights range from 64 to 80 pounds, and heifer birthweights range from 58 to 74 pounds. There is about a ten-pound increase in birth weight for Angus and Red Angus-sired calves compared to Aberdeen.

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Table 6. Simulated steer and heifer calf weaning weight (lb)

Dam		Angus			Red Angus			Aberdeen		
Sire										
Cow Age	Calf Sex	AN	AR	LO	AN	AR	LO	AN	AR	LO
2	Steer	522	531	456	511	520	445	455	464	388
	Heifer	482	491	415	471	480	404	414	423	347
3	Steer	554	558	478	543	545	469	499	501	425
	Heifer	516	518	442	505	507	431	459	460	387
4	Steer	587	591	513	576	578	502	530	534	458
	Heifer	549	551	475	538	540	464	489	493	420
5	Steer	611	613	535	600	601	526	554	555	482
	Heifer	571	572	499	559	561	488	513	517	444
6	Steer	624	627	550	612	614	538	566	570	494
	Heifer	583	587	511	572	573	500	525	529	456
7	Steer	627	631	553	616	617	541	569	571	498
	Heifer	586	590	514	575	576	503	529	533	459
8	Steer	621	622	547	610	611	536	563	565	492
	Heifer	580	582	509	569	570	497	523	524	453
9	Steer	603	607	529	592	594	521	546	550	474
	Heifer	565	567	491	554	556	480	505	509	436
10	Steer	579	581	503	566	570	494	522	523	448
	Heifer	539	540	467	528	529	456	479	483	409

AN = Angus-influenced; AR = Red Angus- influenced; LO = American Aberdeen-influenced.

Using the regression estimates for equation(3) and simulated dam weights and calf birth weights, calving intervals were simulated for each dam breed × sire breed for cow ages two through ten. Little difference was observed in calving intervals by dam age. No significant difference was found for dam and sire breeds. However, the heavier a dam's previous calf was relative to her weight, the longer the calving interval.

4.1.6. Simulated Calf Weaning Weights

Using the regression estimates from equation(4) and simulated cow weight, birth weights, and calving intervals, weaning weights were simulated. Table 6 shows simulated steer and heifer weaning weights. As expected, first-calf heifers and young cows wean lighter calves because younger cows are still growing and likely not producing as much milk as older, mature cows (Andresen et al., 2020). The weaning weights peak at dam ages 6–7. As expected, heifer weaning weights are about 40 pounds lighter than steer calf weaning weights. Of course, calves from LO sires and/or dams weigh substantially less at weaning than the other Angus-derived breeds. Table 7 reports simulated weaning weight to cow weight ratios. The heaviest ratios are Aberdeen-influenced dams × Angus or Red Angus sires. The lightest ratios are from Aberdeen sires.

Table 7. Simulated weaning weight to cow weight ratios

Dam	Angus			Red Angus			Aberdeen		
Sire	AN	AR	LO	AN	AR	LO	AN	AR	LO
Calf Sex									
Steer	0.43	0.44	0.38	0.42	0.42	0.37	0.48	0.48	0.41
Heifer	0.40	0.41	0.35	0.39	0.40	0.34	0.44	0.44	0.38

AN = Angus-influenced; AR = Red Angus-influenced; LO = American Aberdeen-influenced.

Table 8. Annual revenues ($/hd) by dam and sire breed

		Calf Revenue by Sire Breed		
Dam Breed[a]	Cull Cow Revenue	Angus	Red Angus	American Aberdeen
Angus	$131	$861	$864	$794
Red Angus	$134	$850	$852	$780
American Aberdeen	$113	$804	$839	$722

[a]Cows are not purebred, rather influence or "percentage."

4.1.7. Simulated Revenues, Costs, and Returns

Calf sales and cull cow revenues by dam breed are given in Table 8. As expected, revenue per head has a similar pattern as calf weaning weights. Angus- and Red Angus-influenced dams earned, on a per head average, more than Aberdeen-influenced dams regardless of sire breed. Both Angus and Red Angus calf revenues and cull revenues were always higher than the American Aberdeen-influenced dams. These results were driven, primarily, by weights. Heavier Angus- and Red Angus-influenced cows weaned heavier calves and, so, both cull cow and calf revenues were higher. The average revenues during the 10-year period were likely rather high in comparison to other historical returns.

There is one caveat needed. As Aberdeen Angus cows and bulls are smaller-framed, there is the possibility of frame score 3 (FS3) calves. Small-framed calves are often discounted in the sale barn. Newport (2013) reported small-framed calves sold for $22 per head less than comparable larger-framed calves. The data do not include calf frame scores. However, some evidence is available from the regression models. Percentage Aberdeen cows had 23-pound lighter calves at weaning (Table 3) but Aberdeen sires had calves weighing 57 pounds less than Angus-sired calves. Further, Aberdeen-influenced cows weighed 241 pounds less than Angus-influenced cows. So, it seems unlikely that the Aberdeen-influenced cows bred to Angus or Red Angus bulls had FS3 calves. Conversely, it does seem likely that Aberdeen-influenced dams bred to Aberdeen bulls did produce some percentage, perhaps a majority, FS3 calves. So, we apply the $22 per head discount from Newport (2013) to the Aberdeen-sired calves from Aberdeen influence cows.

