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An Economic Analysis of Genetic Information: Leptin Genotyping in Fed Cattle

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Abstract

The use of genetic knowledge is widespread in crop production but is just recently being utilized in livestock production. This study investigates the economic value to feedlots of a polymorphism in the bovine leptin gene. Previous studies indicate that this polymorphism is associated with fat deposition. Since fed cattle are often priced on a grid that considers both yield and quality grades, fat deposition is an important factor in the value and profitability of fed cattle. Using data from 590 crossbred steers and heifers, we estimate growth curves for relevant biological traits, both with and without genotypic information. Using the resulting functions, we then simulate carcass traits to various days-on-feed and compute the associated profit under three price grids. Maximum profits are determined in an unconstrained profit maximization model and in a model that constrains cattle to be marketed in 45-head "potloads." Results indicate that leptin genotypic knowledge has little impact on optimal days-on-feed but may play a role in valuing feeder cattle. The differences in value of cattle varied by as much as $37 per head between genotypes.

Keywords: genetics; leptin genotype; beef cattle; value of information

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Beef cattle are characterized by wide genetic variation across producers and regions, making production of a consistent product difficult (Brester). As a result, Brester argues that the beef industry faces two major disadvantages compared to its major competitors, pork and poultry. First, both the pork and poultry industries have used integration and coordination to reduce cost and thus gain market share at the expense of beef. While beef is still marketed primarily as a commodity, poultry and pork markets have become dominated by branded products. Second, the pork and poultry industries have been more receptive to creating convenient, consistent products demanded by consumers; the beef industry has been less receptive. The separation of key elements in the production and processing sectors has led to a lack of coordination between consumers' preference and producers' objectives (Hennessy et al.). In order to maintain competitiveness, it may be necessary for the beef industry to decrease the information gap between producers and consumers.

The quality and consistency of beef are affected by environment, genetics, and management. Both the pork and poultry industries have been able to create uniform production environments, management practices, and genetic prototypes most suitable for the production of their desired end-products. With beef production, environments and management practices vary depending on location, available resources, and operator characteristics. Genetic information, however, offers the opportunity for producers to find certain traits that are superior to others in their quest to produce a consistent, highly desirable product.

The use of genetic information may allow producers to decrease the variation found in beef despite production taking place in a wide variety of environmental and managerial situations. As such, genetic information can be considered an input into the production process. The price a producer would be willing to pay for an input is equal to "the sum of the money values of the input's characteristics to the purchaser" (Ladd and Martin). Ladd and Gibson describe economic value as "the amount by which net profit may be expected to increase for a single unit of improvement in that trait." Recent advancements in genetic knowledge allow for analyses to evaluate the returns to genetic knowledge.

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Perhaps the most studied gene relevant to beef production is the leptin gene. Leptin is a hormone secreted by fat cells and has been shown to influence carcass fat depositions (Geary et al.). Polymorphisms, or mutations, in the leptin gene have been shown to influence fat deposition in fed beef cattle (Bierman et al.; Buchanan et al.; Kononoff et al.; Larson et al. 2005; Larson et al. 2006). Lambert, DeVuyst, and Moss report differences in the value of cattle based on leptin genotype. Our purpose here is to quantify the value of leptin genotyping in fed cattle and to determine if genotypic knowledge affects optimal marketing dates.

Biology of Leptin

Leptin is a protein hormone produced by white adipose (fatty) tissue. It is released into the blood and transported to the brain. The brain then determines the amount of energy the body will expend (Rodriguez et al.) versus the amount of energy stored as fat. Leptin has been shown to have several effects on animals. Mice, with a naturally occurring mutation in the leptin gene, produce biologically inactive leptin (Kemp). When leptin was administered to these mice, reduced food intake, increased metabolism, and body weight loss resulted (Kemp). Kemp also notes that an increase in reproductive performance also occurred, indicating that leptin is involved with functions other than fat deposition. The energetic status of beef cattle has also been linked to serum leptin levels. Animals with higher leptin levels seem to maintain an energetic homeostasis (Sansinanea et al.). Due to its coordinating effect on whole body metabolism, “leptin may be classified as a ‘metabolism modifier’ ” (Houseknecht et al.).

A nucleotide switch at codon 252 in exon 2 of the leptin gene has been linked to variation in carcass composition (Buchanan et al., Geary et al., Yamada et al.) and feed intake (Lagonigro et al.). The codon 252 polymorphism is a switch from cytosine (*C*) to thymine (*T*) and causes a change in the amino acid incorporated in serum leptin. [An A to T single nucleotide polymorphism at codon 305 in exon 2 has been shown to increase carcass fat thickness in cattle (Buchanan et al.).] An animal can have one of three possible genotypes: *CC* (homozygous ‘lean’), *CT* (heterozygous), and *TT* (homozygous ‘fat’).

