THESIS

EXPLORING HETEROGENEOUS MOTIVES BEHIND ANIMAL WELFARE MANAGEMENT: A FOCUS ON FED CATTLE

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ABSTRACT

EXPLORING HETEROGENEOUS MOTIVES BEHIND ANIMAL WELFARE MANAGEMENT: A FOCUS ON FED CATTLE

This thesis evaluates animal welfare management for fed cattle in two parts. The final marketing stage of the cattle supply chain, which includes transportation from the feedlot, unloading, lairage, and stunning, can subject cattle to significant stress. Yet, previous research has primarily concentrated on animal welfare in upstream segments of the supply chain, such as at ranches and in feedlots. As consumer awareness increases and demand for improved animal welfare rises, it is crucial to evaluate the impacts of animal welfare outcomes on fed cattle production across the supply chain.

First, a lot-level empirical analysis evaluates how animal welfare outcomes in the final marketing stage affect the final grid value of fed cattle carcasses. We hypothesize that poor animal welfare outcomes will be negatively correlated with processed carcass value due to reduced mobility, higher bruising trim, and meat quality defects (e.g., dark cutting). We use data collected from five federally inspected processing plants during 2021-2022 that include lot characteristics, animal welfare outcomes, and exogenous factors. Historical monthly price spreads from the Economic Research Service (ERS) and national weekly slaughter cattle premiums and discounts from the Agricultural Marketing Service (AMS) are used for market and pricing information. We construct grid carcass values for over 600 lots of fed cattle, representing over 87,000 fed cattle. Regression is used to analyze whether and how much mobility, bruising, and quality defects affect grid values conditional on lot characteristics and other exogenous factors. We find that the value after processing varies by the study factors, including animal welfare outcomes, although some negative welfare outcomes are relatively rare in the data. Assuming processors behave as profit maximizers, decreased returns due to poor animal welfare outcomes could incentivize improved animal welfare management in fed cattle production systems.

Second, animal welfare management has broader implications for changing regulatory, market, and private industry requirements for producing animal products. Therefore, the second essay of this thesis broadens into a discussion of the heterogeneous motives behind animal welfare management at the pre-slaughter marketing stage. Animal welfare improvements are a conscious management decision impacting the various strategic goals of business. Beyond profit motives, we explore societal and consumer expectations, corporate responsibility, and market access options that are highlighted by increased investment in animal welfare management. We combine previous literature on these aspects into an over-arching discussion of the opportunities and challenges that producers may face when deciding how to manage animal welfare outcomes. To organize the discussion, we adopt a conceptual framework that incorporates dynamic firm behavior, such as access to differentiated markets and corporate social responsibility, in addition to simple profit maximization.

The two essays combine to explore the trade-off of animal welfare management costs and benefits for producers in the final marketing stage of fed cattle and have the potential to generate future discussion on the feasibility and progress of ever-growing animal welfare requirements for farm animal production.

Keywords: animal welfare, meat processing, fed cattle, agribusiness management, market access

JEL Codes: Q18, L11, L21, Q13, L15, L21, L14

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Synopsis

Consumer demand for animal welfare across food animal production has been growing for decades. The final marketing stage of cattle is the shortest span of the production cycle but introduces significant stress for fed cattle. Negative animal welfare outcomes affect production efficiency and product quality. We evaluate how animal welfare outcomes in the final marketing stage affect the value of fed cattle

We model the grid value of processed fed cattle as a function of lot, market, and animal welfare factors. This study uses a sample of lot-level data consisting of cattle characteristics and animal welfare and meat quality outcomes collected at processing plants during 2021-22. The dataset includes lot characteristics (e.g., lot size, weights), animal welfare outcomes (e.g., mobility, bruising), meat quality (e.g., yield grades, quality grades), and exogenous factors (e.g., plant location, transportation distance, seasonality) for over 600 slaughter lots representing over 87,000 fed cattle. Economic Research Service (ERS) historical monthly price spreads and Agricultural Marketing Service (AMS) National Weekly Direct Slaughter Cattle- Premiums and Discounts reviews provided market and pricing data for a formula-based grid pricing analysis of fed cattle carcass value. Regression is used to analyze whether and to what degree mobility, bruising, and quality defects affect grid purchased carcass value conditional on lot characteristics and other exogenous factors.

We find the value after processing varies by the study factors, including animal welfare outcomes, although some negative welfare outcomes are relatively rare in the data. Our results display a potential animal welfare cost of over $68,000 a day for large-scale processing facilities. This research has implications for discussions of the changing regulatory, market, and private requirements for farm animal production. Discussion prompted by this research relates to animal welfare labeling and evolving production systems.

