Where’s the Beef?
Choosing Between Negotiations and Auctions in Cattle Sales

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Abstract

We study the question of institutional choice—auctions or negotiations?—in a particular industry: the American cattle market. We consider the possibility that collusion in auctions is driving cattle producers away from auctions and towards negotiations. We provide a model that captures many key features of the industry and lays the groundwork for future work that could encapsulate many other facets of choosing between auctions and negotiations.
1 Introduction

Why should Sotheby’s sell a Kandinsky via an auction? For that matter, why should any good be sold in an auction as opposed to a marketplace with prices posted by the seller, or negotiated between buyer and seller? I propose to study a facet of these questions by comparing auctions and negotiations in the context of cattle auctions.

Traditionally, cattle have been sold primarily via auctions. However, in recent years there has been a decline in the usage of auctions as the mode of selling cattle (as can be seen in Fig. 1) accompanied by a higher use of negotiations (also known as “private treaty sales”). To illustrate this point, Grunewald, Schroeder, and Ward (2002) provide the example of Kansas and Texas. In the early 1990s both states negotiated sales constituted 10% of fed cattle cash sales; by 2000, however, negotiated sales constituted 60% of fed cattle cash sales. Thus, we can answer the question “Where’s the beef?” with, “In negotiations.”

![Figure 1: Volume of Cattle (Slaughter and Non-Slaughter) Marketed Through Firms Selling on Auction Markets (Source: 2008 Packers & Stockyards Program Report)](https://example.com/figure1)

Given the advances which have made auctions more convenient—e.g. online and video auctions—it is natural to wonder why sellers are moving away from auctions. One possible explanation is that the auctions are in fact collusive (see Phillips, Menkhaus, and Coatney (2003)[15] or Phillips and Menkhaus (2006)[14]). In brief,
cattle auctions are vulnerable to collusion because there are a small number of bidders with monopsony power buying cattle from a large number of relatively small ranchers. Cattle bidders see each other regularly at the auctions and have ample opportunity to communicate; in fact, the middlemen they hire to represent themselves at the auctions frequently hold multiple accounts. Furthermore, cattle sellers are required to report the number of cattle they are bringing to the auction prior to arrival. Thus, it is likely that cattle buyers can form bidding rings and depress prices. However, as this is a repeated game, sellers can retaliate by bringing fewer cattle to market.

We shall attempt to understand what conditions could have caused this shift and the welfare implications of this alternate market arrangement. For instance, who benefits from negotiations? In theory, auctions allow for price discovery by being relatively open; by contrast, negotiations are not as open. Indeed, the passage of the Livestock Mandatory Reporting Act of 1999, which requires buyers and sellers to report the prices from their negotiations to the US Department of Agriculture, would seem to indicate proponents of the Act believe in this point of view. One noteworthy theoretical paper by Bulow and Klemperer (1996) that compares auctions and negotiations shows that English auctions without reserve prices and \( n + 1 \) bidders generates more profits than the optimal auction with \( n \) bidders. Hence, if a seller believes an additional bidder will enter the auction, she should choose auctions over negotiations. However, Bulow and Klemperer’s model assumes sellers can negotiate optimally, bidders have no bargaining power, bidders and sellers have the same information, and that bidders are symmetric. Thus, their arguments cannot completely explain the presence of negotiations in situations where these assumptions do not hold (e.g. in cattle auctions, where there are multiple sellers who do not necessarily have the ability to negotiate optimally, and where bidders have huge bargaining power). The empirical literature tends to focus on testing theoretical predictions that auctions are favored over negotiations when cost control is important (e.g. Bonaccorsi et
al. (2000)[2]), when there are many bidders, and when the transactions involved are complex (e.g. Bajari et al. (2008)[1], who provide an empirical analysis of auctions versus negotiations in procurement auctions, and Leffler et al. (2003)[10], who study similar issues in the setting of timber auctions).

What my paper does is lay out a model that considers the real-life features of cattle auctions, particularly in light of the choice between auctions and negotiations. It attempts to find the parameter regions that will allow collusion. The analysis of the model is not complete, but lays the groundwork for considering multiple facets of the question of choosing auctions over negotiations (or vice-versa). It also looks deeply into an industry that is rarely studied and illustrates its surprising complexities.

Section 2 provides an overview of the cattle market. Section 3 lays out a model and proposes a solution. Section 4 discusses the model and concludes.

2 An Overview of the Cattle Market

2.1 Cattle sales: A multi-step process

Cattle producers no longer drive cattle overland and place them on railheads as was the case in the 1800s (or as they did in Figure 2). Now, the process of getting the animal to the consumer is more fragmented, as can be seen in Figure 3.

We shall focus for now on the first part of the diagram, namely the part from the animal’s birth to its death in the hands of the meat packers. The destiny of a calf depends on nature and nurture: how much weight it is able to put on and where it is born.