Assuming a yield of 2100 pounds of smooth bromegrass per acre, weighted average required pasture acres over 7 months were 24 acres for Angus, 24.3 acres for Red Angus, and 20.3 acres for Aberdeen cows.[9] Table 9 provides the calculated feed expenses showing Angus cows, on average, cost $640 to feed per year, while Red Angus cows required $645 in feed costs, and Aberdeen cows required $593. These costs are driven by the differences in weight between the breeds. It was assumed that one bull was needed for every 25 cows. Per head costs for owning a bull were

[9]Includes acres needed for 1-year-olds and breeding bulls.

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Table 9. Weighted average feed quantities and costs and other costs by dam breed[a]

	Dam Breed		
	AN	AR	LO
Prairie Hay	5782 lb.	5854 lb.	5074 lb.
	$179	$181	$157
Native Grass	24.0 acres	24.3 acres	20.3 acres
	$383	$389	$325
Range Cubes (20%)	507 lbs.	486 lbs.	723 lbs.
	$78	$74	$111
Total Feed Cost	$640	$645	$593
Other Variable Costs	$116	$116	$98
Fixed Costs	$128	$128	$126
Bull expenses	$50	$50	$50
Total Costs	$934	$939	$867

[a]Assumes smooth bromegrass yields of 2100 lb per acre.
AN = Angus-influenced; AR = Red Angus-influenced; LO = American Aberdeen-influenced.

estimated to be $50, assuming a bull cost $3,000 with a $1000 salvage value, depreciated over 5 years, and required $850 in feed and veterinary expenses annually. Table 9 also reports other variable expenses (veterinary, marketing, labor, etc.) and fixed costs per head.

As expected, sire breeds × dam breeds that weaned heavier calves, received higher revenue per head. Red Angus-sired calves we slightly heavier at weaning than other calves and Red Angus cull cows weighed more at culling, resulting in higher per head revenue. Of course, Aberdeen-sired calves were lighter weight, and these mating systems earned the least revenue per head. Aberdeen-influenced cows weaned lighter calves, earning the lower revenue than Angus- and Red Angus-influenced cows.

Red Angus bulls generated the highest returns per head between the three sire breeds. Calves from the Red Angus sires were slightly heavier than Angus-sired calves and much heavier than Aberdeen-sired calves, resulting in higher returns per head. Somewhat unexpectedly, Aberdeen-influenced cows having higher per head returns than the other dam breeds with the same sire breed in several grass yield scenarios. Across the grass yield scenarios, the highest per head return breeding system was Red Angus sires on Aberdeen-influenced cows. The difference in returns per head is largest in low grass yield scenarios as the larger-framed cows required relatively more acres per head. These results are driven largely by weaning rate ratios and cow feed costs. The highest weaning rate ratios (Table 8) were with Red Angus sires with Aberdeen-influenced cows. With Aberdeen cows having the lower cost per head (Table 9) and higher wean weight ratios with Red Angus bulls, return per head for this paring are higher than other breeding systems.

However, producers are constrained by grazing acres, so net returns per head are often a misleading measure of profitability.[10] Rather, the ability to generate higher returns per acre is the appropriate metric as in equation(1). So, the returns per head reported in Table 10 were divided by the acres required per head to generate returns per acre. These returns are reported in Table 11.

When normalized on acres required per head, there are advantages for the Aberdeen-influenced cow bred to Angus or Red Angus sires. The Aberdeen dam bred to a Red Angus sire

[10]Consider a heavy cow earning $50 and requiring 24 acres and then consider two lighter cows each returning $30 per head and requiring 12 acres. The total return is $60 for the same acreage. Thus, the appropriate metric is returned per acre.

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Table 10. Weighted average returns to fixed costs, labor, and management ($/hd) by dam and sire breed and pasture yield (lb/ac)

Dam	AN			AR			LO		
Sire	AN	AR	LO	AN	AR	LO	AN	AR	LO
Grass Yield									
1500	($96)	($92)	($163)	($111)	($109)	($181)	($75)	$(40)	$(157)
1800	($6)	($3)	($73)	($20)	($18)	($90)	$1	$36	$(81)
2100	$58	$61	($9)	$45	$46	($25)	$56	$90	$(27)
2400	$106	$109	$38	$93	$95	$24	$96	$131	$14
2700	$143	$146	$76	$131	$133	$61	$128	$163	$45

AN = Angus-influenced; AR = Red Angus-influenced; LO = American Aberdeen-influenced.