Between genotypes, significant differences were observed for both 12th rib fat and marbling score (Buchanan et al.). Fatter carcasses have been associated with the *T*-allele while the *C*-allele was associated with leaner carcasses (Kemp; Thue et al.). Kemp also notes that the animals with two copies of the *T*-allele deposited 12th rib fat earlier in the finishing process and at lighter weights.

Certain breeds of cattle (e.g., Hereford and Angus) are often associated with higher fat levels (Fitzsimmons et al.). Fitzsimmons et al. found that these ‘fat’ breeds had the greatest frequency of the ‘fat’ (*T*) allele. Similarly, they note that breeds generally accepted as ‘lean’ breeds (e.g., Charolais and Simmental) possessed a greater frequency of the ‘lean’ (*C*) allele. Leptin gene polymorphisms have been shown to affect fat deposition in beef carcasses (Bierman et al.; Bierman and Marshall; Buchanan et al.; Fitzsimmons et al.; Oprzadek et al.; Tessanne et al.; Thue et al.). Many researchers have conducted studies to investigate this correlation. While the studies have varied considerably, the results all seem to follow the same basic trend: cattle with two copies of the *T*-allele have higher carcass fat content.

Economic Relevance

Hennessy et al. argues three points regarding the value of genetic information. First, while production of a consistent product is difficult, more information about genetics would aid in the production of a more homogeneous product. Second, a processor will not differentiate their product unless they know that a purchased raw material will be consistent during processing. Third, information on raw materials can allow managers to operate more efficiently.

Chvosta et al. and Dhuyvetter et al. discuss the economics of information at breeding bull auctions. Analysis of who bears the cost of presale trait measurement is conducted using SPMs (birth weight, weaning weight, and yearling weight) and EPDs (information inclusive of individual performance and the performance of the animal's relatives used to predict future performance). Chvosta et al. use hedonic pricing to determine the price paid for a bull as a function of the bull's perceived attributes, expected market conditions, and sale terms. Similarly, Dhuyvetter et al. evaluated the price paid for a bull utilizing physical and genetic characteristics, EPDs, and market conditions.

The value of a carcass is determined by three main factors: weight, quality grade, and yield grade. Since quality and yield grade are based, at least in part, upon fat content, leptin's genetic effect on carcass value may be considerable. Increased fat deposition improves quality grade while negatively impacting lean yield. Ladd and Gibson discuss the economics of single trait selection when traits are negatively correlated. A trade-off must be made between the improvement of one trait and the degrading of another. Literature directly addressing the economic impact of leptin genotyping, however, is lacking.

Quality Grade

Leptin has been linked to carcasses containing higher fat content, causing higher marbling scores. Marbling affects the flavor, juiciness, and eating satisfaction in beef (Johnston). Carcass quality grade is based on the amount of marbling in the longisimus muscle on the cut surface between the 12th and 13th ribs (Brester). The four different quality grades for young cattle are prime, choice, select, or standard, with prime representing the highest marbling scores. Emphasis is placed on quality grade because higher marbling scores attract higher prices. Bindon refers to marbling as the 'gold standard' for quality grade. He notes that marbling satisfies a special consumer preference. Countries such as Canada, the United States, and especially Japan pay a premium for these higher quality carcasses. Consequently, marbling has considerable economic value when marketing finished cattle (Johnston).

Marbling is a complex phenomenon that has been studied quite intensely. Although the degree of marbling is a highly heritable trait (Shackelford et al.), the individual genes that contribute to marbling still remain unclear (Wegner et al.; Barendse et al.). Wegner et al. argue that breeding strategies could be greatly simplified if the ability to predict future marbling in young cattle existed.

Yield Grade

With leptin's tie to fat content, leptin genotype is hypothesized to affect yield grade. Yield grade estimates the amount of boneless, closely trimmed retail cuts contained in the more valuable parts of the carcass, i.e., round, loin, rib, and chuck, (Hale et al.). Yield grade utilizes measurements for hot carcass weight, ribeye area, 12th rib fat, and percent kidney, pelvic, and heart fat. There are five numerical classifications of yield grade (1-5), with a yield grade 1 representing the leanest carcasses.

Leptin's effect on fat deposition has several economic implications. Wegner et al. discuss the need for further investigation to clarify the association between the leptin gene and carcass value. Differences in carcass composition may validate genotyping entire herds that contain a high percentage of finished animals with marbling scores near a quality grade/price threshold (Bierman et al.).