Calves are typically born in the spring, but in the southern United States (e.g. Kansas, Oklahoma, and Texas), they can be born in the winter. Calves are usually weaned 7 to 9 months after birth, or until they reach about 400 to 600 lbs in weight. They are then sold (or, in this stage, “backgrounded”) to stocker cattle operations
Figure 2: Sketch from *The Police Gazette*, October 27, 1883 depicting “A Deadhead Passenger” who was evicted because “she had no ticket and would not pay fare” (Source: Fussell [6])

Figure 3: Flowchart from 2007 *Grain Inspection, Packers and Stockyard Administration (GIPSA) Livestock and Meat Marketing Survey (LMMS)*[8]
where they are sold to establishments with surplus forage that beef up the calves’ bone frames and muscles. At this stage, they are known as “yearlings,” “feeder cattle,” or “stocker cattle,” and how long they stay in the backgrounding lots depends on how much weight they gain and in what they eat (different stockers use different feeds). After feeder cattle gain about 750 lbs in weight, they are sold to feedlots to gain more muscle and fat weight. With the help of the feedlot owners, they graduate as “finished” steers and heifers and are bought by slaughterhouses or meat-packers (LMMS Vol. 1, Section 1, p. 3 and conversation with Gilfillian.)

Hence, there are at least three possible points in which cattle can be sold: from the rancher to stocker, from the stocker to feedlot owner, and from the feedlot owner to meat-packer. There are multiple ways in which they can be sold at each juncture, but of primary interest to us is the use of (live) auctions vs. negotiations (called “private treaty sales” in the industry) at each point.

2.1.1 Live auctions

Live auctions are held about once a week in various parts of the US, and are open-outcry with reserve prices set by sellers. At the sale barns (where cattle are auctioned), ranchers come to sale barns having announced the quantity and qualities (age, breed) of cattle they are bringing. A smaller number of experienced buyers come, represented by middlemen with instructions to buy as many head of cattle as they can. Buyers are capacity and budget constrained, but the latter does not seem to be an important consideration (from conversation with Phillips and Gilfillian). Sale barns buy up unsold cattle (sometimes unsold because the seller refuses to accept the winning bid) or try to find buyers who have not come to the auction. They are motivated to do so because they live on commission, and do not wish for sellers to feel as if auctions give them a raw deal (from conversation with Gilfillian).

1As an aside, they do not control when cattle are sold; the cattle can stay in the barns for some time before they are sold.
I watched large portions of three auctions on March 22, 2010 online at CattleUSA.com. The first auction I watched was the Russell, IA Livestock Market. The second auction I watched was the Tulia, TX Livestock Auction. The third auction I watched was the Tama, IA Livestock Auction. I was also able to see part of the Platte Valley, NE Livestock Auction. I include screen-captures of these three auctions in Figures 4, 5, 6, 7.

In each auction, typically one cow at a time was let into the ring, though in the Tama auction, the sale barn was more willing to sell pairs of cattle. There were two men in the ring whose role was to push the cow so the cow would walk around the ring and let the buyers observe it. In all auctions, the caller spoke very quickly; each sale was concluded in about 30 seconds (2000 head of cattle were brought to the Russell auction, which ended in two hours). I was unable to watch the entirety of many of the auctions, so I may not have an accurate conception of the full variety of cattle being brought to auction. Furthermore, it was difficult for me to follow what they were saying. However, in the Russell auction, prices were continuously updated on the screen, so I was able to observe some of the price movements.

The caller would begin by describing the cow. In the Russell auction, he began by describing the breed and mentioned the weight while calling out prices, whereas in the Tulia auction, he stated the weight and breed while calling out prices. The Tama caller seemed to do a bit of both, and sometimes mentioned the seller’s identity. At times, he even mentioned specific characteristics of the cattle that were provided by the seller, e.g. how they were raised and how many shots they had. From what I could tell, all callers began with the reserve price and would call out prices in $0.25 increments.

Reserve prices varied across cows and sellers. At times, bidding would lead to final prices that were higher than the initial reserve prices, but on a few occasions, the

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2That said, the Texan caller did have a slight drawl, which slowed him down only a touch.
caller called out an initial reserve price and received no offers, leading him to re-start bidding from a lower reserve price.

As we can see from the screen-captures of the auctions (particularly Figure 4 and Figure 5), auctions exhibited variety in both cattle breed (and probably in quality).

![Figure 4: Cow from the Russell, IA auction](image)

![Figure 5: Cow from the Tulia, TX auction](image)
In the Russell auction, prices for cows seemed to be around the $50/hundred-lb range, while heifers and steers sold for higher prices. In the parts of the Tulia and Tama auctions I saw, prices were in the $90/hundred-lb and $110/hundred-lb and above ranges, respectively. Overall, heifers and steers seemed to command higher prices. It may be that these cattle are meant for breeding; I did notice in the Russell auction’s LiveCattle.com posting for the auction, it emphasized some sellers were bring very high quality cattle.