Keywords: animal welfare, cattle value, bruising, meat quality

JEL Codes: Q18, L11, L21

1. Introduction

As consumers continue to demand higher levels of animal welfare in food animal production, animal product supply chains must balance the costs and benefits of investing in animal welfare management in their firms. The United States Department of Agriculture (USDA) Food Safety and Inspection Service (FSIS) establishes four main benefits of humane handling of finished cattle: preventing needless suffering of animals, ensuring safe working conditions for employees, improving meat product quality, and minimizing financial losses to slaughter establishments (Public Law 107-171, 2002). While the first three benefits are extensively researched in the animal science literature, the economic implications of animal welfare at slaughter facilities have not been extensively quantified, especially in beef cattle. Therefore, it is crucial to examine how negative animal welfare outcomes impact producers' returns.

The beef processing sector is highly concentrated, with over 80 percent of cattle slaughter conducted by only four companies (MacDonald et al., 2000). These large packing companies have more resources to invest in animal welfare improvements than smaller firms in other supply chain segments such as cow-calf ranchers. Best management practices for slaughter plants include humane handling practices (e.g., appropriate handling tool usage), arrival management procedures (e.g., minimizing truck wait time) and installation of infrastructure to mitigate impacts of extreme weather (e.g., shades and sprinklers; Edwards-Callaway, Calvo-Lorenzo 2020). Use of these management practices is heterogeneous across the industry, however. Some practices are easier to implement, more cost effective, and thus more widely used- such as sprinklers- while other advances in welfare management are slower to be employed for a variety of reasons: cost, proper use and management, and knowledge of benefits. With a high degree of market power in beef processing, animal welfare improvements in this production stage impact a larger number of cattle per plant than individual innovations in cow-calf ranches or feedlots where there are larger amounts of small-scale producers.

Prior research largely focuses on animal welfare concerns in other farm animal product markets or cattle production segments. Dairy cattle welfare, and the associated economic impacts of poor welfare outcomes, is extensively researched in multiple facets due to the longevity of these high producing animals (Bruijnis, Hogeveen, & Stassen, 2012; Edwardes et al., 2022; O'Connor et al., 2020). Animal welfare literature, including in the beef sector, is also more extensive in European markets (Ahmed et al., 2023; Ahmed et al., 2020; Scott et al., 2012). American feedlot systems, however, receive more attention towards animal welfare than other beef production stages due to the high intensity of these operations (Tucker et al., 2015; Park, Foster, & Daigle, 2020). However, public scrutiny has increased research into animal welfare during slaughter (Wigham, Butterworth, & Wotton, 2018). Wigham, Butterworth, and Wotton, 2018, specifically identifies the need to consolidate the range of animal welfare literature and focuses on a review of methods to measure animal welfare that is tailored to the specific challenges faced in slaughter plants. We seek to contribute to this knowledge gap with a new, comprehensive evaluation of the economic effect of animal welfare outcomes in the final marketing stage of fed cattle in the United States.

We contribute to the literature three ways. First, while the effects of welfare in other livestock systems and cattle production supply segments have been investigated, there is little literature on the economic impacts of preslaughter cattle welfare. Focusing on the final marketing stage rounds out the literature by contributing to the discussion of the economics of animal welfare in the entire cattle production chain rather than stopping at the farm or feedlot level. Next, we use an exclusive dataset collected directly from federally inspected processing plants. The data follows over 600 slaughter lots of cattle from transportation through lairage and stunning to the associated meat characteristics of the resulting carcasses. A slaughter lot of cattle is the specific group of cattle that arrives at the processing plant from the same feedlot and remains grouped together through processing (Kline et al., 2020). This dataset provides the opportunity for analysis from direct observations of private production operations and the resulting outcomes from the differing plants and management systems. Finally, the empirical analysis gives quantifiable estimates to hypothesized effects of animal welfare outcomes on fed cattle value. Many individual animal welfare outcomes have been shown to affect cattle value (e.g., bruising trim loss), yet there lacks a comprehensive analysis of extensive, compounding animal welfare concerns on cattle value. The expansive data set used in this study allows the individual welfare outcomes to be evaluated in unison to explore how their effects compare to lots without any negative animal welfare concerns.

In this paper, we begin with a Conceptual Framework establishing the role animal welfare plays in fed cattle value. This involves reviewing the multifaceted outcomes of animal welfare and each's impacts on processing efficiency and beef quality. Next, the Data section explores the unique perspective this study's data provides in investigating the economic effects of stressors in the final marketing stage. Finally, an empirical analysis explores the quantifiable effects of animal welfare outcomes on processing returns.