Notation and Variables

The following notation is used throughout the remainder of this paper.

i	subscript indicating animal identification	$i \in \{1,\ldots,590\}$
j	subscript indicating measurement date	
k	subscript indicating marketing date	$k \in \{160,\ldots,220\}$
BF_{ij}	12th rib fat for the i^{th} calf on the j^{th} date	
REA_{ij}	ribeye area for the i^{th} calf on the j^{th} date	
W_{ij}	weight for the i^{th} calf on the j^{th} date	
HCW_{ik}	hot carcass weight for the i^{th} calf on the k^{th} marketing date	
MS_{ik}	marbling score for the i^{th} calf on the k^{th} marketing date	
KPH_{ik}	percent kidney, pelvic, and heart fat for the i^{th} calf on the k^{th} marketing date	
DOF_i	days-on-feed for the i^{th} calf	
YG_i	USDA yield grade on a scale 1-5 with 1 indicate leanest and 5 indicating fattest carcasses	
QG_i	USDA quality grade: Standard, Select, Choice, and Prime	
P_B	Base carcass price ($/cwt)	
P_{YG}	premium/discount ($/cwt) for USDA yield grade	
P_{GQ}	premium/discount ($/cwt) for USDA quality grade	

$C(DOF_i)$	cost as a function of days-on-feed
IC_i	purchase cost of feeder calf *i*
$OC(DOF_i)$	opportunity cost of investment

Analytical Model

Producers are assumed to maximize the sum of profits, or

$$(1)\quad \max_{DOF_i} \sum_i \pi_i(DOF_i) = \sum_i [P_B + P_{YG}(REA_i(DOF_i), HCW_i(DOF_i), BF_i(DOF_i), KPH_i(DOF_i))) \\ + P_{QG}(MS(DOF_i))] \times HCW_i(DOF_i) - IC_i - C(DOF_i) - OC(DOF_i)$$

A feedlot operator can impact carcass traits, and ultimately profit, by varying days-on-feed. A change in *DOF* will impact price in three ways. First, a change in *DOF* will cause offsetting changes to *YG*. As *DOF* increase, *REA* also increases, having a small positive effect on lean yield and a slight decrease in USDA *YG* score. However, an increase in *DOF* will cause *HCW*, *BF*, and *KPH* to increase, having a negative effect on yield and increasing USDA *YG* score. Additionally, a change in *DOF* will affect *QG*. As *DOF* increase, *MS* will increase, causing *QG* to improve. A trade-off is made between improved *QG* and poorer *YG*. Finally, a change in *DOF* will affect *HCW*. Increasing *DOF* will increase *HCW*, positively affecting carcass value.

In addition to affecting value, a change in *DOF* will affect costs. There are three daily costs during the finishing phase: feed, yardage, and opportunity cost on investment. Marginal feed and yardage costs are constant, while opportunity cost will increase at an increasing rate with *DOF*.

Premiums and discounts for yield and quality grade are based upon carcass characteristics, which in turn are functions of *DOF*. Yield grade, which determines $P_{YG,}$ is given as

$$(2)\qquad YG_{ik} = 2.5 + 2.5 * BF_{ik} + 0.2 * KPH_{ik} + 0.0038 * HCW_{ik} - 0.32 * REA_{ik}$$

(Wagner and Osbourne). Yield grade premiums and discounts are reported in Table 1. Quality grade is measured by marbling score. Quality grade premiums and discounts are reported in Table 2. The cost of acquiring each animal, IC_i, represents a fixed cost. The cost of finishing a feedlot calf, $C(DOF_i)$, includes feed and yardage.

Table 1. Yield Grade Premiums/Discounts*

USDA Grade	Price Level		
	Low	Medium	High
	--------------------$/cwt--------------------		
1	3.18	4.77	7.20
2	1.58	2.38	2.75
3	0.00	0.00	0.00
4	-14.04	-17.55	-20.00
5	-18.32	-22.90	-25.00

*Derived from USDA-AMS.

Table 2. Quality Grade Premiums/Discounts*

USDA Grade	Price Level		
	Low	Medium	High
	-----------------$/cwt----------------		
Prime	12.20	18.30	24.52
Average Choice+**	0.68	1.02	2.21
Choice	0.00	0.00	0.00
Select	-6.45	-8.07	-9.69
Standard	-13.89	-20.84	-30.00

*Derived from USDA-AMS.
**Carcasses grading in the upper two-thirds of Choice.

The model given in (1) is an unconstrained profit maximization problem. However, given the relatively high-cost of transporting cattle from a feedlot to a processing plant, feedlot operators generally market cattle in “potloads” of approximately 45 head. (Weight restrictions on over-the-road semi-tractor trailers limit the number of head.). Incorporating lot sales converts the optimization model to an integer programming model to choose the dates of sales and the approximately 45 head sold on each marketing date. Mathematically, the objective function and constraints are

(3) $$\underset{a_{ik},\, b_k}{Max} \sum_{i,k} a_{ik} \times \pi_{ik}$$

subject to

(4) $$\sum_k a_{ik} = 1 \ \forall i \ ; \qquad \sum_k b_k \le 14 \ ; \qquad \sum_i a_{ik} \le 45 \times b_k \ \forall k \ ;$$

where a_{ik} is a integer variable equal to 1 on calf *i*'s market date and zero otherwise, and b_k is the integer variable equal to 1 if cattle are marketed on date *k* and zero otherwise. Given the number of cattle in the study (see below), no more than 14 potloads of cattle can be marketed.

