

RETAINED INTEREST IN SEEDSTOCK BULLS:
A TRANSACTION COST ANALYSIS

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ABSTRACT

Seedstock cattle producers invest in bulls to introduce high quality genes into their cattle herds. Because the genetic traits bulls pass on to their calves are sometimes unobservable before breeding season, the quality of the bull at the time of the sale is uncertain. Some producers choose to sell bulls with retained semen interest, which grants them rights to the specified percentage of revenues from semen sales from the bull after it has been sold. This thesis examines the practice of retained semen interest in bulls and its effects on sale prices for the bull. After adapting the theory of auctions and share contracts and developing a theory of retained interest, I empirically test my hypotheses that 1) if there is more uncertainty regarding the attributes of the bull, the producer will be more likely to use a retained interest contract, and 2) a retained interest contract increases the value of a bull. I use a logit model to test the first hypothesis and hedonic price model, estimated using OLS, to test the second model. I find evidence to support both predictions, which supports my transaction cost model of contract choice. After controlling for quality, producers are more likely to retain interest in bulls that have greater variation in their quality. Also, bulls that are sold with retained interest earn significant premiums compared to bulls sold with lump sum prices. These results add to the transaction cost and share contract economic literature, as well as inform seedstock producers about the economic costs and benefits of retaining semen interest.

CHAPTER ONE

INTRODUCTION

Bulls may be the most important investment cattle producers make. Because bulls provide the main source of genetic improvement for cow herds, cow-calf producers carefully select bulls based on quality and herd goals. Over the past few decades, more methods for providing information about bull quality have developed, including simple performance measures (SPMs), expected progeny differences (EPDs), ultrasound data, and DNA testing data. The most common methods for assessing genetic information and comparing bulls are the use of SPMs and EPDs. These provide information about the bull as well as calculated estimates of how their progeny will perform. Producers can use this information to determine which bulls fit with their goals and how they value the bulls. These methods of conveying information reduce the uncertainty regarding bulls' qualities *ex ante*.

Bulls are conventionally marketed using sale catalogs that list each bull to be sold along with information about the bull. Bull producers typically list pedigree information, SPMs, and EPDs, and sometimes they include other index values or comments. It is also common for producers to include information for bulls on retention of semen interest. While the specifics of retaining interest differ between producers, retaining interest on a bull allows the producer to access and collect semen from the bull as well as share in the potential future stream of income from semen sales. When a producer indicates they are retaining semen interest on a bull, they provide potential buyers with details about the type of sale payment provision.

The objective of this study is to examine why producers retain interest in bulls and to identify the economic costs and benefits of retaining interest. Retained interest contracts in bulls

are a type of share contract arrangement where the producer receives a lump sum auction price for the bull, plus a share of revenues from semen sales. The two prevailing arguments as to the popularity of share contracts suggest that these types of contracts are chosen for their ability to mitigate risk and for their lower relative transaction costs under some circumstances. This thesis examines 1) why producers retain semen interests, 2) how transaction costs differ between sale contract types, and 3) how retaining semen interests affect bull prices.

My results show that as uncertainty regarding quality of the bull's genetics increases, producers are more likely to sell the bull using a retained interest contract relative to a lump sum contract. Bulls that are sold with retained interest are also shown to receive large premiums at auction even though they are sold with only partial semen rights. This may be because a retained interest contract informs a buyer that the value of the bull's semen is higher than what is conveyed through traditional performance measures, thereby inducing the buyer to pay a greater lump sum auction price for the bull.

The results of this thesis contribute to two strands of literature. First, the empirical results inform the economics literature regarding transaction costs in agricultural share contracts. While most analyses of share contracts are conducted within the field crop sector of agriculture, this work is the first to extend share contract analysis to seedstock livestock. The results of this analysis also provide insights into the value of the information conveyed through retained interest. Bull quality varies, and producers possess information about their bulls above and beyond what is captured in SPMs and EPDs, yet the market for bulls has not turned into a "market for lemons" as Akerlof (1970) has suggested could happen in this situation.

Second, this thesis also communicates new and important information to the cattle industry. Both bull producers and potential buyers can use the empirical results and implications of this thesis to better understand the economic benefits and costs of selling bulls with interest shares. This work adds to the general production agriculture literature that discusses bull price determinants and different contract types for seedstock bulls. While selling bulls with interest shares is fairly popular, there has been almost no analysis of it compared to conventional lump sum auction sales. The extensive discussion of retained interest in this work also provides cattlemen with an accessible source for details on contracting that are not found elsewhere.

The remainder of this thesis is divided into seven chapters. Chapter two provides a background on breeding cattle, bull selection using EPDs, and the retained interest arrangement. Chapter three summarizes the literature relating to bull price determinants, share contracts in various contexts, and presale measurement in auctions. Chapter four lays out the theoretical frameworks and models for both contract choice and hedonic price theory. Chapters five and six describe the data used for this study and the empirical methods used, respectively. Chapter seven discusses results, extensions, and implications of the study. Chapter eight concludes.

CHAPTER TWO

BACKGROUND AND INSTITUTIONAL DETAILS

The cattle industry is comprised of different types of producers based on different segments of the cattle's lifespan. Bull producers raise cattle specifically for their genetics. They do this by producing animals with superior traits, then selling the animals to other cattle producers. Cow-calf producers' primary output is calves raised for beef production. They breed cows and raise the calves through weaning to produce feeder calves. The main focus of this thesis is how seedstock producers sell their bulls to other seedstock producers, commercial operations, and other parties involved in semen sales.

An Overview of Seedstock Genetics

Because bull producers' primary products are genetics, these producers are typically referred to as seedstock producers. These operations run breeding cattle operations similar to cow-calf operations; however, they specialize in raising cattle with superior genetic traits to provide quality genetics and genetic variation to cow-calf operations. Seedstock producers register their cattle with the respective breed association because associations offer trustworthy sources of information on cattle. For cattle to be registered purebred, they must be 95-100 percent purebred animals with full parentage information. This allows the association to keep accurate records and calculate accurate performance measures for all registered animals.

Seedstock operations may sell both bulls and females as sources of genetics. Bulls are typically sold between one year and two years of age to take advantage of their prime breeding window. Females are also sold early in their lives, typically as heifers or young cows. Whereas

breeding females are typically sold to other seedstock producers, bulls are sold to a more diverse group of buyers. Seedstock producers sell their bulls to commercial cow-calf operations, other seedstock producers, or to AI studs. Because of this, bulls, and their semen, represent the largest mechanism for the transmission of cattle genetics.

A cow-calf operation's primary output is calves for slaughter and their herds are predominantly unregistered. Because cow-calf operations, also known as commercial operations, primarily focus on producing calves for beef production, the male calves are typically castrated when they are young. The highest quality heifer calves may be kept as replacements for the cow herd, and the other heifers are culled and sold. After weaning, the culled heifers and steer calves are sold to backgrounders and/or finishers that feed the calves to get them ready for slaughter. Cow-calf operations invest in bulls or bull semen as ways of introducing high-quality genetics into the herd. These operations typically breed their cows through artificial insemination (AI) or naturally by turning out bulls with the herd. AI uses frozen bull semen to breed the cows and offers many advantages. These advantages include access to more bulls than what the cow-calf producer can afford to buy, greater control of making desirable matches between cows and bulls, and less risk of injury to cows and people from having large bulls around.

The use of AI has allowed the market for frozen bull semen to grow. The frozen semen used in AI is collected by either specialized collection companies or AI studs. AI studs are companies or cooperatives that buy bulls, collect and freeze semen, and then sell the semen to cattlemen. Collection companies are agencies that specialize in collecting, testing, and freezing bull semen for producers. The semen can be collected from bulls through different methods, but the most common method is using a mount animal and an artificial vagina (AV). With this

method, bulls are brought into the collection area (usually led by halter or nose ring) where a steer is waiting to act as the mount. Steers, or castrated male cattle, are used as the mount animals because there is no chance of accidental insemination and there is a lesser chance of spreading venereal diseases. The bull mounts the steer as if it were a cow, and an attendant redirects the bull's penis into the AV before ejaculation.

Specialists at the collection companies or AI studs examine the semen collected to check for sperm motility and fertility. If the semen passes the examinations, they mix it with special protein and glucose extenders, fill the straws, and flash freeze the straws in liquid nitrogen.¹ The extenders protect the sperm cells from dying during the freezing and thawing processes. The straws are stored in tanks filled with liquid nitrogen until the cattleman is ready to AI his herd. With semen collection, each high-quality bull may be able to produce thousands of straws of semen over its lifetime, and therefore thousands of progeny, so semen collection is an important aspect of the business of seedstock genetics.

After semen is collected, examined, and frozen, an AI stud company markets it to cow-calf producers and seedstock producers. These companies produce semen catalogs that list available semen, price per straw of semen, and information about the bull. Prices for bull semen typically start around \$15 or \$20 and increase from there with bull quality and availability. Semen buyers can place orders for specific quantities of semen at the listed price, and the stud company will fulfill the order before breeding season.

¹ Straws used for AI are typically ½ cc. This means that semen from one collection process, along with the extenders, can fill tens to hundreds of straws.

Bull Sales via Auction

Seedstock bulls are heterogenous assets. Bulls have different attributes and different combinations of attributes make bulls better suited for different purposes. Calving ease bulls may be used on heifers or cows and usually produce calves with lower birthweights and moderate growth traits. High growth bulls are expected to produce calves with heavier weights upfront (birthweights) and high growth potential (large weaning weights and yearling weights). Curve-bender bulls are bred to get the best of both worlds; they tend to have moderate to low birthweights and birthweight EPDs while having large growth measures. A buyer matches a bull's attributes to the needs of his cow herd.²

Seedstock producers sell their bulls to a variety of different types of operations. Table 1 summarizes the entities involved in cattle breeding operations. Commercial ranches are cow-calf operations that purchase bulls to breed their cows and introduce desirable genetic traits into the herd. Cow-calf producers may also choose bulls for their progenies' expected carcass qualities. Depending on whether the bull will be used on heifers or mature cows and what kind of traits a cow-calf producer wants to see in the calves, he will select bulls based on how well their genetic traits match with his herd goals.

Seedstock producers can also sell their bulls to other seedstock operations or to AI studs. When bulls are sold to other seedstock operations, they will use the bull as a herd sire to breed their own cows. This introduces a new source of genetic variation into the herd. The progeny of the bull will then be sold as seedstock bulls or females. These producers also select bulls based

² For example, a cow-calf producer may visually evaluate his cow herd and determine that the cows are growing to be very large or that the cows are difficult to handle during and after calving. In these situations, the producer might look for a bull that has a smaller frame size and bulls that are known to be more docile.

on calving-ease, growth, and carcass traits and the expected traits of the bull's progeny. After purchasing a bull, a seedstock operation may also lease the bull out to an AI stud, which collects and markets the bull's semen in addition to using the bull in their own herd. This is slightly different than when AI studs buy bulls directly from the original seedstock operation. When studs buy a bull, they do so with the primary purpose of collecting and selling its semen for AI purposes. The semen is sold to commercial or seedstock operations, but the bull will not likely be used for naturally breeding cows.

Bull producers have a few options for how they sell their bulls. Some work solely by private treaty where they privately negotiate a price and contract details with individual buyers throughout the season. This type of sale relies heavily on word of mouth and advertising via sale catalogs to attract buyers. Another option is for producers to enter their bulls into a bull test and sell the bulls through the test auction. Producers typically enter their top bulls into the test where more in-depth information on the bulls is collected, and there is a larger spread of buyers. Bull tests may collect more accurate measurements as well as calculate feed intake measures that are above and beyond what most individual producers can provide. At the end of the test, bulls are sold in an auction. The most popular sale option for bull producers is by auction. Many producers hold an annual bull sale, usually in the spring for yearling bulls, at their ranch or a sale barn nearby. Sales like this rely on ranch reputation, catalog advertising, word of mouth, and breed association advertising to bring in potential buyers.³

³ Another sale method is for producers to sell an interest share in a bull via private treaty negotiations. This typically involves the producer and the buyer sharing the revenue from semen sales; however, there is no auction for the bull, so unlike a retained interest contract the only payment the producer receives for the bull is his percentage of semen revenues. This method is described more in the second section of chapter four.

Entity	Examples	Role	Description
Commerical Ranches	Kaiser Ranch	Buyer of Bulls	Unregistered cow-calf operations.
Seedstock Operations	Connealy Angus, Sitz Angus, Gardiner Angus, Hyline Angus	Seller of Bulls	Produce and sell bulls as sources of high quality genetics by private treaty/negotiation or auction.
		Buyer of Bulls	Buy other registerd bulls to use in their own herd. May lease bulls out to AI studs for semen collection and sales.
AI Studs	Select Sires, Genex, ABS Global, Alta Genetics, ST Genetics	Buyer of Bulls	Buy bulls solely for the purpose of collecting and selling semen.
Collection Agencies	ORIGen, Nebraska Bull Service, Vogler Semen Center, Champion Genetics, Rocky Mountain Sire Services, Hoffman A.I. Breeders	Third party for semen collection	Collect, evaluate, and store semen from bulls for commercial cattlemen, seedstock producers, or AI studs. May market semen as well, though it is less frequent.

Table 1. Description of entities involved in cattle breeding programs.

Sale catalogs play an integral role in bull sales.⁴ They provide buyers with pertinent information about the sale as well as information about the bulls to be sold. Information on bulls typically includes simple performance measures (age, various weights and measurements of the bull, etc.), expected progeny differences (EPDs), pedigree information, and any comments from the producer. Simple performance measures (SPMs) and EPDs make up the foundational data producers report in catalogs. While not all producers report ultrasound, DNA data, or dollar indices, SPMs and EPDs are commonly reported. SPMs allow buyers to assess a bull's basic characteristics such as his growth ability. Because calving and weaning dates vary between animals and producers, producers usually report adjusted weights in catalogs. Adjusted 205 day weight uses a bull's birthweight, weaning weight, and age to create a standardized weaning

⁴ Examples of pages from sales catalogs are included in Appendix A.

weight. Adjusted 365 day weight is similar. It is a standardized yearling weight measure. These adjustments account for producers weighing the bulls at different times (and ages) and create a basis for comparing bulls between producers.

EPDs also allow buyers to compare bull characteristics across producers. These measures are calculated using data from related animals (dam, sire, granddams, grandsires, brothers, sisters, etc.), data from the animal itself, and data from any progeny. EPDs are estimated using best linear unbiased prediction (BLUP) and account for an animal's environment when they are estimated. Some producers include dollar index values to provide a basis for comparison between bulls' calves' expected profitability, ultrasound data that provides more accurate measurements of the bull's carcass data, or DNA testing results.

Retained Semen Interest⁵

The sale catalogs also indicate details regarding the sale contract the producer chooses. The most common arrangement is for producers to sell bulls using lump sum sales in which the bull is sold for one, all-inclusive price. Another arrangement is for producers to specify a share of retained semen interest in bulls sold. Producers can retain interest in all bulls sold at the sale or in a few select bulls sold. When producers retain semen interest on a bull, they retain the right to collect semen from the bull in the future and keep their share of the revenue if the semen is sold for artificial insemination purposes. While specific details vary by producer, the right to collect typically comes with the conditions that the producer will schedule the collection at a

⁵ There are no reliable sources regarding retained semen interest in bull sales, so the information in this section comes from explanations in bull sale catalogs along with details from talking with seedstock producers, cow-calf producers, and other industry experts.

time convenient for both parties. Expenses for collection can be shared or paid fully by either party.

If the bull is sold to a commercial or seedstock operation, collection is typically performed by a third party company at their collection site. Commercial producers collect semen from bulls primarily to use in their own herd and do not often sell the semen to other producers. Seedstock producers may collect semen to use in their herd or to sell. Because collecting the desired amount of semen from the bull can take anywhere between a week and a month, the expenses include boarding fees for keeping the bull at the site. Other expenses include those for collection, testing, and freezing the semen. Depending on how much semen is collected and the preferences of the parties, the semen may be stored at the collection agency for some time and incur storage fees. If the bull is sold to an AI stud and the producer retained an amount of physical semen, the stud will collect the semen at their own facilities and send it to the producer.

Bull producers can also specify a level of retained interest that translates to a percentage of future revenue from semen sales they get to keep. Popular percentages of retained interest are 25, 33, and 50 percent. Though the producer retains an interest in semen sales, they typically sell full possession and full salvage value of the bull.⁶ From anecdotal evidence, bulls sold to commercial operations are rarely collected, so the producers rarely reap the reward from retaining an interest in semen. On the other hand, if the bull sells to a AI stud operation, retaining an interest share in the bull could yield a big pay-off. Typically, bulls that sell to AI studs come

⁶ Rarely, a producer may sell a percentage of possession, as well as percentage of semen rights. In this case, the producer and the buyer may take turns using the bull in their own herd and share any revenue from semen sales. One producer described an arrangement with a buyer that involved selling 50 percent of semen rights and possession of bulls. The buyer would use the bull to breed his cows in the fall and the producer would then get the bull during the spring breeding season.

from superior bloodlines and show immense promise in passing on quality genetics. Semen can sell for 20 to 50 dollars per straw, depending on the quality of the bull and its semen, so even a one-quarter interest in this revenue could have a large pay-out.

A quick back of the envelope calculation shows that a top breed sire may be worth about \$680,000. This calculation is based off details of a top Angus sire that produced over 17,000 registered progeny and lived for seven years.⁷ A more average Angus AI bull may be worth about \$90,000. These numbers were calculated using conservative assumptions regarding semen prices, total progeny produced, and how long semen from the bull was on the market. The difference in these estimated values shows the inherent uncertainty in a bull at time of sale. A bull estimated to be average could turn out to be greater than average and worth more or lower than average and worth nothing.

There are potentially other benefits for bull producers from retaining semen interest. When a producer retains semen interest on the bull, he is listed as part owner of the bull. Producers are then able to register the progeny of the bull without having to pay for semen/AI certificates for each calf. These certificates are necessary to prove parentage for progeny. Another benefit of retaining interest is that for bulls sold with retained semen interest, producers may earn a premium on the sale price. The findings of studies documenting the premiums for retaining interest are summarized in the next chapter and my theory as to why retained bulls earn premiums is discussed in chapter four.

⁷ This is a present value calculation of a bull. The bull used in this calculation is SAV Resource 1441. As mentioned, this bull lived seven years and produced over 17,000 registered calves. I assumed that no more semen from the bull was sold after his death, he produced equally as many commercial calves as he did registered calves, and that semen sold for \$30 per straw. These are conservative estimates, which means the value of the bull was likely greater than \$680,000.

While there are proven benefits of retaining semen interest on bulls sold, little has been written about this practice. Very little exists in the literature about the decision to retain interest on bulls, and no popular articles exist to help inform cattlemen on this convention. The best widely available sources on this practice are in online blogs or forums where producers may reach out to the online community for help interpreting retained interest contracts.⁸ This thesis provides the first and only comprehensive resource for details regarding semen sales and retained interests in seedstock bulls.

⁸ For example, see <https://talk.newagtalk.com/forums/thread-view.asp?tid=978314&mid=8802458#M8802458> and <https://www.cattletoday.com/threads/retaining-semen-interest.25629/>.

CHAPTER THREE

REVIEW OF RELEVANT LITERATURE

Bull Price Determinants and Retained Interest

While many studies have sought to analyze bull price determinants through the years, few have accounted for retained semen interest in their models.⁹ The first systematic exploration of bull price determinants was Dhuyvetter et al. (1996). They use hedonic price models to estimate the marginal implicit prices for bull attributes. They find that various performance measures and marketing factors impacted bull prices. When including EPDs into the models, birthweight is statistically significant for two out of the seven breeds, and the discount for higher birthweights decreases when the birthweight EPD was included in the model. Adjusted weaning weight was significant for six of the seven breeds both when EPDs were included and when they were left out. In this study, the authors also include marketing factors into their models. One marketing factor they consider is retained interest. They find that bulls sold with retained interest received premiums of almost 200 percent.¹⁰ While they find significant evidence of large premiums, the authors do not offer an explanation of why retained interest may impact bull price in this way.

Jones et al. (2008) offers another analysis of bull price determinants and updates the literature since Dhuyvetter et al.'s 1996 work. Similar to Dhuyvetter et al., Jones et al. find that many SPMs and EPDs impact bull price in a significant manner. They also include two binary

⁹ See Vanek, Watts, and Brester (2008), Tang et al. (2020), and Franken and Purcell (2012) for examples of other studies of bull price determinants that do not account for retained interest.

¹⁰ Basic economic theory suggests that if only a share of an asset is sold, the buyer will pay less compared to if they were to buy the whole asset, holding asset attributes constant. Interestingly, a premium for a bull that is sold with retained interest contradicts this intuition.

variables that denote percentage of semen rights sold. Bulls sold with one third semen rights retained receive a 16 percent premium and bulls sold with half semen rights retained receive a 52 percent premium compared to bulls sold without retained interest, *ceteris paribus*.

Chvosta, Rucker, and Watts (2001) analyze the transaction costs of presale measurement and the information provided in presale data for bull auctions. They focus on how EPDs and SPMs impact prices paid for bulls and how each type of performance measure conveys information to potential buyers. Using hedonic regressions, they find that SPMs by themselves typically explain more variation in bull prices than EPDs alone. They then decompose the effects into two categories—the difference due to sale characteristics and the difference due to valuation of characteristics. They find that after the first use of EPDs by three Angus bull producers, the mean price of a bull increased by about \$300. This analysis shows that while buyers may consider SPMs more than EPDs when choosing a bull, the use of EPDs has had significant impact on the price paid for bulls.

In an appendix provided by the authors, Chvosta, Rucker, and Watts (2001) also provide a preliminary analysis of interest share bulls. They find that bulls sold with retained interest, on average, have significantly higher values of performance measures and higher sale prices. Also, using hedonic price regressions they find that after controlling for performance attributes of the bull, there is a premium of almost \$5000 for bulls sold with retained interest. The authors offer a few basic explanations for this premium, including that retained interest provides a signal to buyers that lowers the uncertainty regarding quality and that contingent payment contracts reduce the incentive for presale measurement. Ultimately, the authors do not provide a complete explanation for the premium and the prevalence of retained interest in bulls.

This thesis seeks to fill the gap in the literature on the impact of retained interest on bull sale prices and examine the retained interest decision. Past studies consistently find that retained interest bulls sell for more than bulls with similar attributes sold lump sum. As mentioned above in footnote ten, this premium contradicts the economic intuition that a part of an asset will sell for less than a whole asset. In chapters four and seven of this thesis, I extend the explanation of Chvosta, Rucker, and Watts and present a model, supported by empirical results, to explain the premium for retained interest bulls.

Share Contract Theory and Empirical Applications

The theory of share contracts has been studied extensively with most studies examining the efficiency of share contracts compared to pure wage and fixed rent contracts. Early economic theory predicted share contracts would result in inefficient allocations of resources, yet they are prevalent in agriculture across the world. Arguing that competitive labor markets must clear, Cheung (1968) demonstrates that share contracts will result in an efficient allocation of resources. Tenants can be induced to work past their own optimal amount of labor because they face potential competition from the labor market. The tenant in a share contract will work the efficient amount of labor because there are positive rents from working an additional unit, until the positive rents cancel out the costs of working past their preferred amount of labor. Generally, this theory states that in the presence of competitive markets, share contracts induce the agent to produce or work more than his preferred quantity and this is possible because this “extra” production dissipates the rents available above the agent’s opportunity cost.

Once share contracts were shown to be efficient through Cheung’s analysis, theory then tried to explain the attractive qualities of the contracts. The first argument for the existence of

share contracts to gain traction was the theory of risk sharing. Share contracts allow both parties to share the risk of production and manage risk well in the presence of risky labor markets (Cheung, 1969; Higgs, 1973; Newbery, 1977; and Stiglitz, 1974). Another predominant explanation for the widespread adoption of share contracts is that share contracts reduce relevant transaction costs relative to other contract types. Barzel (1997) theorizes that in a world with positive transaction costs, contracts will be chosen based on the pertinent transaction costs because property rights are never perfectly defined. Whichever party can most affect the flow of income from the asset will be the residual claimant in the contract. This will maximize the value of the asset net the amount of transaction costs. If one party can greatly affect the potential revenue, the other party faces substantial enforcement and monitoring costs depending on the contract type and vice versa. Others have also shown that double sided moral hazard can be mitigated well with share contracts because both parties are residual claimants (Bhattacharyya & Lafontaine, 1995; Ghatak & Pandey, 2000; Sengupta, 1997).

Many empirical tests of share contracts analyze various agricultural contracts and have tested both the risk-based argument and the transaction cost argument. Researchers have found results that both support and contradict the risk sharing argument. For example, Allen and Lueck (1999) analyze sharecropping contracts under varying risk assumptions and find no evidence to support the hypothesis that share contracts reduce risk. On the other hand, Akerberg and Botticini (2002) account for endogenous matching of risk preferences between landowners and tenants and find evidence to show that risk is a significant determinant of contract choice in their data. Fausti et al. (2003) tests how retained ownership of feeder cattle reduces risk and find that

unsystematic risk specific to producers accounts for the reduction in risk due to retained ownership.

Transaction cost analyses of share contracts typically either assume homogeneity in risk preferences across actors or control for risk measures in the empirical models. Main results include support for transaction cost models based on the presence of moral hazard or provision of incentives (Alston, Datta, & Nugent, 1984; Fukunaga & Huffman, 2009; Hobbs, 1996). Allen and Lueck (1993) find that costs of monitoring and negotiating input use in share contracts lead parties to adopt arrangements that better manage transaction costs, especially for contracts related to splitting costs of indivisible inputs. Allen and Borchers (2016) find that farming conservation practices are substitutes for share contracts as both reduce monitoring transaction costs associated with the tenant's incentive to exploit the land. Braido (2008) shows that sharecropping contracts do not reduce incentives of the tenant and that production under these share contracts does not differ from production in fixed rent contracts.

Other empirical analyses of share contracts explore industries such as natural resources (see Black, Leffler, and Rucker, 1996; Hallagan, 1978; Leffler and Rucker, 1991; Mulherin, 1986; and Platteau and Nugent, 1992), franchising (see Brickley, 2002 and Lafontaine, 1992), and vertical integration (see Levy, 1985 and Mortimer, 2008). This thesis will add to the share contract literature by extending the transaction cost analysis to breeding cattle and by providing a theoretical model of the retained interest contracts in seedstock bull auctions. These arrangements combine lump sum payments and revenue sharing, so they differ from pure share contracts analyzed in most sharecropping analyses.

Presale Measurement in Auctions

Barzel (1982) explores how buyers undertake measurement of goods pre-sale due to the uncertainty of the good's attributes and quality. For commodities where the quality or attributes are unknown, consumers will engage in measurement before the sale to better determine how they value the good, how much to buy, and which to choose. Share arrangements may reduce uncertainty regarding the attributes without necessarily reducing risk. Because of the uncertainty, estimating a lump sum value of the good may be difficult, so share arrangements are more efficient. Also, sellers can use their reputation to provide less incentives for measurement. Barzel predicts that goods backed by a brand name or reputation will vary less in quality.

French and McCormick (1984) start with a standard first-price sealed-bid auction model and modify it to show that bidders can recover their costs from information acquisition in a competitive equilibrium. They show that the bidder's best strategy is to bid slightly less than their adjusted valuation of the asset which leads to positive expected profits. Because of the positive expected profits, bidders can expect to recoup the costs they expend to assemble information about the asset. Because bidders expect to make up these costs, sellers are expected to bear the total amount of these costs, so they have an incentive to minimize them. The authors posit that sellers can manage these estimation costs by 1) collecting entry fees to reduce the number of bidders, 2) produce and distribute information themselves, and 3) use negotiation instead of competitive auctions. Sellers will provide their own information as long as bidders see it as reputable. If they do not believe the information provided is reputable, they will ignore the seller provided information and will continue to seek it on their own. Sellers can prove their reputability by 1) posting a bond for the buyer to collect if the information turns out to be

incorrect, 2) use an independent third party to provide the information, or 3) retain a claim in the asset.

Leffler, Rucker, and Munn (2000) develop a model of competitive auction equilibrium where the number of bidders is endogenous and the uncertainty regarding the value of the good can change. The authors find that presale measurement of timber tracts increases as the variance of the tract value increases. They also find that sellers do undertake more measurement as the total expected amount of buyer measurement increases. The seller substitutes their measurement for buyers' measurement. This supports their model that predicts that as uncertainty of the good increases, the incentive for presale measurement also increases. Because the seller ultimately bears all the costs of presale measurement, he has an incentive to reduce these costs. The seller can do this through a few different means. He can provide his own information *ex ante*, increase the costs to the buyer of collecting information, or change the terms of the contract to reduce the uncertainty.

Leffler and Rucker (1991) apply these same predictions to timber sales in North Carolina. They find that as uncertainty regarding the quality of the timber tract increases, the seller is more likely to choose a per unit payment to mitigate the presale measurement costs. They also develop a model for per unit or royalty type payment contracts that includes *ex post* transaction costs. With positive marginal costs of enforcing a degree of harvest, the landowner can induce the timber buyer to harvest more timber than the buyer would originally be willing to harvest. There are still losses, however, from reduced output relative to the optimal amount harvested if it were sold on a lump sum basis, and losses due to opportunistic behavior that the landowner cannot fully eliminate.

Building on these past studies, this thesis takes from the auction literature to model the producer's decision of contract type. I show that seedstock producers use various methods to reduce the uncertainty of a bull's value to reduce aggregate presale measurement and increase the public offering of information about the animal. The theory presented in the next chapter draws from the papers included here to form a model for contract choice in seedstock bull sales in the presence of uncertainty.

CHAPTER FOUR

THEORETICAL MODELS OF CONTRACT CHOICE AND HEDONIC PRICING

A Transaction Cost Model of Bull Sale Contract Choice

When selling bulls, producers choose between sales mechanisms and contract types. The most popular sales mechanisms are auctions and private treaty negotiations.¹¹ This study focuses solely on the choice of contract when bulls are sold at auction; however, one contract type for negotiated sales is included in this theory to provide a frame of reference for the retained interest contract. This negotiated arrangement is when a producer chooses to offer a bull on a pure per unit basis where they lease a bull to an AI stud company to be collected and the parties split the semen revenues. The theory of this pure per unit type of arrangement is described in section two and is presented as a contrasting alternative to the retained interest, mixed contract presented in section three.

At auction, producers choose between selling a bull lump sum with no retained semen interest and selling a bull with a specified percentage of retained interest. When a producer chooses to sell with retained interest, they still receive the up-front auction price for the bull along with per unit payments from any semen sold in the future. This arrangement is analogous to a lump sum payment with contingent royalties used in other contexts such as oil leases.¹² The models for different contract types presented below focus on the relevant transaction costs faced by the seller as the driving force behind contract choice.

¹¹ Other types of sales mechanisms include bull tests, described above in chapter two.

¹² See Black, Leffler, and Rucker (1996) for a transaction cost model of oil leases.

A Model of Lump sum Bull Contracts

This model closely follows the model presented in Leffler and Rucker (1991) and their analysis of timber payment provisions. Consider an arrangement where a seedstock bull is sold on a lump sum basis to the highest bidder at the auction. I assume that bidders are homogeneous in that they all have the same realized value for the bull, v , and have the same “uninformed” distribution of v , $G(v)$. Also, I assume that bidders are all risk-neutral and are profit maximizers. Further, all bidders are able to correctly estimate the total number of bidders for each bull. The producer is also risk-neutral and provides information about the bull to all bidders in the form of the sale catalog. This public information about the bull includes any simple performance measures, EPDs, or index values and it is incorporated into each bidder’s formation of $G(v)$. Each bidder can also incur costs to collect additional information, i_j , about the bull on his own. This private information may come from studying the sales catalog, personally speaking with the producer, visually inspecting the bull prior to the sale, or researching the quality of the bull’s pedigree. The cost to each bidder of collecting private information is M .

Bidders then combine their private information with $G(v)$ to modify their estimate of the bull’s value. They all assume that their private information is the highest valued out of all bidders and adjust for this information to get the adjusted estimated value, u_j . Bidders then further adjust their estimated valuation to correct for the possibility that they win the auction. In other words, the buyer’s adjusted expected value of the asset accounts for the winner’s curse as described in Wilson (1977) and French and McCormick (1984). The winner’s curse refers to the effect of a bidder submitting a bid equal to the adjusted estimated value of the asset and winning the auction. If a bidder has the highest valued private information and submits a bid based on

that, it is likely that his bid will exceed the true value of the asset. This is because the private information he collected is higher than all other private information samples, and is therefore likely to be higher than the asset's true value. The winner's curse correction accounts the possibility that the bidder is overestimating the asset's value given the private information.

If a bidder submits a bid equal to their adjusted expected value of the asset, his expected profit is zero. Because bidders are homogeneous, all bidders then have an expected profit of zero. Each bidder could improve their expected profit by bidding below his adjusted estimated value. The bidder only needs to submit a bid that is slightly larger than the expected value of the next highest bid. This second adjustment maximizes the bidder's expected profit. In the first case, if a bidder submits a bid below the adjusted estimated value but it is not the winning bid, his expected profits are still zero. He is no better off and no worse off. In the next case, if the bid submitted is larger than all other bids (and still below the adjusted estimated value), the bidder will win the auction and have positive expected profits. The bid made by bidder j , B_j , is less than the adjusted estimated value, u_i , by an amount, ΔX_j . In other words, the expected profit to the winning bidder is ΔX_j .

By allowing the number of bidders, N , to be endogenous, a zero profit equilibrium condition can be obtained. Each bidder's expected payout from bidding is:

$$\frac{\Delta X}{N} = \frac{E[u_i - B(N)]}{N} = \frac{v - E[B(N)]}{N} \quad (1)$$

where ΔX equals the expected return to the winning bidder over many bidders and $E[B(N)]$ is the expected winning bid with N bidders. On average with the collection of private information, the winning bidder's adjusted estimate of the expected value of the bull, u_i , will equal the true value, v . That is, $E(u_i) = v$, as shown by Wilson (1977). New bidders will enter the auction until the

expected payoff, $\Delta X/N$, equals the costs of collecting private information, M . This leads to zero expected profits. The equilibrium condition is then:

$$E[B(N^*)] \equiv B^* \equiv v - M \cdot N^* \quad (2)$$

where N^* is the equilibrium number of bidders and B^* is the equilibrium winning bid. This condition is a mathematical identity by the definition of N^* and B^* and will hold for all optimal values of N^* and B^* . In other words, the price received is the actual value minus the aggregate transaction costs associated with presale measurement.

Figure 1 graphically shows the competitive equilibrium for a lump sum bull sale. The top panel shows the expected bid as a function of the number of bidders, and as N increases, the expected bid asymptotically approaches the bull's true value, v . The difference between the expected bid and the true value of the bull is ΔX . The bottom panel shows ΔX as a function of N . As stated above, bidders will enter until $\Delta X/N = M$, or $\Delta X = M \cdot N$. That is the point where the curves in the bottom panel intersect. Taking this optimal number of bidders, N^* , to the graph in the top panel, the equilibrium bid for N^* bidders is equal to $E[B(N)]$ which equals B^* . B^* is less than the true value of the bull, v , by the amount $M \cdot N^*$.