Furthermore, different auctions had slightly different practices. As mentioned before, sometimes different sale barns brought in more than one animal. At one point, the Russell auction brought out three calves at once, probably due to the caller’s prompting. In the part of the Tulia auction I saw, each animal was sold individually. By contrast, in the part of the Tama auction I saw, half of the time, cattle were brought out in groups of two or three, sometimes even six. The Platte Valley auction typically had multiple cattle in the ring—even more than in the Tama auction. Figures 6 and 7 show examples of instances in which multiple cattle were sold together. Finally, it seemed that only the Tama auction had online participants; every so often, the caller mentioned internet bids and internet winners—cattle can also be sold online by buyers watching videos of the auctions. Sellers also post videos of their herds for buyers. There are numerous advantages of online and video sales, which will become more apparent when we delve deeper into the mechanics of cattle.

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3 The staff had ushered out a Longnecker calf and the caller said, somewhat wistfully, “three of these, wish they could be sold together,” which I show in Figure 6. Actually, all auctions had a somewhat festive air and featured moments of friendly banter; the Tama caller exhorted buyers to “pay attention, now” while calling prices, and seemed to have an affection for the cattle—most memorably, he said, “heifer, dear, you’re on your own.” The Russell caller identified a seller as someone’s “boy,” and observed that he liked one of the cows, but it “did get a little grouchy.” He even apologized for saying the wrong number at one point, ruefully noting, “I need to practice.” Finally, though I was unable to see most of the Platte Valley auction, the caller seemed the most casual and admireing of the cattle, exclaiming “golly” and “ho-ly cow!” at some head of cattle he particularly liked.

4 It also seemed as though the Tama caller had a helper who confirmed bidders were raising bids, saying “yep” at certain points. Despite being unable to see him on camera, I am fairly certain this man exists—the Tama caller talked to him at several points, and interrupted his calls at one point to say (I believe to the helper), “what in the world are you doing?”
sales or “marketing.”
2.1.2 Negotiations

Unfortunately, I was unable to observe negotiations or private treaty sales; those are private. Indeed, the relative privacy of negotiations has been a concern of cattle producers—in particular, feedlot owners were concerned that with increased negotiations, voluntary livestock price disclosures were no longer representative of true market conditions, which could mean, in the absence of good information, certain feedlots could get better deals from meat-packers than other feedlots. Spurred by these concerns, cattle producers successfully put pressure on Congress to pass the USDA Livestock Mandatory Price Reporting Act of 1999, which requires packers who slaughter over 125,000 head of cattle per year to report every purchase and sale two times a day. The full welfare implications of this act are still being studied; Grunewald, Schroeder, and Ward (2004) report that on average, cattle producers are neutral to negative on their opinion of the effectiveness of the Act, and experiments by Phillips show that price anchors created by such mandated reports might actually be damaging for the producers.

For our modeling purposes, however, it seems from my conversation with Gilfillian and Phillips that negotiations are done via alternating offers, and are often, but not always, initiated by sellers.

2.2 Other features of the cattle market

2.2.1 The value of cattle

Cattle are graded according to yield and quality. Yield refers to the amount of edible muscle relative to external fat and bone, while quality refers to the amount of (internal) marbled fat within the muscle. From conversation with Phillips, Gilfillian, and Peterson, it seems that cattle buyers are fairly knowledgeable about cattle quality (in the economic sense of the term) and can deduce the quality of a given calf,
steer, heifer, etc. fairly easily. However, certain factors of a cattle’s quality are idiosyncratic. Cattle buyers buying from the rancher want to raise the calf to a certain size. The calf’s ability to grow more is unknown at the time of purchase and depends on idiosyncratic characteristics of both buyer and seller, namely in how both raise and treat cattle (from conversation with Gilfillian).

Cattle ranchers equally capable of raising cattle; Gilfillian emphasized that some raise cattle as their livelihood, but some do so recreationally and are not very clear about the key principles of cattle ranching. Thus, their ability to raise high-quality cattle is low. Indeed, Fussell notes that

Unlike the meat end, the ranching end is not about the money... the majority of the 800,000 ranchers today who raise cattle cannot make a living out of cattle alone.... Only big-time feedlots in conjunction with packers in conjunction with retailers—in other words, the industrial beef chain, supported by government agencies—make big time money (202).

This heterogeneity in cattle producers means, as Gilfillian put it, there is “much disparity” in cattle auctions, where one can expect as much variety as you would expect were you to shop “at a mall.” This he believes is “probably one of the biggest concerns... in the cattle industry today,” perhaps because buyers buying from ranchers want to build a fairly uniform herd, as it is easier and less costly to make cattle grow at same pace. That said, further along the sales chain, it is likelier that stockers and feedlot owners will have more uniform herds.

2.2.2 Costs

For cattle producers, costs in cattle sales (or “cattle marketing,” as it is called in the industry) include transportation, “shrinkage,” bruising, and auction commission (from conversation with Gilfillian; also Rawls and Lane[17]). Transportation costs increase with distance to the point of sale and the costs of trucking the animals. However, there are economies of scale, and in fact, while overloading can damage
cattle by bruising them, underloading can cause cattle to shift too much, which stresses and shrinks them.