Biological Model

Several variables are used to estimate the final carcass characteristics of finished cattle. Data were collected at various times throughout the finishing process. Measurements were taken for *BF*, *REA*, *W*, *MS*, *HCW*, and *KPH*.

Backfat, *BF*, measures the fat thickness three-fourths of the length of the ribeye from the chine bone (Hale et al.). The amount of *BF* an animal has is a good indicator of the level of fat content in the entire carcass. Ultrasonic measurements for *BF* were taken four times during the finishing process, and a final *BF* measurement was taken on the marketing date. 12th rib fat has a negative affect on carcass yield, leading to an increased yield grade (*YG*) and decreased price.

Ribeye area, *REA*, is the size of the longisimus muscle, or ribeye, in square inches measured at the cut surface between the 12^{th} and 13^{th} ribs. A larger *REA* indicates cattle have more than average muscling. Ultrasonic measurements for *REA* were taken twice during the finishing process, and a final *REA* was taken on the marketing date. *REA* has a positive effect on yield, leading to lower USDA *YG* and a higher price.

Marbling score, *MS*, measures the amount of intramuscular fat an animal contains in the longisimus muscle on the cut surface between the 12^{th} and 13^{th} ribs (Brester). *MS* is the primary determinant of quality grade (*QG*) in young cattle. Cattle with higher *MS* receive higher quality grades.

An individual animal's live characteristics and carcass traits result from a complex interaction of environment, management, and genetics. As such, traits are determined simultaneously and are interdependent. To account for simultaneity and contemporaneous error correlation, a system of growth equations for carcass traits is specified. Ribeye area (cm^2), backfat (cm), and live weight (kg) would ideally be estimated simultaneously using three-stage least squares (3SLS). (Units are latter converted to English, in., $in.^2$, and lbs., to compute USDA

YG score.) However, as is often the case with biological data, instrument variables are lacking. Instead, we employ full-information maximum likelihood estimation (FIML). The asymptotic properties of FIML are identical to 3SLS assuming normally distributed errors and FIML estimation is efficient (Greene). Little variation was observed in *KPH* across the actual marketing dates, gender, or genotype from our study cattle. Consequently, *KPH* is held constant at actual post-slaughter values. The specified system is given as

$$
\begin{aligned}
\log(BF_i) &= \left(c(1) + c(2)\cdot CT_i + c(3)\cdot TT_i + c(4)\cdot SEX_i\right)\cdot \log(W_i) + c(5) + c(6)\cdot \log(BF_i(-1)) \\
&\quad + c(7)\cdot nrtreat_i + c(8)\cdot restreat_i + \epsilon_{BF_i} \\
REA_i &= \left(c(9) + c(10)\cdot CT_i + c(11)\cdot TT_i + c(12)\cdot SEX_i + c(13)\cdot nrtreat_i + c(14)\cdot restreat_i\right) \\
&\quad \cdot \log(W_i) + c(15) + \epsilon_{REA_i} \\
\log(W_i) &= c(16) + c(17)\cdot CT_i + c(18)\cdot TT_i + c(19)\cdot SEX_i + c(20)\cdot \log(DOF_i) \\
&\quad + c(21)\cdot \log(W_i(-1)) + c(22)\cdot nrtreat_i + c(23)\cdot restreat_i + \epsilon_{w_i}\ .
\end{aligned} \tag{5}
$$

Dummy variables *CT* and *TT* indicate heterozygous and homozygous "fat" genotypes and *SEX* indicates gender (steer = 0). The variables *nrtreat* and *restreat* indicate the number of times each animal was treated for non-respiratory and respiratory ailments, respectively. Live weight is indicated by *W* and later converted to carcass weight (*HCW*) assuming a 62.5% dressing percentage.

While it is possible to take ultrasound measurements of intramuscular fat, these measurements are not considered reliable. Reported correlations between ultrasonic intramuscular fat measures and carcass marbling score have ranged from 0.35 to 0.87 (Williams). In our study, only post-slaughter marbling scores were taken over the four marketing dates. As a result, it is difficult to estimate marbling score and the resulting *QG*. Instead, we employ data from Bruns et al. to estimate an *MS* growth curve. The resulting curve is given as:

$$MS_{DOF} = e^{5.87 + 0.0029 \times DOF}\ . \tag{6}$$

The resulting estimation is then applied to the actual post-slaughter *MS* to backcast and forecast *MS* to various *DOF*. As reported in Table 3, *TT* cattle did have higher marbling scores. By using actual *MS* and simulating changes according to (6), the relative *MS* differences across genotypes are maintained.