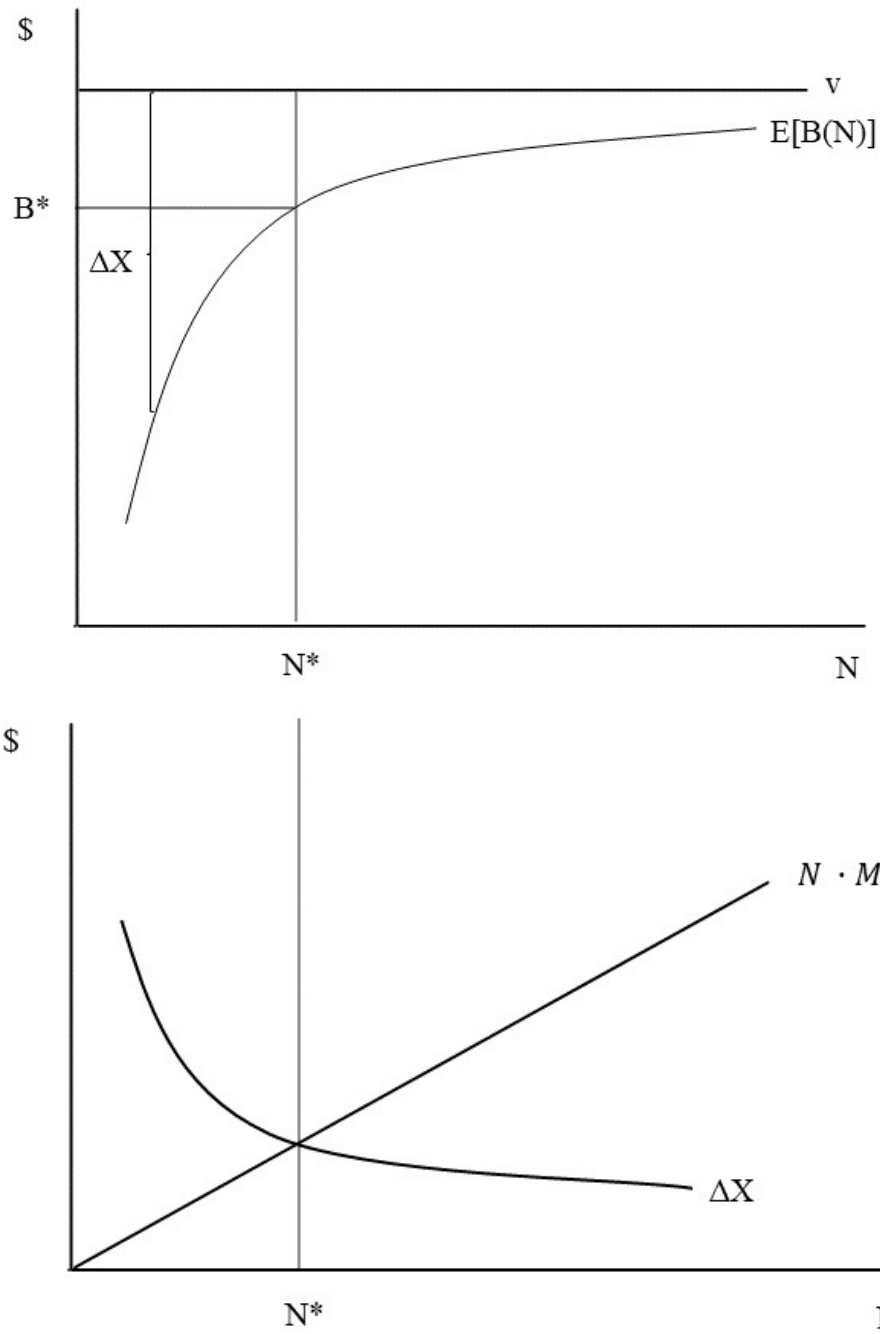


Figure 1. Competitive equilibrium for lump sum bull sale with endogenous number of bidders, N , and pre-sale measurement costs, M .

It is clear from looking at this condition that in a competitive auction the producer will bear the aggregate costs of the presale information collection. Suppose uncertainty increases

such that the cost of collecting information increases from M_0 to a new level M_1 , where $M_1 > M_0$. Bidders spend more on presale measurement, $M \cdot N^*$ increases, and B^* decreases.¹³ The decrease in the equilibrium bid, B^* , is fully borne by the producer. Therefore, the producer will have an incentive to control the amount spent on presale measurement. Barzel (1982) broadly proposes that the seller of a good will have an incentive to influence the amount of information collected by the bidders. He also predicts that for commodities where qualities or attributes are especially unknown/uncertain, buyers will engage in more measurement before the sale to better determine how they value the good, how much to buy, and which unit to buy. In the present context, Barzel's predictions translate to the hypothesis that an increase in aggregate presale measurement costs for bulls whose attributes are most uncertain.

Figure 2 shows the value of a bull in terms of conventional marginal analysis. The true value of a bull is uncertain on sale day; however, buyers may have a general idea of the marginal costs of caring for the bull and using it as a herd sire and the value of its semen. This allows them to form a lump sum valuation of the bull.¹⁴ In the case that the bull is sold lump sum, buyers may assume these costs and value of the semen are for use of the bull in their herd via natural service. With that assumption, the value or price of the semen is shown by P , and the marginal cost of using the bull are shown by MC .¹⁵ The area Z then represents the buyer's surplus from using the bull for natural service; this area also represents the buyer's willingness to pay for the bull. In the lump sum case, the area Z equals v —the value of the bull as denominated above.

¹³ This is easily shown in figure 1. If M increases, the $M \cdot N$ line in the bottom panel rotates counterclockwise through the origin and becomes steeper. The equilibrium number of bidders will decrease, and aggregate presale measurement costs will increase. Thus, ΔX increases and the equilibrium bid, B^* , decreases.

¹⁴ This is modeled to be a one period model, so that the value of a bull is simply area Z .

¹⁵ This is not the marginal costs of collection, which are discussed in the second and third sections of this chapter. The marginal costs discussed here simply correspond to the costs of using a bull in the herd, including feed, veterinary, and boarding costs.

Under the previous discussion regarding uncertainty of the bull incentivizing presale measurement, the auction price for a lump sum bull will equal Z minus the aggregate presale measurement costs.

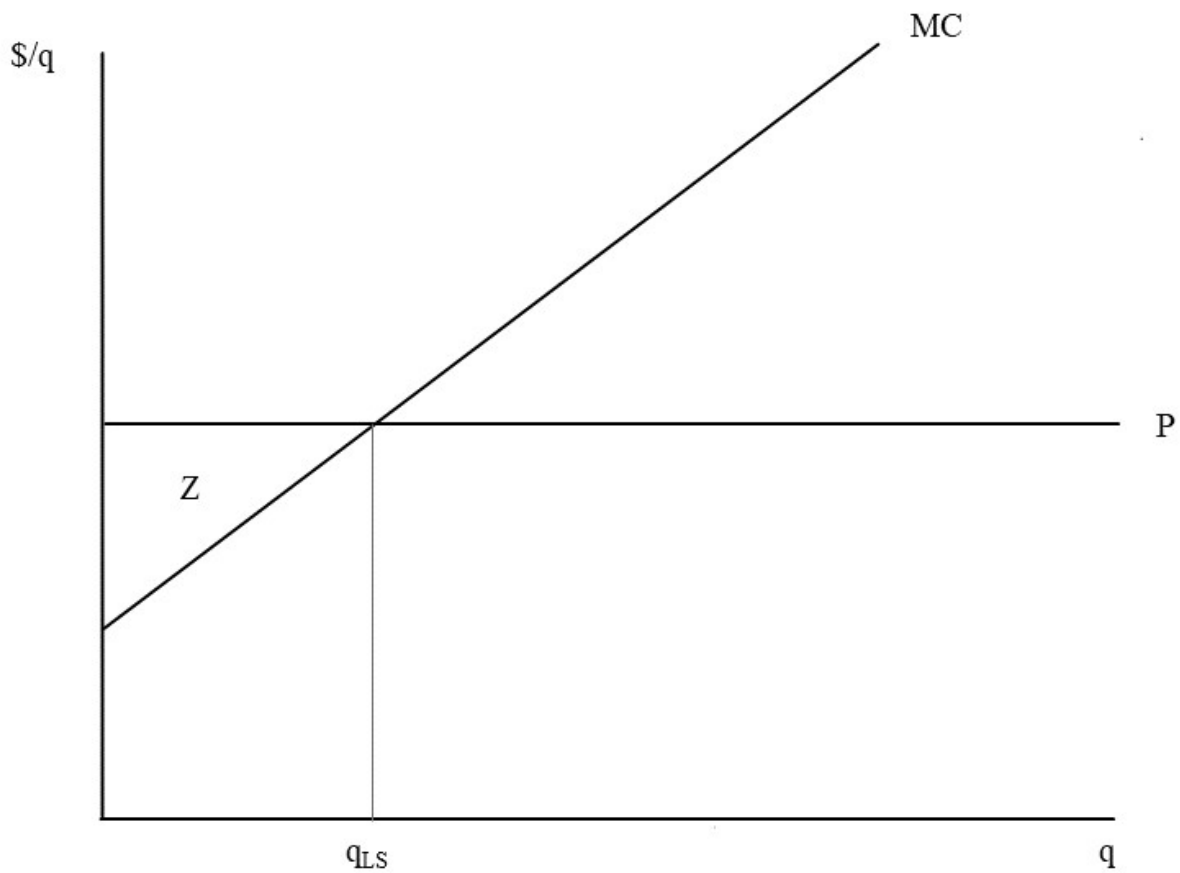


Figure 2. Value of a bull sold lump sum, where P_{LS} is the value of the semen and MC is the marginal cost when the bull is used to breed via natural service.¹⁶

¹⁶ Later in this chapter, I use this same graph to show how retained interest signals new information to buyers that increases the realized value of semen.

An integral detail for this analysis in the context of seedstock bull sales is that there is much uncertainty regarding the potential of a bull before he has produced any offspring.¹⁷ Ultimately, seedstock bulls are sold for their genetics. Because the animals' genes are not seen or easily discerned, there is uncertainty in the quality of the genetics. Though buyers can observe the phenotypes of bulls, they cannot observe genotypes.¹⁸ Buyers must be able to recognize measures of quality in bulls and predict how those genes will interact with their cow herd. Also, most importantly, bulls are typically sold before they have been able to "prove themselves." Seedstock bulls are most frequently sold as "virgin" bulls when they are between one and two years old. This means that they have not sired any offspring that would provide an indication of the actual genetic quality of the bull. Without progeny, bulls have no breeding record, and therefore their potential and true value remain uncertain to buyers. This inherent uncertainty regarding bull quality provides the incentive for buyer presale measurement.

As shown above, these presale measurement costs are borne by the seller; therefore, sellers have an incentive to reduce these costs. Leffler, Rucker, and Munn (2000) show that one way for sellers to reduce presale measurement costs is to provide their own information about the asset to be sold. Barzel (1982) suggests that sellers can use their reputation to provide less incentive for pre-sale measurement because buyers will know that the "brand" is high-quality.

¹⁷ The heterogeneity of seedstock bulls is a driving factor in this analysis. Because bulls are heterogeneous, there is uncertainty regarding the quality and value of the bull. The model presented here, in chapter four, and empirically tested in chapter 6 differs from a model of share contracts in homogeneous assets. A short analysis of share contracts in taxi medallions, a homogeneous asset, is presented in Appendix E.

¹⁸ In genetics, Phenotype is the physical expression of the genes, or the genotype. Genotype is the composition of different genes in an organism. Genotype is unobservable because it is coded in DNA. For example, in cattle, a black Angus bull may have one black allele and one red allele. The bull appears black, as the black allele is the dominant version and red is recessive, but because he also carries the red allele, breeding him with a black cow that has a red allele might end in a red calf. The bull's phenotype, black, does not fully represent his genotype, one black allele and one red. Phenotype can help identify genotype, but it usually cannot inform the buyer about the bull's genotype with certainty.

Another method for mitigating these transaction costs is to increase the cost to the buyers of collecting the information. An example of this is to limit the time available for viewing the asset before the sale (Leffler, Rucker, and Munn 2000). Finally, Leffler, Rucker and Munn and Barzel both state that sellers can reduce presale measurement costs by changing the terms of sale contracts. Leffler and Rucker (1991) test this theory and show that for timber sales in North Carolina, sellers manage presale measurement costs by selling some tracts of timber on a per unit basis versus a lump sum basis depending on the uncertainty of the quality of the tract.

All of the above methods for reducing presale measurement costs are utilized by seedstock bull producers. These producers typically provide information about the bulls through their use of sale catalogs, online pictures and/or videos of the bulls, DNA results, and/or ultrasound EPDs. They tend to use third parties, such as the breed association, to provide these data to show that they are trustworthy. Producers also allow time before the sale for bidders to view the bulls; however, they may limit the in-person viewing time to a few hours prior to or to the day before the sale. This limits the amount of time available for bidders to collect information. While there are many ways the producer may try to manage the presale measurement costs, this study focuses on how contract choice may reduce the burden of these transaction costs on producers.

A Model of Bull Sales as Per Unit Payments

As a method for controlling presale measurement, producers have the option to offer bulls on a pure per unit basis. As stated above in footnote two in chapter two, this arrangement is typically executed through private treaty negotiations where the interest shares are negotiated

between the parties. Although negotiated sales are not the focus of this study, this arrangement provides a baseline of comparison for the retained interest mixed contract discussed in the next section. Relative to the lump sum arrangement, the buyer's total payment for a bull he purchases is determined solely by the amount of semen collected and sold. The total revenue a producer receives from the bull with this arrangement is all from semen sales. In this case, the producer is posited to choose a share percentage or a fixed per straw amount that he will receive from each straw of semen sold with the objective of maximizing his profits.

When bulls are sold with pure per unit payment provisions, the buyer has a reduced incentive to gather information about the bull before the arrangement is made. The producer may offer the same amount of public information he would for a lump sum sale, such as SPMs and EPDs, to bring in potential buyers, but a potential buyer's incentive to collect more information prior to the sale is reduced because the amount he actually pays for the bull is determined by the actual quality of the bull revealed over time. Assuming for simplicity that with these type of arrangements buyers do not engage in additional pre-sale measurement, the relevant transaction costs to the producer are the *ex post* costs of negotiating, monitoring, and enforcing the contract.

Looking at figure three, P is the price of semen per straw and R_0 is the per unit payment. The marginal cost of collection curve, MC_C , is upward sloping because of the nature of the semen collection process in the timeframe of, say, a week. I assume that semen quantity is measured in a standardized unit of semen, such as a certain number of healthy sperm per semen straw. With each consecutive collection attempt in a short period of time, the semen becomes diluted so that each collection sample has less healthy sperm cells (Feurst-Waltl et al., 2006). As the amount of semen collected per week increases, the actual amount of viable sperm decreases

and the number of standardized straws of semen produced decreases. This means that the costs of semen collection increase with each attempt.

The net marginal revenue to the buyer is equal to $(P - R_0)$. From the perspective of the buyer, with the constant net marginal revenue and the upward sloping marginal cost, his optimal quantity of semen to collect from the bull is $q_b(R_0)$. This is the quantity of semen that equates marginal revenue and marginal cost of collection and is therefore the buyer's profit maximizing quantity. From the perspective of the producer, a higher quantity of semen, q_e , would be preferred because this is where the marginal cost of collecting semen is equal to its price.

Because the producer's marginal revenue from the next unit of semen, R , is higher than the marginal costs of enforcing collection of that next unit, the producer has an incentive to specify and enforce a quantity of semen; however, it is costly for the producer. He may incur monitoring and enforcement costs to induce the buyer to collect more than $q_b(R_0)$. Let $C_E = C_E[q - q_b(R_0)] + F_E$ be the producer's enforcement cost function where q is the actual level of semen collected after enforcement and F_E is the fixed cost of monitoring and enforcement. Assume that $\partial C_E / \partial q > 0$ and $\partial^2 C_E / \partial q^2 > 0$ for all $q_e > q_b(R_0)$.

Figure three outlines the role of the costs of enforcement for a given level of retained interest and equivalent per unit payment, R_0 . The buyer prefers to stop collecting semen at $q_b(R_0)$, where his net marginal revenue equals marginal cost. The producer is able to enforce a higher quantity, but incurs extra costs to do so. These enforcement costs start at $q_b(R_0)$ and increase from there. The producer's preferred output is then $q^*(R_0)$ or where the MC_E equals the per unit payment. This is where the producer's marginal revenue from semen sales, (R_0) , equals the marginal cost of enforcing that level of output, MC_E . The $q^*(R)$ line shows the combinations of

optimal quantities and levels of retained interest given the costs of enforcement. For each different value of R , the optimal q can be similarly determined with the result being the $q^*(R)$ line. The producer will then choose the combination of R and q on the line that maximizes his profits. In making that choice, however, the producer faces the constraint that buyer profits, π_b , cannot be negative.

The buyer's zero profit line is also the average cost of collection curve, AC . This is because the buyer's net revenue per unit equals average revenue per unit, and buyer profits are zero where average revenue equals average cost. The producer is limited in his choice of retained interest and output combinations. A buyer will not agree to an arrangement that will leave him with negative profits. Ultimately, the producer is constrained by this condition, yet there is an area where the $q^*(R)$ line lies above where $\pi_b = 0$. This demonstrates that, given positive, finite costs of enforcement, there are times when it is optimal for the producer to allow for buyer profits to be positive.¹⁹

As seen on the graph, the areas of positive buyer profit correspond to combinations of q and R along the $q^*(R)$ line between points Y and Z. The buyer has positive profits with these combinations and because of this, the producer can enforce a higher level of output. If a producer could costlessly enforce a higher level of output, such that MC_E was zero, the producer would choose R to maximize his profits and leave the buyer with zero profits. This would be a combination of q and R along the buyer zero profit line. Overall, the producer's set of optimal combinations of R and q are represented on the graph by a bolder line.

¹⁹ See Leffler and Rucker (1991) for a discussion of how buyer profits might be competed away along margins other than those in figure three.

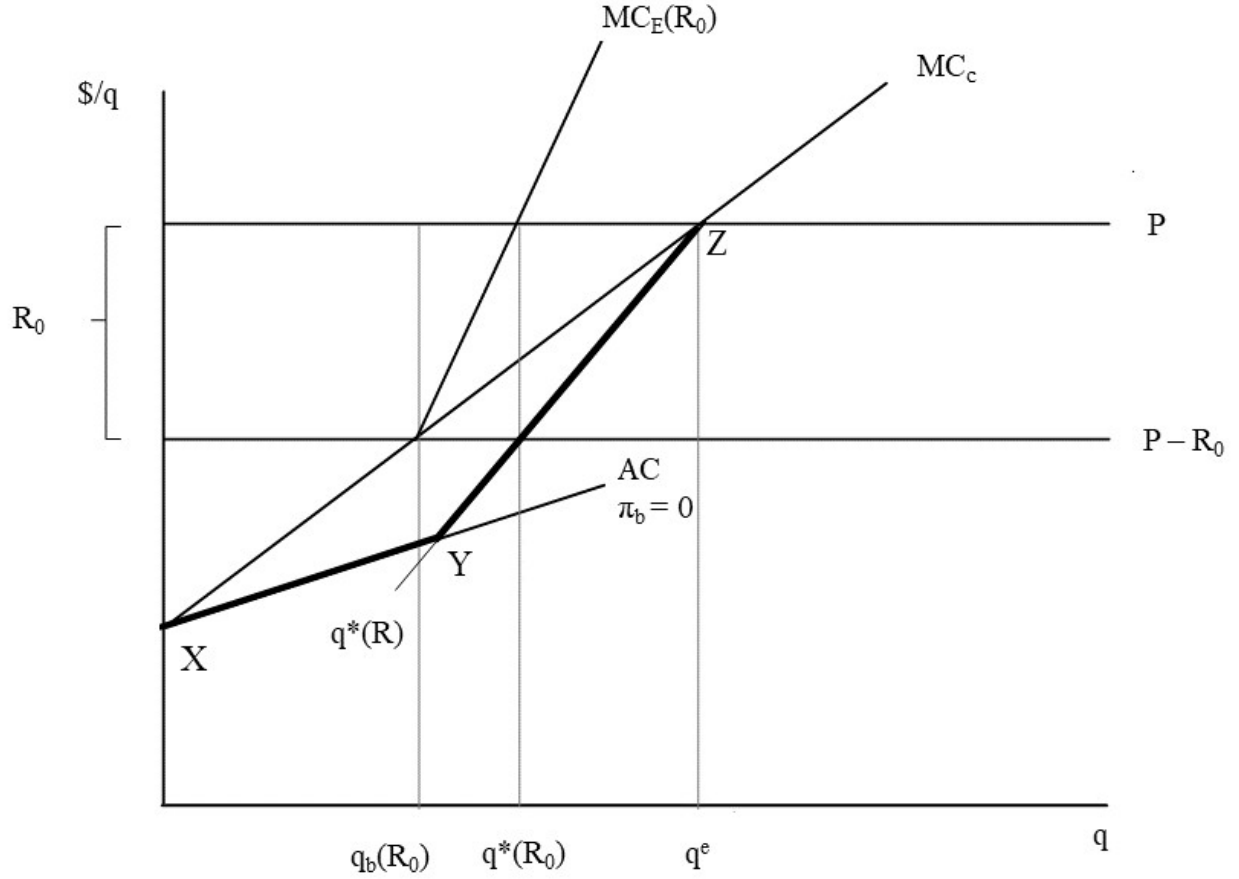


Figure 3. Per unit payment contracts for bulls sold with retained semen interest, as adapted from Leffler and Rucker (1991).

The producer's problem is to choose a share percentage, represented by R , and enforce a quantity of semen collection, q , to maximize his profit subject to non-negative buyer profit.

$$\begin{aligned} \max_{q,R} \pi_P &= R \cdot q - C_E[q - q_b(R)] - F_E \\ \text{subject to } \pi_b &= (P - R)q - C_c(q) \geq 0, \end{aligned} \quad (3)$$

where π_P is producer profits, π_b is the buyer's profits, and $C_c(q)$ are total costs of collection.

The Lagrangian for a constrained maximum is:

$$\mathcal{L} = R \cdot q - C_E[q - q_b(R)] - F_E + \lambda[(P - R)q - C_C(q)] \quad (4)$$

The Kuhn-Tucker conditions for a maximum in equation 4 are:

$$\frac{\partial \mathcal{L}}{\partial q} = R - MC_E + \lambda[(P - R) - MC_C] = 0 \quad (5)$$

$$\frac{\partial \mathcal{L}}{\partial R} = q - \frac{\partial C_E}{\partial q_b} \frac{\partial q_b}{\partial R} + \lambda[-q] = 0 \quad (6)$$

$$\frac{\partial \mathcal{L}}{\partial \lambda} = (P - R)q - C_C(q) \geq 0 ; \lambda \geq 0 ; \lambda \left[\frac{\partial \mathcal{L}}{\partial \lambda} \right] = 0 \quad (7)$$

The interpretation of these conditions is fairly straightforward. First, assume that the buyer profit constraint is binding, or that $\partial \mathcal{L} / \partial \lambda = 0$. Then $\lambda > 0$ to satisfy the complementary slackness condition in equation seven. Equation five shows that the optimal quantity is where the marginal benefit to the producer, R , is equal to the marginal costs. The marginal costs in this case are the marginal costs of enforcement along with the amount of profits given up to the buyer due to imperfect enforcement from the increase in the output. Equation six shows that the optimal per unit payment (and corresponding retained interest level) is where the producer's marginal benefit of the output, accounting for the change in this valuation when buyer profits are positive, equals the change in the costs of enforcement due to the change in R that causes a change in the buyer's preferred amount of semen collected, q_b . This equates to the marginal benefit of increasing R equaling the marginal costs of enforcing the different output level. This region of optimal quantities and output levels is represented by line segment $\overline{XY}$ in figure three.

Instead, suppose that the buyer profit constraint is not binding, and the buyer is allowed to earn positive profits. In this case, $\partial \mathcal{L} / \partial \lambda > 0$, and $\lambda = 0$. Equation five then shows that the optimal output, q , is where $R = MC_E$, or where marginal revenue to the producer equals marginal cost of enforcement. Equation six, when buyer profits are positive, shows that the optimal per

unit payment is where output level equals the change in enforcement costs due to the change in R that comes about from the change in q_b . This region of optimal quantities and output levels is represented by line segment $\overline{YZ}$ in figure three.

Figure four shows the areas that correspond to buyer profit, producer profit, the loss due to opportunistic behavior, and loss due to under-collection for a case when the buyer profit constraint is not binding. The area labeled π_P indicates the producer's profits when he specifies a per unit payment equal to R^* and enforces a collection level of q^* . The area labeled π_B^+ shows the buyer's positive profits that he gains from collecting q^* units of semen and selling for a net price of $(P - R^*)$. The area E shows the losses in revenues due to enforcement costs. Area π_B^- represents the losses the buyer must incur to produce more than they would prefer. The area S shows the losses to the producer due to opportunistic behavior, or shirking, on the part of the buyer. Altogether, with a per unit payment provision, the producer's profits equal $\pi_P - F_E$ where F_E is the fixed cost of enforcement. Buyer profits overall equal $\pi_B^+ - \pi_B^-$.

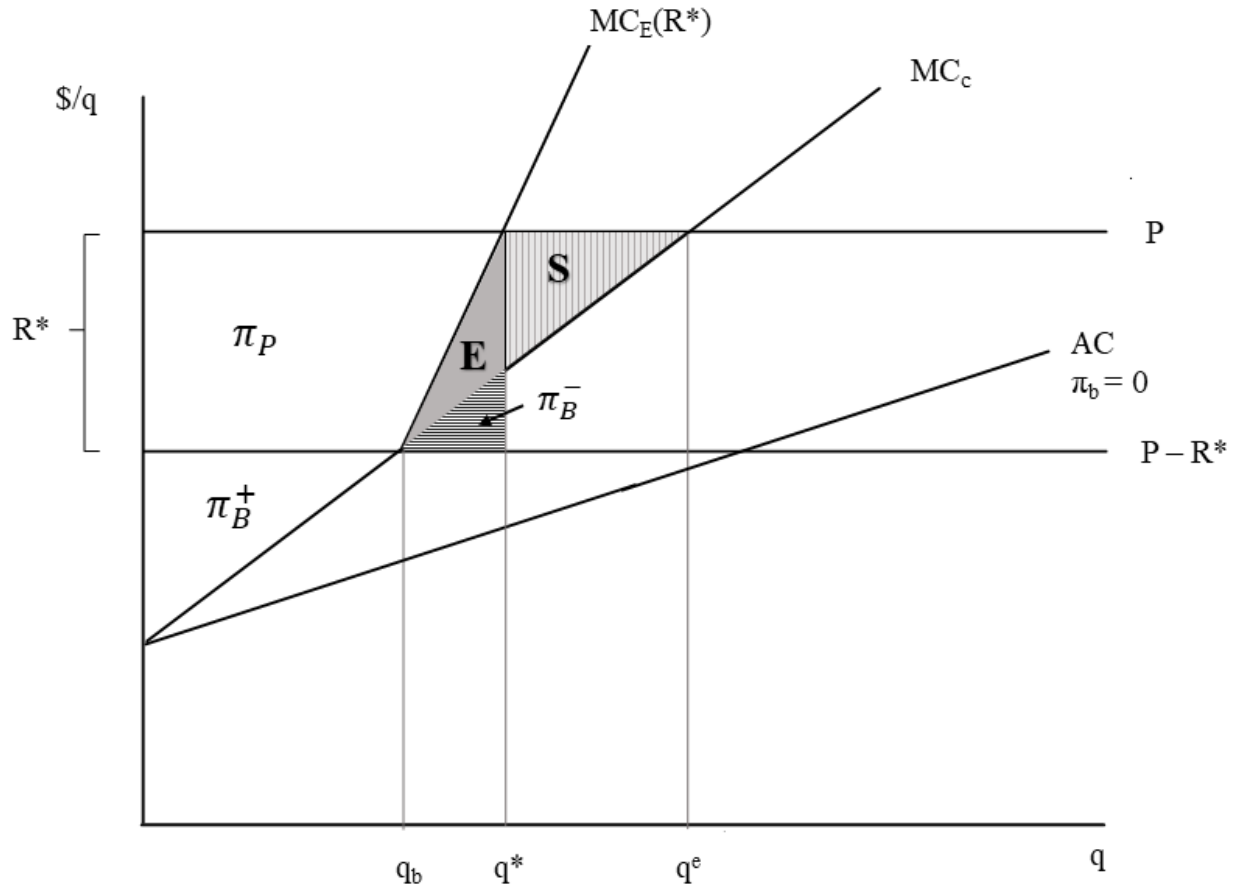


Figure 4. Distribution of gains and losses for an optimal level of per unit payment, R^* , and optimal enforced level of collection, q^* .

A Model of Retained Semen Interest as a Mixed Contract Type

As a method for controlling presale measurement, a retained semen interest contract reduces the incentive for potential buyers to undertake presale measurement; this then reduces presale measurement costs incurred by the producer. The retained interest contract effects prices of bulls in two ways. The first is that selling a bull with retained interest signals new information to buyers that the bull has high breeding potential, which increases the value of the semen. The second effect of a retained interest contract is that it reduces uncertainty regarding the value of the bull.

Figure five shows how retaining interest in a bull sends a signal to buyers and how that signal affects the value of semen and the potential gains to the buyer. When a bull is sold with retained interest, this signal informs buyers that the value of semen is higher than for a comparable bull sold lump sum. This increases the price of the semen from P_{LS} to P_{RI} .²⁰ While there is this increase in the value of semen, there is a corresponding reduction in the net marginal revenue of semen (from the buyer's perspective) due to the retained interest percentage. This is shown in the graph where P_{RI} is above $P_{RI} - R_0$. Whereas in figure 2 under the lump sum contract, the buyer's valuation of the bull was area Z, with a retained interest contract, the buyer's valuation is now shown by areas Y and Z.²¹ This is assuming the increase in the price from the signal of retained interest is greater than the reduction in the buyer's marginal revenue from the producer's retained interest share. Under these conditions, a buyer values the bull more when it is sold with retained interest than he would if it were sold lump sum.²² This additional amount is shown by area Y. Like with the lump sum contract, the amount the buyer would be willing to pay for the bull is areas Y and Z minus the presale measurement costs and costs to the buyer from the producer's enforced level of output.

²⁰ I model this as a variance preserving shift in the price for semen, so the price increases but the uncertainty does not change due to the signal of retained interest.

²¹ Both figure two figure five show the valuation of the bull in a one period model.

²² The depiction of the impacts of the retained interest provision is consistent with my empirical findings regarding the effects of retained interest on bull prices, as show in chapter seven.

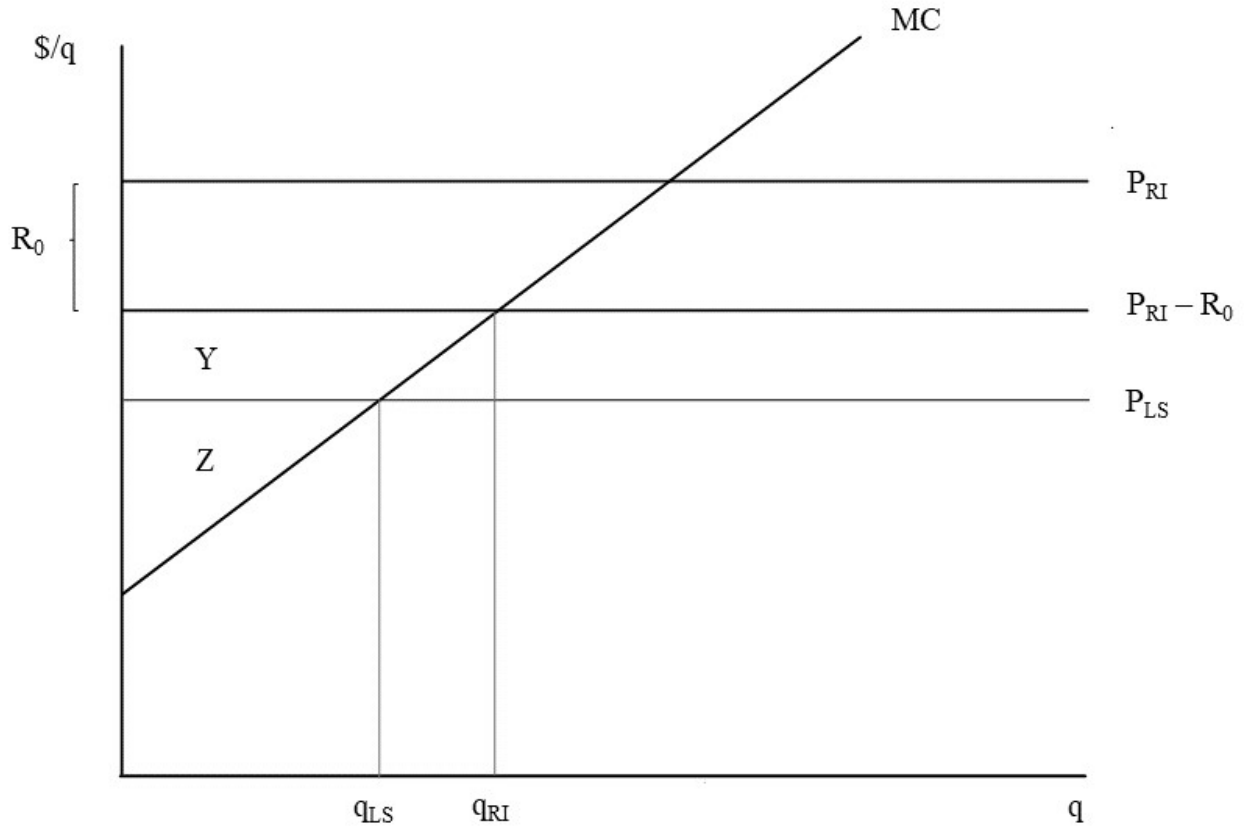


Figure 5. Change in expected value of a bull and areas of gain to the buyer when a bull is sold with retained interest.

In the case of retained interest arrangements in bulls, the total payment from buyer to producer is determined by three factors. The first is the auction price paid for the bull, the second is the amount of semen collected and sold, and the third is the level of retained interest. Because this arrangement includes a lump sum auction price component, buyers still have an incentive for presale measurement; however the incentive for presale measurement decreases as the uncertainty of the bull's quality decreases.²³ Assuming pre-sale measurement costs do decrease

²³ This can be easily shown. From the producer's perspective, a bull sold lump sum will bring him π_p profits with a variance of σ_p^2 . If this bull were to be sold with retained interest, the bull now brings the owner $\alpha \cdot \pi_p$ where α is the retained interest percentage. The variance of profits with retained interest is then $\alpha^2 \cdot \sigma_p^2$. Because α is bound between zero and one, α^2 will be less than one. Therefore, the variance of producer profits in a retained interest contract is less than the variance of profits in a lump sum contract.

with retained interest bulls, then the relevant transaction costs of a mixed type, retained interest provision compared to lump sum provision are the difference in *ex ante* presale measurement costs between the two arrangements and the *ex post* costs of monitoring and enforcing the contract. This is because the per unit payment arrangement reduces the buyer's incentive to collect the efficient quantity of semen.

Looking at figure six, P_{RI} is the value of semen per straw and R is the per unit payment associated with the retained interest percentage.²⁴ The retained interest percentage is translated into per unit amount such that $R_0 = \left(\frac{\text{retained interest \%}}{100} \cdot P_{RI} \right)$. This translates retained interest into a fixed per unit amount similar to the model for pure per unit payments presented above. The marginal cost curve, MC_C , is again upward sloping because of the nature of the semen collection process. As in the previous model, the net marginal revenue to the buyer is equal to $(P_{RI} - R_0)$. From the perspective of the buyer, with the net marginal revenue and the upward sloping marginal cost, the optimal quantity of semen to collect from the bull is $q_b(R)$. From the perspective of the producer, a higher quantity of semen would be preferred, namely at q_e where the marginal cost curve intersects the price.

The producer prefers the higher level of semen collected and incurs costs to enforce the buyer to go above their own preferred level of output. The producer's costs of enforcement are again given by $C_E = C_E[q - q_b(R)] + F_E$ and the same assumptions regarding the first and second partial derivatives with respect to q hold. With enforcement, the buyer collects $q^*(R_0)$ units of semen. The line showing the optimal quantity to enforce as a function of the per unit

²⁴ This value of semen per straw is based on the above assumption that the signal of retained interest changes the value of the semen.

payment, $q^*(R)$ has the same interpretation as presented in the pure per unit payment provision; however, the buyer zero profit constraint changes between the two models with per unit payments.

In this mixed arrangement, the average cost of collection now has to account for the auction price paid for the bull, A . From the perspective of the buyer, the most he would be willing to pay at auction for a bull is up to the amount of profits he could expect from the semen sales. On the graph, this is represented by area A^+ minus area A^- . Because this lump sum amount is based on the future amounts of semen collected and the retained interest percentage, A is a function of q and R .