“Shrinkage” refers to weight loss during the sales process, which could be from fecal/urinary excretion or from tissue shrink. Excretory shrink could be due to cattle being unable to eat or drink while on the road, while tissue shrink comes from stress endured during traveling; Gilfillian gave the example of calves who have trouble eating after being transported because they are stressed from the travel itself and from being separated from their mothers. Tissue shrink is more important, as it is harder to replace and affects the cattle’s grade. Bruising also decreases cattle grade, as bruises are trimmed by meat-packers. Unsurprisingly, most bruising happens during the transportation process, when cattle are crowded and pushed together.

Finally, as mentioned before, auctioneers charge commission to cover a variety of costs, including feed, vaccines, castration and dehorning services, and the like. They may be charged per head of cattle, as a percentage of revenue, or both.

### 2.2.3 Prices and quantity

Cattle ranchers choose how many head of cattle to produce based on what they think the economic climate for cattle will be, but changing herd size is a slow process—it takes approximately 30 months to change the inventory by diverting heifers from the slaughterhouse to breeding, and four to five years to increase cattle inventory.

Cattle prices are seasonal—for instance, in the spring there is great demand for (but low supply of) calves. Prices are also dependent on what choices buyers have, e.g. if a buyer has bought most of the cattle he needs via negotiations, he can buy fewer in auctions. However, prices are often set based on predictions of what meat-packers will offer at the end of the production chain; this information is encapsulated in cattle futures.
2.3 Where does collusion occur?

The 2008 Annual Report released by the Packers and Stockyards Program in GIPSA mentions the existence of business practice units that investigate “alleged anti-competitive practices and unfair and deceptive trade practices at auction markets, livestock dealers and order buyers, slaughtering packers... and meat dealers and brokers” (p. 19). In fact, GIPSA was created to administer the Packers and Stockyards Act of 1921, which was passed by Congress to guard against anti-competitive behavior on the part of meat-packers. Trends in the cattle industry over the last century have only increased buyer concentration—in 2007, the top four meat packers slaughtered and processed more than 80% of the fed cattle sold in the United States (LMMS Vol 3, Section 1, p. 11[8])—and is clearly still a current concern.

A famous lawsuit in the cattle industry is Pickett v. Tyson (2005) in which Henry Lee “Leroy” Pickett, Mike Callicrate, and five other ranchers filed a class-action suit on behalf of 30,000 ranchers against Tyson, charging that Tyson had engaged in price-fixing and violated the Packers and Stockyards Act. (Ultimately, the court ruled in favor of Tyson.)\(^5\) Additionally, the Justice Department believes the livestock industry has anti-competitive practices that it should look into (Reuters (2009)[18] as well as conversation with Gilfillian and Peterson). Finally, as mentioned before, Phillips notes the collusive elements exist in how auctions are currently run: a small number of bidders—representing these powerful meat-packers, for instance—who interact repeatedly in an open auction.

Does collusion take place in the earlier auctions? The literature is reticent on the matter, and when I directed the question to Jess Peterson, Executive Vice President of the United States Cattlemen’s Association, he expressed deep skepticism this was

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\(^5\)There is actually more meat to the suit, but a further discussion would bring this paper on a tangent. However, Fussell provides the meat of the matter in her in-depth account of the suit and fleshes out some of the political dealings between the packers, USDA, and different lobbying organizations.
possible:

I really doubt that collusion takes place at the livestock market. We would find collusion more actively taking place in the meatpacking industry... there are only four major meatpackers... The ability for collusion to take place in the livestock market is extremely limited... the nice thing about live cattle auction is that... it’s competitive bidding, and you don’t really see cattle buyers acting together to lower prices, because it’s not really possible, because it’s not how it’s set up, because it’s reputation-based.

He also noted that buyers and sellers interact with each other frequently and reputation effects would be strong; hence, buyers have an interest in maintaining good relations with sellers. In fact, he emphasized most are friendly with each other. To be sure, the auctions I watched were very friendly environments.

His argument was strongly founded on the perception that auctions are inherently competitive and open. But this may not be the full picture of how all cattle auctions are run. Indeed, Hal Gilfillian, a Vice Chairman of the Texan Beef Council representing the Independent Cattlemen’s Association of Texas, mentioned that

...you may go to local sale barn and they’ve got 1250 or 2000 head of cattle there, and they may only have 1 or 2 guys actually buy. And so you know you’re...pardon my language, you do feel like you’re getting screwed. There’s not a whole lot you can do, because once you make the commitment that you’re gonna sell, you haul the cattle there and you drop them off... But if you’re a small operator, if you’re a small rancher, that’s really the only option you have to sell your cattle... There’s nobody interested in coming to your place to buy that small of a herd.

Furthermore, Phillips noted in personal correspondences that

Some sellers are aware of the small number of buyers at auctions and the collusion. Others are not. In fact, it may be that most are not aware.