Table 3. Average Actual Weights and Measurements

	Steers			Heifers		
	CC	*CT*	*TT*	*CC*	*CT*	*TT*
Number	34	99	59	109	98	91
W initial (lbs.)	594.9	597.2	594.5	590.9	589.1	615.1
BF initial (in.)	0.10	0.11	0.11	0.13	0.13	0.15
REA initial (in.^{2})	9.8	7.8	8.0	7.9	8.1	7.9
HCW	787.6	775.6	780.6	716.9	720.0	730.7
BF final (in.)	0.50	0.54	0.56	0.53	0.50	0.60
REA final (in.^{2})	12.6	11.9	11.8	13.3	13.2	12.7
KPH	2.0	2.0	1.9	1.9	2.0	2.0
YG (calculated)	2.5	2.9	3.0	2.2	2.2	2.6
MS[*]	452.6	441.6	458.5	440.8	449.3	473.3
DOF actual	193.6	194.8	194.1	192.9	190.3	186.0

[*]300 = slight 0 (Select); 400 = small 0 (low Choice); and 500 = modest 0 (average choice).

Data

Data were collected from cattle in a commercial feedlot in Britton, SD, from fall 2004 through early summer 2005. Weights, measurements, and blood samples were taken from 612 head of crossbred steers and heifers. After lost ear tags, missed tag transfers in the processing plant, and other carcasses “lost” in the processing plant, data on 590 cattle were usable. Data were collected on November 10, 2004; January 5, 2005; February 10, 2005; and March 28, 2005; and on four marketing dates: April 19, May 5, May 18, and June 6, 2005. Live weights and ultrasound measurements of *BF* were taken on all four pre-marketing dates. Ultrasound measurements of *REA* were taken on the November and February dates. Additionally, the feedlot operator recorded all treatments due to non-respiratory and respiratory ailments for each animal. At slaughter, *HCW* were recorded. Twenty-four hours post slaughter, measurements were taken on *REA* and *BF* and subjective estimates of *MS* and *KPH* were recorded. Summary statistics for initial weights and measurements and carcass weights and measurements are given in Table 3. Table 4 reports the number of steers and heifers by genotype. At our request, the feedlot operator put together three pens (approximately 200 head per pen) of feeder cattle with similar phenotype. Two of the pens were heifers and the other steers. Thus, the number of heifers is approximately double the number of steers.

Table 4. Number of Cattle by Genotype and Sex

Genotype	Steer	Heifer	Totals
CC	34	109	143
CT	99	198	297
TT	59	91	150
Totals	192	398	590

Actual costs from the producer were used to determine daily feed costs of $1.36 per head per day. Yard costs of $0.29 per head per day were assumed. Initial costs of calves were calculated using data from the ND Agricultural Statistics Service. A price differential of $5/cwt was assumed for steer vs. heifer calves. An interest rate of 5.5 percent was used for the opportunity cost of investment in calves and incurred operating expenses.

On November 10, 2004, blood samples were taken via venopuncture. Leptin genotype was analyzed by an allelic discrimination assay. Briefly, genomic DNA was purified (Perfect gDNA, Eppendorf AG, Hamburg, Germany), and specifically designed probes were used to detect the *C/T* polymorphism at codon 252 (Primer Express, Applied Biosystems, Forest City, CA; Buchanan et al. 2002) using real-time PCR technology (Prism 7000, Applied Biosystems).

Regression Results

The model specified in (5) was estimated twice, with and without genotypic information. The resulting parameter estimates and standard errors are reported in Table 5. Most variables are significant at p=0.01. In the model considering genotypic information, genotype is significant in two of the three equations. Lagged dependent variables are significant in all equations. Treatments for ailments are generally insignificant which is likely due to overall good health of the herd and aggressive treatment of suspected ailments. Hiefers (*SEX*=1) had significantly greater *BF* and *REA* and lower *W*.

The hypothesized and previously reported relationship between carcass traits and leptin genotype are confirmed. In the *BF* and *REA* equations, *CT* and *TT* dummy variables significantly influence the animals' characteristics. The presence of *T*-alleles increases *BF* and decreases *REA*. Weights, *W*, are not affected by leptin genotype. This is also confirmed by Larson. Using the same data as this study, he reports that actual *HCW* did not differ across genotype. This result suggests that this polymorphism affects how nutrients are partitioned between muscle and fat. The *C*-allele tends toward increased muscle size. The *T*-allele tends toward increased fat deposition.