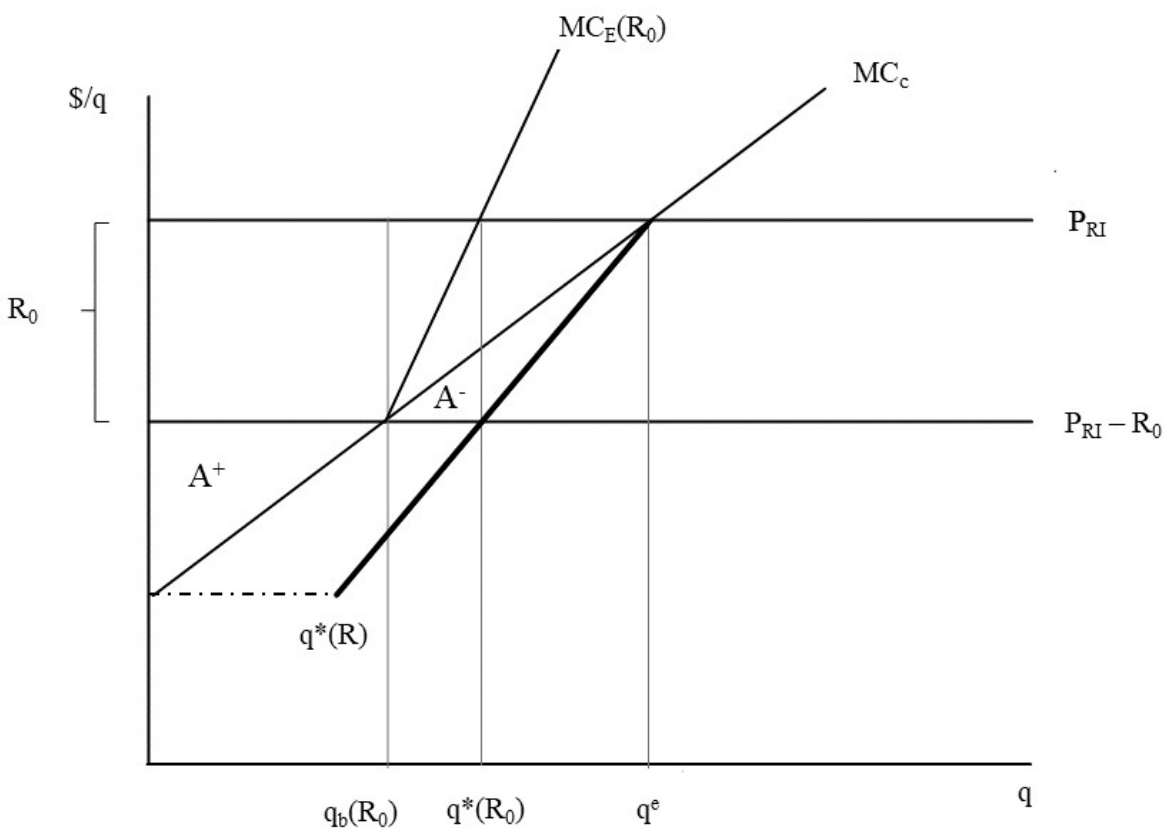


Figure 6. Mixed, retained interest contract for bull sales including lump sum payment from auction.

As can be seen on the graph, all else equal, an increase in R will decrease A , the lump sum auction price for the bull. This is because as R increases, the buyer will incur greater losses as he is forced to collect and sell more semen than his preferred quantity. The buyer is only willing to pay A up front if he expects some future profits from semen sales. Assuming a buyer knows that the producer will enforce a higher level of semen collection and sales, the buyer knows that he will incur costs (from collecting more than his optimal amount). If those expected losses are larger than the revenues he expects to make from semen sales, he would expect negative profits and would not enter into this contract by purchasing the bull at auction.

Assuming the producer chooses q and R such that buyer profits are zero after including the auction price for the bull, $A(q, R)$, the producer's problem is to choose a per unit payment that corresponds to a retained interest level and quantity to maximize his profit subject to zero buyer profit.

$$\begin{aligned} \max_{q, R} \pi_P &= R \cdot q + A(q, R) - C_E[q - q_b(R)] - F_E \\ \text{subject to } \pi_b &= (P - R)q - A(q, R) - C_C(q) = 0, \end{aligned} \quad (8)$$

The Lagrangian for a constrained maximum is:

$$\mathcal{L} = R \cdot q + A(q, R) - C_E[q - q_b(R)] - F_E + \lambda[(P - R)q - A(q, R) - C_C(q)] \quad (9)$$

The first order conditions for a maximum in equation 9 are:

$$\frac{\partial \mathcal{L}}{\partial q} = R + \frac{\partial A}{\partial q} - MC_E + \lambda \left[(P - R) - \frac{\partial A}{\partial q} - MC_C \right] = 0 \quad (10)$$

$$\frac{\partial \mathcal{L}}{\partial R} = q + \frac{\partial A}{\partial R} - \frac{\partial C_E}{\partial q_b} \frac{\partial q_b}{\partial R} + \lambda \left[-q - \frac{\partial A}{\partial R} \right] = 0 \quad (11)$$

$$\frac{\partial \mathcal{L}}{\partial \lambda} = (P - R)q - A(q, R) - C_C(q) = 0 \quad (12)$$

Interpretation of the conditions presented in equations 10, 11, and 12 are similar to the conditions presented under a pure per unit model. The lump sum payment, $A(q, R)$, enters the first order conditions because it is a function of the choice variables. Equation 10 states that the optimal quantity to enforce is where the per unit payment from retained interest plus the change in the lump sum price due to the change in quantity enforced equals the marginal costs of enforcement and the value to the producer of the change in buyer profits due to the change in quantity. Equation 11 states that the optimal per unit payment (and the corresponding retained interest level) is where the quantity of semen collected plus the change in the lump sum payment due to the change in R equals the change in enforcement costs from the change in R and the producer's valuation of the additional buyer profits. Using the intuition discussed earlier, $\frac{\partial A}{\partial R}$ will be negative. This represents the tradeoff between increasing R and subsequently lowering A . Comparing equation 11 to equation 6, when a producer receives A for the bull along with the per unit payments, the decrease in A due to the increase in R "discounts" his marginal benefit of R .

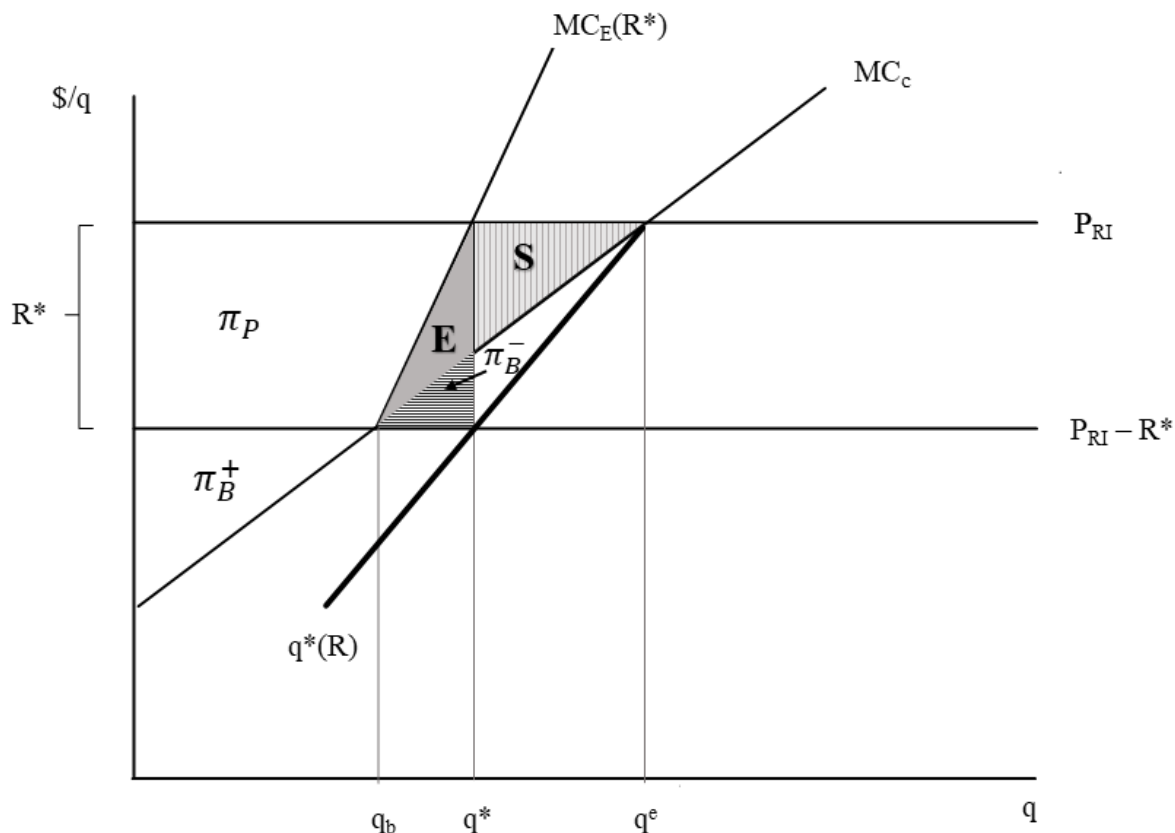


Figure 7. Profits and losses of a mixed contract that includes a lump sum auction price and retained semen interest.

Figure seven designates the areas of profits and losses under a mixed per unit payment provision. The producer's profit is area $\pi_P + (\pi_B^+ - \pi_B^-)$. The buyer's profit is area $\pi_B^+ - \pi_B^- - A$, which equals zero.

The Choice Between Contracts

Ultimately, the choice between the payment provisions described above will hinge on the relevant transaction costs associated with each arrangement. The producer will choose the arrangement based on which has the highest net expected returns. With the lump sum contract,

the producer's net expected profits are B^* and total pre-sale measurement costs are $(M \cdot N^*)$ such that $\pi_P = v - M \cdot N^* = B^*$. With the pure per unit contract, producer profits are π_P , and costs include the transaction costs, $E + S + F_E$. Realistically, because pure per unit contracts are often executed using negotiation, there are additional transaction costs associated with this sales mechanism. Under the mixed per unit contract, the producer profits are $A + \pi_P$ and transaction costs include enforcement, monitoring, and presale measurement costs.

The prevalence of pure lump sum and mixed per unit arrangements suggests that there is something relatively unattractive about the pure per unit type to producers.²⁵ This could be because, assuming enforcement costs do not change between the pure per unit and the mixed retained interest contract, the mixed provision increases the price of semen and to the producer, offers the appeal of the lump sum auction price for the bull. Another explanation is that either enforcement costs in the pure per unit provision are higher than in the mixed arrangement, or that there are prohibitively large fixed transaction costs associated with the pure per unit provision. Examples of this could be costs of finding AI studs willing to enter into that type of contract or costs of drawing up a formal contract to protect both parties, or the costs of negotiating as opposed to using an auction.

While this analysis focuses on transaction costs associated with contract types, the other prevailing argument surrounding contract choice is risk-aversion. In the case of bull sale contracts, if a producer is risk-averse, he will want to pass the risk of the bull onto the buyer. As Leffler and Rucker (1991) state, presale measurement acts to reduce the total risk to both the producer and the buyer. As risk increases, or as the variation in bull quality increases, the value

²⁵ I do not observe private treaty sales or negotiated sales of bulls in these data or in my discussions with producers, so my predictions regarding contract choice using different sales mechanisms are limited.

of presale measurement increases and therefore, these risky bulls would tend to be sold with lump sum contracts. From this, I predict that if producers choose between a lump sum and a retained interest contract based on the amount of risk in each contract type, they will sell bulls that have more variation in quality using lump sum contracts. This is the opposite prediction from the transaction cost model laid out above in this chapter.

Summary of Hedonic Price Theory

In contrast to conventional consumer theory, Lancaster (1966) theorized that goods are not valued because of the utility they give, but because of the utility from the different characteristics or attributes of the good. He also posited that goods have many different attributes and different goods may have some attributes in common. From this, Rosen (1974) put the theory into mathematical terms. He formalized the hedonic price theory by demonstrating that the value of each attribute in the bundle has its own marginal valuation, and the summation of the marginal valuations of attributes determines the value of the good. The theory laid out in this section follows Rosen's formalization of hedonic pricing theory as well as how it was explained in Purdie (2009) and Elizondo (2011).

Let a seedstock bull have a vector of attributes, $\bar{z} = (z_1, z_2, \dots, z_n)$, where z_i represents the i^{th} attribute. Define the elements of $\bar{z}$ such that all elements have positive marginal utility and are "goods." For bulls, this equates to multiplying some attributes, such as birthweight EPD, by negative one so that as the buyer's utility function is increasing in that attribute. Also, let the price for a bull be a function of its attributes, such that $p(\bar{z}) = p(z_1, z_2, \dots, z_n)$. The market price

for a bull, $p^*(\bar{z})$, is ultimately determined by the interaction between utility maximizing buyers and profit maximizing producers.

Given this, define a buyer's utility function to be $U(x, z_1, z_2, \dots, z_n)$ where x is defined to be a composite good whose price is normalized to one. Assuming that the buyer's budget constraint is binding, it can be represented as $y = x + p(\bar{z})$. The buyer's optimization problem is to choose x and $\bar{z} = (z_1, z_2, \dots, z_n)$ to maximize his utility:

$$\begin{aligned} \max_{x, \bar{z}} U(x, z_1, z_2, \dots, z_n) \\ \text{subject to } y = x + p(\bar{z}). \end{aligned} \quad (13)$$

The Lagrangian for this constrained optimization problem is then:

$$\mathcal{L} = U(x, z_1, z_2, \dots, z_n) + \lambda(y - x - p(\bar{z})). \quad (14)$$

The first order conditions for a constrained maximum are:

$$\frac{\partial \mathcal{L}}{\partial x} = U_x - \lambda = 0; \quad (15)$$

$$\frac{\partial \mathcal{L}}{\partial z_i} = U_{z_i} - \lambda \left[\frac{\partial p(\bar{z})}{\partial z_i} \right] = 0; \quad (16)$$

$$\frac{\partial \mathcal{L}}{\partial z_j} = U_{z_j} - \lambda \left[\frac{\partial p(\bar{z})}{\partial z_j} \right] = 0; \quad (17)$$

$$\frac{\partial \mathcal{L}}{\partial \lambda} = y - x - p(\bar{z}) = 0. \quad (18)$$

Equations 16 and 17 can be simplified to:

$$\frac{\left[\frac{\partial p(\bar{z})}{\partial z_i} \right]}{\left[\frac{\partial p(\bar{z})}{\partial z_j} \right]} = \frac{U_{z_i}}{U_{z_j}} \quad \forall i, j = 1, \dots, n, i \neq j. \quad (19)$$

Equation 15 and 16 can be simplified as:

$$\frac{\partial p}{\partial z_i} = p_{z_i} = \frac{U_{z_i}}{U_x} \quad \forall i = 1, \dots, n. \quad (20)$$

Equation 19 simply states that, the marginal rate of substitution between any two attributes must equal the ratio of their marginal prices at an optimum. Similarly, equation 20 states that the marginal rate of substitution between the composite good and each attribute must equal the partial of the bull's price with respect to that attribute.

Define a buyer's value bid function as the expenditure the buyer is willing to pay for alternate values of $\bar{z}$ at the given levels of utility, u , and income, y ,

$$\theta(z_1, z_2, \dots, z_n; u, y). \quad (21)$$

The bid function is defined implicitly as

$$U(y - \theta, z_1, z_2, \dots, z_n) = u.$$

The consumer's optimal utility is then a function of income and the attributes of the bull.

Differentiate equation 21 with respect to z_i to obtain the following first order condition:

$$\theta_{z_i} = \frac{U_{z_i}}{U_x} > 0 \text{ by the structure of } \bar{z} \text{ and } x, \forall i = 1, \dots, n. \quad (22)$$

The first order conditions in equations 17 and 19 require that for an optimum, the bid's marginal valuation must equal its marginal price, $\theta_{z_i} = p_{z_i}$. This corresponds to a tangency between $p(\bar{z})$ and $\theta(z; u^*, y)$. Figure 8 shows this condition for two different buyers, one with a bid function θ^1 and the other with θ^2 , holding marginal price constant and holding all but one attribute constant at their optimal levels.

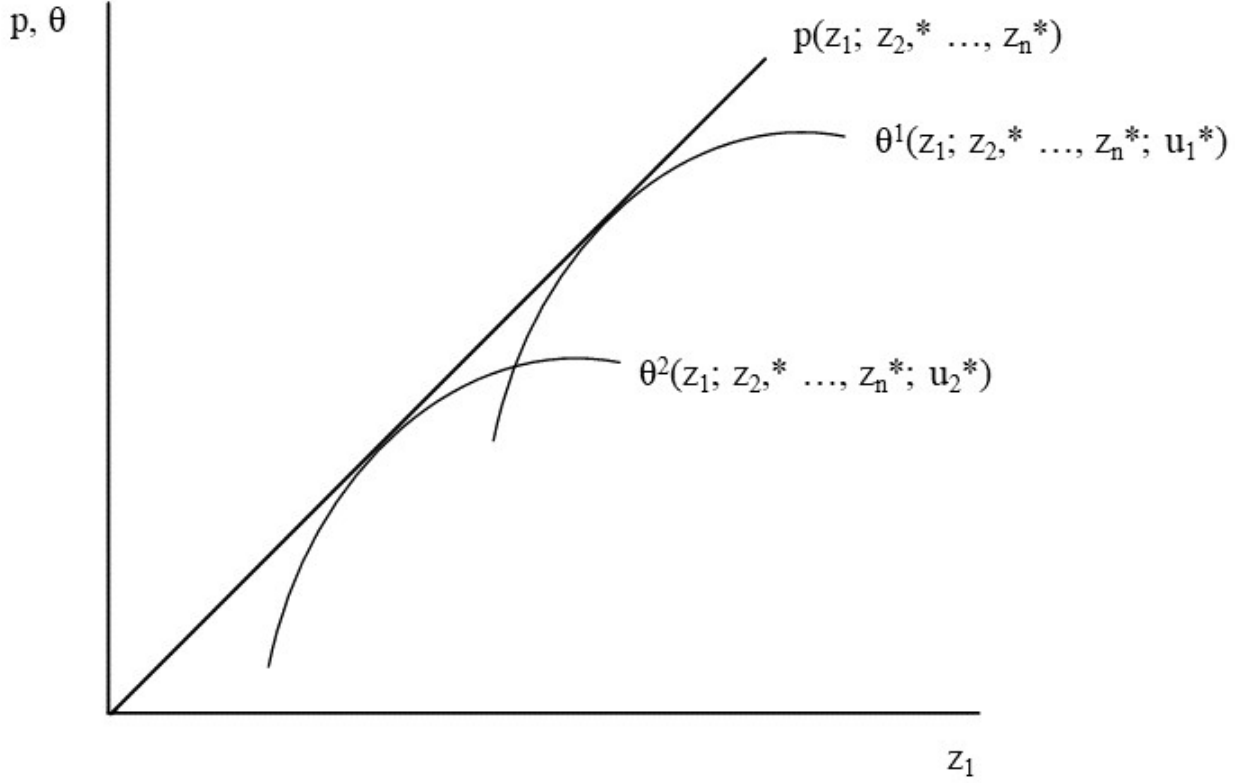


Figure 8. Optimal consumption under a hedonic model.

On the production side, the producer must choose how many bulls to offer for sale each year and what attributes to select for. Cost of production depends on the attributes, the number of bulls raised, and other cost shifters, such as input prices and technology. The total costs can be represented as $C(M, \bar{z}, \beta)$ where M represents number of bulls produced, $\bar{z}$ is the vector of attributes, and β are the cost shifters. The producer's optimization problem is then:

$$\max_{M, \bar{z}} \pi = M \cdot p(\bar{z}) - C(M, \bar{z}, \beta). \quad (23)$$

The first order conditions are:

$$\frac{\partial \pi}{\partial z_i} = \pi_{z_i} = M \cdot p_{z_i} - C_{z_i} = 0 \Rightarrow p_{z_i} = \frac{C_{z_i}}{M}, \quad \forall i = 1, \dots, n, \quad (24)$$

$$\frac{\partial \pi}{\partial M} = \pi_M = p(\bar{z}) - C_M = 0 \Rightarrow p(\bar{z}) = C_M. \quad (25)$$

Equation 24 states that the producer should choose attributes such that the marginal revenue from each attribute is equal to the attribute's marginal cost per bull. Equation 25 states that the optimum number of bulls produced is where the marginal cost per animal equals the bull's price.

Similar to the buyer's side, Rosen (1974) defines an offer function, $\phi(z_1, z_2, \dots, z_n; \pi, \beta)$, as the price per animal that the producer will accept for a bull with attributes $\bar{z}$ to yield profits π given β . Then the offer function is obtained from:

$$\pi = M \cdot \phi - C(M, \bar{z}),$$

and solving for ϕ ,

$$\phi = \frac{\pi - C(M, \bar{z})}{M}. \quad (26)$$

Differentiate equation 26 with respect to z_i to get the following first order condition:

$$\phi_{z_i} = \frac{C_{z_i}}{M} > 0 \quad \forall i = 1, \dots, n. \quad (27)$$

Equations 24 and 26 together show that the marginal offer for an attribute must equal its marginal price, such that $\phi_{z_i} = p_{z_i}$. This condition corresponds to a tangency between $p(\bar{z})$ and $\phi(\bar{z}; \pi, \beta)$. Figure 9 shows two different bull producers with two different offer functions, ϕ^1 and ϕ^2 , assuming a constant marginal price and holding all attributes except z_1 constant at their optimal levels.

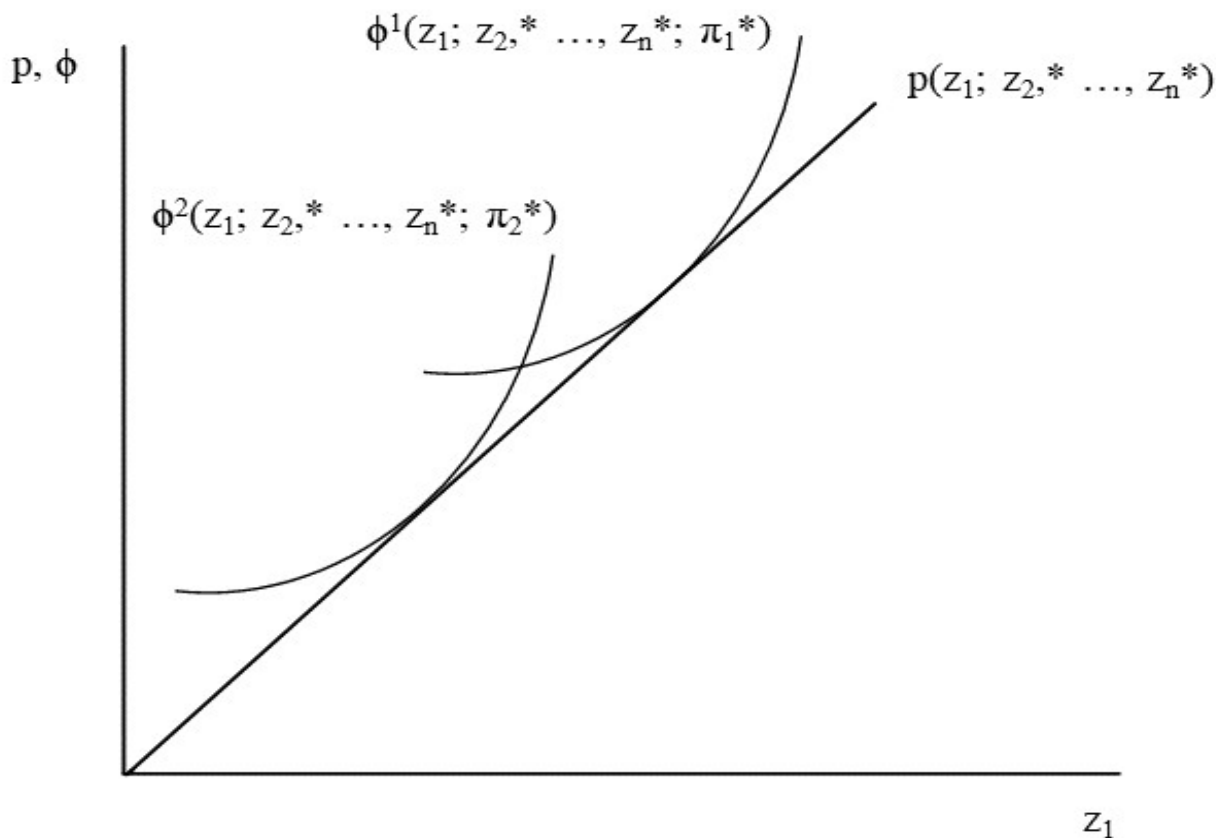


Figure 9. Optimal production under a hedonic model.

The market equilibrium price function, $p(\bar{z})$, is determined by the interactions between buyers' bid functions and bull producers' offer functions. Buyers want to pay the lowest bid to maximize their utility and producers want to receive the highest offer to maximize their profits. The market equilibrium occurs where the two functions are tangent. For simplicity, it is assumed that each attribute has a constant marginal price. Figure 10 shows the equilibrium and interaction between buyers and producers in the market for seedstock bulls.

This thesis attempts to estimate the marginal price for retained interest bulls as compared to lump sum bulls by evaluating how the observed bull price changes for a discrete change in retained interest (a zero to one change) and a continuous change in retained interest percentage

(changes between levels of retained interest). I do not attempt to identify the marginal supply function or marginal bid and the associated supply and demand parameters. Because of this, I avoid identification problems highlighted in critiques of the hedonic model.

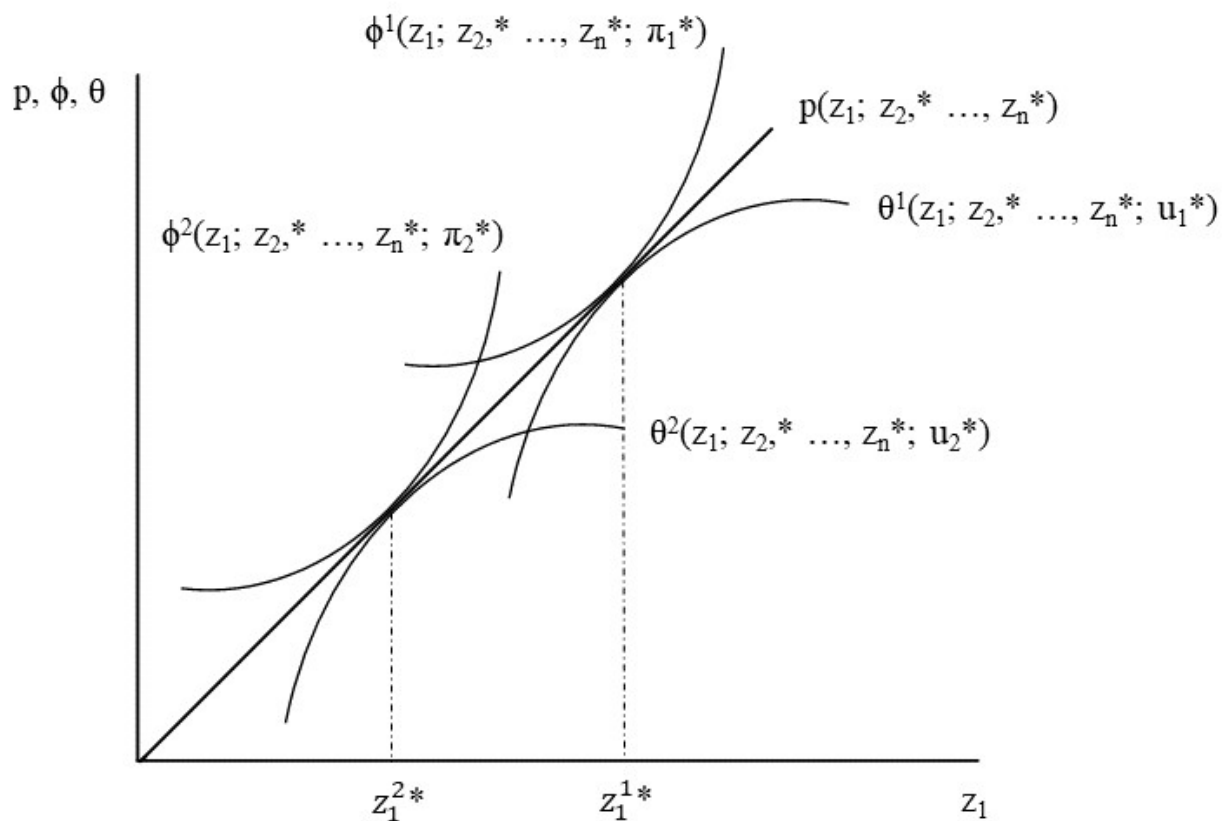


Figure 10. Market equilibrium and generation of the price function in a hedonic model.

CHAPTER FIVE

DESCRIPTION OF THE DATA USED

This section outlines the data collected and used for this thesis. All prices, including sale price and futures prices, were converted to real terms by multiplying the observed price by 100, then dividing by the price deflator. For this project, I used the BLS PPI for farm products for slaughter steers and heifers with 2019 as the base year. The price index for 2020 is the average of the first three quarters of the year as fourth quarter data had not yet been released.

For this thesis, I used multiple datasets from different sources. While both datasets are data from Angus bull auctions, I kept the two separate. One dataset comes from one producer in Montana, and it spans almost 40 years. The other dataset comes from a conglomerate of producers in Nebraska and South Dakota and only spans ten years. Because of the difference in geographic regions and timespans, I did not pool these data. The regional differences may be minor and could be controlled for in regressions, but instead I chose to estimate different regressions for each dataset. Estimating separate regressions also allows me to exploit the extended temporal span of the one dataset.

One Montana Producer

The first set of data came from a local Montana Angus producer with a reputation for selling high quality seedstock bulls. These data contain observations on bull sales from 1982 through 2020, with a few missing years. Data from 2000-2001, 2003, 2013-2015, and 2019 were missing because the producer was not able to locate their sale records for those years. For this study, I assume there is nothing systematic about which years were missing. This is plausible as

the producer randomly lost the records for only those years. With this assumption, the data represent a wide time frame of bull production by this producer.

These data were collected using marked sale catalogs from each year's sale and supplemented with sale receipts for the 1999-2020 available years. The data from 1982 through 1997 were originally collected and reported in 1996/1997 by a previous applied economics graduate student (see Chvosta, 1997). For most years, a member of the producer's family marked sale catalogs with sale prices during the auction. They also tended to write in buyer names. When the sale catalogs were not marked, I collected price data and buyer names using sale receipts. The sale receipts indicated lot number(s) purchased, price for each bull, buyer name, and occasionally the address of the buyer. Because the data in the sale catalogs were only recorded on the hard copies, I then entered the different data points for each bull by hand into a spreadsheet.

As these data represent a wide time frame, thirty years of data spread over thirty-eight years, the kinds of data reported in the sale catalogs were not always consistent. In the early 1980s, this producer did not report EPDs on their bulls. He reported birthweight (BW), adjusted 205 day weight (ADJ205), final weight of bull around sale time (FW), adjusted 365 day weight (ADJ365), nursing ratio/weaning ratio (NR), and growth/yearling ratio (GR). In 1988, the producer started reporting EPDs in their catalog. Included were birthweight EPD (BWEPD), weaning weight EPD (WWEPD), milk EPD (MILKEPD), and yearling weight EPD (YWEPD). Final weight stopped being reported in 1990 unless noted in a comment in the catalog. Birthweight was not reported in the 1992 catalog for an unknown reason. These measures of genetic quality were reported semi-consistently from 1988 onward. Other measures, such as

scrotal circumference, pulmonary arterial pressure (PAP) score, and various dam records were reported intermittently during the sample time period—each for a year or two before dropping out again. In 2004, the producer started reporting \$Value indices, including Weaned Calf Value (\$W), Feedlot value (\$F), Grid Value (\$G), and Beef Value (\$B). The producer no longer reported these index values after 2018.

The producer also indicated in sale catalogs the amount of semen interest retained. This was included in a comment under the EPDs and SPMs table and below other comments from the producer. In 2007, the producer moved away from reporting retained semen interest in the catalogs, and instead announced the percentage of retained interest from the sale block. While this made it difficult from my perspective to track which bulls were sold with retained interest, the producer and his son were able to remember which bulls they kept interest in. Because they have run a mid-size operation in the past fifteen years (selling about 60 bulls per year) and deal with repeat buyers often, they were able to identify which bull sold with retained interest and the level of retained interest.²⁶

Because of the inconsistent use of some measures through the years, those variables were not utilized in my analysis. These dropped variables include final weight, scrotal circumference, PAP score, and all \$Value indices. Summary statistics of the relevant variables included in the empirical analysis for this local producer are presented in table two. The SPMs and EPDs are reported in pounds and age is reported in days from date of birth to date of sale.

²⁶ They were also able to remember the names of the buyers of these bulls and mentioned that they would talk with these repeat buyers about whether or not they would retain interest. Because of this, I use the whole sample in my analysis and assume that seriously interested buyers did know which bulls were retained interest bulls before the bull was auctioned off.

Summary statistics by retained interest level and by decile group are presented in Appendix B. Results of a t-test for difference in means, presented in table three, show that retained interest bulls have significantly different levels of some attributes.²⁷ Overall, retained interest bulls have higher sale prices, higher birthweights, and higher 205 and 365 day weights. The t-statistics on the weaning weight and yearling weight EPDs are on either side of the ten percent significance cut-off. From this, retained interest bulls are generally larger and are expected to have larger progeny.

Variable	Obs	Mean	Std. Dev.	Min	Max
Real Price	1,766	4718.41	4560.68	1266.93	89667.28
Retained Interest Dummy	1,766	0.056	0.230	0.000	1.000
SD of Prices	1,766	1223.009	3080.323	103.268	10415.540
Birthweight	1,766	82.375	7.725	55.000	108.000
Adjusted 205 day weight	1,766	700.836	70.422	485.000	970.000
Adjusted 365 day weight	1,766	1165.494	106.313	864.000	1610.000
Age	1,766	420.815	60.900	89.000	1169.000
Birthweight EPD	1,766	3.272	1.373	-1.400	7.300
Weaning weight EPD	1,766	36.931	12.135	1.000	86.000
Yearling weight EPD	1,766	63.722	20.894	3.000	138.000
Price Ratio	1,672	0.295	0.072	0.179	0.448
DE Birthweight	1,766	100.193	9.069	67.256	132.480
DE Adjusted 205 day weight	1,766	100.161	8.721	69.357	133.692
DE Adjusted 365 day weight	1,766	100.131	7.625	72.141	134.066
DE Birthweight EPD	1,766	100.525	42.599	-84.783	326.087
DE Weaning weight EPD	1,766	100.125	20.278	2.542	182.043
DE Yearling weight EPD	1,766	100.437	18.152	7.031	157.404

Table 2. Summary statistics for local MT producer, all bulls, all years. Performance measures are presented in both their raw and “de-trended” form, indicated by the DE prefix and described later in this chapter. The Price Ratio variable, described later in this chapter, proxies for expected profitability of cow-calf producers. The variable SD of prices is a proxy for uncertainty and is described later in this chapter.

²⁷ The t-test compared lump sum bulls to retained interest bull, so a negative t-statistic shows that lump sum bulls have a significantly lower mean for that attribute.

One Montana Producer			
Variable	Actual Difference in Means	t Statistic	p-value
Real Price	-10064.66	-7.42	<.0001
Birthweight	-2.492	-3.21	0.0017
Adjusted 205 day weight	-51.045	-8.3	<.0001
Adjusted 365 day weight	-100.943	-9.86	<.0001
Age	-5.108	-0.81	0.4194
Birthweight EPD	-0.195	-1.29	0.2011
Weaning weight EPD	-1.877	-1.65	0.1025
Yearling weight EPD	-3.123	-1.69	0.0931

Table 3. Results from t-tests for difference in means between bulls sold lump sum (where retained interest equals zero) and bulls sold with retained interest.