(Given the widespread awareness of meatpacker collusiveness, he is referring to collusion from sources other than meatpackers)

In fact, Phillips drew a link between collusion in auctions to increased use of negotiations:

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6Specifically, he believed that open-outcry hindered, rather than helped, collusion!
But all sellers are seeing low prices and so there is a natural evolution towards finding a market institution that does better for the seller. Private negotiation is the result.

We take this as the inspiration for our stylized model.

3 The Model

3.1 Modeling Assumptions

Suppose we have \( N \) sellers (indexed by \( i \)) and \( M \) buyers (indexed by \( j \)), with \( N \geq M \geq 2 \). Suppose they interact with each other over infinite periods with a discount factor \( \delta \in (0, 1) \). We shall suppose sellers begin each period with \( H_i(t) \leq [H, \bar{H}] \) head of cattle (set exogenously), and this fact is common knowledge. It is likely that the quantity of cattle each period differs and may depend on prevailing environmental or market conditions (e.g. the demand for beef, which is dependent on, for instance, the health of the economy); furthermore, we let herd size be time variant so it can include cattle unsold in previous periods. We shall suppose that \( H \leq H_1(t) \leq \cdots \leq H_N(t) \leq \bar{H} \).

We will let \( x_i \) denote seller \( i \)'s distance to the sale barn, \( y_j \) denote buyer \( j \)'s distance to the sale barn, and \( z_{ij} \) denote the distance between seller \( i \) and buyer \( j \).

3.1.1 Marginal benefit of a head of cattle

From Section 2, we can assume Buyer \( j \) derives a benefit \( v + V_j(t) \) each period \( t \) from each head of cattle, where \( v \) is common knowledge and \( V_j(t) \) is independent and private, being drawn each period from \( U[\underline{v}, \bar{v}] \) with \( \bar{v} \geq \underline{v} > 0 \). We will index the buyers so that \( \underline{v} \leq V_1(t) \leq \cdots \leq V_M(t) \leq \bar{v} \). In essence, \( V_j(t) \) reflects Buyer \( j \)'s private marginal benefit from buying in period \( t \). Note this means buyers and sellers
cannot learn from one period to the next.\footnote{As with the time-varying herd sizes, it might be the case that each buyer receives a different draw from each period due to external conditions beyond their control; that said, someone who is a “high quality” buyer in one period (e.g., one with a great ability to fatten the calf at lowest cost) will likely continue to be a high quality buyer in the next, so $V_j(t)$ would likely not change very much from one period to the next.}

Finally, for simplicity, we assume continuous cattle quantities.

### 3.1.2 Costs

As described in the Section 2, the key costs for sellers are transportation costs, bruising/shrinkage costs, and auction commission; costs for buyers are similar, though they do not pay commission. Hence, we let $T(q)d$ represent the costs from transporting $q$ head of cattle over a distance $d$. We will assume $T$ is increasing but exhibits economies of scale, which matches our understanding of transportation costs.

The buyer incurs a bruising/shrinkage cost $\gamma v$, which takes cattle values as its argument; it depends on value because the amount a calf bruises or shrinks depends on its original quality. The buyer incurs this cost twice when buying cattle sold via auctions (since cattle are transported twice), but only once when buying cattle via negotiations (since cattle are transported only once).\footnote{Strictly speaking, this relates to the calf’s underlying value, but instead of changing the calf’s underlying value, we treat this as a transportation-related loss, which seems consistent with Gilfillian’s description of how sellers view shrinkage.}

Finally, in live auctions, sale barns charge a commission of $c_1$ per head of cattle and $c_2$ on the seller’s revenues. These costs are paid by the seller.

### 3.2 The stage game

In period $t$, sellers choose $q_i(t) \leq H_i$ head of cattle to bring to the auctions and a corresponding reserve price $r_i(q_i(t))$. The remaining $H_i - q_i(t)$ head of cattle are sold via negotiations. In period $t + 1$, sellers will have new cattle of quantity $H_i$ as well as whatever cattle remains unsold in period $t$.

The tree below illustrates the stage game at period $t$:
Note that when quantities are announced in advance, as we have assumed they are (and as they are in real life), buyers can plan ahead and have no trouble accommodating all the cattle; that is to say, we can assume away capacity constraints.

3.2.1 Payoffs

We will temporarily drop the $t$’s for the purpose of clarity, but keep in mind that these payoffs are for the stage game at period $t$. We will write the buyer and seller auction payoffs assuming they pay a constant price for now, as these expressions will become useful later.