2. Conceptual Framework

Previous research suggests that multiple factors affect the value of fed cattle (Grethe, 2017; Davis et al., 2022b; Sullivan et al., 2022). Here, we conceptualize fed cattle carcass value (V) to be influenced by these factors according to (Equation 1):

$$V = f(L, T, Q(W), M, W(L, T)) \tag{1}$$

where L = Lot Characteristics, T = Transportation and Lairage Characteristics, Q = Meat quality characteristics, W = Animal welfare characteristics, and M= Market Characteristics. The literature generally agrees that factors associated with L, T, Q, and M may directly affect V. However, empirical findings about how much these factors matter in terms of their statistical or economic significance vary. We add to the literature by considering W as an additional factor that could directly or indirectly affect V and providing empirical evidence on the magnitude of the effect.

First, lot characteristics (L) include physical attributes of the fed cattle (e.g., gender, breed, weight, health status) as well as attributes of the lots (e.g., total head, shift processed, special marketing designations). The effects of these traits can be seen throughout the various stages of the beef supply chain (Schroeder et al., 1988; Williams et al., 2012; Zimmerman et al., 2012). Many of these traits are genetically determined or determined by upstream segments of livestock supply chains (ranches, feedlots) before being shipped to the packing plants. Therefore, many of the characteristics which affect animal welfare outcomes are beyond the control of processing plants without a coordinated effort. Despite final carcass values being discovered at the postmortem stage, it is important to note that management responsibility to improve animal welfare will be spread across feedlots, transporters, and processors.

Second, transportation and lairage characteristics (T) related to the movement of cattle from the feedlot to the slaughter plant (i.e., transportation distance, truck density) and the time spent in holding at the plant (i.e., in lairage) before stunning (e.g., unloading waiting time, lairage density). Schroeder and Graff 2000 find the average cost of transportation to be less than 25 cents per hundredweight and thus negligible to the production costs of processing fed cattle. While the dollar cost may have increased since that study, similar increases across all input costs mean the transportation costs are still likely a small portion of total costs. However, transportation can be key in animal welfare outcomes and returns for processors and feedlots. Long travel distances and wait times to unload also result in higher weight losses to carcass shrink (Warriss, 1990). Weight loss is most rapid in the first 12 hours without food or water, therefore, slaughter lots traveling extreme distances or experiencing extended wait times to unload may be susceptible to greater decreases on returns (Warriss, 1990). Extended waiting to unload can further exacerbate carcass shrinks by extending the time animals are deprived of food or water beyond expected travel times. High truck stocking densities reduce the monetary cost of transporting large lots by eliminating the cost of extra transport trucks. However, they can reduce carcass weight, exacerbate bruising, and increase the risk of injury or death (Grandin, 2007). Deaths during transit, or at any point before stunning, result in a complete monetary loss as these animals cannot be processed and added to the food supply chain (Warriss, 1990). Lairage is another important period that introduces many stressors for cattle; this wait time from truck unloading through stunning can involve movement through novel environments and food or water deprivation. The Humane Slaughter Act of 1978 does require in its animal handling section that animals in lairage have access to food and water (CFR, 1979). However, confined lairage areas can cause overcrowding that prohibits access to provided water or restricts the ability to lay down, further exacerbating animal welfare concerns from fatigue and water deprivation.

Third, meat quality characteristics (Q) include factors associated with yield grade and quality grade. Yield grades estimate the percentage of boneless, closely trimmed, high-value retail cuts on a carcass (Radunz, 2012; Hale et al., 2013). Carcasses are scored from 1 to 5, Yield Grade 1 being the highest yielding and 5 being the lowest. USDA quality grade is determined based on maturity of the carcass and marbling within the ribeye that impact meat palatability (Radunz 2012; Hale et al., 2013). The three most common beef quality grades sold to consumers are Prime, Choice, and Select while lower grades are typically sold as ungraded or made into processed products (Meadows, 2013). Color is an important factor in beef quality grading, and consumers repeatedly reduce their willingness to pay for discolored beef (Feuz et al., 2020). Discolored beef can vary in severity, with dark cutter beef being the most severe.

Market characteristics (M) include price discounts and premiums for the quality factors. These premiums and discounts are summarized by the weekly USDA fed cattle price adjustments. Pricing of fed cattle often varies drastically between packers, regions, and producer

(Ward, Schroeder, & Feuz, 2017). As our cattle lots span numerous processors, geographical regions, and feedlots, it is crucial to choose a pricing strategy that uniformly and accurately values the carcass value regardless of unpredictable, often confidential contract pricing structures. Additionally, we focus on the final marketing stage and must focus on impacts of management practices in this segment despite other stages of the production cycle also affecting animal welfare.