Nebraska and South Dakota Producers

The second dataset I use in this thesis is from a group of 13 Angus producers in Nebraska and South Dakota. These data were collected by a regional representative of the American Angus Association (AAA) while at the sales. The representative marked each catalog with sale price and then turned the catalogs into the AAA. These data were then collected from the AAA office in Kansas City by the same previous grad student mentioned above (Chvosta, 1997). After dropping producers that did not distinguish between retained interest and lump sum sales, there were nine producers left. Data consist of bull sale observations from 1986 through 1996. Unfortunately, each producer does not appear in the data each year. Table four outlines each producer's appearance in each year and shows the total producers in each year and the total years of data for each producer.

Similar to the one Montana producer, none of these producers used EPDs before 1988. After 1988, EPDs and SPMs were reported fairly consistently across producers each year. The EPDs recorded by these producers were BWEPD, WWEPD, YWEPD, and MILKEPD. The SPMs recorded were BW, ADJ205, and ADJ365. None of the producers recorded PAP scores, and scrotal circumference was recorded sporadically across producers and years. Summary statistics for the relevant variables by producer are presented in table five. Summary statistics by retained interest level and by decile group are presented in Appendix B. Table six shows the results of the t-test of difference of means between lump sum and retained interest bulls. Similar to the one Montana producer sample, retained interest bulls in this sample have significantly higher average prices, 205 and 365 day weights, and weaning and yearling weight EPDs; however, there is no significant difference between average birthweights between groups.

Producer ID	1986	1987	1988	1989	1990	1991	1992	1993	1994	1995	1996	Total Years/ Producer
1							X	X	X	X		4
2					X	X	X	X	X	X	X	7
3	X	X	X	X	X	X	X	X	X	X		10
4					X	X	X	X		X		5
5						X		X	X	X		4
6											X	1
7					X	X	X	X	X	X	X	7
8	X	X	X	X	X	X	X	X	X	X		10
9									X		X	2
Total Producers/ Year	2	2	2	2	5	6	6	7	7	7	4	

Table 4. Nebraska and South Dakota producer appearances by year.

Variable	Obs	Mean	Std. Dev.	Min	Max
Real Price	3,259	5084.67	3578.72	1357.07	72377.20
Retained Interest Dummy	3,259	0.033	0.179	0.000	1.000
SD of Prices	3,259	899.417	2095.107	117.240	7166.166
Birthweight	3,259	87.190	10.358	50.000	121.000
Adjusted 205 day weight	3,259	680.401	71.332	452.000	925.000
Adjusted 365 day weight	3,259	1236.743	108.339	840.000	1589.000
Age	3,259	392.391	33.332	285.000	580.000
Birthweight EPD	3,259	3.628	1.963	-5.000	9.700
Weaning weight EPD	3,259	28.532	7.824	-0.600	53.000
Yearling weight EPD	3,259	46.707	12.309	4.600	88.000
Price Ratio	2,966	0.289	0.051	0.179	0.349
DE Birthweight	3,259	100.002	11.337	56.305	137.273
DE Adjusted 205 day weight	3,259	99.913	7.482	68.625	125.239
DE Adjusted 365 day weight	3,259	100.036	6.719	78.777	133.528
DE Birthweight EPD	3,259	99.395	53.946	-167.169	397.466
DE Weaning weight EPD	3,259	99.785	23.047	-2.708	184.939
DE Yearling weight EPD	3,259	99.966	21.719	9.783	178.575

Table 5. Summary statistics for the nine Nebraska and South Dakota producers. Performance measures are presented in both their raw and “de-trended” form, indicated by the DE prefix. The Price Ratio variable, described later in this chapter, proxies for expected profitability of cow-calf producers. The variable SD of prices is a proxy for uncertainty and is described later in this chapter.

Nine Nebraska and South Dakota Producers			
Variable	Actual Difference in Means	t Statistic	p-value
Real Price	-8369.95	-8.14	<.0001
Birthweight	0.282	0.3	0.7672
Adjusted 205 day weight	-77.108	-10.49	<.0001
Adjusted 365 day weight	-140.457	-16.47	<.0001
Age	1.525	0.44	0.6629
Birthweight EPD	-0.131	-0.74	0.4578
Weaning weight EPD	-7.289	-10.97	<.0001
Yearling weight EPD	-11.349	-10.67	<.0001

Table 6. Results from t-tests for difference in means between bulls sold lump sum (where retained interest equals zero) and bulls sold with retained interest.

How the Data Were Cleaned

Because the data were entered into a spreadsheet by hand, the types of data varied through the years, and the position of the data in the catalogs changed over time, initially the data contained a lot of errors. This could have originated from incorrect information printed in the catalog or as the result of human error when the data were digitized. After proofing the data, cleaning, and proofing again, the data were verified to be reliable and correct.

Examples of this process are that there were a few cases of misprints in the catalog and few cases where the data were entered into the spreadsheet incorrectly. After screening the data using descriptive statistics and looking for outliers or other odd entries, I found an instance where birthweight had an unusually low entry (BW was equal to eight), one where weaning weight EPD was unusually large (WWEPD was equal to 323), and many times when the nursing ratio was unusually large (in the 600-700 range). After identifying which bulls these outliers came from, I checked the data for bulls surrounding the odd observation. The large nursing ratios

were consistently large for one year, and for that same year the adjusted 205 day weights were consistently low (in the area of 100). Looking back to the catalogs, it was apparent that the adjusted 205 day weight and the nursing ratio had gotten mixed up for that year when entered into the spreadsheet. This was understandable as that year the catalog design changed and the position of these two performance measures switched places. I was able to enter the correct values from the catalog into the spreadsheets to correct the problem.

As for the other cases of outliers, I checked the catalogs to see if the birthweight and weaning weight mistakes were the cause of human error or if the catalogs were incorrect. In these cases, the catalogs did reflect the numbers I observed (BW = 8 and WVEPD= 323). Because it is impracticable for a calf to be born alive and weigh eight pounds, I dropped that observation assuming it was a misprint in the catalog. Also, because the highest breed average weaning weight EPD through the years has been equal to 60 pounds, a weaning weight of 323 is implausible and was likely a misprint in the catalog. That observation was deleted. Because I had sufficient institutional knowledge of bull performance measures, I was able to identify these mistakes and correct them or drop those observations with mistakes.

Construction of Additional Variables

After the data were cleaned, I constructed various other variables to indicate different retained interest levels, to “de-trend” EPDs and SPMs, to act as controls for future economic expectations, and to create proxies for uncertainty of bull quality.

Variables for retained interest were created depending on their intended use. Though retained interest was indicated in the catalog, it was entered into the spreadsheets as interest sold,

so there are two continuous variables that indicate percent interest. One represents percent interest retained, and the other represents percent interest sold. From these variables, I constructed binary variables as indicators of retained interest. The retained interest dummy equals one if the bull was sold with some level of semen interest retained and equals zero otherwise. Then there are other binary variables for each level of retained interest—zero, thirty-three percent, or fifty percent. A bull sold with no retained interest is sold lump sum with full possession, full semen rights, and full salvage value; the producer does not retain any ownership of the bull.

EPDs and SPMs were “de-trended” using the same approach as Chvosta, Rucker, and Watts (2001), although this is not truly de-trending the measures. Instead, the purpose is to normalize each year’s average performance measures to 100 so that an individual bull’s “de-trended” measure shows how it compares to its cohort. The de-trending equation for bull i in year t is as follows:

$$De-trended\ Measure_{it} = \frac{Performance\ Measure_{it}}{Herd\ Average\ Performance\ Measure_t} \times 100$$

For example, if bull i has a WWEPD of 35 and the herd average WWEPD for that year is 30, then the de-trended WWEPD for bull i is 116.67. Bulls above the herd average will have de-trended measures greater than 100 and bulls below the herd average will have values less than 100. Birthweight EPD, weaning weight EPD, milk EPD, and yearling weight EPD were de-trended in this manner. This construction is useful in that it provides a simple interpretation. A

one unit increase in the de-trended measures corresponds to a one percentage point increase relative to the cohort average.

Also, following Chvosta, Rucker, and Watts, I construct a price ratio that relates the expected price of beef to the expected price of corn. I use CME futures prices from March for September contracts of each commodity to represent the expected prices. Annual bull sales are typically held in the spring, anywhere from late January to late April. The one Montana producer in my data typically holds their sale in mid-to-late March while the Nebraska and South Dakota producers hold their sales between mid-February and mid-April. Cow-calf operations usually sell calves after weaning which takes place during the fall. The timing of bull sales and weaned calf sales indicate that March prices for September corn and beef contracts will reflect cattlemen's expectations of future feed costs and future feeder calf prices. This price ratio of beef to corn prices proxies for the expected profitability of feeder calves.

The next variables I constructed were proxies for the uncertainty regarding quality of bulls. These were constructed by ranking bulls based on their sale price and separating them into ten groups (deciles). Each group then contains $1/10^{\text{th}}$ of the sample and represent the 10^{th} , 20^{th} , 30^{th} , ..., 90^{th} percentile of bulls. I used price to rank and separate bulls because it is the best available measure of overall quality. Because price reflects the buyer's valuation of the bull and takes multiple performance measures and characteristics (including those only seen with visual inspection) into account, it is a good all-around indicator of quality. I assume that the observed sale price is directly related to the seller's expected price *ex ante*, and therefore the expected price and observed sale price are good measures of quality of the bull. This assumption allows me to base the decile groups on price because it is exogenous. Without the assumption, basing

the deciles on price would be problematic because price is determined after the contract choice and might be considered endogenous.

After separating bulls out by rank of price, I created a variable that equaled the standard deviation of prices for each of the decile groups. Because there are ten groups, bulls within the same decile group will have the same value for this variable. For example, if bull i is in decile group six, and the standard deviation for price for group six equals 400, then the standard deviation of prices variable will equal 400 for bull i as well as for all other bulls in that decile group. I used it as a continuous variable because it best captures the differences in magnitude of variation in each group. This variable best represents the uncertainty of quality in each group. Figures 11 and 12 show the standard deviation of prices for each decile group for each of the two datasets. The striking feature of this graph is that the highest group, the bulls sold with the highest prices, has much greater variation than the lower groups.

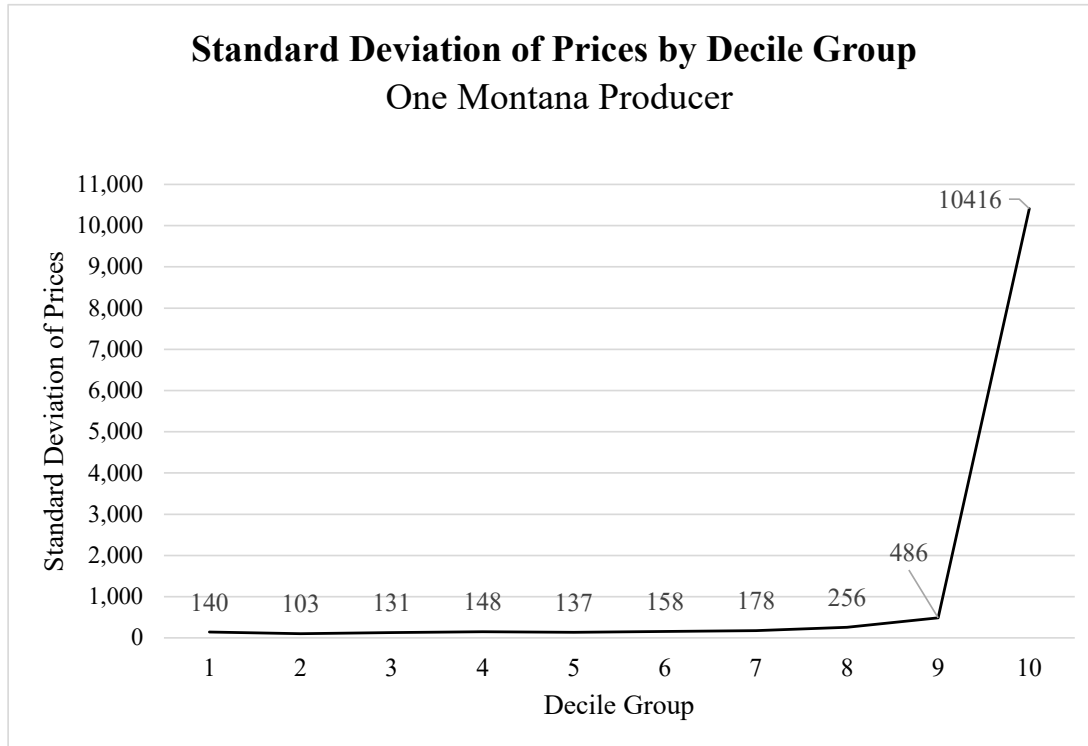


Figure 11. Standard deviation of prices by decile group for the one Montana producer

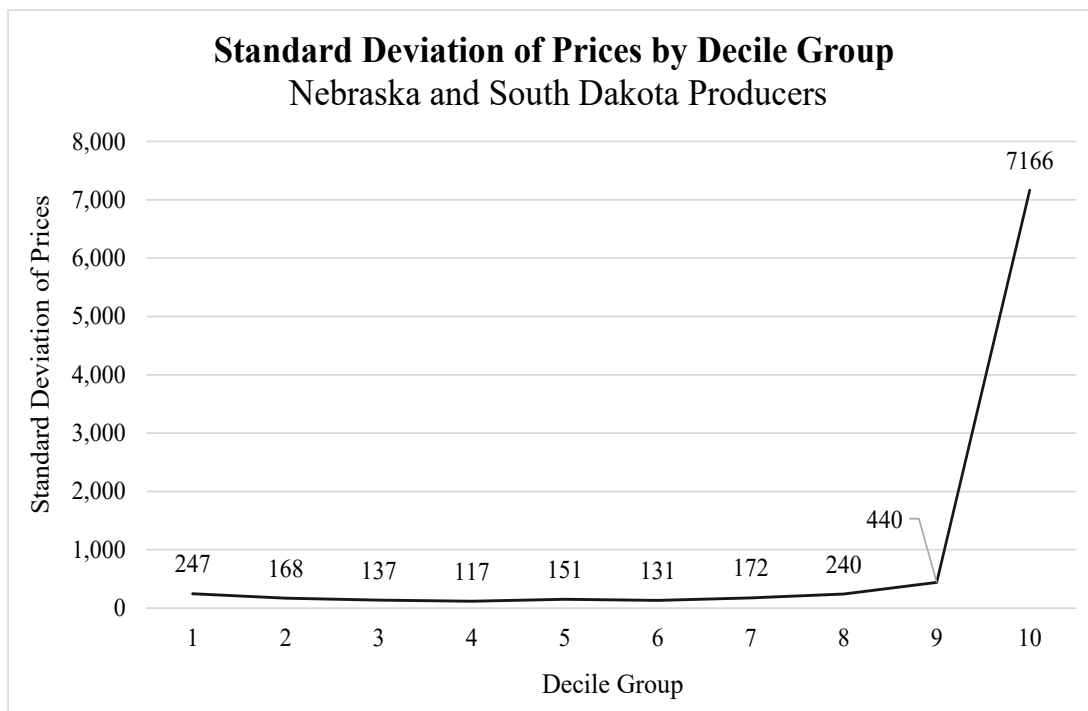


Figure 12. Standard deviation of prices by decile group for the nine Nebraska and South Dakota producers.

The second proxy for uncertainty I created was a set of binary variables for the decile groups to create bins. These variables are binary variables for each decile group, so “group 1” equals one if the bull was in the lowest decile group and zero otherwise, etc. for the other groups.²⁸ Including simple dummy variables for the groups allows for differentiated effects based on group. This means a bull being in the top decile group can affect the contract choice differently than a bull being in a middle group. This is important because I predict that bulls in the top group will be more likely to be sold with retained semen interest contracts due to the uncertainty. The decile group a bull is in is not necessarily perfectly correlated to the magnitude of variation in prices, though. In short, this variable does not monotonically increase as decile group increases.²⁹

Finally, the third proxy was a simple continuous variable equal to the decile group. This variable is a continuous variable from zero to nine that equals the rank of the decile group into which the bull is sorted. Including this variable in this way limits the marginal effects to be the same between groups. For example, the effect on contract choice between groups one and group two is the same as the effect between groups nine and ten because there is a one unit increase in the variable between each decile group. Once again, the decile group a bull is in is not necessarily perfectly correlated to the magnitude of variation in prices.

²⁸ When SAS ranked the bulls into 10 groups, it assigned a rank of 0 to the lowest group and 9 to the highest group. Because of this, group 1 is the same as decile rank 0 and group 10 is the same as decile rank 9.

²⁹ For example, in figure 12, decile zero has a standard deviation of prices equal to 247 dollars, then standard deviation of prices decreases until decile four, where it bounces back up to 151 dollars. It then decreases at decile 6 and then increases through the last deciles.

CHAPTER SIX

EMPIRICAL METHODOLOGY

From the theory outlined above, there are testable predictions about the retained interest decision and the impact of retained interest on bull sale prices. One prediction is that as uncertainty in bull quality increases, producers will be more likely to sell bulls via retained interest contracts to reduce presale measurement costs. I test this prediction using a binary choice model to model the factors that impact the decision to retain interest. Another prediction from the theory is that producers will receive higher prices for bulls sold with retained interest because of the signal it sends to buyers about the value of the bull. This is tested using a hedonic price regression.

Binary Choice Model

In this study, I empirically test the first prediction using a logit model for the retained interest decision. In the share contract literature, contract choice is typically modeled using logit or probit models (see for example Akerberg and Botticini 2002; Allen and Lueck 1993, 1999; Fukunaga and Huffman 2009; Leffler and Rucker 1991). The logit model is estimated using maximum likelihood estimation. Though producers can specify any percentage of semen interest to retain, the most common levels are one third and one half. For this analysis, I did not differentiate between retention levels, and simply modeled retained interest as a yes or no decision.

The empirical model for the logistic regression is

$$Y_{it} = \alpha X_{it} + \beta Z_{it} + \delta D_t + \phi P_i + \varepsilon_{it} \quad (28)$$

$$Y_{it} = \begin{cases} 1 & \text{if retained interest} > 0 \\ 0 & \text{if retained interest} = 0 \end{cases}$$

where Y_i is a binary variable for retained interest for bull i in year t , X_i is a proxy for uncertainty, Z_i is a vector of bull characteristics and measurements, D_t is a vector of year dummy variables, P_i is a vector of producer dummy variables, and ε_{it} is the error term. The alternative proxies for uncertainty, as described in chapter five above, include dummies for which decile group a bull is in, the decile group number, and the standard deviation of prices for each decile group. The vector of bull characteristics includes both SPMs and EPDs as controls for bull attributes and quality. The year dummy variables control for unobservable changes from year to year that may affect the retained interest decision. One such change may be the growing popularity of artificial insemination through the time period of the sample. As more seedstock and commercial producers use AI, the demand for frozen semen increases, and this provides an incentive for AI studs or collection companies to collect and supply a higher quantity of semen. This may translate back to affect the retained interest decision from year to year, so the year dummy variables are included to control for these changes.

The prediction that producers will retain interest as uncertainty increases is tested in this model using the proxies for uncertainty. These proxies are created to capture the amount of variation in the quality of the bulls. The model in chapter four yield that prediction that an increase in the variation in quality will lead to an increase in the probability that a producer retains interest; the coefficient for the uncertainty proxies should be positive. Including SPMs and EPDs as controls for quality allows me to isolate the change of probability that solely comes from the uncertainty. As described above, a risk-based model of contract choice predicts that an increase in variation in bull prices will increase the probability that a producer chooses a lump

sum contract. Because this prediction and the prediction from my transaction cost model are opposite, I am able to identify which model is supported by the data.

Hedonic Price Model

The second empirical model in this study tests the impact of retained interest on the auction price of a bull. This is done using a hedonic price model, originally developed by Rosen (1974). It allows me to estimate marginal valuations for each attribute of the bull. As previously stated, other studies that analyze bull price determinants use hedonic price regressions to measure the marginal valuations of attributes (see Chvosta, Rucker, and Watts 2001; Dhuyvetter et al. 1996; Franken and Purcell 2012; Jones et al. 2008; Tang et al. 2020; Vanek, Watts, and Brester 2008). I take elements from these past studies (such as what performance measures to use, the use of de-trended measures, and the use of a price ratio), but put emphasis on the retained interest variable.

The hedonic price model for bull i in year t is

$$\text{Sale price}_{it} = \gamma R_{it} + \theta X_{it} + \tau F_t + \delta D_t + \phi P_i + \mu_{it} \quad (29)$$

where R_{it} is the retained interest binary variable, X_{it} is a vector of bull characteristics, D_t is a vector of year dummy variables, P_i is a vector of producer dummies, and μ_{it} is the error term.³⁰

The vector of bull characteristics includes the “de-trended” SPMs and EPDs and their squared terms and are used to control for quality. The variable F_t is the futures beef to corn price ratio that is included as a proxy for future calf prices. Year dummy variables are once again included

³⁰ Producer dummies are included for the hedonic regressions using the data from the nine NE and SD producers, but not for the regressions using the data from the one MT producer.

to control for unobservable changes in bull prices through the years. Producer dummies, P_i , are included to control for unobservable characteristics about producers that affect price; some possible examples include reputation and marketing skills.

The main coefficient of interest is γ , which shows the impact of retained interest on price. I expect it to be positive due to the positive quality signal to buyers from retaining interest in a bull. Because producers typically retain interest on their higher quality bulls that sell for higher prices, it is worth considering whether retained interest is endogenous to the sale price. While this is a valid concern, the producer decides to retain interest before the sale. Because it is determined prior to the sale, however, retained interest is exogenous to the competitive bidding process that determines sale price.

The coefficients on the “de-trended” SPMs and EPDs are expected to have mixed signs depending on which attribute they represent. Adjusted 205 day weight and adjusted 365 day weight are both expected to have positive coefficients as they represent potential for growth. Both commercial cattlemen looking for bulls to sire feeder calves and seedstock producers looking for herd sires likely prefer larger animals with high growth. Weaning weight and yearling weight EPDs are expected to have positive coefficients for the same reasons. Birthweight EPD is expected to have a negative sign because it is used to predict the progeny’s birthweight compared to progeny of other bulls. Buyers prefer smaller or average sized calves to reduce potential problems calving large calves.³¹ Birthweight is also expected to have a negative sign. Bulls with larger birthweights are typically larger at weaning and as yearlings, but their size

³¹ Larger calves with higher birthweights increase the chance that the cow or heifer will need assistance giving birth. Therefore, higher birthweight EPD bulls are not desirable for heifers (who have never calved before) or smaller cows.

may indicate there will be difficulties calving its progeny in the future. For these reasons, the sign on the birthweight coefficient may appear to be ambiguous but including the variables for adjusted 205 and 365 day weights controls for those weights. This means that, holding adjusted 205 and 365 day weights constant, a producer would prefer a bull to have a lower birthweight.

CHAPTER SEVEN

RESULTS AND DISCUSSION

Binary Choice ModelLinear Probability Model Results

I first estimate equation 28 as a linear probability model (LPM) using ordinary least squares. While the LPM has been criticized for being inefficient, predicting probabilities outside of the 0-1 range, and assuming a linear relationship, it provides a good start for preliminary analysis.³² One major advantage of this model is that it is able to estimate coefficients for dummy variables where the dummy represents group membership but every observation in the group has the same response (Caudill 1987, 1988). This is relevant to my data because there are a few decile groups where all bulls in that group were sold lump sum. The LPM is able to estimate coefficients for all of the group dummies, even if they do not have any variation in the response variable by group. In comparison, a logit model is not able to estimate coefficients for groups that all have the same response because of the nature of maximum likelihood estimation and the use of a bounded density function.³³

Results from the LPM regressions for both sets of producers are presented in tables 14 and 15 in Appendix C. For the first specification of this model, I include dummy variables for each decile group, so that there are nine dummy variables in the model with the lowest group

³² See Amemiya (1981), Caudill (1987), or Maddala (1986, p. 16) for further discussion of the limitations of linear probability models.

³³ See Caudill (1988) for a more in-depth explanation.

serving as the base category. These bins for the decile group allows the effects of each decile group to vary by group, as opposed to forcing the effects to be equal across groups. The second specification, shown in column two, uses the number of the decile group as the proxy for uncertainty. Unlike the bins, this proxy restricts the effects to be the same for all groups. Specification four includes the standard deviation of prices by decile group as the proxy for uncertainty. Specifications three and five include the squared terms for the decile group and standard deviation of prices, respectively.

Though the linear probability model is able to estimate coefficients for the bin specification, it also has its limitations. One major limitation is that the LPM may predict probabilities outside the range of zero to one. In this case, over one third of the LPM's predicted probabilities were less than zero and outside of the desired range of zero to one. For this reason, the LPM is not the preferred model for modelling the retained interest decision.

In the first specification, the group bins are not statistically significant for the lower groups; only the top two bins are significant. These significant coefficients for the ninth group's bin show that a bull in that group is around five percent more likely to be sold with retained interest compared to bulls in the first group. Bulls in the tenth and highest group are around 18 percent (for bulls in the nine Angus producers sample) and 35 percent (for bulls in the local Montana producer sample) more likely to be sold with retained interest. These results support the prediction that increases in uncertainty will lead to more bulls sold with retained interest. Looking back at figure 11 and 12 in chapter five, it is clear that the highest two decile groups have more variation in prices and therefore more uncertainty, and the results from the LPM support that.

The coefficients and significance of the other specifications provide more evidence that increased uncertainty increases the probability that a bull is sold with retained interest. In specification two, an increase from one group to the next group significantly increases the probability a bull is sold with retained interest. Comparing this result with those from the first specification, the significance of the top two groups outweighs the lack of significance of the other groups, so when effects are restricted to be equal between groups, the overall effect is significant. In specification three, standard deviation of prices is significant at the one percent level, so as the variation increases so does the probability of retained interest.

Logit Model Results

The conclusions from the linear probability model are supported by the results from the logit model. Results from the logit are presented in table 7 for the one Montana producer and in table 8 for the nine Nebraska and South Dakota producers. The different model specifications correspond to the use of different proxies for uncertainty. The coefficients reported are the coefficients generated from the logistic regression and do not represent marginal effects. A quick look at the coefficients on the proxies for uncertainty in table seven shows that generally, as uncertainty increases the probability that the producer retains interest also increases. Marginal effects of the variables with significant coefficients are reported in the columns next to the logit coefficients.

Marginal effects, except those for middle group and high group, in tables reporting logit results were calculated as follows. The predicted probability, $\hat{p}$, was calculated at the sample means for all independent variables included. The marginal effect of a one unit change in the

predicted probability from a one unit change in X was calculated by taking the derivative of $\hat{p}$ with respect to X . Then this marginal effect was multiplied by the standard deviation of X . The effects can be interpreted as the change in the predicted probability that a bull will be sold with retained interest resulting from a one standard deviation change in the X variable, holding all other variables constant at their mean. The interpretation of the coefficients on Mid Group and High Group can be similarly interpreted, except they represent the effect of a change from 0 to 1 instead of a one standard deviation change.

Table 7: Logit Results, One Montana Producer

VARIABLES	(1) Modified Bins	Maginal Effects	(2) Decile	Maginal Effects	(3) Decile	Maginal Effects	(4) SD of Prices	Maginal Effects	(5) SD of Prices	Maginal Effects
Mid Group	1.151 (1.068)									
High Group	3.550*** (1.044)	0.9315								
Decile Group			1.181*** (0.157)	0.0165	-1.249*** (0.382)	-0.0129				
Decile Group Squared					0.178*** (0.0327)	0.0296				
SD of Prices							0.000306*** (3.37e-05)	0.2277	0.00654*** (0.00151)	0.0068
SD of Prices Squared									-5.81e-07*** (1.40e-07)	-0.0321
Birthweight	0.0372* (0.0223)	0.0132	0.0435* (0.0237)	0.0089	0.0443* (0.0241)	0.0085	0.0394* (0.0229)	0.0110	0.0415* (0.0235)	0.0099
Adjusted 205 day weight	0.00561* (0.00314)	0.0101	0.00411 (0.00327)		0.00450 (0.00337)		0.00601* (0.00316)	0.0061	0.00467 (0.00330)	
Adjusted 365 day weight	0.0110*** (0.00232)	0.000025	0.00860*** (0.00235)	0.000040	0.00864*** (0.00242)	0.000039	0.0107*** (0.00227)	0.000004	0.00910*** (0.00238)	0.0000
Age	0.0103*** (0.00337)	0.0061	0.0108*** (0.00406)	0.0068	0.0110*** (0.00400)	0.0065	0.00998*** (0.00336)	0.0088	0.0104*** (0.00368)	0.0078
Birthweight EPD	-0.320** (0.133)	-0.0815	-0.303** (0.140)	-0.0821	-0.317** (0.143)	-0.0841	-0.319** (0.139)	-0.0844	-0.313** (0.141)	-0.0835
Weaning Weight EPD	-0.0615* (0.0335)	-0.0649	-0.0715** (0.0323)	-0.0539	-0.0802** (0.0326)	-0.0455	-0.0828** (0.0338)	-0.0430	-0.0821** (0.0326)	-0.0437
Yearling Weight EPD	0.0476** (0.0227)	0.0356	0.0504** (0.0226)	0.0393	0.0546** (0.0229)	0.0331	0.0564** (0.0234)	0.0307	0.0551** (0.0227)	0.0324
Constant	-34.69*** (4.426)		-37.69*** (5.014)		-30.71*** (4.824)		-34.00*** (4.381)		-32.86*** (4.650)	
Year Effects	YES		YES		YES		YES		YES	
Observations	1,766		1,766		1,766		1,766		1,766	

Standard errors in parentheses

*** p<0.01, ** p<0.05, * p<0.1

The first model includes two binary variables, middle group and high group, as explanatory variables along with SPMs and EPDs as controls. This is a modification of the bins used in the LPM to allow for the use of a logit model and maximum likelihood estimation. The middle group variable equals one if the bull was in decile group four through seven. The high group variable equals one if the bull was in the decile group eight or nine. The low group was left out of the model and is the basis for comparison. The coefficient for High Group is statistically significant at the one percent level for both data sets. This means that, compared to the low group, the probability of retained interest increases if the bull is in the higher decile groups.

The second model includes the variable Decile Group whose values are the decile group into which the bull was sorted—zero to nine. The results from this model show that higher decile groups have a higher probability that a bull will be sold with retained interest. The fourth model, which includes the standard deviation of prices per decile group, shows a similar result. These confirm the hypothesis that bulls in the higher decile groups, where uncertainty of quality is highest, are more likely to be sold with retained interest contracts.

The coefficients on the third and fifth model are slightly different because those models include quadratic terms. The third model includes the decile group and the decile group squared. The coefficient on the linear term is not significant while the coefficient on the quadratic term is significant at the one percent level. The fifth model includes the standard deviation of prices and standard deviation of prices squared. Both coefficients are significant, and from looking at the marginal effects, the positive sign on the linear term and negative sign of the quadratic term

imply that the probability a bull is sold with retained interest increases as the variation in prices for the decile group increases.³⁴

Results from the logistic regression for the nine other Angus producers are shown in table 8. Comparing these results to those from the one Montana producer, the signs and significance of almost all the proxies for uncertainty are the same between data sets. Overall, these results are especially striking because of the included controls for quality. Holding the characteristics of the bull equal, if there is more uncertainty in the overall quality of the bull, the bull is more likely to be sold with retained interest. These results strongly support the prediction from the theoretical model discussed above in chapter four, which is that retained interest contracts are more likely to be chosen when there is more uncertainty because the mixed contracts lower the aggregate transaction costs associated with presale measurement. I find no evidence to support the predictions of the risk-based model presented at the end of chapter four. When variation in bull quality increases, producers are more likely to sell bulls with retained interest instead of trying to push that risk onto buyers through lump sum contracts.

³⁴ The logit model estimates the logit, or the log of odds, of the dependent variable equaling one, where the log of odds equals $\ln\left(\frac{p}{1-p}\right)$, and assumes the independent variables are linear in the logit. When quadratic terms are introduced into the logit estimating equation, the relationship between the independent variables and the logit of Y are no longer linear.

Table 8: Logit Results, Nebraska and South Dakota Producers

VARIABLES	(1) Modified Bins	Marginal Effects	(2) Decile	Marginal Effects	(3) Decile	Marginal Effects	(4) SD of Prices	Marginal Effects	(4) SD of Prices	Marginal Effects
Mid Group	1.946* (1.056)	0.274								
High Group	4.288*** (1.057)	1.015								
Decile Group			0.964*** (0.136)	0.035	-0.215 (0.439)	-0.123				
Decile Group Squared					0.0879** (0.0346)	0.165				
SD of Prices							0.0003*** (0.000045)	0.154	0.0101*** (0.00177)	0.002
SD of Prices Squared									-1.31e-06*** (2.35e-07)	-0.022
Birthweight	0.0340* (0.0201)	0.016	0.0338* (0.0205)	0.017	0.0335 (0.0207)		0.0246 (0.0208)		0.0331 (0.0207)	
Adjusted 205 day weight	0.00621** (0.00315)	0.0063	0.00633** (0.00318)	0.0059	0.00649** (0.00321)	0.0055	0.00658** (0.00322)	0.0052	0.00681** (0.00322)	0.0046
Adjusted 365 day weight	0.00994*** (0.00213)	0.000005	0.00794*** (0.00221)	0.000047	0.00757*** (0.00223)	0.00007	0.01122*** (0.00206)	0.000001	0.00848*** (0.00221)	0.000026
Age	0.000227 (0.00547)		-0.00138 (0.00574)		-0.00170 (0.00582)		-0.00258 (0.00575)		-0.000756 (0.00574)	
Birthweight EPD	-0.444*** (0.117)	-0.1210	-0.416*** (0.119)	-0.1211	-0.409*** (0.120)	-0.1210	-0.423*** (0.117)	-0.1212	-0.420*** (0.120)	-0.1211
Weaning Weight EPD	-0.0115 (0.0339)		-0.00860 (0.0340)		-0.0114 (0.0338)		-0.00987 (0.0329)		-0.0176 (0.0332)	
Yearling Weight EPD	0.0215 (0.0211)		0.0173 (0.0210)		0.0182 (0.0209)		0.0263 (0.0204)		0.0229 (0.0207)	
Constant	-24.52*** (3.673)		-25.08*** (3.761)		-20.84*** (4.011)		-24.28*** (3.621)		-22.86*** (3.749)	
Year Effects	YES		YES	YES	YES	YES	YES	YES	YES	YES
Producer Effects	YES		YES	YES	YES	YES	YES	YES	YES	YES
Observations	3,259		3,259		3,259		3,259		3,259	

Standard errors in parentheses

*** p<0.01, ** p<0.05, * p<0.1

One method for checking the performance of a logit model is to calculate the percent correct predictions.³⁵ To do this, I calculate predicted probabilities of retained interest for each observation, where $\hat{p}_i = [1 + \exp(-X_i\alpha)]^{-1}$ is the predicted probability for a logit model, X_i is the matrix of the bull's characteristics, and α is the vector of regression coefficients. The traditional cut-off point for deciding whether a predicted probability corresponds to a response of zero or one is 0.5. However, as demonstrated in Munn and Rucker (1998), a cut-off of 0.5 is arbitrary and using the mean of the dependent variable may be able to better show the performance of the logit model. For these data, the mean of the dependent variable, the retained interest dummy, is 0.056 and 0.033 for the one Montana producer and nine other producers, respectively. This shows that using the arbitrary threshold value of 0.5, a value around ten times higher than the mean, may cause the calculations of correct predictions to be underestimated.

Table nine presents information on how the different threshold limits effect the percent correct predictions of the logit model. This table shows the performance checks for the second model specification.³⁶ Each panel of the table shows the actual number versus the predicted number of bulls sold lump sum (0) or with retained interest (1). With the threshold of 0.5, the logit does well at predicting lump sum bulls; however, only 3.7 and 12.1 percent of retained interest bulls were correctly predicted to be sold with retained interest. When the threshold is lowered to the mean of retained interest, the model does substantially better at correctly predicting retained interest bulls, increasing the percent correctly predicted from 3.7 and 12.1 percent to 91.7 and 93.9 percent. This subsequently lowers the percent of lump sum bulls

³⁵ As suggested in Maddala (1986) and used in Munn and Rucker (1998).