Table 5. Full-information Maximum Likelihood Regression Results

Variable	With Genotype			Without Genotype		
	log(*BF*) (std.err.)	*REA* (std.err.)	log(*W*) (std.err.)	log(*BF*) (std.err.)	*REA* (std.err.)	log(*W*) (std.err.)
intercept	-12.706[a] (0.176)	-190.467[a] (3.923)	1.845[a] (0.122)	-12.724[a] (0.176)	-190.102[a] (3.949)	1.838[a] (0.122)
$CT*W_i$	0.005[b] (0.003)	-0.190[a] (0.074)	-0.004 (0.006)	--	--	--
$TT*W_i$	0.011[a] (0.004)	-0.429[a] (0.085)	0.008 (0.006)	--	--	--
$SEX*W_i$	0.034[a] (0.003)	0.830[a] (0.063)	-0.016[a] (0.006)	0.033[a] (0.003)	0.863[a] (0.063)	-0.017[a] (0.006)
log(*W*)	2.039[a] (0.030)	42.698[a] (0.652)	--	2.049[a] (0.30)	42.403[a] (0.651)	--
$nrtreat*W_i$	--	0.014 (0.063)	--	--	0.002 (0.062)	--
$restreat*W_i$	--	0.100 (0.072)	--	--	0.136[b] (0.072)	--
nrtreat	-0.024 (0.017)		0.003 (0.005)	-0.022 (0.017)		0.003 (0.656)
restreat	-0.031 (0.020)		-0.008 (0.006)	-0.037 (0.020)		-0.009 (0.006)
log(*BF*(-1))	0.060[a] (0.019)	--	--	0.063[a] (0.019)	--	--
log(*DOF*)	--	--	0.158[a] (0.002)	--	--	0.158[a] (0.002)
log(*W*(-1))	--	--	0.594[a] (0.019)	--	--	0.595[a] (0.019)
R^2	0.779	0.775	0.907	0.777	0.771	0.907

[a]Significant at $p = 0.01$.
[b]Significant at $p = 0.1$.

Simulation and Optimization Model

The estimated growth models for *REA*, *BF*, *W*, and *MS* were used to backcast and forecast carcass traits to *DOF* of 160 to 220, both with and without genotypic information. First, the simulated carcass characteristics were used to compute profit as in (1) for both information scenarios and the three price levels. A grid search was used to find the *DOF* for each animal to maximize equation (1). Second, an integer programming model, as in (3) and (4), is used to find optimal *DOF* and maximum profit when head sold per date are constrained to potloads (45 head).

For the unconstrained profit maximization model, the average optimal *DOF* is reported in the top of Table 6. For heifers, average optimal DOF is higher for *CC* and *CT* genotype cattle than *TT* cattle and slightly larger for *CC* than *CT* cattle. Being leaner than *TT* cattle, the *CC* and *CT* can be fed to higher weights and not reach *YG* 4 and 5 discounts. For steers, average optimal *DOF* was about two days longer for *CT* cattle than *TT* cattle and about one day longer than *CC* cattle. This is similar to the actual marketing of the cattle (Table 3) where *CT* were fed just over one day longer on average than *CC* and almost one day longer than *TT*.

The unconstrained maximum profits, as in (1), are reported in the top of Table 7. For both information scenarios, the three price levels, and both steers and heifers, average profit is highest for *TT* cattle. Although fed roughly the same time as the other genotypes, higher prices per pound are received due to higher *QG*. In Figures 1 and 2, the distributions of yield and quality grades by genotype are reported for steers and the medium price grid. As can be seen, *TT* cattle are most likely to be *YG*3, but are also the most likely to grade Low Choice or Average Choice+. Given little difference in *DOF* and *HCW*, the higher premiums and lower discounts for *QG* Select made the *TT* cattle the most profitable. The *CT* cattle are likely to be *YG*3 and were the least likely to reach High Choice and Prime premiums. The result is that *CT* cattle were the least profitable. The *CC* cattle were the most likely to grade *YG*2 and the most likely to grade Average Choice+, but *CC* cattle also had the highest percentage *QG* Select or Standard. *CC* cattle profitability thus was less than *TT* but higher than *CT*.

Heifers earn less profit than steers in all scenarios. Optimal *DOF* are lower for heifers which reduced their feed cost but also results in lighter carcass weights. Heifers earn more premiums for high *QG* but also more discounts for low *QG*. In net, the revenue for heifers per head was lower than for comparable steers.

Across information scenarios, the value of genotypic information ranges from less than \$0.01 per head with a high price to \$4.83 with *TT* heifers and a low carcass price. This is due to little difference in optimal *DOF* between the information scenarios. In terms of influencing marketing date decisions, leptin genotype appears to be of little value.

Table 6. Average Optimal Days-on-feed

Price	Unconstrained Profit Max. with Genotype						Unconstrained Profit Max. without Genotype					
	Steers			Heifers			Steers			Heifers		
	CC	*CT*	*TT*	*CC*	*CT*	*TT*	*CC*	*CT*	*TT*	*CC*	*CT*	*TT*
Low	175.4	178.0	176.3	176.6	176.0	169.9	175.6	178.5	176.3	177.2	175.9	169.9
Medium	175.4	178.9	176.3	177.2	176.2	169.9	175.6	178.9	176.3	177.3	176.3	169.9
High	175.4	178.9	176.7	177.9	176.8	170.5	175.6	178.9	176.3	178.0	176.9	170.5
Price	Potload Constrained with Genotype						Potload Constrained without Genotype					
	Steers			Heifers			Steers			Heifers		
	CC	*CT*	*TT*	*CC*	*CT*	*TT*	*CC*	*CT*	*TT*	*CC*	*CT*	*TT*
Low	178.1	180.8	179.4	178.3	177.4	172.3	177.9	181.3	178.1	178.9	177.7	171.9
Medium	177.9	180.3	179.9	179.5	178.3	173.2	178.5	181.7	179.7	179.6	178.3	172.0
High	178.9	181.8	181.0	179.7	178.4	173.9	178.7	181.9	179.9	180.3	179.2	172.4