Auction payoffs

Let $\pi_{i,s}^{auc}(p, q)$ denote Seller $i$’s payoffs from selling $q > 0$ at price $p$ at the one-stage auction; then

$$\pi_{i,s}^{auc}(p, q) = ((1 - c_2)p - c_1)q - T(q)x_i$$

Similarly, let $\pi_{j,b}^{auc}(p, q)$ denote Buyer $j$’s payoffs from buying $q$ at price $p$ at the one-stage auction, so

$$\pi_{j,b}^{auc}(p, q) = (V_j - p)q - T(q)y_j$$

Note that if Seller $i$ brings $q$ head of cattle, then his break-even price, which we
denote by $r_i(\cdot)$, is equal to

$$r_i(q) = \frac{T(q)x_i + c_1q}{(1 - c_2)q}$$

Negotiation payoffs

As $V_j$ is private information, should Seller $i$ choose to negotiate, we assume he will choose a buyer to negotiate at random. For any quantity $q > 0$, let

$$S_{ij}(q) := ((1 - \gamma)v + V_j)q - T(q)z_{ij}$$

In essence, $S_{ij}(q)$ is the surplus Buyer $j$ can expect to receive from negotiating with Seller $i$ (before subtracting his payment for the cattle). However, as noted before, $j$ is chosen by chance—he certainly would be uninterested in bargaining if $S_{ij} < 0$, which Seller $i$ cannot know prior to negotiating with him. Hence, if $\alpha_i$ represents $i$’s bargaining power, his payoffs from negotiating over $q$ head of cattle are

$$\pi_{i,s}^{nego}(q) = \frac{\alpha_i S_{ij}(q)}{M}$$

and Buyer $j$’s payoffs from negotiating with $i$ are

$$\pi_{ji,b}^{nego}(q) = S_{ij}(q) - \frac{\alpha_i S_{ij}(q)}{M}$$

where for each $q$, we have defined

$$S_{ij}(q) := \left( (1 - \gamma)v + \sum_{j=1}^{M} E[V_j|S_{ij} > 0] \right) q - T(q) \sum_{j=1}^{M} z_{ij} \mathbb{P}(S_{ij} > 0)$$

If we use an infinite period alternating-offers model and let $\rho_i$ represent $i$’s discount factor while bargaining and $\rho_B$ represent the buyer discount factor while bargaining, then $\alpha_i = \frac{\rho_i(1 - \rho_B)}{1 - \rho_i \rho_B}$; see Fudenberg and Tirole.
3.3 Outcomes in the competitive (non-collusive) setting

Before considering what subgame-perfect equilibrium supports collusion, we consider the non-collusive outcomes.

First, we determine the auction outcomes. If we let $W_j(q)$ denote Buyer $j$’s willingness-to-pay for the $q$th head of cattle, then we have

$$W_j(q) = (1 - 2\gamma)v + V_j - T'(q)y_j$$

We also let $W^{(m)}(\cdot)$ denote the $(M - m + 1)$th order statistic and $G^{(m)}(\cdot)$ denote its cumulative distribution function. Note that $P(W_j \leq y) = F(y + T'(q)y_j - (1 - 2\gamma)v)$.

We would like to determine how many head of cattle each buyer wins and at what price. But trying to do so can prove to be confusing (in the Appendix, I provide a more detailed description of how this could unfold for the $N = 2$ case). Hence, for the purpose of tractability we assume that $T(q) = A + Tq$ for $A, T > 0$. With this simplifying assumption, willingness-to-pay becomes $W_j = V_j - Ty_j$ for each $j$. If $W_j = W^{(1)}$, then he wins all the cattle brought to market and pays $W^{(2)}$. Hence, if each seller $i$ has brought $q_i$ to market, seller $i$’s expected payoff at period $t$ is

$$\pi^{auc}_{i,s}(E[W^{(2)}], q_i) = \left( (1 - c_2)E[W^{(2)}] - c_1 - Tx_i \right) q_i - Ax_i$$

$$= \left( (1 - c_2)\frac{2v - (M - 1)\bar{v} + ((1 - 2\gamma)v - Ty_j)}{M + 1} - c_1 - Tx_i \right) q_i - Ax_i$$

Now we calculate Buyer $j$’s payoffs. Note that if Buyer $j$ wins the cattle, he obtains

$$\pi^{auc}_{j,b}(E[W^{(2)}], \sum_{i=1}^{N} q_i) = ((1 - 2\gamma)v + V_j - E[W^{(2)}] - Ty_j) \sum_{i=1}^{N} q_i$$

while if he loses, he receives $\pi^{auc}_{-j,b}(0, 0) = -Ay_{-j}$. Thus, his expected payoffs from

22
auctions are 

\[ \mathbb{P}(\text{win})\pi_{j,b}^{auc} \left( E[W^{(2)}], \sum_{i=1}^{N} q_i(t) \right) + \mathbb{P}(\text{lose})\pi_{-j,b}^{auc}(0,0) \]

\[ = \left( \int_{(1-2\gamma)v+\bar{v}-Ty_j}^{(1-2\gamma)v+\bar{v}-Ty_j} f(w)G^{(2)}(w)dw \right) \left( (1-2\gamma)v + V_j - E[W^{(2)}] - Ty_j \right) \sum_{i=1}^{N} q_i - Ay_i \]

\[ = \left( \frac{2}{M+1} + \frac{1}{(\bar{v}-\bar{v})^M} \right) \left( (1-2\gamma)v + V_j - E[W^{(2)}] - Ty_j \right) \sum_{i=1}^{N} q_i - Ay_i \]