³⁶ The results from the second specification are nearly identical to the other model specifications, so the other tables are left out for the sake of brevity.

correctly predicted from over 99 percent down to around 81 percent. Overall, the logit model does predict retained interest fairly well.

	0.5 Threshold					Mean Threshold				
	Predicted Outcome					Predicted Outcome				
	Actual Outcome	0	1	Total	% Correct	Actual Outcome	0	1	Total	% Correct
Nince Angus Producers	0	3146	5	3151	99.8	0	2564	587	3151	81.4
	1	104	4	108	3.7	1	9	99	108	91.7
	Total	3250	9			Total	2573	686		
	% Correct	96.8	44.4			% Correct	99.7	14.4		
	Predicted Outcome					Predicted Outcome				
	Actual Outcome	0	1	Total	% Correct	Actual Outcome	0	1	Total	% Correct
One Montana Producer	0	1654	13	1667	99.2	0	1362	305	1667	81.7
	1	87	12	99	12.1	1	6	93	99	93.9
	Total	1741	25			Total	1368	398		
	% Correct	95.0	48.0			% Correct	99.6	23.4		

Table 9. Comparison of actual versus predicted outcomes as a performance check on the logit model for specification two.

Joint significance test results are presented in table ten. These tests show the joint significance of the performance measure controls—the SPMs and EPDs. The Wald test results show that for both data sets when both SPMs and EPDs are included, the SPMs are jointly significant while the EPDs are not jointly significant. Altogether, all performance measures are jointly significant. This is not surprising given the significance of the individual coefficients. When only EPDs or SPMs are included in the logits, both sets of performance measures are jointly significant. These results suggest that, when deciding which bulls to sell on a retained interest basis, producers may not put as much emphasis on EPD values after first considering the bull's individual attributes as measured by SPMs.

One Montana Producer

	Specification 1		Specification 2		Specification 3		Specification 4		Specification 5	
	Wald Statistic	P-value	Wald Statistic	P-value	Wald Statistic	P-value	Wald Statistic	P-value	Wald Statistic	P-value
SPMs	21.8672	0.0002	19.9832	0.0005	20.5521	0.0004	34.9218	<.0001	23.6422	<.0001
EPDs	4.6754	0.1972	4.5811	0.2052	5.0828	0.1658	7.6524	0.0538	5.6375	0.1306
All	29.273	0.0001	26.4148	0.0004	27.5836	0.0003	41.9037	<.0001	30.9219	<.0001

Nine Nebraska and South Dakota Producers

	Specification 1		Specification 2		Specification 3		Specification 4		Specification 5	
	Wald Statistic	P-value	Wald Statistic	P-value	Wald Statistic	P-value	Wald Statistic	P-value	Wald Statistic	P-value
SPMs	40.596	<.0001	33.443	<.0001	32.429	<.0001	44.821	<.0001	34.6553	<.0001
EPDs	0.999	0.804	0.507	0.9175	0.517	0.9151	1.927	0.5877	0.6043	0.8954
All	52.576	<.0001	40.712	<.0001	39.337	<.0001	64.941	<.0001	43.719	<.0001

Table 10: Wald test results for joint significance of logit results

Results of robustness checks of the logit model are reported in Appendix C. These checks include examining the role of observations with high sale prices in driving the results. With the results of the logit model and how the proxies for uncertainty are constructed, there is concern that very few highly priced bulls are the cause for the high standard deviation of prices in the very top group. To look closely at this, I split the bulls into more than ten groups and run the logit regressions again to see how the top five, two, and one percent of bulls affect the results. I also examined how adjusting these observations affects the results by winsorizing the standard deviation of prices at the 95th percentile.³⁷ All in all, the results from these additional checks show that the statistical significance of the uncertainty proxies does not change and the magnitude of the marginal effects change only slightly. Importantly, I used winsorizing instead of dropping the top high-priced observations because the focus of this study is to see how the

³⁷ Winsorizing is a process used to reduce the effects of outliers or other influential data points. Instead of cutting out the observations with very high/low values, the values are reduced to the next highest value. For example, winsorizing at the 95th percentile replaces the data with the highest five percent of values to the value of the data at the 95th percentile. See Tukey (1962) for a thorough description of winsorizing.

variation/uncertainty in bulls affects contract choice; dropping top observations would drop valuable information from the data.

Other performance checks of the logit model are also included in Appendix C. These checks examine the effect of the inclusion of other variables in the logit model. First, instead of using the standard deviation of prices as a proxy for uncertainty, I use the coefficient of variation (CV).³⁸ Using the CV instead did not change the results in any meaningful way; it is still positively and significantly related to higher probabilities in retained interest contracts. Secondly, I use standardized performance measures in the logit regressions instead of the raw form. This puts the different measures into the same units so that the coefficients can be easily compared to one another. I did this by subtracting the mean and dividing by the standard deviation of the variable.³⁹ The results suggest that uncertainty is the relative most important determinant of retained interest.

The third change was to add price into the logit regressions. This acted as a proxy for value of the bull, and according to the theory, should not have an effect on the probability a bull is sold with retained interest. When included, the coefficient on the price variable is significant; however, the coefficients for the uncertainty proxies generally remain significant. One explanation for this is that the proxies for uncertainty are imperfect and do not capture all of the variation in bulls, so the value of the bull is able to pick up on some of the residual variation.

³⁸ The coefficient of variation (CV) is defined as the standard deviation divided by the mean. I calculated this for each of the ten groups and used it as an ancillary proxy for uncertainty. Because CV takes both the SD and mean into account, it adjusts for both variance preserving shifts and mean preserving spreads. My theory predicts that mean preserving spreads do not affect the level of uncertainty and therefore the level of presale measurement; only changes in variance will induce changes to the levels of uncertainty and presale measurement.

³⁹ See Gelman (2008) for a discussion of standardized beta coefficients both where the data are normalized by subtracting the mean and dividing by the standard deviation and where they are normalized by subtracting the mean and dividing by two times the standard deviation.

This makes sense as there are many unknown characteristics of bulls and variation in attributes that are not explicitly quantifiable. Finally, the fourth change was to include proxies for farm reputation for the data from the nine Nebraska and South Dakota producers. The proxies come from the coefficients from interaction terms between the retained interest dummy and each producer dummy in the hedonic price model, discussed below. These coefficients, added to the coefficient on the retained interest dummy, represent each producer's return on retained interest relative to the producer in the base category. The results of these regressions are presented in Appendix C. The results show that farm reputation negatively effects the producer's choice to retain interest. This is an interesting result as simple economic theory predicts that if producers' have higher returns on retaining interest, they will retain interest in more bulls.

Extensions

In addition to the binary logit model, other models are estimated and compared to previous results. I first estimated a Tobit model to see how the results change when retained interest is estimated as a censored, continuous variable. With more analysis and examination of the data, retained interest is more like a categorical variable instead of a continuous variable. Though a producer can choose any percent of retained interest between zero and one, in practice, they choose between common levels of retained interest such as zero, 25, 33, or 50 percent. The data show that most of the retained interest bulls in the samples are sold with 33 percent retained interest and very few (0.34 and 0.43 percent) are sold with 50 percent retained interest. This leads me to think that the retained interest variable is not truly continuous if retained interest is

positive. I estimated the Tobit, but because of the nature of the data, the results do not add new information to this analysis. Results are presented in Appendix C.

Following the results of the Tobit, I conclude that retained interest acts more as an ordered categorical variable instead of a continuous variable. I extended the logit analysis through the use of an ordered logit where the values of zero, one-third, and one-half represented the ordered response levels of retained interest. The ordered logit estimates two equations where the equations compare 1) the log odds (or the logit) a bull is sold with no retained interest versus one-third or one-half interest and 2) the log odds that a bull is sold with zero or one-third interest versus one-half interest. The proportional odds assumption assures that the estimated coefficients for both equations are the same, so that only one model is estimated. The estimated coefficients for the ordered logit model are presented in Appendix C. A Brant test shows that the proportional odds assumption is not violated. Because there are only three groups and there are few observations in the one-half interest group, the estimates from the ordered logit are very similar to those from the binary logit. Because of this, the ordered logit model does not provide additional information above the binary logit.

Hedonic Price Model

Ordinary Least Squares Results

Results from the hedonic price regressions are presented in table 11 for the one Montana producer and in table 12 for the nine Nebraska and South Dakota producers. The different model specifications correspond to the use of squared terms for the de-trended performance measures

and year (and producer) dummies. The coefficients from a hedonic price regression estimated using OLS represent the estimated marginal valuations of each attribute.

Table 11: Hedonic Price Regression Results for Various Models, One Montana Producer

VARIABLES	(1) Real Price	(2) Real Price	(3) Real Price	(4) Real Price
Retained Interest	8,292*** (1,315)	7,941*** (1,265)	8,086*** (1,274)	7,672*** (1,219)
DE Birthweight	-0.404 (11.14)	155.0 (138.3)	1.139 (10.31)	121.5 (132.0)
DE Adjusted 205 Day Weight	80.94*** (16.11)	-236.1 (248.6)	76.32*** (15.02)	-269.4 (237.7)
DE Adjusted 365 Day Weight	89.66*** (17.84)	-631.5* (360.5)	94.85*** (16.99)	-750.9** (374.5)
DE Birthweight EPD	-7.951*** (2.309)	-12.92*** (4.947)	-8.461*** (2.139)	-10.57** (5.016)
DE Weaning Weight EPD	-1.818 (9.430)	-47.33 (58.51)	0.0603 (8.791)	-29.60 (52.68)
DE Yearling Weight EPD	21.34*** (7.822)	-63.16 (50.72)	21.15*** (7.507)	-28.72 (47.43)
DE Birthweight Squared		-0.770 (0.714)		-0.590 (0.681)
DE Adjusted 205 Day Weight Squared		1.597 (1.311)		1.749 (1.250)
DE Adjusted 365 Day Weight Squared		3.574* (1.860)		4.191** (1.926)
DE Birthweight EPD Squared		0.0234 (0.0179)		0.00839 (0.0195)
DE Weaning Weight EPD Squared		0.228 (0.333)		0.146 (0.298)
DE Yearling Weight EPD Squared		0.437 (0.282)		0.262 (0.265)
Price Ratio	2,859** (1,132)	2,482** (1,114)		
Constant	-14,771*** (1,405)	35,693** (14,776)	-14,652*** (1,352)	42,598*** (15,216)
Observations	1,672	1,672	1,766	1,766
R-squared	0.343	0.359	0.381	0.396
Year Effects	NO	NO	YES	YES

Robust standard errors in parentheses

*** p<0.01, ** p<0.05, * p<0.1

Table 12: Hedonic Price Regression Results for Various Models, Nebraska and South Dakota Producers

VARIABLES	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
	Real Price	Real Price	Real Price	Real Price	Real Price	Real Price	Real Price	Real Price
Retained Interest	6,535*** (977.2)	6,320*** (926.4)	6,333*** (951.6)	6,072*** (909.3)	6,093*** (944.2)	5,892*** (900.3)	5,915*** (914.9)	5,643*** (875.5)
DE Birthweight	-8.952 (7.608)	-4.849 (84.35)	-9.274 (6.994)	27.60 (78.24)	-10.08 (7.436)	118.0 (78.85)	-10.36 (6.749)	150.4** (72.09)
DE Birthweight Squared		-0.0107 (0.421)		-0.181 (0.391)		-0.647 (0.394)		-0.815** (0.360)
DE Adjusted 205 Day Weight	20.02 (16.36)	-245.9 (295.6)	18.09 (15.14)	-241.0 (291.6)	20.79 (16.08)	-246.9 (292.6)	19.90 (14.88)	-222.6 (286.8)
DE Adjusted 205 Day Weight Squared		1.344 (1.533)		1.312 (1.512)		1.362 (1.519)		1.237 (1.489)
DE Adjusted 365 Day Weight	172.5*** (19.67)	-540.8 (510.5)	173.1*** (18.47)	-574.7 (494.1)	176.5*** (19.72)	-541.9 (502.0)	175.9*** (18.54)	-638.1 (490.7)
DE Adjusted 365 Day Weight Squared		3.534 (2.615)		3.702 (2.532)		3.554 (2.572)		4.024 (2.515)
DE Birthweight EPD	-9.259*** (1.658)	-12.79*** (2.705)	-9.292*** (1.563)	-11.37*** (2.494)	-9.445*** (1.655)	-18.33*** (2.828)	-9.477*** (1.555)	-16.65*** (2.616)
DE Birthweight EPD Squared		0.0159 (0.0106)		0.00951 (0.00999)		0.0442*** (0.0115)		0.0363*** (0.0108)
DE Weaning Weight EPD	3.237 (5.252)	4.500 (18.31)	1.944 (4.698)	8.152 (16.71)	4.823 (4.920)	5.953 (17.66)	3.323 (4.437)	11.84 (16.28)
DE Weaning Weight EPD Squared		-0.00228 (0.102)		-0.0317 (0.0944)		-0.00574 (0.0976)		-0.0470 (0.0911)
DE Yearling Weight EPD	11.95** (5.502)	66.37*** (20.34)	12.38** (5.087)	30.14 (19.17)	10.29** (5.235)	48.48** (19.58)	10.88** (4.900)	9.982 (19.00)
DE Yearling Weight EPD Squared		-0.274** (0.121)		-0.0866 (0.114)		-0.189 (0.117)		0.0115 (0.112)

Table 12 (cont): Hedonic Price Regression Results for Various Models, Nebraska and South Dakota Producers

Price Ratio	179.6 (1,164)	973.0 (1,060)			2,500* (1,283)	2,983** (1,300)		
Constant	-14,012*** (1,190)	31,829* (18,664)	-15,041*** (1,201)	32,409* (18,953)	-14,569*** (1,154)	26,479 (18,394)	-14,698*** (1,155)	29,959 (18,783)
Observations	2,966	2,966	3,259	3,259	2,966	2,966	3,259	3,259
R-squared	0.314	0.323	0.355	0.362	0.359	0.369	0.403	0.413
Year Effects	NO	NO	YES	YES	NO	NO	YES	YES
Farm Effects	NO	NO	NO	NO	YES	YES	YES	YES

Robust standard errors in parentheses

*** p<0.01, ** p<0.05, * p<0.1

For the one Montana producer, across model specifications, there are significant premiums for bulls sold with retained interest. All coefficients on the retained interest dummy are significant at the one percent level. The lowest estimated premium comes from model four, which includes quadratic terms for the performance measures and year dummy variables. This specification estimates a premium of around \$7700. Comparing this premium to other measures of central tendency of the data shows that the premium is large and economically significant. The mean bull price for this producer for the whole sample is around \$4700 and the median for the sample is \$3819. Also, the mean bull price for the top decile group is about \$13,000. Even with other bases of comparison, the premiums for retained interest are very large.

The results are similar for the nine other Angus producers. In all model specifications, the retained interest is significant at the one percent level. The most conservative estimate of the premium for retained interest bulls is about \$5600. For this sample, the mean is a little over \$5000 and the median is \$4410. The mean of the top decile group is about \$12,200. Like the results for the one Montana producer, the premiums for retained interest bulls are sizeable and show that retained interest has economic significance as well as statistical significance, even when controlling for quality measures.

These results are striking because, as previously mentioned in footnote ten, basic economic reasoning predicts that selling a share of a bull will result in a lower price for the share than for a comparable whole bull (sold lump sum). In a world with perfect information, bulls sold with retained interest would sell for less compared to comparable bulls sold lump sum. This is because there is no uncertainty of the bull's attributes with perfect information, so bulls with comparable and known attributes will sell for less if the buyer is only getting a share of the bull.

The premiums estimated in the hedonic regressions along with the above hypothetical description, emphasize the presence of uncertainty regarding a bull's attributes.

The large premiums for retained interest bulls for all producers supports the hypothesis that retaining interest on a bull sends a positive signal to buyers about the quality of the bull. Because the models control for some quality measures using SPMs and EPDs, the signal of retained interest shows that the bull has potential above and beyond what is conveyed by traditional measures of quality. These regressions do not and are not able to control for all aspects of bull quality; however, it is unlikely that including more performance measures would completely diminish the estimated impact of retained interest.

Joint F tests, presented in table 13, revealed that SPMs by themselves are jointly significant at the one percent in determining bull prices. EPDs are also jointly significant at the one percent level across all specifications and samples. Chvosta, Rucker, and Watts (2001) report that in joint tests of SPMs and EPDs by themselves, both are statistically significant at the one percent level, but that the F-value for the test of SPMs is more than six times as large as the F-value for the test of EPDs. I found very similar results, where the F-values for the SPMs are five to seven times larger than the F-value for EPDs, in both samples. Their interpretation of this is that buyers place less emphasis on EPDs than SPMs when selecting a bull. Along these lines, my results suggest that though buyers do consider EPDs, SPMs are marginally preferred to EPDs when it comes to bull selection.

	One Montana Producer		9 South Dakota and Nebraska Producers	
	F-statistic	P-value	F-statistic	P-value
SPMs	63.39	0.000	73.47	0.000
EPDs	9.16	0.000	13.2	0.000
Year Effects	13.26	0.000	26.5	0.000
Farm Effects	-	-	24.51	0.000

Table 13. Results of F-test for joint significance in hedonic regressions.

As a robustness check, I winsorized prices at the 99th, 95th, and 90th percentiles. This replaces the top values with the values of prices at the 99th, 95th, etc. percentiles. Results using the winsorized prices are less influenced by the extreme high prices; these results are reported in Appendix D. Accordingly, the coefficients on the retained interest dummy variable decrease as more data are winsorized; however, the retained interest variable remains statistically, and economically, significant through each level of winsorization. Though replacing high values with lower values may seem like an attractive way to decrease the effect of extreme values on regression results, this causes problems when the data replaced are true data points that represent true valuations of bulls. The highly priced bulls in my sample are not errors; there is information contained in the price of those bulls that is essential to the understanding of the effect of retained interest. For this reason, I believe the main results presented above offer better insights into the effects of retained interest compared to the results from using winsorized data.

Quantile Regression Results⁴⁰

In addition to using OLS to estimate the hedonic price model, I also estimate quantile regressions to better model the effects of retained interest across varying levels of price. Quantile regressions use the least absolute deviations (LAD) estimator to estimate parameters for explanatory variables at different quantiles of the dependent variable. Coefficients in quantile regressions represent the effect of a one unit change in the dependent variable on the conditional q^{th} quantile of Y, and like OLS, the coefficients represent the marginal effects.

Results from the quantile regression models are presented in tables 14 and 15. Graphs of the effects of the main variable of interest, the retained interest dummy variable, are shown in figures 13 and 14. I estimate parameters for nine quantiles simultaneously. I choose these quantiles, equal to 0.1, 0.2, ..., 0.9, so the parameter estimates represent effects of retained interest for bulls in each decile group.⁴¹ From these results and graphs, the effects of retained interest clearly increase as the estimated quantile increases. Even at the lowest quantile level estimated, the .10 quantile, retained interest is statistically significant. Retained interest bulls earn a premium between \$2300 and \$2600 at the 0.1 quantile and premiums between \$16,000 and almost \$21,000 at the 0.9 quantile compared to bulls sold lump sum, *ceteris paribus*.⁴² One striking result is that within each specification, the premiums for retained interest bulls increase

⁴⁰ See Bekkerman, Brester, and McDonald (2013) for further discussion of the use of quantile regressions in estimating seedstock bull prices.

⁴¹ The quantiles do not match perfectly to the decile groups created in the data, as the decile groups include the distribution of prices between the estimated quantiles. However, they are similar enough to compare the effects at each quantile with the mean prices of the deciles.

⁴² Premiums depend on which data set was used and what model specification is referenced. The range presented here represents the lowest to the highest estimates across both the nine South Dakota and Nebraska producers and the one Montana producer.

monotonically and are statistically significant at the one percent level. This suggests that retained interest bulls earn premiums regardless of where the bulls lie on the overall value spectrum.

Table 14: Results from Quantile Regression of Bull Prices, One Montana Producer

VARIABLES	(1) q10	(2) q20	(3) q30	(4) q40	(5) q50	(6) q60	(7) q70	(8) q80	(9) q90
Retained Interest	2,419*** (320.4)	2,633*** (403.3)	3,562*** (518.6)	4,316*** (603.0)	4,924*** (575.7)	5,666*** (893.9)	7,685*** (2,012)	10,329*** (2,122)	20,725*** (4,383)
DE Birthweight	0.650 (6.173)	1.614 (4.023)	5.534* (3.333)	3.936 (2.564)	5.837 (5.127)	7.473 (6.307)	10.19 (6.960)	18.39* (10.34)	33.73* (18.01)
DE Adjusted 205 Day Weight	38.14*** (4.437)	41.07*** (5.504)	44.12*** (7.491)	50.75*** (5.576)	59.29*** (5.290)	67.17*** (7.125)	70.27*** (9.024)	82.69*** (11.66)	113.2*** (17.92)
DE Adjusted 365 Day Weight	27.46*** (5.909)	43.79*** (6.518)	50.56*** (7.175)	59.25*** (7.153)	66.85*** (8.641)	75.62*** (8.257)	78.89*** (11.64)	80.31*** (10.67)	80.54*** (19.48)
DE Birthweight EPD	-3.662** (1.434)	-4.831*** (0.888)	-6.293*** (1.240)	-6.533*** (1.075)	-6.724*** (1.302)	-7.349*** (1.556)	-8.624*** (1.604)	-10.43*** (2.269)	-13.05*** (3.412)
DE Weaning Weight EPD	-0.928 (3.408)	-1.285 (3.052)	-0.890 (3.856)	-2.836 (3.096)	-5.501 (4.058)	-9.969* (5.103)	-6.498 (6.267)	-3.740 (9.269)	-9.479 (13.05)
DE Yearling Weight EPD	9.708** (4.784)	10.28*** (3.191)	11.36*** (3.567)	15.41*** (2.728)	17.78*** (3.747)	23.14*** (4.892)	22.58*** (5.384)	22.39*** (6.196)	32.10*** (11.07)
Price Ratio	3,918*** (522.1)	4,191*** (439.3)	4,298*** (477.2)	4,189*** (501.4)	4,152*** (586.4)	3,422*** (635.2)	3,563*** (704.8)	2,733* (1,448)	5,486*** (1,428)
Constant	-5,836*** (1,065)	-7,447*** (536.4)	-8,543*** (635.8)	-9,733*** (571.9)	-11,137*** (655.1)	-12,403*** (919.2)	-13,064*** (1,401)	-14,499*** (1,236)	-19,001*** (1,988)
Observations	1,672	1,672	1,672	1,672	1,672	1,672	1,672	1,672	1,672

Standard errors in parentheses

*** p<0.01, ** p<0.05, * p<0.1

Table 15: Results from Quantile Regression of Bull Prices, Nebraska and South Dakota Producers

VARIABLES	(1) q10	(2) q20	(3) q30	(4) q40	(5) q50	(6) q60	(7) q70	(8) q80	(9) q90
Retained Interest	2,653*** (330.6)	2,841*** (292.7)	2,893*** (300.5)	3,292*** (500.8)	4,232*** (614.7)	4,592*** (538.8)	5,215*** (1,139)	7,505*** (1,432)	16,232*** (4,216)
DE Birthweight	-10.07*** (3.786)	-15.97*** (5.624)	-13.99*** (4.714)	-11.06* (5.786)	-11.45* (6.211)	-10.93* (6.353)	-11.62 (7.772)	-2.207 (10.57)	-2.911 (14.83)
DE Adjusted 205 Day Weight	22.95*** (6.348)	31.99*** (8.205)	24.59*** (6.842)	22.68** (8.980)	23.48*** (8.565)	20.91*** (6.696)	23.13*** (8.105)	18.61* (9.505)	34.63** (15.31)
DE Adjusted 365 Day Weight	74.66*** (9.523)	89.04*** (7.444)	106.9*** (6.907)	113.6*** (7.884)	126.2*** (6.721)	140.4*** (7.235)	156.9*** (9.783)	179.4*** (9.471)	210.0*** (15.85)
DE Birthweight EPD	-3.769*** (1.391)	-3.245*** (1.145)	-4.044*** (1.351)	-5.044*** (1.777)	-6.076*** (1.485)	-7.019*** (1.439)	-8.456*** (1.668)	-10.86*** (2.294)	-11.14*** (3.574)
DE Weaning Weight EPD	-4.451 (3.915)	-5.339*** (2.618)	-3.675* (1.981)	-3.600 (2.495)	-1.346 (2.464)	0.569 (3.579)	3.379 (5.356)	5.538 (4.156)	-7.895 (6.615)
DE Yearling Weight EPD	9.728** (3.861)	9.609*** (2.465)	10.83*** (1.988)	14.28*** (3.059)	14.55*** (3.576)	16.71*** (3.996)	15.91** (6.184)	17.73*** (5.136)	32.15*** (9.278)
Price Ratio	-82.61 (537.3)	887.4 (596.6)	967.9 (626.4)	684.1 (626.8)	401.7 (759.7)	368.1 (656.7)	501.3 (811.7)	734.5 (910.6)	96.28 (1,840)
Constant	-5,993*** (546.1)	-7,470*** (577.9)	-8,537*** (579.7)	-9,077*** (760.4)	-10,011*** (676.3)	-11,115*** (640.8)	-12,509*** (816.9)	-14,855*** (1,088)	-18,276*** (1,664)
Observations	2,966	2,966	2,966	2,966	2,966	2,966	2,966	2,966	2,966

Standard errors in parentheses

*** p<0.01, ** p<0.05, * p<0.1

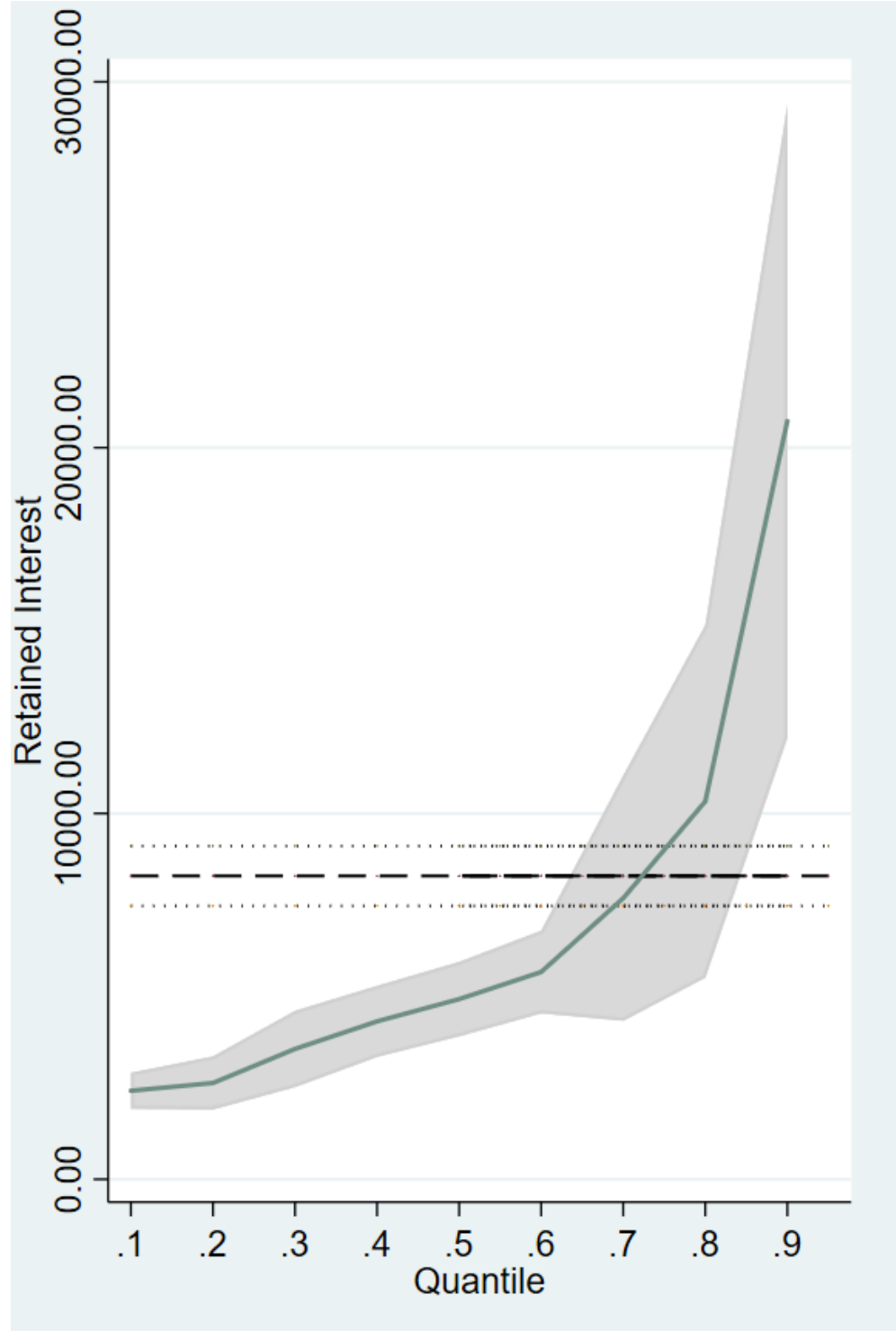


Figure 13. Quantile regression coefficient estimates for the retained interest dummy compared to the OLS coefficient estimate shown by the bold, dashed line, one Montana Producer.

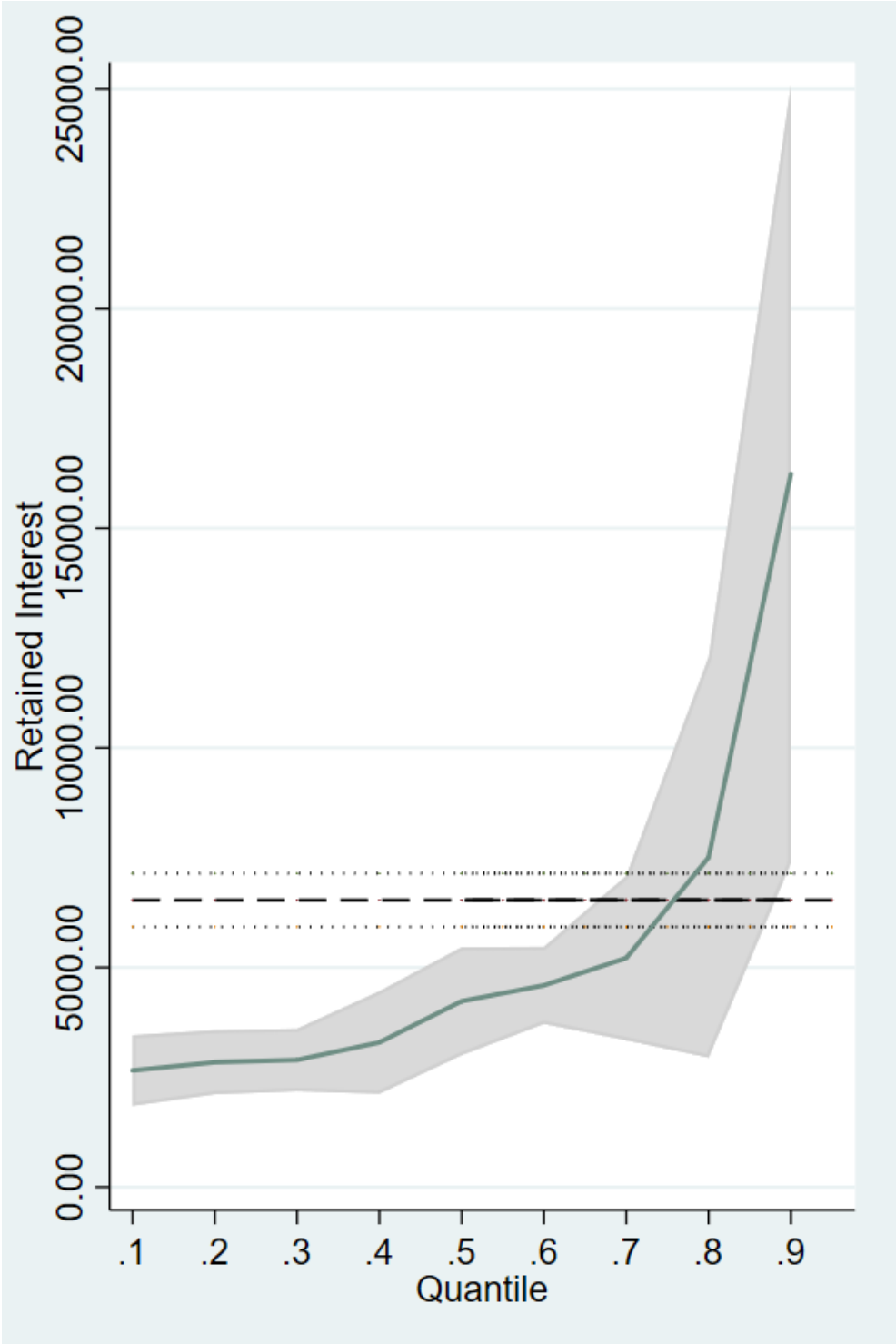


Figure 14. Quantile regression coefficient estimates for the retained interest dummy compared to the OLS coefficient estimate shown by the bold, dashed line, Nebraska and South Dakota producers.

CHAPTER EIGHT

CONCLUDING REMARKS

This thesis examines bull producer's decision to retain semen interest in seedstock bulls and the impact of retained interest on bull sale prices. Using data from a local Montana Angus producer and nine other Angus producers in Nebraska and South Dakota, I analyze 1) how uncertainty of bull quality affects the decision to retain interest, and 2) the estimated premiums for retained interest bulls. My results broadly support the hypotheses that as uncertainty increases, as measured by the standard deviation of prices within ranked groups, the probability the bull is sold with retained interest also increases. The results also show that producers receive large premiums, between \$5000 and \$7700, for retained interest bulls.

These results provide the first systematic examination of retained semen interest contracts in seedstock bulls. Because there is great uncertainty when it comes to assessing bull quality before the sale, there are large transaction costs associated with bidders collecting private information about the bull. The seller, who bears these costs, has an incentive to reduce these costs, and one possibility to accomplish that is to sell the bull with retained interest. The data show that bulls in the top decile group, where there is the most *ex ante* uncertainty, are more likely to be sold with retained interest contracts. I also find that the signal from retained interest substantially increases the expected price of semen as seen in the higher auction prices for retained interest bulls compared to bulls sold lump sum.

The uncertainty in quality is the driver underlying these results, and the uncertainty is a product of the heterogeneity of bulls. The quality of a bull varies greatly, so producers take measures to reduce this uncertainty and maximize their expected profits. On the other hand, for

assets with homogeneous quality, there is little to no uncertainty regarding the attributes *ex ante*. This is the case for taxi medallions as explained further in Appendix E. The results in Appendix E provide a baseline for comparison for the effect of share contracts on prices and demonstrate the economic significance of the information signaled by retained interest found in this thesis.