Table 7. Average Profit ($/head)

Price	Unconstrained Profit Max. with Genotype						Unconstrained Profit Max. without Genotype					
	Steers			Heifers			Steers			Heifers		
	CC	*CT*	*TT*	*CC*	*CT*	*TT*	*CC*	*CT*	*TT*	*CC*	*CT*	*TT*
Low	27.34	13.48	44.51	-4.10	-7.79	20.23	23.13	11.73	40.24	-7.44	-11.74	15.40
Medium	90.36	75.84	110.19	55.15	50.32	79.26	88.08	74.66	107.60	53.83	48.10	76.03
High	153.39	138.26	175.87	114.45	108.45	138.31	153.16	138.26	175.87	114.14	108.27	138.31

Price	Potload Constrained with Genotype						Potload Constrained without Genotype					
	Steers			Heifers			Steers			Heifers		
	CC	*CT*	*TT*	*CC*	*CT*	*TT*	*CC*	*CT*	*TT*	*CC*	*CT*	*TT*
Low	24.75	11.04	41.82	-6.12	-9.45	17.96	20.81	8.64	37.52	-9.20	-13.63	13.47
Medium	87.70	73.32	106.47	53.35	48.58	76.97	85.48	71.41	104.35	51.46	46.08	74.31
High	149.95	135.57	172.41	112.44	106.93	136.40	150.03	135.39	172.37	111.80	106.12	136.63
Low	Weighted average profit per head = $5.93						Weighted average profit per head = $2.20					
Medium	Weighted average profit per head = $66.31						Weighted average profit per head = $63.78					
High	Weighted average profit per head = $126.45						Weighted average profit per head = $125.94					

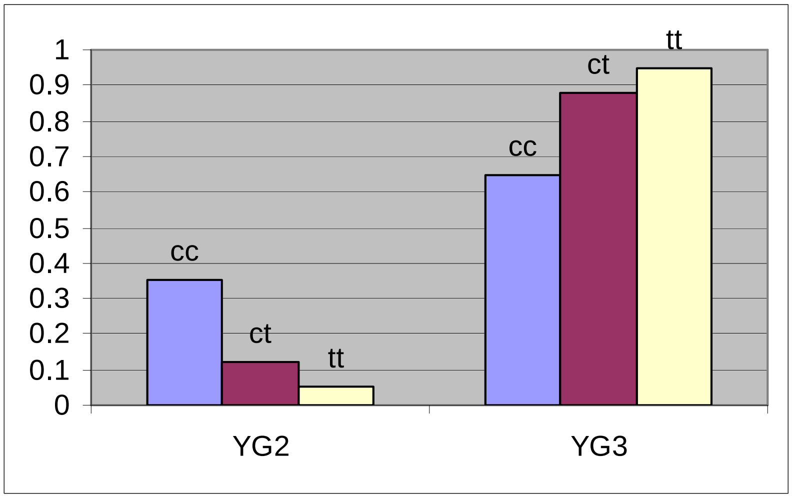

Figure 1. Yield Grade Distribution by Genotype for Steers and Medium Price (Unconstrained Profit Maximization)

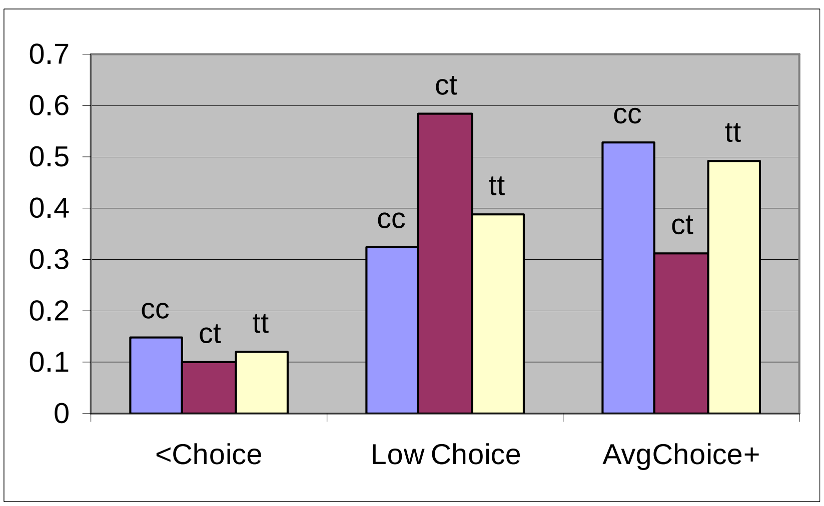

Figure 2. Quality Grade Distribution by Genotype for Steers and Medium Price (Unconstrained Profit Maximization)

Where leptin genotype appears to be of economic relevance is valuing feeder cattle. Between genotypes, the *TT* cattle are more profitable than *CC* or *CT* cattle and *CC* cattle are more profitable than *CT* cattle. The difference in profitability for the same gender and price grid is over $37 in the most extreme case, both with and without leptin genotype information.