Next, we turn to negotiations. In the non-collusive setting, we simply calculate through the payoffs from Section 3.2.1. Note that \( \{ S_{ij} > 0 \} = \left\{ V_j > \frac{T(q)z_{ij}}{q} - (1 - \gamma)v \right\} \), so if we let

\[ h_{ij}(q) := \frac{T(q)z_{ij}}{q} - (1 - \gamma)v \]

\[ k_{ij}(q) := 1 - \frac{h_{ij}(q)-\bar{v}}{\bar{v}-\bar{v}} \]

for all \( q > 0 \), we have

\[ S_{ij}(q) = \left( (1-\gamma)v + \frac{\bar{v}^2 - h_{ij}^2(q)}{2(\bar{v}-\bar{v})k_{ij}(q)} \sum_{j=1}^{M} z_{ij} \right) q - (A + Tq)k_{ij}(q) \sum_{j=1}^{M} z_{ij} \]

We can take this and substitute back into our payoff functions in 3.3.1.

It is evident that

**Proposition 1.** In the non-collusive setting, \( q_i^c = H_i \) is the optimal quantity when

\[ (1 - c_2)E[W^{(2)}] - c_1 - Tx_i > \frac{\pi_{i,s}^{nego}(q)}{dq} \]

for all \( q \in [0,H_i) \).
3.4 Subgame perfect equilibrium

Proposition 2. If for all $i$,

$$\delta > \frac{r_i(q_i^*) \sum_{k=1}^{N} q_k^* + TM \sum_{j=1}^{M} y_j}{r_i q_i^* \sum_{k=1}^{N} q_k^* - \sum_{j=1}^{M} \frac{(1-\alpha_i)S_j(q_i^*)}{N}}$$

$$V_j(t) - \frac{1}{M} \sum_{k=1}^{N} r_k q_k^* + Ty_j > \left( \frac{2}{M+1} + \frac{1}{\overline{v} - \underline{v})^M} \right) \cdot ((1-2\gamma)v + V_j - E[W^{(2)}] - Ty_j)$$

where

$$r_i(q) := \max \left\{ r_i(q), \frac{T'(q)x_i + c_1 - d_n^{\text{seg}}(H_i-q)}{1 - c_2} \right\}$$

and $q_i^*$ maximizes Seller i’s payoffs assuming that he receives $r_i(q)$, then the following is a subgame perfect equilibrium:

**Seller equilibrium strategies:**

(S1) Sellers choose $r_i(\cdot)$ as their reserve price and bring $q_i^*(t)$ to auction each period.

(S2) For Seller $i$: If in the previous period buyers bid any price lower than the reserve price, then in the current period, $i$ only sells via negotiations and will do so for all future periods.

**Buyer equilibrium strategies:**

(B1) At each node, every buyer decides to collude and pays each seller’s reserve price $r_i$. The bidding ring allots each member an equal number of cattle. If any member deviates, everyone reverts back to competitive bidding (akin to grim trigger).
If Seller $i$ approaches Buyer $j$ with an offer to negotiate at any node, $j$ negotiates as long as $S_{ij} > 0$ at that node.

Proof. The derivations are provided in the appendix. We consider each part of the (proposed) subgame perfect equilibrium in turn.

Consider the buyers. Note that (B2) always holds. As for (B1), as the auctions are open, bidding above the ring’s bid is evident and punishment is immediate. Suppose $j$ attempts to bid more for some of Seller $i$’s cattle; then the other bidders will immediately bid as they would in a competitive environment for Seller $i$ and all other remaining sellers. When Equation (2) holds, such a deviation decreases payoffs. Equation (1) comes from the conditions implied by (S2).

Now, consider the sellers. This $r_i$ is the minimum price Seller $i$ would accept—he needs to at least match his break-even price, and he needs to set $r_i$ (and $q_i$) so that the marginal benefit of going to auctions is equal to the marginal benefit of going to negotiations (otherwise he could adjust $r_i$ and $q_i$). Different $r_i$’s would not be renegotiation-proof, and as mentioned before, in real cattle auctions, buyers could refuse to bid, forcing the caller to set a new reserve price. Setting the reserve price to this minimum acceptable price skips that step. Furthermore, the seller would not deviate from this choice of $q_i$ as it maximizes payoffs by construction. \qed

We must have

$$r_i(q^*_i) + r'(q^*_i)q^*_i \leq E[W^{(2)}]$$

as $E[W^{(2)}]$ is the best price the seller can get, and the right-hand-side is the minimum price the seller can get, and it turns out this implies $q^*_i \leq q^*_c$. Hence,

**Proposition 3.** When Equation (4) holds with

- strict inequality, $q^*_i < H_i$
• equality and the conditions for Proposition 1 hold, then $q_i^* = H_i$

Again, verification is provided in the Appendix.