REFERENCES CITED

- Akerberg, Daniel A, and Maristella Botticini. 2002. 'Endogenous matching and the empirical determinants of contract form', *Journal of Political Economy*, 110: 564-91.
- Akerlof, George A. 1970. 'The Market for "Lemons": Quality Uncertainty and the Market Mechanism', *The Quarterly Journal of Economics*, 84: 488-500.
- Allen, Douglas W, and Allison Borchers. 2016. 'Conservation practices and the growth of US cash rent leases', *Journal of Agricultural Economics*, 67: 491-509.
- Allen, Douglas W, and Dean Lueck. 1993. 'Transaction costs and the design of cropshare contracts', *The RAND Journal of Economics*: 78-100.
- . 1999. 'The role of risk in contract choice', *Journal of Law, Economics, and Organization*, 15: 704-36.
- Alston, Lee J, Samar K Datta, and Jeffrey B Nugent. 1984. 'Tenancy choice in a competitive framework with transactions costs', *Journal of Political Economy*, 92: 1121-33.
- Amemiya, Takeshi. 1981. 'Qualitative response models: A survey', *Journal of economic literature*, 19: 1483-536.
- Barzel, Yoram. 1982. 'Measurement cost and the organization of markets', *The Journal of Law and Economics*, 25: 27-48.
- . 1997. *Economic analysis of property rights* (Cambridge university press).
- Bekkerman, Anton, Gary W Brester, and Tyrel J McDonald. 2013. 'A semiparametric approach to analyzing differentiated agricultural products', *Journal of Agricultural and Applied Economics*, 45: 79-94.
- Bhattacharyya, Sugato, and Francine Lafontaine. 1995. 'Double-sided moral hazard and the nature of share contracts', *The RAND Journal of Economics*: 761-81.
- Black, Geoffrey, Keith B Leffler, and Randal R Rucker. 1996. 'Transaction Costs Versus Risk Aversion in Contract Choice: An Examination of Private Oil Leasing Practices', Working Paper.
- Braido, Luis HB. 2008. 'Evidence on the incentive properties of share contracts', *The Journal of Law and Economics*, 51: 327-49.
- Brickley, James A. 2002. 'Royalty rates and upfront fees in share contracts: evidence from franchising', *Journal of Law, Economics, and Organization*, 18: 511-35.

- Caudill, Steven B. 1987. 'Dichotomous choice models and dummy variables', *Journal of the Royal Statistical Society: Series D (The Statistician)*, 36: 381-83.
- . 1988. 'An advantage of the linear probability model over probit or logit', *Oxford Bulletin of Economics and Statistics*, 50: 425-27.
- Cheung, Steven NS. 1968. 'Private property rights and sharecropping', *Journal of Political Economy*, 76: 1107-22.
- . 1969. 'Transaction costs, risk aversion, and the choice of contractual arrangements', *The Journal of Law and Economics*, 12: 23-42.
- Chvosta, Jan. 1997. 'The information content of seller-provided presale data in cattle auctions', Montana State University-Bozeman, College of Agriculture.
- Chvosta, Jan, Randal R Rucker, and Myles J Watts. 2001. 'Transaction Costs and Cattle Marketing: The Information Content of Seller-Provided Presale Data at Bull Auctions', *American Journal of Agricultural Economics*, 83: 286-301.
- Dhuyvetter, Kevin C, Ted C Schroeder, Danny D Simms, Ronald P Bolze Jr, and Jeremy Geske. 1996. 'Determinants of purebred beef bull price differentials', *Journal of Agricultural and Resource Economics*: 396-410.
- Elizondo, Vanessa Valentina. 2011. 'An economic analysis of the wild horse and burro program', Montana State University-Bozeman, College of Agriculture.
- Fausti, Scott, Brad Johnson, William Epperson, and Nancy Grathwohl. 2003. 'Risk and the Economic Incentive to Retain Ownership of Steer Calves'.
- Franken, Jason, and Joe Purcell. 2012. 'Factors Influencing Bull Price: Evidence from Missouri Auction Data', *Journal of Agribusiness*, 30: 107-23.
- French, Kenneth R, and Robert E McCormick. 1984. 'Sealed bids, sunk costs, and the process of competition', *Journal of business*: 417-41.
- Fuerst-Waltl, Birgit, Hermann Schwarzenbacher, Christa Perner, and Johann Sölkner. 2006. 'Effects of age and environmental factors on semen production and semen quality of Austrian Simmental bulls', *Animal Reproduction Science*, 95: 27-37.
- Fukunaga, Keita, and Wallace E Huffman. 2009. 'The role of risk and transaction costs in contract design: evidence from farmland lease contracts in US agriculture', *American Journal of Agricultural Economics*, 91: 237-49.

- Gelman, Andrew. 2008. 'Scaling regression inputs by dividing by two standard deviations', *Statistics in medicine*, 27: 2865-73.
- Ghatak, Maitreesh, and Priyanka Pandey. 2000. 'Contract choice in agriculture with joint moral hazard in effort and risk', *Journal of Development Economics*, 63: 303-26.
- Hallagan, William S. 1978. 'Share contracting for California Gold', *Explorations in Economic History*, 15: 196-210
- Higgs, Robert. 1973. 'Race, tenure, and resource allocation in southern agriculture, 1910', *The Journal of Economic History*: 149-69.
- Hobbs, Jill E. 1996. 'Transaction costs and slaughter cattle procurement: processors' selection of supply channels', *Agribusiness: An International Journal*, 12: 509-23.
- Jones, Rodney D, Tyler Turner, Kevin C Dhuyvetter, and Thomas L Marsh. 2008. 'Estimating the economic value of specific characteristics associated with Angus bulls sold at auction', *Journal of Agricultural and Applied Economics*, 40: 315-33.
- Lafontaine, Francine. 1992. 'Agency theory and franchising: some empirical results', *The RAND Journal of Economics*: 263-83.
- Lancaster, Kelvin J. 1966. 'A new approach to consumer theory', *Journal of Political Economy*, 74: 132-57.
- Leffler, Keith B, and Randal R Rucker. 1991. 'Transactions costs and the efficient organization of production: a study of timber-harvesting contracts', *Journal of Political Economy*, 99: 1060-87.
- Leffler, Keith B, Randal R Rucker, and Ian A Munn. 2000. 'Transaction costs and the collection of information: presale measurement on private timber sales', *Journal of Law, Economics, and Organization*, 16: 166-88.
- Levy, David T. 1985. 'The transactions cost approach to vertical integration: an empirical examination', *The Review of Economics and Statistics*: 438-45.
- Maddala, Gangadharrao S. 1986. *Limited-dependent and qualitative variables in econometrics* (Cambridge university press).
- Mortimer, Julie H. 2008. 'Vertical contracts in the video rental industry', *The Review of Economic Studies*, 75: 165-99.
- Mulherin, J Harold. 1986. 'Complexitiy in Long-term Contracts: An Analysis of Natural Gas Contractual Provisions', *JL Econ. & Org.*, 2: 105.

- Munn, Ian A, and Randal R Rucker. 1998. 'Predicting Forestry Consultant Participation Based on Physical Characteristics of Timber Sales', *Journal of Forest Economics*, 4: 105-26.
- Newbery, David MG. 1977. 'Risk sharing, sharecropping and uncertain labour markets', *The Review of Economic Studies*: 585-94.
- Platteau, J-Ph, and Jeffrey Nugent. 1992. 'Share contracts and their rationale: Lessons from marine fishing', *The Journal of Development Studies*, 28: 386-422.
- Purdie, Amy Joanne. 2009. 'Market valuation of certified green homes: a case study of Colorado's Built Green and Energy Star programs', Montana State University-Bozeman, College of Agriculture.
- Rosen, Sherwin. 1974. 'Hedonic prices and implicit markets: product differentiation in pure competition', *Journal of Political Economy*, 82: 34-55.
- Sengupta, Kunal. 1997. 'Limited liability, moral hazard and share tenancy', *Journal of Development Economics*, 52: 393-407.
- Stiglitz, Joseph E. 1974. 'Incentives and risk sharing in sharecropping', *The Review of Economic Studies*, 41: 219-55.
- Tang, Minfeng, Nathanael Thompson, Christopher N Boyer, Nicole JO Widmar, Terry S Stewart, Donna L Lofgren, and Nick Minton. 2020. 'Temporal Changes in Angus Bull Attribute Valuations in the Midwest', *Journal of Agricultural and Resource Economics*, 45: 518.
- Tukey, John W. 1962. 'The future of data analysis', *The annals of mathematical statistics*, 33: 1-67.
- U.S. Bureau of Labor Statistics, Producer Price Index by Commodity: Farm Products: Slaughter Steers and Heifers [WPU013101], retrieved from FRED, Federal Reserve Bank of St. Louis; <https://fred.stlouisfed.org/series/WPU013101>.
- Vanek, Joseph K, Myles J Watts, and Gary W Brester. 2008. 'Carcass quality and genetic selection in the beef industry', *Journal of Agricultural and Resource Economics*: 349-63.
- Wilson, Robert. 1977. 'A bidding model of perfect competition', *The Review of Economic Studies*, 44: 511-18.

APPENDICES

APPENDIX A

EXAMPLES OF BULL SALE CATALOGS AVAILABLE TO BUYERS

This appendix provides example pages of bull sale catalogs. These figures come from 2020, 2015, and 1985. The catalogs from 1985 and 2015 come from the same producer and show the progression of information available to buyers before the sale. The catalog from 2020 comes from a well-known Angus producer's recent sale. This shows how different producers report different performance measures in their catalogs.

206 D of B: 4/15/19 Tattoo: 964C Reg # 19737476
Sired by: **Connealy Stronghold**

Quaker Hill Rampage 0A36 MCC Daybreak
QH Blackcap 6E2 of 4V16 4355
Phyllis of Conanga 479L Mohnen Long Haul 502
Phyllis of Conanga 479L Poppy of Conanga 765

CED	BW	WW	YW	HP	MILK	Our Docility Score
+8	+1.1	+65	+112	+9.7	+26	1

CW	MARB	RE	\$M	\$F	\$G	\$B	\$C
+42	+.54	+1.05	74	85	57	142	258

BW	63
205 ratio	101
365 ratio	101
Actual Scrl	42.0
Frame Score	5.8
Dam's WR	2/103
Dam's YR	2/103

- Recommended for large framed heifers or cows
- This wide topped bull is extra soggy
- Out of a wide, husky Rampage daughter

210 D of B: 3/21/19 Tattoo: 9623 Reg # 19737474
Sired by: **Connealy Stronghold**

MGR Treasure V A R Discovery 2240
Jillie of Conanga 7178 SJH Impression of 6108 1614
Jillan of Conanga 8785 Rito 2 878 of 2536 BVND 878
Jill Deena of Conanga 64100

CED	BW	WW	YW	HP	MILK	Our Docility Score
+8	+0.5	+77	+139	+6.9	+20	2

CW	MARB	RE	\$M	\$F	\$G	\$B	\$C
+60	+.24	+.72	48	108	36	145	236

BW	59
205 ratio	87
365 ratio	101
Actual Scrl	39.0
Frame Score	5.9
Dam's WR	1/87
Dam's YR	1/101

- Recommended for heifers or cows
- A gentle, growthy, calving ease prospect here
- Out of a quiet acting, first calf Treasure daughter

207 D of B: 4/11/19 Tattoo: 932C Reg # 19737459
Sired by: **Connealy Stronghold**

Baldridge Jennings 2064 Baldridge Waylon W34
Basque of Conanga 6512 Baldridge Maverick T43
Baska of Conanga 048X ALC Big Eye D09N
Baskina of Conanga 6457

CED	BW	WW	YW	HP	MILK	Our Docility Score
+4	+2.1	+60	+102	+11.2	+31	2

CW	MARB	RE	\$M	\$F	\$G	\$B	\$C
+40	+.29	+.70	65	78	39	116	215

BW	80
205 ratio	91
365 ratio	95
Actual Scrl	37.0
Frame Score	5.8
Dam's WR	2/99
Dam's YR	2/101

- Recommended for cows
- Strongholds are generally very docile - like this bull
- Dam is a bigger statured young Jennings daughter

211 D of B: 3/20/19 Tattoo: 9607 Reg # 19737468
Sired by: **Connealy Stronghold**

V A R Discovery 2240 A A R Ten X 7008 S A
Georgia of Conanga 7215 Deer Valley Rita 0308
Georgina of Conanga 015 S A V Bismarck 5682
Gerogio of Conanga 870A

CED	BW	WW	YW	HP	MILK	Our Docility Score
+9	+1.0	+89	+151	+14.1	+26	2

CW	MARB	RE	\$M	\$F	\$G	\$B	\$C
+72	+.56	+.82	66	114	52	166	281

BW	66
205 ratio	113
365 ratio	109
Actual Scrl	39.0
Frame Score	5.9
Dam's WR	1/113
Dam's YR	1/109

- Recommended for heifers or cows
- Big growth numbers on this masculine, deep chested bull
- Dam is a nicely undered first calf Discovery daughter

208 D of B: 4/11/19 Tattoo: 937C Reg # 19737460
Sired by: **Connealy Stronghold**

K C F Bennett Homestead K C F Bennett Energizer
Enza of Conanga 6601 K C F Miss Quality P164
Enza of Conanga 210 Connealy Contrast
Enza of Conanga 05

CED	BW	WW	YW	HP	MILK	Our Docility Score
+3	+3.3	+72	+127	+13.2	+26	2

CW	MARB	RE	\$M	\$F	\$G	\$B	\$C
+55	+.75	+.64	61	100	58	158	266

BW	82
205 ratio	97
365 ratio	101
Actual Scrl	40.0
Frame Score	5.8
Dam's WR	2/96
Dam's YR	2/99

- Recommended for cows
- A slick haired, wide based, well muscled bull
- Dam is a broody young Homestead daughter

212 D of B: 3/21/19 Tattoo: 9620 Reg # 19737472
Sired by: **Connealy Stronghold**

Connealy Concord Connealy Consensus
Pretty Pat of Conanga Eura Elga of Conanga 9109
Pretty Petra of Conanga 3104 A A R Ten X 7008 S A
Pretty Patti of Conanga 1418

CED	BW	WW	YW	HP	MILK	Our Docility Score
+12	-1.3	+57	+104	+11.0	+28	2

CW	MARB	RE	\$M	\$F	\$G	\$B	\$C
+30	+.36	+.85	76	66	44	109	217

BW	61
205 ratio	100
365 ratio	100
Actual Scrl	36.0
Frame Score	5.8
Dam's WR	1/100
Dam's YR	1/100

- Recommended for heifers or cows
- High \$M on this nicely made calving ease bull
- Out of a feminine, first calf Concord daughter

209 D of B: 4/12/19 Tattoo: 940C Reg # 19737461
Sired by: **Connealy Stronghold**

V A R Index 3282 G A R Ingenuity
Emalia of Conanga 6605 Sandpoint Blackbird 8809
Emalia of Conanga 369C Connealy Counselor
Emra of Conanga 193E

CED	BW	WW	YW	HP	MILK	Our Docility Score
+11	+0.2	+75	+122	+12.4	+30	2

CW	MARB	RE	\$M	\$F	\$G	\$B	\$C
+46	+.85	+.74	69	79	61	140	251

BW	70
205 ratio	113
365 ratio	104
Actual Scrl	41.0
Frame Score	5.9
Dam's WR	2/108
Dam's YR	2/101

- Recommended for heifers or cows
- This big spread bull boasts a big weaning ratio
- Dam is a gentle, nicely undered Index daughter

213 D of B: 3/25/19 Tattoo: 9653 Reg # 19737477
Sired by: **Connealy Stronghold**

Connealy Concord Connealy Consensus
Bottle Bree of Conanga 795 Eura Elga of Conanga 9109
Bottle Britt of Conanga 5580 PA Fortitude 2500
Bottle Bliss of Conanga 9102

CED	BW	WW	YW	HP	MILK	Our Docility Score
+10	+1.8	+84	+141	+8.1	+13	2

CW	MARB	RE	\$M	\$F	\$G	\$B	\$C
+62	+.70	+.95	49	111	58	170	269

BW	63
205 ratio	92
365 ratio	88
Actual Scrl	36.0
Frame Score	5.8
Dam's WR	1/92
Dam's YR	1/88

- Recommended for heifers or cows
- A slick haired, smooth shouldered, big ribeyed bull
- Out of a smaller statured, first calf Concord daughter

Figure A-1. Example page from a 2020 bull sale catalog.

HYLINE RAINMAKER 004									
BULL		Reg: 17979008	tattoo: K004	calved: 10/15/13	\$W				
HYLINE RAINMAKER 1995		G D A R RAINMAKER 340#		40.53					
HYLINE RAIN MAKER 1058-B1		HYLINE BLACKCAP 345		\$F					
HYLINE EILEENMERE 312#		HYLINE RIGHT TIME 338#		33.56					
		HYLINE EILEENMERE 184#		\$G					
HYLINE RIGHT TIME 338#		LEACHMAN RIGHT TIME#		18.52					
HYLINE BARBARA 413		HYLINE PRIDE 265		\$B					
HYLINE PRIDE 457#		WH A032 RITO 8756-8704		67.80					
		HYLINE PRIDE 051							
Birth Wt	205 Wt	WR	365 Wt	YR	BW	Wean	Year	Milk	
80	844	110	1326	102	+2.8	+54	+87	+25	

Dam Production: 3 WR 106, 1 YR 102

HYLINE GIT-R-DONE 134									
BULL		Reg: 17983765	tattoo: K134	calved: 11/11/13	\$W				
G A R RETAIL PRODUCT#		G A R PRECISION 1680#		35.52					
WULFES GIT-R-DONE 730		G A R EXT 4927		\$F					
G BAR ERICA DIANNA 0709		FINKS 5522-6148#		28.49					
		WULFES ERICA DIANNA C116		\$G					
R A GENETIC TREND#		P S HIGH POCKETS#		na					
R&RPOLLY 413		HYLINE PRIDE LUCY 9043		\$B					
HYLINE POLLY 033		HYLINE MEDALLION 71		na					
		HYLINE POLLY 9033							
Birth Wt	205 Wt	WR	365 Wt	YR	BW	Wean	Year	Milk	
81	787	102	1273	97	+1.9	+47	+81	+23	

Dam Production: 3 WR 102, 1 YR 100

HYLINE IMAGE MAKER 114									
BULL		Reg: 17979018	tattoo: K114	calved: 8/15/13	\$W				
H A IMAGE MAKER 0415#		HERO 6267 OF R R 2418#		38.64					
HYLINE IMAGE MAKER 1048		H A RITO BLACKCAP 9038		\$F					
HYLINE PRIDE T L 319		D H D TRAVELER 6807#		46.53					
		HYLINE PRIDE 265		\$G					
TC FRANKLIN 619#		TC TOTAL 410#		27.53					
HYLINE EILEENMERE 928		TC MARCIA 1069#		\$B					
HYLINE EILEENMERE 184#		HYLINE RITO 498		91.25					
		PARSONS PRIDE 1503							
Birth Wt	205 Wt	WR	365 Wt	YR	BW	Wean	Year	Milk	
78	750	98	1236	98	+2.2	+56	+96	+22	

Dam Production: 1 WR 98, na

HYLINE TRANSFUSION 204									
BULL		Reg: 17981821	tattoo: K204	calved: 12/20/13	\$W				
S A V IRON MOUNTAIN 8066		TC GRIDIRON 258#		42.25					
HYLINE TRANSFUSION 191		S A V MADAME PRIDE 3249		\$F					
HYLINE PRIDE 559		N BAR EMULATION EXT#		55.70					
		HYLINE PRIDE 870		\$G					
HYLINE IMAGE MAKER 1048		H A IMAGE MAKER 0415#		na					
HYLINE DIAMOND LIL 137		HYLINE PRIDE T L 319		\$B					
HYLINE DIAMOND LIL 934		HYLINE S V F RITO 1116#		na					
		HYLINE DIAMOND LIL 447							
Birth Wt	205 Wt	WR	365 Wt	YR	BW	Wean	Year	Milk	
77	815	106	1346	108	+1.5	+62	+104	+18	

Dam Production: 1 WR 106, na

HYLINE RAINMAKER 054									
BULL		Reg: 17979012	tattoo: K054	calved: 10/11/13	\$W				
HYLINE RAINMAKER 1995		G D A R RAINMAKER 340#		26.18					
HYLINE RAIN MAKER 1058-B1		HYLINE BLACKCAP 345		\$F					
HYLINE EILEENMERE 312#		HYLINE RIGHT TIME 338#		16.32					
		HYLINE EILEENMERE 184#		\$G					
HYLINE NEW TREND 6602		E E 394 HY TREND 819		na					
HYLINE LUCY 414		HYLINE PRIDE 856		\$B					
HYLINE PRIDE LUCY 220		HYLINE RIGHT TIME 338#		na					
		HYLINE PRIDE LUCY 859							
Birth Wt	205 Wt	WR	365 Wt	YR	BW	Wean	Year	Milk	
85	744	97	1253	98	+4.3	+42	+71	+24	

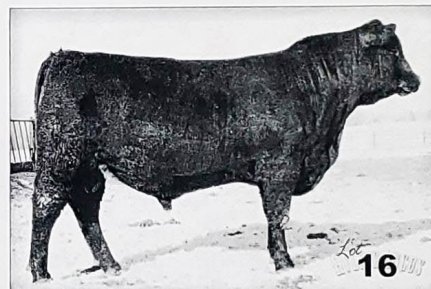
Dam Production: 2 WR 107, na

HYLINE RAINMAKER 044									
BULL		Reg: 17979011	tattoo: K044	calved: 2/11/14	\$W				
HYLINE RAINMAKER 1995		G D A R RAINMAKER 340#		33.64					
HYLINE RAIN MAKER 1058-B1		HYLINE BLACKCAP 345		\$F					
HYLINE EILEENMERE 312#		HYLINE RIGHT TIME 338#		32.27					
		HYLINE EILEENMERE 184#		\$G					
HYLINE RIGHT TIME 338#		LEACHMAN RIGHT TIME#		18.30					
HYLINE PRIDE 410		HYLINE PRIDE 265		\$B					
HYLINE PRIDE 463#		WH A032 RITO 8756-8704		67.44					
		HYLINE PRIDE 8322							
Birth Wt	205 Wt	WR	365 Wt	YR	BW	Wean	Year	Milk	
83	753	111	1220	117	+4.2	+51	+85	+27	

Dam Production: 3 WR 115, 2 YR 116

HYLINE O'REILLY FACTOR 94									
BULL		Reg: 17981650	tattoo: K094	calved: 11/11/13	\$W				
S A V FINAL ANSWER 0035#		SITZ TRAVELER 8180#		33.44					
VIN-MAR O'REILLY FACTOR		S A V EMULOUS 8145		\$F					
VIN-MAR EDELLA 2827#		CIRCLE A 216 LTD 9374		35.88					
		R R EDELLA PURSUIT 5827		\$G					
HYLINE AMBUSH 6700		PARAMONT AMBUSH 2172#		na					
HYLINE LUCY PRIDE 7008		HYLINE PRIDE 265		\$B					
HYLINE LUCY PRIDE 476		TRAVELER 3173 G D A R#		na					
		HYLINE LUCY PRIDE 429							
Birth Wt	205 Wt	WR	365 Wt	YR	BW	Wean	Year	Milk	
80	765	100	1251	96	+1.2	+45	+85	+25	

Dam Production: 2 WR 100, 1 YR 98



16		HYLINE RAINMAKER 024						
BULL	Reg: 17979010	tattoo: K024	calved: 9/12/13	\$W				
HYLINE RAINMAKER 1995		G D A R RAINMAKER 340#		30.90				
HYLINE RAIN MAKER 1058-B1		HYLINE BLACKCAP 345		\$F				
HYLINE EILEENMERE 312#		HYLINE RIGHT TIME 338#		20.22				
		HYLINE EILEENMERE 184#		\$G				
HYLINE AMBUSH 6700		PARAMONT AMBUSH 2172#		na				
HYLINE LASS 155		HYLINE PRIDE 265		\$B				
HYLINE LASS 331		R A GENETIC TREND#		na				
		HYLINE LASS 0022						
Birth Wt	205 Wt	WR	365 Wt	YR	BW	Wean	Year	Milk
82	751	98	1319	1Y1	+2.7	+43	+7.4	+23
Dam Production: 2 WR 101, 1 YR 101								

LOT
304
BULL

HYLINE POWER PLAY 304

Reg. 10583030 Tattoo: 304-304
Calved: January 20, 1984

P S Power Play 8974207GDF	{	Early Sunset Emulous 60E*	{	Biffles Emulous 775
		P S Menteith Blanche 205		Early Sunset Pride 88
Pride of Hyline 972 7561288	{	Hyline O Bardolliermere 17	{	O Bardolliermere of R R 3
		Eileenmar E 5 of Hyline		Eileenmar 17 of V G
*Pathfinder				Hyland Black Boy 5
				Eileenmar 17 of V G

BW	WW	NR	GR	YR	FW	SCROTAL RATIO
75	595	89	98	94	970	106

Dam has average of 103 on seven calves at weaning and has a Maternal breeding value of 101.

LOT
437
BULL

HYLINE SHANIGAN 437

Reg. 10583033 Tattoo: 437-437
Calved: January 20, 1984

Shoshone Shanigan OVY7 9517028	{	Shoshone Shannon HC3	{	Shoshone Titan FD60
		Shoshone Queen V Y 07		Shoshone Rosemary C3
Polly E 1 of Hyline 7770134	{	Bardolier 2371 of Hyline	{	Black Prince E 5 of V D
		Pride of Hyline 17		Indian Maid of Moss 3
*Pathfinder				Bardolier 200 of G D A R
				Elba Nola E 6 of Hyline

BW	WW	NR	GR	YR	FW	SCROTAL RATIO
85	585	93	116	98	1030	116

Dam has a Growth breeding value of 104 and a Maternal breeding value of 99.

LOT
314
BULL

HYLINE POWER PLAY 314

Reg. 10583071 Tattoo: 314-314
Calved: January 20, 1984

P S Power Play 8974207GDF	{	Early Sunset Emulous 60E*	{	Biffles Emulous 775
		P S Menteith Blanche 205		Early Sunset Pride 88
Pride of Hyline 135 9971565	{	PBC 707 1M D3226	{	R R Rito 707*
		Pride of Hyline 7919		Princess Marshall 5W35
Pathfinder				Schebrook Shoshone
				Pride of Hyline 747

BW	WW	NR	GR	YR	FW	SCROTAL RATIO
75	615	92	122	106	1085	110

You will like this calf. His dam is a tremendous daughter of 149. Once again, note there are four Pathfinder sires in his pedigree. Dam has a Growth breeding value of 105 and a Maternal breeding value of 101.

LOT
324
BULL

HYLINE POWER PLAY 324

Reg. 10583121 Tattoo: 324-324
Calved: January 21, 1984

P S Power Play 8974207GDF	{	Early Sunset Emulous 60E*	{	Biffles Emulous 775
		P S Menteith Blanche 205		Early Sunset Pride 88
Eldorene of Hyline 716 8980597	{	Rito 707 of Ideal 533 70*	{	R R Rito 707*
		Eldorene E 4 of Hyline		Skymere of Ideal 312
*Pathfinder				Hyland Black Boy 5
				Eldorene E 7 of V G

BW	WW	NR	GR	YR	FW	SCROTAL RATIO
75	655	98	109	103	1075	120

Once again we have a Powerplay, Rito 149 cross and we are confident you will like this one too, as he is a very well-made bull. Dam is a half sister to the dam of Hyline Easy Money and Hyline Band 302, both of whom are working in registered herds. Dam has a Growth breeding value of 104 and a Maternal breeding value of 100.

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LOT
325
BULL

HYLINE POWER PLAY 325

Reg. 10583123 Tattoo: 325-325
Calved: January 21, 1984

P S Power Play 8974207GDF	{	Early Sunset Emulous 60E*	{	Biffles Emulous 775
		P S Menteith Blanche 205		Early Sunset Pride 88
Blackcap Effie of R V D 7821 9196376	{	Rito 707 of Ideal 533 70*	{	R R Rito 707*
		Blackcap Effie of R R 1128		Skymere of Ideal 312
*Pathfinder				Granite Elevate 2
				Blackcap Effie of R R 5

BW	WW	NR	GR	YR	FW	SCROTAL RATIO
75	645	95	92	95	1000	117

Dam has a Growth breeding value of 103 and a Maternal breeding value of 100.

LOT
335
BULL

HYLINE POWER PLAY 335

Reg. 10583043 Tattoo: 335-335
Calved: January 22, 1984

P S Power Play 8974207GDF	{	Early Sunset Emulous 60E*	{	Biffles Emulous 775
		P S Menteith Blanche 205		Early Sunset Pride 88
Pride of Hyline 7512 8434350	{	O Bardolliermere 39 of V D	{	Hyline O Bardolliermere 22
		Pride of Hyline 20		Polly E 4 of V D
*Pathfinder				O Bardolliermere of R R 3
				Eldorene Eileen 4 of V G

BW	WW	NR	GR	YR	FW	SCROTAL RATIO
80	575	87	87	87	910	113

Dam has a Growth breeding value of 101 and Maternal breeding value of 100.

LOT
344
BULL

HYLINE POWER PLAY 344

Reg. 10583041 Tattoo: 344-344
Calved: January 24, 1984

P S Power Play 8974207GDF	{	Early Sunset Emulous 60E*	{	Biffles Emulous 775
		P S Menteith Blanche 205		Early Sunset Pride 88
Eileen 741 of Hyline 8162590	{	Rito 707 of Ideal 533 70*	{	R R Rito 707*
		Blackcap Eileen E5 of Hyline		Skymere of Ideal 312
*Pathfinder				Hyland Black Boy 5
				Blackcap Eileen 4 of V G

BW	WW	NR	GR	YR	FW	SCROTAL RATIO
75	615	92	122	106	1085	110

You will like this calf. His dam is a tremendous daughter of 149. Once again, note there are four Pathfinder sires in his pedigree. Dam has a Growth breeding value of 105 and a Maternal breeding value of 101.

LOT
354
BULL

HYLINE POWER PLAY 354

Reg. 10583091 Tattoo: 354-354
Calved: January 24, 1984

P S Power Play 8974207GDF	{	Early Sunset Emulous 60E*	{	Biffles Emulous 775
		P S Menteith Blanche 205		Early Sunset Pride 88
Pride of Hyline 7943 9468594	{	Rito 707 of Ideal 533 70*	{	R R Rito 707*
		Blackcap Eileen E5 of Hyline		Skymere of Ideal 312
*Pathfinder				Hyland Black Boy 5
				Eldorene E 7 of V G

BW	WW	NR	GR	YR	FW	SCROTAL RATIO
80	630	94	81	90	940	117

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Figure A-3. Example page from 1985 bull sale catalog.

APPENDIX B

ADDITIONAL SUMMARY STATISTICS

This appendix provides additional summary statistics for both datasets. Tables B-1 and B-2 show the summary statistics for bulls separated by contract type—lump sum or retained interest—for the one Montana producer and the nine Nebraska and South Dakota producers, respectively. Tables B-3 and B-4 give summary statistics for bulls separated by decile group for both datasets.

Table B-1:
Descriptive Statistics for Bulls Sold With Retained Interest, One Montana Producer

Variable	Obs	Mean	Std. Dev.	Min	Max
Real Price	99	14218.86	13490.34	1589.93	89667.28
Decile Group	99	8.424	1.213	0	9
SD of Prices	99	7268.29	4685.56	139.71	10415.54
Birthweight	99	84.727	7.486	68	102
Adjusted 205 day weight	99	749.02	58.766	625	895
Adjusted 365 day weight	99	1260.778	98.632	1006	1551
Age	99	425.636	60.924	104	740
Birthweight EPD	99	3.456	1.465	-1.3	7.3
Weaning weight EPD	99	38.703	10.948	3	67
Yearling weight EPD	99	66.67	17.619	31.6	117
Price Ratio	96	.317	.067	.179	.448
DE Birthweight	99	102.07	8.578	83.346	120.043
DE Adjusted 205 day weight	99	107.983	7.277	91.289	124.118
DE Adjusted 365 day weight	99	109.165	6.23	91.603	127.995
DE Birthweight EPD	99	101.895	47.37	-84.783	293.478
DE Weaning weight EPD	99	110.322	21.713	10.759	166.424
DE Yearling weight EPD	99	112.058	16.224	68.881	154.688

Table B-1 (cont.)
Descriptive Statistics for Bulls Sold Lump Sum, One Montana Producer

Variable	Obs	Mean	Std. Dev.	Min	Max
Real Price	1667	4154.20	2376.67	1266.93	39310.19
Decile Group	1667	4.267	2.771	0	9
SD of Prices	1667	863.99	2541.68	103.27	10415.54
Birthweight	1667	82.235	7.718	55	108
Adjusted 205 day weight	1667	697.975	70.033	485	970
Adjusted 365 day weight	1667	1159.835	104.069	864	1610
Age	1667	420.528	60.904	89	1169
Birthweight EPD	1667	3.261	1.368	-1.4	7.1
Weaning weight EPD	1667	36.826	12.197	1	86
Yearling weight EPD	1667	63.547	21.064	3	138
Price Ratio	1576	.294	.072	.179	.448
DE Birthweight	1667	100.081	9.088	67.256	132.48
DE Adjusted 205 day weight	1667	99.696	8.579	69.357	133.692
DE Adjusted 365 day weight	1667	99.595	7.36	72.141	134.066
DE Birthweight EPD	1667	100.443	42.313	-84.783	326.087
DE Weaning weight EPD	1667	99.519	20.034	2.542	182.043
DE Yearling weight EPD	1667	99.746	18.03	7.031	157.403

Table B-2:**Descriptive Statistics for Bulls Sold with Retained Interest, NE and SD Producers**

Variable	Obs	Mean	Std. Dev.	Min	Max
Real Price	108	13177.25	10668.26	2895.09	72377.20
Decile Group	108	8.398	1.16	1	9
SD of Prices	108	4769.95	3268.10	131.38	7166.17
Birthweight	108	86.917	9.71	56	106
Adjusted 205 day weight	108	754.954	75.27	576	925
Adjusted 365 day weight	108	1372.546	86.403	1159	1557
Age	108	390.917	35.739	288	487
Birthweight EPD	108	3.755	1.79	-1.6	8.2
Weaning weight EPD	108	35.58	6.752	3.7	52
Yearling weight EPD	108	57.68	10.824	5	82
Price Ratio	106	.272	.059	.179	.349
DE Birthweight	108	100.592	10.706	63.061	123.242
DE Adjusted 205 day weight	108	106.305	7.374	85.297	123.756
DE Adjusted 365 day weight	108	108.584	6.851	90.543	127.222
DE Birthweight EPD	108	95.162	43.736	-30.27	205.96
DE Weaning weight EPD	108	110.472	23.146	11.78	183.68
DE Yearling weight EPD	108	110.775	22.205	9.783	164.202

Table B-2 (cont.):**Descriptive Statistics for Bulls Sold Lump Sum, NE and SD Producers**

Variable	Obs	Mean	Std. Dev.	Min	Max
Real Price	3151	4807.30	2656.69	1357.07	35601.68
Decile Group	3151	4.369	2.819	0	9
SD of Prices	3151	766.76	1909.43	117.24	7166.17
Birthweight	3151	87.199	10.38	50	121
Adjusted 205 day weight	3151	677.846	69.808	452	920
Adjusted 365 day weight	3151	1232.089	105.982	840	1589
Age	3151	392.442	33.252	285	580
Birthweight EPD	3151	3.624	1.969	-5	9.7
Weaning weight EPD	3151	28.291	7.746	-.6	53
Yearling weight EPD	3151	46.331	12.184	4.6	88
Price Ratio	2860	.289	.051	.179	.349
DE Birthweight	3151	99.982	11.359	56.305	137.273
DE Adjusted 205 day weight	3151	99.694	7.39	68.625	125.239
DE Adjusted 365 day weight	3151	99.743	6.52	78.777	133.528
DE Birthweight EPD	3151	99.54	54.262	-167.169	397.466
DE Weaning weight EPD	3151	99.419	22.959	-2.708	184.939
DE Yearling weight EPD	3151	99.595	21.61	10.266	178.575

TableB-3:
Summary Statistic by Decile Group, One Montana Producer
Group 1

	N	Mean	SD	Min	Max
Real Price	174	1836.03	139.71	1266.93	2035.12
Retained Interest	174	.006	.076	0	1
SD of Prices	174	139.71	0	139.71	139.71
Birthweight	174	81.115	8.107	55	105
Adjusted 205 day weight	174	647.316	60.954	504	841
Adjusted 365 day weight	174	1098.58	98.53	864	1365
Age	174	414.017	58.353	89	806
Birthweight EPD	174	3.323	1.116	.6	5.7
Weaning weight EPD	174	34.759	12.812	4.7	64
Yearling weight EPD	174	62.149	21.852	3	104
Price Ratio	157	.253	.059	.179	.448
DE Birthweight	174	99.45	9.559	67.256	120.867
DE Adjusted 205 day weight	174	92.906	7.44	71.565	118.616
DE Adjusted 365 day weight	174	94.429	6.632	76.187	113.568
DE Birthweight EPD	174	102.968	35.353	19.608	186.275
DE Weaning weight EPD	174	90.931	19.695	22.516	138.659
DE Yearling weight EPD	174	94.056	16.995	7.031	130.143