When the cattle are constrained to marketing in potloads, as in (3) and (4), results are similar to the individually optimized case. On the bottom of Table 6, average optimal *DOF* are given by genotype, gender, and information scenario. Average optimal *DOF* increase from the individually optimized profit model. The increases range from around two days to just over eight days in comparison to the model given by (1) and reported in the top of Table 6. As previously, optimal *DOF* increases with price and is higher for *CT* and *CC* than *TT* cattle.

Maximum profits under the potload-quantity constrained model are reported on the bottom of Table 7. Similar to the individually optimized profits model, the *TT* cattle have the highest profit for each information scenario and gender and *CT* have the lowest profits. The differences across information scenarios are again fairly small, but caution should be exercised in interpreting these results. There is no guarantee that for a given genotype, gender, and price combination that the unconstrained model will have a higher profit than its constrained equivalent. The only guarantee, for any given price grid, is that total profit across all genotype and gender combinations will be higher for the unconstrained model. The last three lines of Table 7 report profit per head for the price grids and information scenarios. The difference in average profits range from $0.51 to $3.73 per head. As with the unconstrained profit maximization model, genotype does not appear to have a large economic value in determining optimal marketing dates. Again, some caution is advised in generalizing the actual values to other feedlots. Recall from Table 4 that the number of heifers is approximately double the number of steers.

Summary and Implications

Improved understanding of genetics may lead to improved consistency and quality of beef products. To date, few genetic polymorphisms have been used to improve quality, consistency, or profitability of beef cattle. One of the first, codon 252 of exon 2 on the leptin gene has been aggressively marketed as a “marbling gene.” Our results and those of other researchers show that this gene is a fatness gene. It increases both an economically desirable trait, marbling, and an economically undesirable trait, external carcass fat thickness. Beef producers and their breed associations in the United States and Canada will face many decisions in the near future regarding which genes, including possibly leptin gene polymorphisms, should be exploited to improve marketability and profitability. Successfully utilizing genetic information requires trading off the desirable impacts with undesirable impacts given current economic conditions, i.e., prices.

Here we investigate the economic value of the leptin gene to feedlot operators. First, we consider how optimal marketing dates and profits are affected by utilizing leptin genotypic information. Second, we compare how leptin genotypes compare in terms of profit. Data from

590 crossbred steers and heifers are used to estimate growth curves for economically relevant carcass traits. Profit maximization models determine optimal marketing dates and maximum profit, both with and without genotypic knowledge.

Our results suggest that leptin genotypic information has low value when determining optimal marketing dates. However, leptin genotype has a large impact on the value of a finished steer or heifer. Our results show that fat or *TT* genotype cattle were more valuable than *CC* or *CT* cattle when priced on quality grids. Given that *CT* cattle share some of the characteristics of *TT* cattle, our expectations were that *CT* cattle would be more profitable than *CC*. The results countered those expectations as *CC* cattle were more profitable than *CT* cattle. Given that our study considered one feedlot and price grids that reward marbling, our quantitative results should not be generalized to other locations and all price grids. More analyses across a wide range of environments, managers, and price grids are necessary to definitively determine the value of one genotype versus another. However, our results do indicate that leptin genotype plays a large role in determining the value of a fed steer or heifer.

Collection of genetic information is costly. Commercial laboratories charge up to $50 per sample to determine one single nucleotide polymorphism (SNP). Over twenty SNPs in the leptin gene alone have been discovered (Konfortov et al.). While it is likely that most of the these SNPs are economically irrelevant, others are considered biologically “non-conservative” and may influence carcass traits and value and costs of production, such as feed intake and efficiency. Further, other SNPs on several other genes likely play a role in fat deposition and marbling. When various combinations of SNPs, called haplotypes, are evaluated, the cost of genotyping/haplotying increases.

Collection of genotypic and haplotypic information at the feedlot level is unlikely to prove economically viable. Alternatively, market channels may develop with genetic information collected at the seed stock producer level. If genetically segregated seed stock herds are developed, the genotypes/haplotypes of progeny will be known. However, several necessary steps will need to be taken first. We suggest three of these necessary steps. One, the value of genotypes and haplotypes to the feedlot operator must be determined, as was the goal of this paper. Second, reliable mechanisms need to be developed to credibly relay genetic information from the seed stock producer, to the cow-calf producer, to the feedlot operator. Third, a differentiated products market must be developed where superior genotypes/haplotypes earn premiums over less valued genotypes/haplotypes. Given the independent nature of cow-calf producers and feedlot operators, these three steps will not be easy to implement. Unfortunately for the beef sector, with the high degree of integration and coordination in the pork industry, the challenges of utilizing genotypic/haplotypic information may be lower for that sector and may be more quickly overcome.

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