4 Conclusion

This paper lays out a general model for understanding cattle auctions. To complete the full analysis, I would make welfare comparisons and look at comparative statics (e.g. vary the herd sizes, size of interval on which valuations were drawn, number of sellers/buyers, and the various cost parameters).\textsuperscript{10} I could also consider the effect of different rules in the auctions, e.g. allowing sellers to reject the auction outcomes or the effect of letting sale barns buy up leftover cattle or find alternate buyers for the leftover cattle (as some do in real life). Perhaps for increased tractability, I could assume that the valuations were drawn from a Bernoulli instead of from the uniform distribution—even when I used $N = M = 2$ with the uniform distribution, the algebra was sufficiently dense to be uninformative.

The advantage of the general model is it can be used to evaluate different sized bidding rings, e.g. a bidding ring which does not contain all bidders or competing bidding rings. The question would then be how many and how large do bidding rings have to be to drive sellers away from negotiations. One consideration will be whether the $j$ with $W_j = W^{(1)}$ is in the ring or not, and what the values of his compatriots are—the comparative statics for those values could be useful to analyze. There would be a number of cases to consider: when the bidding ring doesn For future research, it could be fruitful to consider an approach along the lines of Marshall et. al.\textsuperscript{[11]}. Collusion, as we have discussed, could be a major factor in this transition from auctions to negotiations, but information may be important as well. Through experiments, Cason and Plott (2005)\textsuperscript{[4]} show that forced information disclosure hurts\textsuperscript{10}\textsuperscript{I would also specify the game more precisely.}
the disclosing party. Thomas and Wilson (2002)[19] confront the informational issue more explicitly in their experimental study of “multilateral negotiations,” i.e. negotiations in which one buyer plays sellers off each other to obtain concessions in prices. Their experiments suggest, among other things, buyers prefer multilateral negotiations. This body of research leads might imply that price anchors created by Livestock Mandatory Reporting Act would hurt cattle ranchers in their negotiations. As experiments may not necessarily generalize, a theoretical approach may be fruitful in offering a unified framework for interpreting empirical evidence and evaluating each institution’s relative efficiency.

References


Appendix

A Justification for assuming $T(q) = A + Tq$: An illustration of what goes wrong

This comment just makes the case that my assumption was not unreasonable; the calculations do get out of hand otherwise. Let $M = 2$. Suppose $W_j(q) > W_{3-j}(0)$ for $q \in [0, q_{j_1}]$ for some $q_{j_1}$ and $j$; then $j$ pays $[(1 - 2\gamma)v + W_{3-j}(0)]q_{j_1}$.

Now it’s $3 - j$’s turn. Suppose $W_{3-j}(q) > W_{3-j}(q_{j_1})$ for $q \in [0, (3-j)_{1}]$ for some $q_{(3-j)_1}$ and $j$; then $j$ pays $[(1 - 2\gamma)v + W_{3-j}(q_{j_1})]q_{(3-j)_1}$.

It goes on—both flip back and forth and eventually, we have $j$ pays $(1 - 2\gamma)vq_{ja} + (W_{3-j}(0) - W_{3-j})(q_{j_1})q_{j_1} + \cdots + (W_{3-j}(q_{ja-1}) - W_{3-j}(q_{ja}))$; we can write a similar expression for $3 - j$; and $q_{ja} + q_{jb} = \sum_{i=1}^{N} H_i$ (if those two $q$’s represent the total quantities both bidders end up winning).

B Derivations for the proposed SPE

B.1 Expression (1) (derived from (S2)

The ring is able to obtain $\sum_{i=1}^{N} q_i^*$ by paying $\sum_{i=1}^{N} r_i q_i^*$. If it evenly divides cattle and costs (as we have specified Section 3.4), then the collusive payoffs for Buyer $j$ is

$$\pi_{j,b}^{col} = \pi_{j,b}^{auc} \left( \frac{\sum_{i=1}^{N} r_i q_i^*}{M}, \frac{\sum_{i=1}^{N} q_i^*}{M} \right)$$

Suppose the ring decides to offer a price $\hat{r} < r_I(q_I^*)$ to Seller $I$. Then it still successfully obtains $q_I^*$ (since the seller is a hostage at the auction) but henceforth, it obtains the negotiation payoff. Note that we have to adjust the negotiations payoff from before—we have to weight it with the probability that he is able to interact with
Seller I (namely, 1/N). Furthermore, ring members do not know their own valuations \( V_j \) in the future, as they receive new draws each period. Accounting for these and setting the ring payoffs from deviating to be less than the ring payoffs from paying the reserve yields Expression (1).

### B.2 Expression (4)

Note that the first order condition that Seller \( i \) needs to solve is

\[
0 = (1 - c_2)(r_i(q_i^*) + r'(q_i^*)q_i^*) - c_1 - T x_i + \frac{d\pi_{i,s}^{nego}(H_i - q_i^*)}{dq}
\]

\[
= (1 - c_2)(E[W^{(2)}]) - c_1 - T x_i + \frac{d\pi_{i,s}^{nego}(H_i - q_i^*)}{dq}
\]

where \( q_i^c \) represents the optimal quantity in the non-collusive setting. Hence, as \( \pi_{i,s}^{nego} \) is concave in \( H_i - q \) (but convex in \( q \)) we have the implications established in Section 3.4.