Group 2

Real Price	179	2206.00	103.27	2035.36	2407.64
Retained Interest	179	0	0	0	0
SD of Prices	179	103.27	0	103.27	103.27
Birthweight	179	81.045	7.468	60	100
Adjusted 205 day weight	179	653.592	56.371	510	811
Adjusted 365 day weight	179	1097.397	73.791	933	1342
Age	179	411.816	47.304	95	757
Birthweight EPD	179	3.21	1.301	-.5	7.1
Weaning weight EPD	179	31.163	11.696	9.8	65
Yearling weight EPD	179	53.616	20.064	18	100
Price Ratio	170	.269	.066	.179	.448
DE Birthweight	179	98.544	8.708	73.761	119.532
DE Adjusted 205 day weight	179	94.675	7.237	74.184	111.282
DE Adjusted 365 day weight	179	95.131	5.474	76.223	111.279
DE Birthweight EPD	179	96.053	39.14	-17.553	247.826
DE Weaning weight EPD	179	90.671	19.342	32.341	147.041
DE Yearling weight EPD	179	90.973	17.83	40.475	130.277

Group 3

Real Price	175	2636.01	131.35	2424.27	2860.39
Retained Interest	175	0	0	0	0
SD of Prices	175	131.35	0	131.35	131.35
Birthweight	175	81.897	8.702	60	108
Adjusted 205 day weight	175	671.257	60.525	539	840
Adjusted 365 day weight	175	1118.737	89.407	895	1528
Age	175	414.914	70.695	348	1169
Birthweight EPD	175	3.407	1.308	-1.4	5.7
Weaning weight EPD	175	34.095	11.186	8.7	63
Yearling weight EPD	175	58.893	20.298	13.3	109
Price Ratio	164	.296	.063	.179	.448
DE Birthweight	175	99.365	10.574	71.719	132.48
DE Adjusted 205 day weight	175	96.305	7.329	79.351	116.678
DE Adjusted 365 day weight	175	96.328	6.242	75.449	115.564
DE Birthweight EPD	175	103.116	43.22	-69.782	249.221
DE Weaning weight EPD	175	94.777	18.871	40.444	143.18
DE Yearling weight EPD	175	94.623	18.121	36.147	143.912

Group 4

Real Price	181	3096.95	147.74	2861.88	3374.59
Retained Interest	181	0	0	0	0
SD of Prices	181	147.74	0	147.74	147.74
Birthweight	181	81.713	8.234	60	108
Adjusted 205 day weight	181	681.127	63.321	510	846
Adjusted 365 day weight	181	1137.215	91.875	890	1395
Age	181	423.503	71.44	348	801
Birthweight EPD	181	3.213	1.408	.1	7.1
Weaning weight EPD	181	36.29	11.803	6.4	64
Yearling weight EPD	181	62.448	20.435	13.8	104
Price Ratio	174	.301	.077	.179	.448
DE Birthweight	181	99.317	9.49	70.614	124.32
DE Adjusted 205 day weight	181	97.779	7.923	70.865	115.626
DE Adjusted 365 day weight	181	97.898	6.359	81.523	116.064
DE Birthweight EPD	181	98.37	41.519	3.511	210.642
DE Weaning weight EPD	181	98.203	20.468	30.66	150.424
DE Yearling weight EPD	181	97.497	17.841	37.374	139.415

Group 5

Real Price	174	3610.91	137.20	3392.27	3817.13
Retained Interest	174	0	0	0	0
SD of Prices	174	137.20	0	137.20	137.20
Birthweight	174	82.575	7.135	60	105
Adjusted 205 day weight	174	707.057	62.109	517	855
Adjusted 365 day weight	174	1171.874	97.668	870	1468
Age	174	424.069	72.915	97	815
Birthweight EPD	174	3.305	1.293	-.4	6.8
Weaning weight EPD	174	39.845	11.195	12	73
Yearling weight EPD	174	69.152	19.467	23	123
Price Ratio	169	.304	.076	.179	.448
DE Birthweight	174	100.769	8.488	73.693	127.992
DE Adjusted 205 day weight	174	99.771	7.873	77.411	119.745
DE Adjusted 365 day weight	174	99.395	6.573	72.141	120.566
DE Birthweight EPD	174	102.762	41.826	-26.087	326.087
DE Weaning weight EPD	174	100.948	16.884	31.119	139.436
DE Yearling weight EPD	174	100.99	15.769	41.984	143.912

Group 6

Real Price	180	4047.88	157.64	3821.06	4348.33
Retained Interest	180	.011	.105	0	1
SD of Prices	180	157.64	0	157.64	157.64
Birthweight	180	82.117	6.704	60	98
Adjusted 205 day weight	180	710.156	65.108	485	920
Adjusted 365 day weight	180	1182.694	100	944	1482
Age	180	426.561	69.422	92	807
Birthweight EPD	180	3.137	1.258	-.7	6.3
Weaning weight EPD	180	40.012	13.256	13.6	86
Yearling weight EPD	180	69.083	22.723	24	138
Price Ratio	169	.299	.079	.179	.448
DE Birthweight	180	100.328	7.911	72.197	120.478
DE Adjusted 205 day weight	180	100.011	8.198	69.357	131.895
DE Adjusted 365 day weight	180	100.278	6.596	80.183	121.242
DE Birthweight EPD	180	106.449	44.67	-21.485	319.565
DE Weaning weight EPD	180	101.112	19.929	44.253	162.169
DE Yearling weight EPD	180	100.975	17.322	49.688	151.492

Group 7

Real Price	173	4641.42	177.71	4353.27	4925.95
Retained Interest	173	0	0	0	0
SD of Prices	173	177.71	0	177.71	177.71
Birthweight	173	83.613	7.55	60	102
Adjusted 205 day weight	173	738.647	72.238	568	970
Adjusted 365 day weight	173	1197.549	98.122	973	1478
Age	173	422.249	68.626	91	786
Birthweight EPD	173	3.337	1.387	-1.4	7
Weaning weight EPD	173	40.21	11.591	8.6	67
Yearling weight EPD	173	69.775	20.087	13.9	112
Price Ratio	162	.308	.078	.179	.448
DE Birthweight	173	101.46	8.911	73.138	125.393
DE Adjusted 205 day weight	173	103.602	7.639	83.621	133.692
DE Adjusted 365 day weight	173	101.951	6.701	80.466	122.824
DE Birthweight EPD	173	102.613	40.756	-69.782	215.452
DE Weaning weight EPD	173	104.235	17.026	39.316	150.425
DE Yearling weight EPD	173	104.22	16.395	36.678	140.625

Group 8

Real Price	177	5356.29	255.60	4930.48	5810.17
Retained Interest	177	.068	.252	0	1
SD of Prices	177	255.60	0	255.60	255.60
Birthweight	177	83.141	7.804	60	105
Adjusted 205 day weight	177	724.898	58.471	599	904
Adjusted 365 day weight	177	1207.102	105.875	992	1610
Age	177	423.689	39.438	358	590
Birthweight EPD	177	3.293	1.434	-.4	6.9
Weaning weight EPD	177	37.041	11.343	3	72
Yearling weight EPD	177	63.826	19.897	29	113
Price Ratio	166	.315	.073	.179	.448
DE Birthweight	177	100.625	9.334	73.761	122.934
DE Adjusted 205 day weight	177	104.1	6.48	86.428	121.432
DE Adjusted 365 day weight	177	104.133	6.663	76.532	134.066
DE Birthweight EPD	177	99.045	41.158	-26.087	241.304
DE Weaning weight EPD	177	103.858	19.324	10.759	150.628
DE Yearling weight EPD	177	104.408	16.157	64.105	154.688

Group 9

Real Price	175	6556.19	486.37	5828.37	7597.92
Retained Interest	175	.091	.289	0	1
SD of Prices	175	486.37	0	486.367	486.367
Birthweight	175	83.053	6.994	60	102
Adjusted 205 day weight	175	727.251	56.469	592	895
Adjusted 365 day weight	175	1208.057	99.63	1014	1527
Age	175	421.166	44.442	97	560
Birthweight EPD	175	3.317	1.431	-1.3	6.7
Weaning weight EPD	175	36.819	11.407	4.2	80
Yearling weight EPD	175	62.637	20.16	17	134
Price Ratio	168	.303	.065	.179	.448
DE Birthweight	175	100.714	7.983	73.761	120.043
DE Adjusted 205 day weight	175	104.828	6.759	84.183	126.49
DE Adjusted 365 day weight	175	104.591	5.971	88.838	121.185
DE Birthweight EPD	175	99.194	41.758	-84.783	231.429
DE Weaning weight EPD	175	105.104	19.302	15.409	157.8
DE Yearling weight EPD	175	105.53	17.816	18.662	150.658

Group 10

Real Price	178	13153.04	10415.54	7615.68	89667.28
Retained Interest	178	.382	.487	0	1
SD of Prices	178	10415.54	0	10415.54	10415.54
Birthweight	178	83.522	8.006	60	105
Adjusted 205 day weight	178	747.635	62.882	613	939
Adjusted 365 day weight	178	1236.101	98.235	1033	1551
Age	178	425.989	53.998	104	740
Birthweight EPD	178	3.189	1.724	-1.3	7.3
Weaning weight EPD	178	39.147	11.793	1	78
Yearling weight EPD	178	65.817	18.556	32	117
Price Ratio	173	.304	.06	.179	.448
DE Birthweight	178	101.405	9.184	71.571	125.249
DE Adjusted 205 day weight	178	107.664	7.411	89.828	128.545
DE Adjusted 365 day weight	178	107.184	7.211	84.787	127.995
DE Birthweight EPD	178	94.848	53.707	-84.783	293.478
DE Weaning weight EPD	178	111.421	21.888	2.542	182.043
DE Yearling weight EPD	178	111.174	17.689	63.186	157.403

Table B-4:
Summary Statistics by Decile Group, NE and SD Producers
Group 1

	N	Mean	SD	Min	Max
Real Price	325	2075.93	246.65	1357.07	2454.67
Retained Interest Dummy	325	0	0	0	0
SD of Prices	325	246.65	0	246.65	246.65
Birthweight	325	89.511	9.632	64	115
Adjusted 205 day weight	325	645.292	66.275	471	817
Adjusted 365 day weight	325	1159.138	101.833	840	1435
Age	325	379.858	27.683	289	545
Birthweight EPD	325	3.833	1.843	-1.1	9.7
Weaning weight EPD	325	23.701	7.615	-.6	43
Yearling weight EPD	325	38.171	11.722	6	74
Price Ratio	269	.286	.055	.179	.349
DE Birthweight	325	101.096	10.4	73.243	137.273
DE Adjusted 205 day weight	325	95.564	7.078	74.593	112.444
DE Adjusted 365 day weight	325	94.668	5.653	79.888	112.904
DE Birthweight EPD	325	104.934	48.119	-59.892	310.35
DE Weaning weight EPD	325	90.025	24.552	-2.708	161.599
DE Yearling weight EPD	325	89.261	22.318	17.91	158.254

Group 2

Real Price	322	2744.50	168.48	2462.07	3008.95
Retained Interest Dummy	322	.003	.056	0	1
SD of Prices	322	168.48	0	168.48	168.48
Birthweight	322	88.258	9.546	64	115
Adjusted 205 day weight	322	659.22	67.56	506	851
Adjusted 365 day weight	322	1192.966	87.315	935	1395
Age	322	382.661	28.45	285	554
Birthweight EPD	322	3.729	1.807	-1.4	8.2
Weaning weight EPD	322	25.974	7.251	1.2	44
Yearling weight EPD	322	42.281	11.222	12	76
Price Ratio	263	.273	.062	.179	.349
DE Birthweight	322	100.859	10.582	69.519	129.319
DE Adjusted 205 day weight	322	97.276	7.191	72.131	116.861
DE Adjusted 365 day weight	322	96.967	5.385	78.777	113.442
DE Birthweight EPD	322	101.845	47.707	-48.924	236.867
DE Weaning weight EPD	322	93.99	20.914	3.869	151.942
DE Yearling weight EPD	322	93.917	18.81	23.687	148.352

Group 3

Real Price	330	3239.00	137.20	3018.53	3477.07
Retained Interest Dummy	330	0	0	0	0
SD of Prices	330	137.20	0	137.20	137.20
Birthweight	330	87.021	10.647	50	116
Adjusted 205 day weight	330	659.588	62.231	510	834
Adjusted 365 day weight	330	1192.373	88.016	945	1401
Age	330	392.77	32.404	311	549
Birthweight EPD	330	3.65	1.916	-5	9.2
Weaning weight EPD	330	25.986	6.888	6.3	44
Yearling weight EPD	330	41.939	11.32	4.6	72
Price Ratio	269	.294	.048	.179	.349
DE Birthweight	330	99.403	11.679	60.413	131.608
DE Adjusted 205 day weight	330	97.673	6.392	79.583	115.103
DE Adjusted 365 day weight	330	97.157	5.593	79.694	114.806
DE Birthweight EPD	330	100.334	54.784	-167.169	321.24
DE Weaning weight EPD	330	95.955	21.723	30.823	154.291
DE Yearling weight EPD	330	94.417	21.535	10.266	148.813

Group 4

Real Price	329	3694.25	117.24	3484.05	3885.65
Retained Interest Dummy	329	0	0	0	0
SD of Prices	329	117.24	0	117.24	117.24
Birthweight	329	86.116	10.481	58	121
Adjusted 205 day weight	329	669.447	62.868	500	847
Adjusted 365 day weight	329	1216.83	89.685	936	1462
Age	329	395.456	38.997	286	566
Birthweight EPD	329	3.26	1.786	-1.7	8.2
Weaning weight EPD	329	26.691	7.334	8	53
Yearling weight EPD	329	43.457	11.345	16.6	75
Price Ratio	297	.293	.051	.179	.349
DE Birthweight	329	98.605	11.419	65.53	134.393
DE Adjusted 205 day weight	329	98.629	6.577	82.279	116.492
DE Adjusted 365 day weight	329	98.125	5.434	78.861	120.219
DE Birthweight EPD	329	91.535	49.543	-65.337	245.326
DE Weaning weight EPD	329	95.179	21.983	30.248	165.858
DE Yearling weight EPD	329	95.264	20.665	36.637	156.043

Group 5

Real Price	321	4116.62	151.29	3890.28	4385.56
Retained Interest Dummy	321	.003	.056	0	1
SD of Prices	321	151.29	0	151.29	151.29
Birthweight	321	86.349	10.033	52	115
Adjusted 205 day weight	321	664.442	64.897	496	839
Adjusted 365 day weight	321	1220.103	91.655	939	1428
Age	321	392.648	36.24	305	560
Birthweight EPD	321	3.582	1.984	-1.5	9
Weaning weight EPD	321	27.61	7.015	7	49
Yearling weight EPD	321	45.54	10.724	17	81
Price Ratio	294	.298	.044	.179	.349
DE Birthweight	321	98.821	11.27	60.406	130.382
DE Adjusted 205 day weight	321	98.922	7.102	75.06	123.929
DE Adjusted 365 day weight	321	99.076	5.793	79.114	116.053
DE Birthweight EPD	321	97.912	55.268	-50.531	359.353
DE Weaning weight EPD	321	97.757	21.738	28.862	156.678
DE Yearling weight EPD	321	98.391	21.289	45.4	163.575

Group 6

Real Price	328	4631.23	131.38	4409.95	4885.46
Retained Interest Dummy	328	.003	.055	0	1
SD of Prices	328	131.38	0	131.38	131.38
Birthweight	328	86.463	10.858	60	118
Adjusted 205 day weight	328	676.884	69.589	494	843
Adjusted 365 day weight	328	1236.317	100.504	935	1585
Age	328	394.076	34.906	294	561
Birthweight EPD	328	3.58	2.031	-1.9	9.2
Weaning weight EPD	328	27.673	6.953	8.1	44
Yearling weight EPD	328	46.052	10.727	18	73
Price Ratio	312	.293	.048	.179	.349
DE Birthweight	328	99.711	11.798	69.479	132.908
DE Adjusted 205 day weight	328	99.716	7.025	78.426	120.75
DE Adjusted 365 day weight	328	100.297	6.275	83.493	133.528
DE Birthweight EPD	328	99.348	57.999	-60.897	397.466
DE Weaning weight EPD	328	97.809	22.554	39.63	174.892
DE Yearling weight EPD	328	99.526	20.802	49.417	165.665

Group 7

Real Price	329	5174.02	172.05	4895.23	5462.35
Retained Interest Dummy	329	.006	.078	0	1
SD of Prices	329	172.05	0	172.05	172.05
Birthweight	329	87.41	10.43	62	114
Adjusted 205 day weight	329	674.103	64.719	452	880
Adjusted 365 day weight	329	1237.629	93.034	984	1480
Age	329	391.535	29.126	301	556
Birthweight EPD	329	3.576	2.112	-1.7	8.7
Weaning weight EPD	329	29.106	7.19	4.5	51
Yearling weight EPD	329	48.148	10.779	14.4	82
Price Ratio	316	.289	.05	.179	.349
DE Birthweight	329	100.665	11.127	72.022	127.276
DE Adjusted 205 day weight	329	100.206	7.235	68.625	125.216
DE Adjusted 365 day weight	329	100.594	5.655	80.576	121.412
DE Birthweight EPD	329	101.685	60.972	-54.008	348.464
DE Weaning weight EPD	329	100.734	22.946	20.656	182.815
DE Yearling weight EPD	329	101.793	20.368	42.983	161.907

Group 8

Real Price	319	5905.07	239.60	5462.71	6334.63
Retained Interest Dummy	319	.028	.166	0	1
SD of Prices	319	239.60	0	239.60	239.60
Birthweight	319	86.978	11.058	50	119
Adjusted 205 day weight	319	698.364	62.558	522	912
Adjusted 365 day weight	319	1271.69	98.454	981	1488
Age	319	394.549	30.579	297	559
Birthweight EPD	319	3.676	2.06	-2.9	9.1
Weaning weight EPD	319	31.024	7.082	14	50
Yearling weight EPD	319	50.759	10.868	18	77
Price Ratio	303	.291	.05	.179	.349
DE Birthweight	319	100.049	11.964	57.619	127.955
DE Adjusted 205 day weight	319	101.872	6.812	81.213	123.756
DE Adjusted 365 day weight	319	102.412	5.992	87.118	119.435
DE Birthweight EPD	319	100.877	56.259	-69.725	272.237
DE Weaning weight EPD	319	106.31	22.182	47.757	176.795
DE Yearling weight EPD	319	106.4	21.357	48.539	174.321

Group 9

Real Price	329	7032.04	440.48	6360.50	7862.04
Retained Interest Dummy	329	.073	.26	0	1
SD of Prices	329	440.48	0	440.48	440.48
Birthweight	329	86.103	10.925	50	113
Adjusted 205 day weight	329	714.134	69.385	510	920
Adjusted 365 day weight	329	1287.799	100.528	1019	1537
Age	329	397.787	31.64	319	545
Birthweight EPD	329	3.699	2.116	-2	8.8
Weaning weight EPD	329	32.537	7.168	13	50
Yearling weight EPD	329	52.965	10.904	24.6	81
Price Ratio	324	.285	.051	.179	.349
DE Birthweight	329	99.563	12.21	56.305	132.553
DE Adjusted 205 day weight	329	103.616	6.603	79.77	119.93
DE Adjusted 365 day weight	329	104.041	5.768	88.427	125.951
DE Birthweight EPD	329	98.082	56.088	-70.782	294.217
DE Weaning weight EPD	329	108.465	21.701	42.016	177.293
DE Yearling weight EPD	329	108.189	19.723	63.098	166.556

Group 10

Real Price	327	12196.92	7166.17	7918.29	72377.20
Retained Interest Dummy	327	.214	.411	0	1
SD of Prices	327	7166.17	0	7166.17	7166.17
Birthweight	327	87.716	9.43	56	116
Adjusted 205 day weight	327	742.248	66.365	531	925
Adjusted 365 day weight	327	1352.208	95.421	1063	1589
Age	327	402.349	35.698	288	580
Birthweight EPD	327	3.7	1.917	-1.6	8.2
Weaning weight EPD	327	35.007	6.709	3.7	53
Yearling weight EPD	327	57.732	10.374	5	88
Price Ratio	319	.283	.05	.179	.349
DE Birthweight	327	101.262	10.556	63.061	132.128
DE Adjusted 205 day weight	327	105.627	7.022	85.297	125.239
DE Adjusted 365 day weight	327	106.995	5.902	90.359	127.222
DE Birthweight EPD	327	97.511	50.63	-38.06	332.129
DE Weaning weight EPD	327	111.613	20.668	11.78	184.939
DE Yearling weight EPD	327	112.492	19.088	9.783	178.575

APPENDIX C

ADDITIONAL RESULTS FROM THE BINARY CHOICE MODEL

This appendix provides additional results from the binary choice model, discussed in the first section of chapter seven. Results from the linear probability models are shown in tables C-1 and C-2. Results from the logit regressions when bulls are split into more groups, rather than just ten decile groups, are presented in tables C-3 through C-6. Results from other robustness checks, such as using winsorized data, using coefficient of variation as a proxy, and using standardized data, are presented in tables C-7 through C-12. Results from additional regressions, including price or farm reputation proxies are presented in tables C-13 through C-15. The results from the tobit model and ordered logit model are presented in tables C-16 through C-19.

Table C-1: Linear Probability Model Results for the One Montana Producer

VARIABLES	(1) Bins	(2) Decile	(3) Decile	(4) SD of Prices	(5) SD of Prices
Group 2	-0.00639 (0.0214)				
Group 3	-0.0113 (0.0215)				
Group 4	-0.0127 (0.0214)				
Group 5	-0.0205 (0.0220)				
Group 6	-0.0106 (0.0219)				
Group 7	-0.0282 (0.0227)				
Group 8	0.0350 (0.0226)				
Group 9	0.0586** (0.0228)				
Group 10	0.345*** (0.0234)				
Decile Group		0.0233*** (0.00211)	-0.0593*** (0.00647)		
Decile Group Squared			0.00911*** (0.000678)		
SD of Prices				3.35e-05*** (1.62e-06)	0.000225*** (5.06e-05)
SD of Prices Squared					-1.80e-08*** (4.75e-09)
Birthweight	0.000618 (0.000762)	0.000575 (0.000824)	0.000709 (0.000785)	0.000653 (0.000761)	0.000542 (0.000759)
Adjusted 205 day weight	1.44e-06 (0.000103)	-9.21e-05 (0.000111)	-1.00e-05 (0.000106)	1.59e-05 (9.91e-05)	-3.57e-05 (9.96e-05)
Adjusted 365 day weight	0.000277*** (6.77e-05)	0.000326*** (7.30e-05)	0.000283*** (6.96e-05)	0.000323*** (6.64e-05)	0.000280*** (6.71e-05)
Age	-4.01e-05 (8.01e-05)	-5.51e-05 (8.66e-05)	-2.04e-05 (8.26e-05)	-4.71e-05 (8.03e-05)	-4.40e-05 (8.00e-05)

Table C-1 (continued): Linear Probability Model Results for the One Montana Producer

Birthweight EPD	0.00566 (0.00427)	0.00456 (0.00461)	0.00449 (0.00440)	0.00554 (0.00427)	0.00578 (0.00426)
Weaning Weight EPD	-0.00224* (0.00124)	-0.00134 (0.00134)	-0.00149 (0.00128)	-0.00219* (0.00124)	-0.00219* (0.00124)
Yearling Weight EPD	0.000761 (0.000717)	1.15e-05 (0.000770)	0.000373 (0.000734)	0.000520 (0.000713)	0.000704 (0.000712)
Constant	-0.322*** (0.0894)	-0.355*** (0.0957)	-0.292*** (0.0913)	-0.377*** (0.0846)	-0.332*** (0.0851)
Observations	1,766	1,766	1,766	1,766	1,766
R-squared	0.257	0.125	0.206	0.248	0.254

Standard errors in parentheses

*** p<0.01, ** p<0.05, * p<0.1

Table C-2: Linear Probability Model Results for the Nebraska and South Dakota Producers

VARIABLES	(1) Bins	(2) Decile	(3) Decile	(4) SD of Prices	(5) SD of Prices
Group 2	-0.00363 (0.0132)				
Group 3	-0.00484 (0.0131)				
Group 4	-0.00912 (0.0134)				
Group 5	-0.00716 (0.0134)				
Group 6	-0.00999 (0.0135)				
Group 7	-0.00698 (0.0135)				
Group 8	0.00813 (0.0140)				
Group 9	0.0494*** (0.0142)				
Group 10	0.181*** (0.0152)				
Decile Group		0.0109*** (0.00128)	-0.0319*** (0.00383)		
Decile Group Squared			0.00485*** (0.000409)		
SD of Prices				2.51e-05*** (1.54e-06)	0.000189*** (3.59e-05)
SD of Prices Squared					-2.22e-08*** (4.85e-09)
Birthweight	-0.000953** (0.000403)	-0.000757* (0.000414)	-0.000955** (0.000406)	-0.00102** (0.000402)	-0.000989** (0.000401)
Adjusted 205 day weight	3.53e-05 (6.07e-05)	9.45e-05 (6.23e-05)	4.24e-05 (6.12e-05)	5.73e-05 (6.06e-05)	3.88e-05 (6.05e-05)
Adjusted 365 day weight	0.000189*** (4.26e-05)	0.000221*** (4.38e-05)	0.000214*** (4.29e-05)	0.000201*** (4.20e-05)	0.000193*** (4.19e-05)
Age	-0.000300*** (9.08e-05)	-0.000267*** (9.32e-05)	-0.000247*** (9.12e-05)	-0.000276*** (8.98e-05)	-0.000286*** (8.96e-05)

Table C-2 (cont.): LPM Results for the Nebraska and South Dakota Producers

Birthweight EPD	0.00133 (0.00225)	-0.000309 (0.00231)	0.000437 (0.00226)	0.000885 (0.00224)	0.00119 (0.00223)
Weaning Weight EPD	0.000691 (0.000806)	0.000753 (0.000831)	0.000657 (0.000813)	0.000838 (0.000807)	0.000724 (0.000805)
Yearling Weight EPD	-0.000467 (0.000513)	-0.000228 (0.000528)	-0.000336 (0.000517)	-0.000335 (0.000509)	-0.000441 (0.000508)
Constant	-0.0459 (0.0580)	-0.193*** (0.0586)	-0.0796 (0.0582)	-0.0910 (0.0567)	-0.0932* (0.0565)
Observations	3,259	3,259	3,259	3,259	3,259
R-squared	0.142	0.086	0.124	0.136	0.142

Standard errors in parentheses

*** p<0.01, ** p<0.05, * p<0.1

Table C-3: Comparison of Logit Results When Bulls Are Ranked Into More Groups, One Montana Producer

VARIABLES	(1) 10 Groups	Marginal Effects	(2) 20 Groups	Marginal Effects	(3) 50 Groups	Marginal Effects	(4) 100 Groups	Marginal Effects
Group	1.125*** (0.126)	0.0202	0.617*** (0.0670)	0.0100	0.248*** (0.0269)	0.0081	0.124*** (0.0134)	0.0076
Birthweight	0.0290 (0.0196)		0.0317 (0.0200)		0.0314 (0.0201)		0.0314 (0.0201)	
Adjusted 205 day weight	-0.000382 (0.00264)		-0.000851 (0.00270)		-0.00105 (0.00272)		-0.00102 (0.00272)	
Adjusted 365 day weight	0.00618*** (0.00161)	0.00049	0.00569*** (0.00165)	0.00079	0.00568*** (0.00166)	0.00080	0.00566*** (0.00166)	0.00082
Age	-0.000863 (0.00238)		-0.000342 (0.00240)		-0.000815 (0.00241)		-0.000704 (0.00241)	
Birthweight EPD	0.0711 (0.0972)		0.0622 (0.0985)		0.0565 (0.0991)		0.0550 (0.0992)	
Weaning Weight EPD	-0.0440* (0.0257)	-0.0734	-0.0433* (0.0259)	-0.0735	-0.0450* (0.0259)	-0.0732	-0.0448* (0.0260)	-0.0733
Yearling Weight EPD	0.0169 (0.0158)		0.0192 (0.0161)		0.0207 (0.0161)		0.0204 (0.0162)	
Constant	-19.87*** (2.792)		-20.75*** (2.871)		-20.62*** (2.872)		-20.72*** (2.871)	
Observations	1,766		1,766		1,766		1,766	

Standard errors in parentheses

*** p<0.01, ** p<0.05, * p<0.1

Table C-4: Comparison of Logit Results When Bulls Are Ranked Into More Groups, Nebraska and South Dakota Producers

VARIABLES	(1) 10 Groups	Marignal Effects	(2) 20 Groups	Marignal Effects	(3) 50 Groups	Marignal Effects	(4) 100 Groups	Marignal Effects
Group	0.842*** (0.110)	0.0188	0.477*** (0.0598)	0.029	0.202*** (0.0248)	0.0206	0.102*** (0.0125)	0.0186
Birthweight	-0.0212 (0.0142)		-0.0209 (0.0145)		-0.0214 (0.0146)		-0.0209 (0.0146)	
Adjusted 205 day weight	0.000405 (0.00240)		-4.03e-05 (0.00242)		-0.000206 (0.00241)		-0.000255 (0.00242)	
Adjusted 365 day weight	0.00733*** (0.00180)	0.000094	0.00675*** (0.00182)	0.00017	0.00650*** (0.00182)	0.00023	0.00646*** (0.00182)	0.00023
Age	-0.00878*** (0.00339)	-0.0047	-0.00947*** (0.00339)	-0.0073	-0.00996*** (0.00340)	-0.0064	-0.00999*** (0.00340)	-0.0064
Birthweight EPD	-0.0226 (0.0795)		-0.00188 (0.0805)		0.00954 (0.0812)		0.00926 (0.0812)	
Weaning Weight EPD	0.0196 (0.0305)		0.0216 (0.0304)		0.0202 (0.0301)		0.0203 (0.0302)	
Yearling Weight EPD	-0.0111 (0.0191)		-0.0159 (0.0192)		-0.0158 (0.0190)		-0.0159 (0.0190)	
Constant	-13.88*** (2.311)		-13.58*** (2.333)		-13.51*** (2.346)		-13.60*** (2.349)	
Observations	3,259		3,259		3,259		3,259	

Standard errors in parentheses

*** p<0.01, ** p<0.05, * p<0.1

Table C-5: Comparison of Logit Results When Bulls Are Ranked Into More Groups, One Montana Producer

VARIABLES	(1) 10 Groups	Marginal Effects	(2) 20 Groups	Marginal Effects	(3) 50 Groups	Marginal Effects	(4) 100 Groups	Marginal Effects
SD of Prices	0.000264*** (2.48e-05)	0.2263	0.000275*** (2.24e-05)	0.1928	0.000237*** (2.81e-05)	0.1368	0.000312*** (8.29e-05)	0.145697
Birthweight	0.0396** (0.0193)	0.1679	0.0410** (0.0205)	0.0101	0.0448** (0.0191)	0.0082	0.0416** (0.0190)	0.009792
Adjusted 205 day weight	0.00349 (0.00249)		0.00389 (0.00262)		0.00550** (0.00242)	0.0079	0.00548** (0.00233)	0.007535
Adjusted 365 day weight	0.00709*** (0.00158)	0.0001	0.00706*** (0.00169)	0.0002	0.00833*** (0.00156)	0.0001	0.00829*** (0.00153)	0.0001
Age	-0.00139 (0.00205)		-0.000316 (0.00194)		-0.00152 (0.00184)		-0.00111 (0.00176)	
Birthweight EPD	0.0803 (0.0972)		0.0734 (0.106)		0.0365 (0.101)		0.0177 (0.100)	
Weaning Weight EPD	-0.0460* (0.0262)	-0.0709	-0.0443 (0.0298)		-0.0317 (0.0285)		-0.0254 (0.0282)	
Yearling Weight EPD	0.00868 (0.0158)		0.00678 (0.0178)		-0.00727 (0.0164)		-0.00977 (0.0161)	
Constant	-16.63*** (2.451)		-17.19*** (2.528)		-18.73*** (2.362)		-18.44*** (2.283)	
Observations	1,766		1,766		1,766		1,766	

Standard errors in parentheses

*** p<0.01, ** p<0.05, * p<0.1

Table C-5: Comparison of Logit Results When Bulls Are Ranked Into More Groups, Nebraska and South Dakota Producers

VARIABLES	(1) 10 Groups	(2) 10 Groups	(3) 20 Groups	(4) 20 Groups	(5) 50 Groups	(6) 50 Groups	(7) 100 Groups	(8) 100 Groups
SD of Prices	0.000290*** (3.69e-05)	0.202	0.000246*** (3.04e-05)	0.117	0.000192*** (3.00e-05)	0.074	0.000233*** (3.83e-05)	0.066
Birthweight	-0.0271* (0.0142)	-0.025	-0.0258* (0.0143)	-0.023	-0.0282** (0.0139)	-0.021	-0.0239* (0.0139)	-0.024
Adjusted 205 day weight	0.00138 (0.00238)		0.00124 (0.00245)		0.00197 (0.00240)		0.00208 (0.00238)	
Adjusted 365 day weight	0.00860*** (0.00180)	0.000035	0.00892*** (0.00182)	0.000016	0.00995*** (0.00176)	0.0000049	0.0106*** (0.00174)	0.0000023
Age	-0.00811** (0.00335)	-0.0048	-0.00874*** (0.00336)	-0.0088	-0.00854** (0.00333)	-0.0093	-0.00796** (0.00327)	-0.0105
Birthweight EPD	-0.0443 (0.0795)		-0.0433 (0.0810)		-0.0747 (0.0796)		-0.0868 (0.0793)	
Weaning Weight EPD	0.0313 (0.0307)		0.0411 (0.0317)		0.0359 (0.0313)		0.0312 (0.0321)	
Yearling Weight EPD	-0.00347 (0.0190)		-0.00495 (0.0197)		0.00755 (0.0194)		0.0148 (0.0197)	
Constant	-11.37*** (2.300)		-11.53*** (2.265)		-13.40*** (2.213)		-14.98*** (2.145)	
Observations	3,259		3,259		3,259		3,193	

Standard errors in parentheses

*** p<0.01, ** p<0.05, * p<0.1

Table C-7: Logit Results with Winsorized SD of Prices, One Montana Producer

VARIABLES	(1) Winsorized SD	Marginal Effects	(2) Winsorized SD	Marginal Effects
Winsorized SD of Prices	0.00892*** (0.000693)	0.2291	0.0191*** (0.00358)	0.3373
Winsorized SD of Prices Squared			-1.87e-05*** (6.34e-06)	-0.2546
Birthweight	0.0424** (0.0207)	0.0094	0.0375* (0.0206)	0.0121
Adjusted 205 day weight	0.000994 (0.00272)		0.000105 (0.00276)	
Adjusted 365 day weight	0.00652*** (0.00171)	0.00035	0.00642*** (0.00171)	0.00038
Age	-0.000644 (0.00216)		-0.000686 (0.00223)	
Birthweight EPD	0.0491 (0.105)		0.0520 (0.104)	
Weaning Weight EPD	-0.0562** (0.0268)	-0.0676	-0.0522** (0.0266)	-0.0702
Yearling Weight EPD	0.0211 (0.0167)		0.0205 (0.0166)	
Constant	-15.58*** (2.599)		-15.16*** (2.607)	
Observations	1,766		1,766	

Standard errors in parentheses

*** p<0.01, ** p<0.05, * p<0.1

Table C-8: Logit Results with Winsorized SD of Prices, Nebraska and South Dakota Producers