Table 11. Weighted average returns to fixed costs, labor, and management ($/ac) by dam and sire breed and pasture yield (lb/ac)

Dam	AN			AR			LO		
Sire	AN	AR	LO	AN	AR	LO	AN	AR	LO
Grass Yield									
1500	($3)	($3)	($5)	($3)	($3)	($5)	($3)	($1)	($6)
1800	$0	$0	($3)	($1)	($1)	($3)	$0	$2	($3)
2100	$2	$3	$0	$2	$2	($1)	$3	$4	($1)
2400	$5	$5	$2	$4	$4	$1	$5	$7	$1
2700	$8	$8	$4	$7	$7	$3	$8	$10	$3

AN = Angus-influenced; AR = Red Angus-influenced; LO = American Aberdeen-influenced.

generated the highest per acre returns with a $1–$6 per acre advantage over an Angus sire. Angus and Red Angus sires had very similar results, with $1 per acre of each and certainly with the confidence of our model results Aberdeen-sired calves were the lowest returning. These matings had the lowest weaning weights, resulting in low per head and per acre returns. Robustness of these results was evaluated by varying grazing efficiency and hay feeding loss. Neither change the qualitative conclusions. Improved grazing utilization improves profitability of all breeds and favors Aberdeen-influenced cows. Improved hay feeding efficiency improves profitability of all breeds with negligible impact on relative returns.

5. Conclusions and Implications

We investigated the differences in profitability between Angus, Red Angus, and Aberdeen-influenced beef cow herds due to birth weight, calving interval, weaning weight, and feed expense. Regression models of calving weights, calving intervals, and calf weaning weights were estimated by cow breed using data from the Dickinson Research Extension Center. Using these models, revenues by dam and sire breed were simulated for 10 years of price data. Pasture, hay, and protein supplementation needs were estimated using Cowculator (Lalman and Gill, 2013), and associated feed costs were calculated by breed. Returns to fixed costs, labor, and management were computed by sire breed and dam breed, resulting in nine sire by dam breed returns.

Using Angus and Red Angus sires, results indicate there are differences in returns per acre across the three cow breeds when measured in the more appropriate metric, dollars per acre. Smaller cows bred to Red Angus bulls resulted in the highest returns across all grass yield scenarios, by $1–$6 per acre. This mating resulted in the highest weaning weight to cow weight ratios (Table 7) and the lowest per cow (Table 9). Although calves weaned from this mating were lighter than calves from Angus-influenced and Red Angus-influenced dams, the reduction in feed cost and higher stocking rate offset the lower weaning weight. However, while confidence intervals were beyond the scope of our model, the differences in returns are likely not statistically significant.

A couple of strong caveats are necessary. Feed costs were simulated and not benchmarked to this herd's data. Nutritional requirements for Aberdeen-influenced cows in comparison to other beef breeds have not been established. So, we used standard assumptions for feed intake based on weight and known Angus requirements. However, there is potential that differences in selection pressures have resulted in differences in metabolic efficiency between the three breeds—differences that cannot be accounted for with just cow weight, stages of gestation and lactation, and cow age.

Also, a caution is needed regarding sample size: we have one environment. Cows and calves in other environments will perform better or worse in comparison to the environment in western North Dakota. For example, Russell (2014) found that lighter-weight cows were economically superior in nutritionally challenging environments. The colder North Dakota environment may favor a larger cow. Data from several locations are necessary to fully weigh the relative economic merits of Angus-derived breeds.

As U.S. beef cow herd weights have steadily increased (Wiseman et al., 2018), there is growing evidence that mature cow size has exceeded the optimal weight for the industry. From cow-calf producer to the consumer, it is reasonable to ask, even speculate, that cow size is heavier than economically optimal. Bir et al. (2018) found lighter-weight cows are more profitable than heavier-weight cows. Smaller cows require less forage than larger cows, so stocking rates are higher. Aberdeen-influenced herds can assist in downsizing cow sizes but their genetics might offset the gains from increased stocking rates. Here, our analyses find there a small but likely statistically insignificant economic advantage with Aberdeen-influenced cows bred to Angus or Red Angus sire in comparison to Angus and Red Angus cows. So, we cannot definitely conclude that the smaller-framed Aberdeen-influenced cows have economic advantages over their larger-framed cousins. However, there is no evidence of a disadvantage either.

From an industry perspective, smaller cattle better align with consumer preferences. Behrends et al. (2009) and Maples, Lusk, and Peel (2018) reported consumers were willing to pay a premium for thick cut steaks. However, as cow size increases, so does muscle cross-section area in carcasses. This means steaks must be cut thin to meet portion sizes. The current grading system rewards larger ribeye area as it is an indicator of carcass yield. In short, there are misaligned incentives in the beef sector. The higher value of thick cut, smaller cross-sectional area steaks is not being captured and passed through the chain to cow-calf producers. A marketing channel that captures the higher consumer willingness-to-pay and rewards carcasses with smaller ribeye area could possibly improve sector profits. In that case, Aberdeen-influenced cattle are well suited to match consumer preferences. It is worth noting that center cuts (ribeye, T bone, and sirloin steaks) only comprise about 16% of the meat from a boneless, trimmed beef (SDSU, 2020). So, it may be that larger carcass generate the highest return to the beef sector even accounting for lost value from thinner cut steaks. Before recommending an industry shift, the relative performance of Aberdeen-influenced cattle in feedlots and their carcass merit must be evaluated. Armed with multi-environment cow-calf data, feedlot data, and carcass data, a full assessment of the industry impacts of using smaller-framed breeding stock can be completed.

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