VARIABLES	(1) Winsorized SD	Marginal Effects	(2) Winsorized SD	Marginal Effects
Winsorized SD of Prices	0.00715*** (0.000745)	0.1640	0.0171*** (0.00412)	0.2963
Winsorized SD of Prices Squared			-2.05e-05** (8.30e-06)	-0.2151
Birthweight	-0.0252* (0.0147)	-0.0235	-0.0247* (0.0146)	-0.0238
Adjusted 205 day weight	0.000837 (0.00244)		0.000680 (0.00243)	
Adjusted 365 day weight	0.00763*** (0.00184)	0.00007	0.00738*** (0.00184)	0.00009
Age	-0.00996*** (0.00342)	-0.0064	-0.00968*** (0.00341)	-0.0069
Birthweight EPD	-0.0121 (0.0823)		-0.0101 (0.0817)	
Weaning Weight EPD	0.0343 (0.0305)		0.0294 (0.0304)	
Yearling Weight EPD	-0.00904 (0.0187)		-0.00958 (0.0187)	
Constant	-9.435*** (2.326)		-9.506*** (2.333)	
Observations	3,259		3,259	

Standard errors in parentheses

*** p<0.01, ** p<0.05, * p<0.1

Table C-9: Logit Results Using Coefficient of Variation
as Proxy for Uncertainty, One Montana Producer

VARIABLES	(1)	Marginal Effects
Coefficient of Variation	3.337*** (0.312)	0.1983
Birthweight	0.0397** (0.0193)	0.0108
Adjusted 205 day weight	0.00352 (0.00249)	
Adjusted 365 day weight	0.00710*** (0.00158)	0.00019
Age	-0.00139 (0.00205)	
Birthweight EPD	0.0803 (0.0973)	
Weaning Weight EPD	-0.0461* (0.0262)	-0.0729
Yearling Weight EPD	0.00877 (0.0158)	
Constant	-16.76*** (2.449)	
Observations	1,766	

Standard errors in parentheses

*** p<0.01, ** p<0.05, * p<0.1

Table C-10: Logit Results Using Coefficient of Variation as Proxy for Uncertainty, Nebraska and South Dakota Producers

VARIABLES	(1)	Marginal Effects
Coefficient of Variation	3.674*** (0.472)	0.1446***
Birthweight	-0.0273* (0.0141)	-0.0219*
Adjusted 205 day weight	0.00138 (0.00238)	
Adjusted 365 day weight	0.00870*** (0.00180)	0.0000199***
Age	-0.00801** (0.00335)	-0.00801**
Birthweight EPD	-0.0468 (0.0794)	
Weaning Weight EPD	0.0316 (0.0308)	
Yearling Weight EPD	-0.00282 (0.0190)	
Constant	-11.67*** (2.283)	
Observations	3,259	

Standard errors in parentheses

*** p<0.01, ** p<0.05, * p<0.1

Table C-11: Standardized Coefficients for Logit Regression, One Montana Producer

VARIABLES	(1) Modified Bins	(2) Decile	(3) Decile	(4) SD of Prices	(5) SD of Prices
Mid Group	2.153** (1.044)				
High Group	4.738*** (1.019)				
Decile Group		3.231*** (0.361)	1.541*** (0.363)		
Decile Group Squared			1.007*** (0.241)		
SD of Prices				0.937*** (0.0792)	18.83*** (3.175)
SD of Prices Squared					-6.673*** (1.174)
Birthweight	0.254* (0.147)	0.224 (0.151)	0.227 (0.154)	0.230 (0.152)	0.232 (0.154)
Adjusted 205 day weight	0.0974 (0.179)	-0.0269 (0.186)	-0.0386 (0.190)	0.123 (0.181)	-0.00319 (0.189)
Adjusted 365 day weight	0.713*** (0.169)	0.657*** (0.171)	0.686*** (0.175)	0.819*** (0.171)	0.722*** (0.176)
Age	-0.0205 (0.134)	-0.0526 (0.145)	-0.0642 (0.145)	-0.0854 (0.130)	-0.0669 (0.141)
Birthweight EPD	0.0865 (0.131)	0.0977 (0.133)	0.105 (0.136)	0.117 (0.138)	0.107 (0.136)
Weaning Weight EPD	-0.493 (0.308)	-0.533* (0.312)	-0.591* (0.321)	-0.618* (0.330)	-0.616* (0.324)
Yearling Weight EPD	0.207 (0.318)	0.353 (0.330)	0.415 (0.340)	0.275 (0.346)	0.407 (0.342)
Constant	-4.640*** (0.424)	-6.153*** (0.495)	-5.832*** (0.389)	-3.905*** (0.194)	2.280** (1.027)
Observations	1,766	1,766	1,766	1,766	1,766

Standard errors in parentheses

*** p<0.01, ** p<0.05, * p<0.1

Table C-12: Standardized Coefficients of Logit Regressions, Nebraska and South Dakota Producers

VARIABLES	(1) Modified Bins	(2) Decile	(3) Decile	(4) SD of Prices	(5) SD of Prices
Mid Group	2.129** (1.043)				
High Group	4.298*** (1.024)				
Decile Group		2.419*** (0.317)	1.616*** (0.452)		
Decile Group Squared			0.494* (0.268)		
SD of Prices				0.608*** (0.0772)	15.16*** (2.487)
SD of Prices Squared					-5.371*** (0.909)
Birthweight	-0.178 (0.144)	-0.219 (0.147)	-0.229 (0.148)	-0.281* (0.147)	-0.226 (0.147)
Adjusted 205 day weight	0.0415 (0.169)	0.0289 (0.171)	0.0230 (0.171)	0.0981 (0.170)	0.0185 (0.171)
Adjusted 365 day weight	0.895*** (0.193)	0.794*** (0.195)	0.780*** (0.196)	0.932*** (0.195)	0.828*** (0.197)
Age	-0.260** (0.112)	-0.293*** (0.113)	-0.301*** (0.113)	-0.270** (0.112)	-0.288** (0.113)
Birthweight EPD	-0.121 (0.154)	-0.0443 (0.156)	-0.0301 (0.157)	-0.0870 (0.156)	-0.0552 (0.157)
Weaning Weight EPD	0.168 (0.243)	0.153 (0.239)	0.159 (0.238)	0.245 (0.241)	0.175 (0.239)
Yearling Weight EPD	-0.0677 (0.239)	-0.137 (0.235)	-0.148 (0.235)	-0.0428 (0.234)	-0.113 (0.234)
Constant	-5.743*** (0.504)	-6.074*** (0.403)	-5.926*** (0.349)	-4.512*** (0.188)	0.392 (0.778)
Observations	3,259	3,259	3,259	3,259	3,259

Standard errors in parentheses

*** p<0.01, ** p<0.05, * p<0.1

Table C-13: Logit Results with Real Price Included, One Montana Producer

VARIABLES	(1) Modified Bins	Marginal Effects	(2) Decile	Marginal Effects	(3) Decile	Marginal Effects	(4) SD of Prices	Marginal Effects	(5) SD of Prices	Marginal Effects
Mid Group	1.834* (1.047)	0.1289								
High Group	3.285*** (1.056)	0.7512								
Decile Group			0.706*** (0.134)	0.0779	-0.119 (0.430)	-0.0797				
Decile Group Squared					0.0647* (0.0350)	0.2052				
SD of Prices							0.000148*** (4.01e-05)	0.1127	0.00656*** (0.00139)	0.0066
SD of Prices Squared									-5.95e-07*** (1.28e-07)	-0.0282
Real Price	0.000231*** (3.96e-05)	0.1936	0.000169*** (3.84e-05)	0.1650	0.000149*** (3.82e-05)	0.1502	0.000226*** (4.82e-05)	0.1965	0.000167*** (4.19e-05)	0.1636
Birthweight	0.0384* (0.0213)	0.0102	0.0352* (0.0213)	0.0135	0.0349 (0.0214)		0.0369* (0.0213)	0.0124	0.0368* (0.0214)	0.0125
Adjusted 205 day weight	-0.000930 (0.00277)		-0.00176 (0.00281)		-0.00175 (0.00283)		0.000156 (0.00274)		-0.00112 (0.00281)	
Adjusted 365 day weight	0.00537*** (0.00172)	0.0023	0.00521*** (0.00170)	0.0013	0.00541*** (0.00172)	0.0010	0.00632*** (0.00171)	0.0004	0.00559*** (0.00173)	0.0009
Age	-0.00101 (0.00233)		-0.00120 (0.00242)		-0.00126 (0.00243)		-0.00139 (0.00223)		-0.00116 (0.00236)	

Table C-13 (cont): Logit Results with Real Price Included, One Montana Producer

Birthweight EPD	0.0434 (0.106)	0.0497 (0.106)	0.0543 (0.106)	0.0638 (0.108)	0.0522 (0.106)
Weaning Weight EPD	-0.0456* (0.0267)	-0.0719 (0.0267)	-0.0728 (0.0270)	-0.0498* (0.0274)	-0.0715 (0.0270)
Yearling Weight EPD	0.0225 (0.0165)	0.0255 (0.0167)	0.0268 (0.0168)	0.0209 (0.0169)	0.0261 (0.0167)
Constant	-15.31*** (2.818)	-16.52*** (2.846)	-14.25*** (2.930)	-14.79*** (2.627)	-14.91*** (2.716)
Observations	1,766	1,766	1,766	1,766	1,766

Standard errors in parentheses

*** p<0.01, ** p<0.05, * p<0.1

Table C-14: Logit Results with Price Included, Nebraska and South Dakota Producers

VARIABLES	(1) Marginal Effects	(2) Decile	(3) Decile	(4) Marginal Effects	(5) SD of Prices	Marginal Effects
Mid Group	1.996* (1.043)					
High Group	3.650*** (1.036)					
Decile Group		0.632*** (0.111)	0.378 (0.501)			
Decile Group Squared			0.0193 (0.0379)			
SD of Prices				0.000163*** (4.61e-05)	0.00857*** (0.00157)	0.0081
SD of Prices Squared					-1.12e-06*** (2.08e-07)	-0.0506
Real Price	0.000124*** (2.27e-05)	0.1007 (2.31e-05)	0.000101*** (2.37e-05)	0.0844 (2.63e-05)	0.000113*** (2.49e-05)	0.0932
Birthweight	-0.0191 (0.0149)	-0.0222 (0.0150)	-0.0225 (0.0150)	-0.0257* (0.0150)	-0.0209 (0.0149)	
Adjusted 205 day weigh	-0.000703 (0.00246)	-0.000650 (0.00247)	-0.000659 (0.00247)	0.000145 (0.00246)	-0.000855 (0.00247)	
Adjusted 365 day weigh	0.00692*** (0.00184)	0.00649*** (0.00184)	0.00646*** (0.00185)	0.00024 (0.00186)	0.00692*** (0.00186)	0.00014
Age	-0.0108*** (0.00344)	-0.0110*** (0.00345)	-0.0110*** (0.00346)	-0.0048 (0.00343)	-0.0108*** (0.00346)	-0.0050

Table C-14 (cont): Logit Results with Price Included, Nebraska and South Dakota Producers

Birthweight EPD	0.00844 (0.0839)	0.0273 (0.0839)	0.0291 (0.0840)	0.00181 (0.0844)	0.0154 (0.0842)
Weaning Weight EPD	0.0217 (0.0316)	0.0206 (0.0311)	0.0208 (0.0310)	0.0295 (0.0317)	0.0218 (0.0312)
Yearling Weight EPD	-0.00822 (0.0198)	-0.0115 (0.0195)	-0.0118 (0.0195)	-0.00359 (0.0196)	-0.00863 (0.0195)
Constant	-9.927*** (2.539)	-10.51*** (2.423)	-9.636*** (2.935)	-9.368*** (2.383)	-9.604*** (2.421)
Observations	3,259	3,259	3,259	3,259	3,259

Standard errors in parentheses

*** p<0.01, ** p<0.05, * p<0.1

Table C-15: Logit Results When Farm Reputation Proxies Are Included, Nebraska and South Dakota Producers

VARIABLES	(1) Modified Bins	Marginal Effects	(2) Decile	Marginal Effects	(3) Decile	Marginal Effects	(4) SD of Prices	Marginal Effects	(5) SD of Prices	Marginal Effects
Mid Group	2.119** (1.043)	0.3269								
High Group	4.353*** (1.027)	1.0338								
Decile Group			0.887*** (0.115)	0.0452	-0.0386 (0.426)	-0.0275				
Decile Group Squared					0.0677** (0.0324)	0.2013				
SD of Prices							0.000300*** (3.80e-05)	0.1543	0.00970*** (0.00157)	0.0033
SD of Prices Squared								-1.26e-06*** (2.09e-07)	-0.000154*** (4.73e-05)	-0.0281
Farm Reputation	-0.000137*** (4.61e-05)	-0.0966	-0.000147*** (4.59e-05)	-0.0996	-0.000152*** (4.64e-05)	-0.1010	-0.000149*** (4.88e-05)	-0.1004	-0.000154*** (4.73e-05)	-0.1016
Birthweight	-0.0110 (0.0146)		-0.0136 (0.0149)		-0.0143 (0.0151)		-0.0202 (0.0148)		-0.0143 (0.0150)	
Adjusted 205 day weight	0.00333 (0.00255)		0.00337 (0.00256)		0.00340 (0.00257)		0.00413 (0.00257)		0.00344 (0.00258)	
Adjusted 365 day weight	0.00712*** (0.00187)	0.00012	0.00581*** (0.00190)	0.0005	0.00558*** (0.00191)	0.0006	0.00754*** (0.00191)	0.00007	0.00607*** (0.00192)	0.0004
Age	-0.00559 (0.00363)		-0.00647* (0.00366)	-0.0146	-0.00663* (0.00367)	-0.0142	-0.00558 (0.00365)	-0.00617* (0.00367)	-0.00617* (0.00367)	-0.0154

Table C-15 (cont): Logit Results When Farm Reputation Proxies Are Included, Nebraska and South Dakota Producers

Birthweight EPD	-0.0981 (0.0812)	-0.0601 (0.0822)	-0.0539 (0.0828)	-0.0854 (0.0825)	-0.0676 (0.0828)
Weaning Weight EPD	0.00961 (0.0309)	0.00777 (0.0301)	0.00797 (0.0299)	0.0173 (0.0304)	0.00842 (0.0299)
Yearling Weight EPD	-0.00250 (0.0194)	-0.00838 (0.0190)	-0.00921 (0.0190)	0.00119 (0.0188)	-0.00569 (0.0188)
Constant	-13.86*** (2.517)	-14.50*** (2.419)	-11.09*** (2.829)	-12.18*** (2.426)	-11.99*** (2.454)
Observations	3,259	3,259	3,259	3,259	3,259

Standard errors in parentheses

*** p<0.01, ** p<0.05, * p<0.1

Table C-16: Tobit Model Results, One Montana Producer

VARIABLES	(1) Modified Bins	(2) Decile	(3) Decile	(4) SD of Prices	(5) SD of Prices
Mid Group	0.361** (0.169)				
High Group	1.012*** (0.181)				
Decile Group		0.225*** (0.0284)	-0.177*** (0.0579)		
Decile Group Squared			0.0312*** (0.00550)		
SD of Prices				7.45e-05*** (8.05e-06)	0.00167*** (0.000302)
SD of Prices Squared					-1.49e-07*** (2.79e-08)
Birthweight	0.00792 (0.00487)	0.00749 (0.00479)	0.00753 (0.00461)	0.00903** (0.00453)	0.00765* (0.00455)
Adjusted 205 day weight	0.000455 (0.000639)	0.000177 (0.000631)	6.32e-05 (0.000615)	0.000525 (0.000587)	0.000136 (0.000601)
Adjusted 365 day weight	0.00168*** (0.000415)	0.00137*** (0.000396)	0.00139*** (0.000386)	0.00176*** (0.000390)	0.00147*** (0.000384)
Age	0.000239 (0.000508)	0.000562 (0.000531)	0.000142 (0.000507)	-9.15e-05 (0.000453)	6.64e-05 (0.000476)
Birthweight EPD	0.0132 (0.0244)	0.0115 (0.0238)	0.0142 (0.0230)	0.0139 (0.0230)	0.0146 (0.0228)
Weaning Weight EPD	-0.0122* (0.00681)	-0.0102 (0.00662)	-0.0125** (0.00634)	-0.0124* (0.00649)	-0.0133** (0.00630)
Yearling Weight EPD	0.00327 (0.00411)	0.00322 (0.00403)	0.00490 (0.00388)	0.00297 (0.00390)	0.00509 (0.00385)
Constant	-4.317*** (0.728)	-4.812*** (0.745)	-3.425*** (0.661)	-3.971*** (0.646)	-3.773*** (0.654)
Observations	1,766	1,766	1,766	1,766	1,766

Standard errors in parentheses

*** p<0.01, ** p<0.05, * p<0.1

Table C-17: Tobit Model Results, Nebraska and South Dakota Producers

VARIABLES	(1) Modified Bins	(3) Decile	(5) Decile	(7) SD of Prices	(9) SD of Prices
Mid Group	0.392** (0.188)				
High Group	0.969*** (0.198)				
Decile Group		0.198*** (0.0292)	-0.0902 (0.0745)		
Decile Group Squared			0.0225*** (0.00643)		
SD of Prices				8.44e-05*** (1.17e-05)	0.00219*** (0.000402)
SD of Prices Squared					-2.82e-07*** (5.34e-08)
Birthweight	-0.00364 (0.00414)	-0.00378 (0.00414)	-0.00430 (0.00410)	-0.00620 (0.00403)	-0.00459 (0.00406)
Adjusted 205 day weight	0.000369 (0.000622)	0.000400 (0.000624)	0.000258 (0.000615)	0.000378 (0.000600)	0.000232 (0.000608)
Adjusted 365 day weight	0.00226*** (0.000500)	0.00198*** (0.000494)	0.00192*** (0.000488)	0.00239*** (0.000498)	0.00204*** (0.000488)
Age	-0.00272*** (0.000993)	-0.00289*** (0.001000)	-0.00290*** (0.000982)	-0.00262*** (0.000970)	-0.00280*** (0.000973)
Birthweight EPD	-0.0206 (0.0230)	-0.0191 (0.0229)	-0.0132 (0.0227)	-0.0186 (0.0224)	-0.0131 (0.0225)
Weaning Weight EPD	0.00437 (0.00791)	0.00420 (0.00787)	0.00492 (0.00775)	0.00884 (0.00766)	0.00550 (0.00768)
Yearling Weight EPD	0.000448 (0.00502)	-0.000325 (0.00502)	-0.00115 (0.00493)	0.000819 (0.00480)	-0.000543 (0.00485)
Constant	-3.592*** (0.710)	-3.862*** (0.704)	-2.782*** (0.708)	-3.311*** (0.678)	-3.181*** (0.682)
Observations	3,259	3,259	3,259	3,259	3,259

Standard errors in parentheses

*** p<0.01, ** p<0.05, * p<0.1

Table C-18: Ordered Logit Coefficients, One Montana Producer

VARIABLES	(1) Modified Bins	(2) Decile Group	(3) Decile Group	(4) SD of Prices	(5) SD of Prices
Mid Group	1.695 (1.061)				
High Group	4.708*** (1.020)				
Decile Group		1.089*** (0.125)	-0.549 (0.365)		
Decile Group Squared			0.118*** (0.0293)		
SD of Prices				0.000130*** (1.21e-05)	0.0142*** (0.00211)
SD of Prices Squared					-6.63e-07*** (9.95e-08)
Birthweight	0.0357* (0.0192)	0.0392** (0.0196)	0.0412** (0.0199)	0.0402** (0.0189)	0.0406** (0.0198)
Adjusted 205 day weight	0.00166 (0.00245)	0.000488 (0.00252)	0.000568 (0.00257)	0.00354 (0.00247)	0.000804 (0.00255)
Adjusted 365 day weight	0.00560*** (0.00160)	0.00533*** (0.00158)	0.00539*** (0.00161)	0.00703*** (0.00156)	0.00536*** (0.00162)
Age	-3.81e-05 (0.00235)	-0.000549 (0.00244)	-0.000630 (0.00244)	-0.000991 (0.00205)	-0.000464 (0.00244)
Birthweight EPD	0.0564 (0.0949)	0.0542 (0.0956)	0.0565 (0.0969)	0.0625 (0.0964)	0.0569 (0.0965)
Weaning Weight EPD	-0.0434* (0.0254)	-0.0421* (0.0253)	-0.0459* (0.0260)	-0.0435* (0.0262)	-0.0464* (0.0259)
Yearling Weight EPD	0.0164 (0.0151)	0.0176 (0.0154)	0.0205 (0.0158)	0.00827 (0.0158)	0.0209 (0.0157)
Observations	1,766	1,766	1,766	1,766	1,766

Standard errors in parentheses

*** p<0.01, ** p<0.05, * p<0.1

Table C-19: Ordered Logit Coefficients, Nebraska and South Dakota Producers

VARIABLES	(1) Modified Bins	(2) Decile Group	(3) Decile Group	(4) SD of Prices	(5) SD of Prices
Mid Group	2.110** (1.043)				
High Group	4.279*** (1.024)				
Decile Group		0.849*** (0.111)	-0.0137 (0.423)		
Decile Group Squared			0.0630** (0.0321)		
SD of Prices				0.000294*** (3.65e-05)	0.00930*** (0.00156)
SD of Prices Squared					-1.21e-06*** (2.07e-07)
Birthweight	-0.0166 (0.0140)	-0.0205 (0.0143)	-0.0214 (0.0144)	-0.0264* (0.0142)	-0.0212 (0.0143)
Adjusted 205 day weight	0.000372 (0.00234)	0.000197 (0.00236)	0.000111 (0.00236)	0.00105 (0.00234)	3.88e-05 (0.00236)
Adjusted 365 day weight	0.00851*** (0.00178)	0.00757*** (0.00179)	0.00744*** (0.00180)	0.00888*** (0.00179)	0.00789*** (0.00181)
Age	-0.00804** (0.00336)	-0.00903*** (0.00338)	-0.00931*** (0.00339)	-0.00849** (0.00334)	-0.00896*** (0.00339)
Birthweight EPD	-0.0655 (0.0790)	-0.0260 (0.0799)	-0.0185 (0.0805)	-0.0477 (0.0799)	-0.0305 (0.0805)
Weaning Weight EPD	0.0252 (0.0307)	0.0233 (0.0300)	0.0241 (0.0300)	0.0358 (0.0303)	0.0264 (0.0301)
Yearling Weight EPD	-0.00614 (0.0191)	-0.0114 (0.0186)	-0.0122 (0.0185)	-0.00448 (0.0185)	-0.00978 (0.0185)
Observations	3,259	3,259	3,259	3,259	3,259

Standard errors in parentheses

*** p<0.01, ** p<0.05, * p<0.1

APPENDIX D

ADDITIONAL RESULTS FROM THE HEDONIC PRICE MODEL

This appendix presents additional results from the hedonic price model as discussed in section two of chapter seven. The two tables in this appendix, tables D-1 and D-2, show results from the hedonic price model, estimated using OLS, when the dependent variable is winsorized. This is provided as a robustness check.

Table D-1: Results of Hedonic Price Model With Winsorized Prices, One Montana Producer

VARIABLES	Normal	Normal	Winsorized at 99th	Winsorized at 99th	Winsorized at 95th	Winsorized at 95th	Winsorized at 90th	Winsorized at 90th
Retained Interest	8,292*** (1,315)	7,941*** (1,265)	5,856*** (580.2)	5,644*** (579.9)	2,870*** (207.6)	2,799*** (211.8)	1,781*** (139.1)	1,749*** (142.0)
DE Birthweight	-0.404 (11.14)	155.0 (138.3)	7.590 (8.469)	57.23 (103.8)	10.88** (5.172)	75.59 (61.93)	9.890** (4.269)	76.22 (50.56)
DE Birthweight Squared		-0.770 (0.714)		-0.243 (0.523)		-0.323 (0.313)		-0.333 (0.256)
DE Adjusted 205 Day Weight	80.94*** (16.11)	-236.1 (248.6)	76.05*** (9.348)	-141.6 (135.5)	65.05*** (6.074)	58.66 (73.71)	59.15*** (5.151)	94.35 (61.79)
DE Adjusted 205 Day Weight Squared		1.597 (1.311)		1.090 (0.707)		0.0290 (0.378)		-0.179 (0.315)
DE Adjusted 365 Day Weight	89.66*** (17.84)	-631.5* (360.5)	75.81*** (11.39)	-299.9 (189.0)	63.09*** (7.031)	-54.66 (94.35)	58.20*** (5.872)	12.17 (78.53)
DE Adjusted 365 Day Weight Squared		3.574* (1.860)		1.863* (0.973)		0.583 (0.475)		0.228 (0.391)
DE Birthweight EPD	-7.951*** (2.309)	-12.92*** (4.947)	-8.705*** (1.864)	-16.56*** (3.965)	-7.709*** (1.220)	-15.30*** (2.618)	-6.751*** (0.982)	-12.34*** (2.051)
DE Birthweight EPD Squared		0.0234 (0.0179)		0.0387*** (0.0147)		0.0375*** (0.0106)		0.0276*** (0.00837)
DE Weaning Weight EPD	-1.818 (9.430)	-47.33 (58.51)	-2.253 (6.133)	-35.79 (34.98)	-4.579 (3.861)	-12.04 (18.83)	-5.065 (3.140)	-6.273 (14.15)
DE Weaning Weight EPD Squared		0.228 (0.333)		0.172 (0.192)		0.0381 (0.0958)		0.00555 (0.0719)

Table D-1 (cont): Results of Hedonic Price Model With Winsorized Prices, One Montana Producer

DE Yearling Weight EPD	21.34*** (7.822)	-63.16 (50.72)	20.43*** (5.793)	-31.07 (29.72)	20.11*** (3.987)	-15.65 (18.87)	18.14*** (3.320)	-10.92 (14.93)
DE Yearling Weight EPD Squared		0.437 (0.282)		0.264 (0.162)		0.186* (0.101)		0.152* (0.0789)
Price Ratio	2,859** (1,132)	2,482** (1,114)	3,686*** (740.1)	3,402*** (731.6)	3,740*** (497.3)	3,551*** (488.5)	3,717*** (427.2)	3,589*** (422.5)
Constant	-14,771*** (1,405)	35,693** (14,776)	-13,752*** (1,070)	17,754* (10,058)	-11,649*** (691.7)	-6,225 (5,459)	-10,399*** (566.0)	-11,401** (4,538)
Observations	1,672	1,672	1,672	1,672	1,672	1,672	1,672	1,672
R-squared	0.343	0.359	0.470	0.486	0.464	0.472	0.439	0.445

Robust standard errors in parentheses

*** p<0.01, ** p<0.05, * p<0.1

Table D-2: Results of Hedonic Price Model With Winsorized Prices, Nebraska and South Dakota Producers

VARIABLES	Normal	Normal	Winsorized at 99th	Winsorized at 99th	Winsorized at 95th	Winsorized at 95th	Winsorized at 90th	Winsorized at 90th
Retained Interest	6,535*** (977.2)	6,320*** (926.4)	4,296*** (419.1)	4,242*** (428.0)	2,385*** (183.4)	2,391*** (189.4)	1,529*** (120.5)	1,572*** (120.9)
DE Birthweight	-8.952 (7.608)	-4.849 (84.35)	-6.412 (5.289)	15.48 (47.91)	-6.179 (4.252)	6.606 (37.54)	-6.601* (3.740)	-8.997 (33.68)
DE Birthweight Squared		-0.0107 (0.421)		-0.108 (0.244)		-0.0626 (0.193)		0.0144 (0.173)
DE Adjusted 205 Day Weight	20.02 (16.36)	-245.9 (295.6)	28.50*** (9.103)	-250.2* (133.6)	25.59*** (6.725)	-147.7* (88.36)	23.48*** (5.726)	-91.71 (72.00)
DE Adjusted 205 Day Weight Squared		1.344 (1.533)		1.398** (0.687)		0.867* (0.450)		0.573 (0.363)
DE Adjusted 365 Day Weight	172.5*** (19.67)	-540.8 (510.5)	146.5*** (9.323)	4.896 (163.1)	128.4*** (7.087)	143.5 (115.8)	112.0*** (5.958)	221.7** (92.84)
DE Adjusted 365 Day Weight Squared		3.534 (2.615)		0.702 (0.831)		-0.0746 (0.586)		-0.542 (0.465)
DE Birthweight EPD	-9.259*** (1.658)	-12.79*** (2.705)	-8.549*** (1.181)	-11.35*** (2.306)	-7.069*** (0.967)	-9.879*** (1.992)	-6.036*** (0.839)	-8.620*** (1.741)
Squared		0.0159 (0.0106)		0.0137 (0.00939)		0.0138* (0.00810)		0.0126* (0.00694)
DE Weaning Weight EPD	3.237 (5.252)	4.500 (18.31)	-1.307 (3.727)	0.366 (13.77)	-1.601 (2.831)	-0.0603 (10.65)	-1.416 (2.395)	-2.182 (8.865)
DE Weaning Weight EPD Squared		-0.00228 (0.102)		-0.00534 (0.0717)		-0.00536 (0.0543)		0.00649 (0.0447)

Table D-2 (cont): Results of Hedonic Price Model With Winsorized Prices, Nebraska and South Dakota Producers

DE Yearling Weight EPD	11.95** (5.502)	66.37*** (20.34)	16.76*** (3.425)	51.00*** (14.19)	15.27*** (2.659)	38.44*** (12.54)	13.69*** (2.250)	34.94*** (10.20)
DE Yearling Weight EPD Squared		-0.274** (0.121)		-0.173** (0.0768)		-0.117* (0.0640)		-0.108** (0.0515)
Price Ratio	179.6 (1,164)	973.0 (1,060)	4,959 (725.7)	351.8 (727.1)	-124.0 (581.2)	32.75 (587.2)	18.24 (511.6)	83.57 (516.7)
Constant	-14,012*** (1,190)	31,829* (18,664)	-12,612*** (794.0)	5,490 (7,943)	-10,576*** (599.4)	-4,507 (5,378)	-8,815*** (507.5)	-9,401** (4,450)
Observations	2,966	2,966	2,966	2,966	2,966	2,966	2,966	2,966
R-squared	0.314	0.323	0.376	0.380	0.379	0.382	0.364	0.368

Robust standard errors in parentheses

*** p<0.01, ** p<0.05, * p<0.1

APPENDIX E

ANALYSIS OF TAXI MEDALLIONS AS A HOMOGENEOUS ASSET

The analysis of seedstock bull interest shares in this thesis provides an explanation on how uncertainty of quality of a heterogeneous asset can affect contract choice. The results show that for a sample of Angus producers, as uncertainty increases the producers are more likely to sell the bull with a retained interest contract. I also find that the retained interest contract increases the value of the bull. Comparatively, taxi medallions are a homogeneous asset with little uncertainty regarding their attributes. This additional analysis of sales of shares of medallions serves as a basis of comparison for the analysis of bull interest shares presented above.

Taxi medallions are transferable licenses that allow for the operation of a taxi. These licenses are the result of government regulation on the supply of taxicabs and, because they are transferable, have market value. Many large cities have taxi medallion programs, with New York City, Chicago, Boston, and Philadelphia allowing for the transfer of medallions. These cities also collect sale data when licenses are transferred. I use this sale data for New York City from 2004 to 2015 to examine the effects of share sales on the price of a medallion. I then compare these results to the results from similar hedonic regressions using my bull sale data.

I first estimate a hedonic price regression model using OLS where the dependent variable is the real price per medallion. This is the observed sale price. I use three specifications that correspond to different ways of modelling the share of the medallion. All specifications include controls for other factors such as gas prices, unemployment, population, various medallion characteristics, and month by year effects. The first specification simply estimates a regression equation with a dummy variable equal to one if the sale was a share of a medallion. The second specification uses the percent of the medallion sold, entered as a continuous variable, to measure

the effect of shares on price. The third specification utilizes separate dummy variables for each share percentage observed in the data.

The results of these regressions are presented in table E-1. All results show that shares of medallions sell for less than a whole medallion, and these results are mostly statistically significant. In comparison, for bull interest share sales, bulls sold with retained interest earn large premiums.

Table E-1: Results of the Hedonic Price Regression for Taxi Medallion Observed Price

VARIABLES	(1) Observed Price	(2) Observed Price	(3) Observed Price
Share Dummy	-276,520** (128,559)		
Percent Share		665,119*** (145,596)	
Percent Share = 0.025			-593,880*** (120,081)
Percent Share = 0.10			-535,807*** (144,545)
Percent Share = 0.25			-495,280*** (125,782)
Percent Share = 0.30			17,127 (124,438)
Percent Share = 0.33			-573,392*** (125,579)
Percent Share = 0.45			-541,983*** (135,677)
Percent Share = 0.50			-200,451* (119,218)
Constant	1.438e+07*** (1.924e+06)	1.306e+07*** (1.710e+06)	1.454e+07*** (1.756e+06)
Observations	1,176	1,176	1,176
R-squared	0.901	0.911	0.915
Other Controls	YES	YES	YES

Robust standard errors in parentheses

*** p<0.01, ** p<0.05, * p<0.1

The second part of this analysis is very similar to the first; however, I use an approximation of the true value of the medallion as the dependent variable. The true value of the

medallion is the observed price multiplied by reciprocal of the percent sold. For example, if 50 percent of a medallion sold, the true value of that medallion is approximated to be

$$\frac{1}{0.5} * \textit{observed price} = 2 * \textit{observed price}.$$

Other than the dependent variable, the specifications in this part are the same as in the first part. Results of these regressions are presented in table E-2. A striking feature of these results is that almost none of the measures of the share are statistically significant. The coefficient on the dummy variable for a 30 percent share is significant, but there is only one observation where the percent share is 30 percent, so this result does not necessarily discredit the overwhelming lack of significance on the other variables.

Table E-2: Results of the Hedonic Price Regression for Taxi
Medallion Approximated True Values

VARIABLES	(1) Medallion True Value	(2) Medallion True Value	(3) Medallion True Value
Share Dummy	644,179 (407,412)		
Percent Share		-750,385 (761,324)	
Percent Share = 0.025			607,527 (452,110)
Percent Share = 0.10			910,533 (747,919)
Percent Share = 0.25			393,069 (472,538)
Percent Share = 0.30			1.625e+06*** (490,751)
Percent Share = 0.33			-712,898 (499,352)
Percent Share = 0.45			225,049 (540,348)
Percent Share = 0.50			640,343 (443,384)
Constant	3.477e+07*** (6.326e+06)	3.628e+07*** (6.966e+06)	3.840e+07*** (8.126e+06)
Observations	1,176	1,176	1,176
R-squared	0.759	0.758	0.767
Other Controls	YES	YES	YES

Robust standard errors in parentheses

*** p<0.01, ** p<0.05, * p<0.1

Comparing the results from the two models, shares of medallions are sold for less full medallions and, when comparing true values of medallions sold as shares and those sold whole, there is no difference in value. This means that if a share of a medallion comes up for sale, it will sell for less than a whole medallion, and if the whole medallion were to be sold rather than just a share, the price would be no different than prices for other whole medallions. Table 44 presents similar regressions using my bull sale data for the second model while including controls for EPDs and SPMs. Unlike the results from the taxi medallion regressions using true value, when price is adjusted to approximate the true value of a bull, retained interest bulls still sell for significantly more than lump sum bulls. This finding further verifies the finding that retained interest contracts signal information to buyers and increases the value of the bull.

Table E-3: Results of the Hedonic Price Regression for Bull Approximated True Value

VARIABLES	One Montana Producer			Nebraska and South Dakota Producers		
	(1) True Value	(2) True Value	(3) True Value	(1) True Value	(2) True Value	(3) True Value
Retained Interest	34,722*** (3,889)			29,284*** (2,353)		
Percent Sold		-96,851*** (10,887)			-81,144*** (6,949)	
Percent Sold = 0.5			24,097*** (2,588)			40,101*** (9,912)
Percent Sold = 0.66			35,415*** (4,141)			27,695*** (2,276)
Constant	-16,999*** (2,488)	79,298*** (10,429)	-17,223*** (2,520)	-14,617*** (2,174)	66,972*** (6,951)	-14,173*** (2,153)
Observations	1,672	1,672	1,672	2,966	2,966	2,966
R-squared	0.450	0.438	0.453	0.563	0.573	0.573
Other Controls	YES	YES	YES	YES	YES	YES

Robust standard errors in parentheses

*** p<0.01, ** p<0.05, * p<0.1