In addition to the above categories of factors, we add to the economics literature on the determinants of fed cattle value by also considering animal welfare characteristics (W). They include attributes associated with physical animal defects or related indicators of potential animal welfare concerns (e.g., mobility, bruising, open mouth bruising). These factors can have direct and indirect effects on fed cattle values. Animal welfare outcomes directly impact fed cattle values if they result in poorer meat quality grades after processing (Q). While animal welfare outcomes are crucial indicators of general animal well-being, they each also impact economic productivity from either an efficiency or product quality standpoint. In a production setting, proper animal welfare management is crucial for productivity, appealing to consumer preferences, and maintaining a positive public reputation.

A wide variety of factors may affect and gauge animal welfare in the pre-slaughter stage. Factors indirectly impacting animal welfare include condition prior to transport, sex class, breed, handling, and environmental characteristics. These indirect factors affect how animals cope with stressors rather than directly affecting animal welfare. Impacting elements can be measured through observable outcomes such as health condition, temperament, humidity, or facility design. For an extensive discussion of animal welfare factors and indicators, see Davis et al., 2022; we will focus on a subset of these outcomes that could be observed and measured-including carcass bruising, dark-cutting, mobility, and heat stress- for the purposes of this paper.

Besides being a physical indicator of animal welfare, carcass bruising also decreases fed cattle value by reducing both meat quality and quantity (Warriss, 1990; Kline et al., 2020). Extensive bruising requires carcass trimming to remove damaged meat that is visually appealing to consumers (Warriss, 1990). However, most substantial monetary losses come from quality downgrading of carcasses with extensive bruising (Warriss, 1990). Carcass bruising costs the U.S. beef industry over $35 million a year (Charban, 2018). Both yield and quality downgrades decrease revenue on bruised carcasses by eliminating potential price premiums for superior beef carcasses.

Additionally, the dark, firm, dry meat referred to as dark-cutters/dark-cutting (DC) beef is not only an extreme of consumer discrimination against discolored beef but is also an indicator of poor animal welfare (Warriss, 1990). Excessive stress generates physiological reactions which can cause a high muscle pH post-mortem that results in meat that looks dark, firm, and dry (i.e., dark cutters)- all of which are unappealing characteristics to consumers (Sullivan et al., 2022; Warriss, 1990; Ponnampalam et al., 2017). Dark-cutter meat is highly discounted, resulting in a loss to the beef industry of nearly $170 million a year (Ponnampalam et al., 2017; Underwood et al., 2007).

Mobility is an important indicator of cattle welfare as it is impacted by both natural factors, Temperature-Humidity Index (THI), sex, and age, as well as human controlled factors such as days on feed, transportation, and lairage conditions (Davis et al., 2022b). Despite recent industry initiatives to benchmark and monitor cattle mobility in processing plants through programs like the National Beef Quality Audit (NBQA) and the Full Value Beef Cattle Mobility Assessment Program led by Elanco Animal Health, mobility and lameness are often underrepresented in animal welfare studies (Edwards-Callaway & Calvo-Lorenzo, 2020; Eastwood et al., 2017; Davis et al., 2022b). Significant lameness issues can lead to detrimental economic losses for processors. Nonambulatory, or "downer", cattle "cannot rise from a recumbent position or cannot walk, including, but not limited to, those with broken appendages, severed tendons or ligaments, nerve paralysis, fractured vertebral column, or metabolic conditions" (CFR, 2016). These animals are labeled as condemned during an antemortem inspection by USDA Food Safety and Inspection Service (FSIS). They are euthanized and disposed of rather than entering the supply chain (Edwards-Callaway & Calvo-Lorenzo, 2020). Additionally, lame, ambulatory cattle may have lower carcass weights and decreased carcass quality due to reduced feed efficiency (Dudley, 2017). Lots with a high volume of significant lameness issues may also slow line efficiency during processing, but the average lot production is most likely unaffected by poor mobility as most cattle will have regular mobility.

Finally, heat stress is another key welfare factor affecting productivity and meat quality. Heat stressed cattle exhibit lower carcass weights, meat tenderness, and poor meat color (Nardone et al., 2010; Summer et al., 2019). Temperature and humidity both impact the severity of heat stress. The Australian Veterinary Handbook specifies a THI threshold of 72 or less for no heat stress risk (LiveCorp and Meat and Livestock Australia, 2023). The majority of fed cattle are finished in Texas, Kansas, and Nebraska where THI exceeds most other general beef producing states (St-Pierre et al., 2003). Without heat abatement, losses in growth and deaths caused by heat stress are estimated at $282 million per year annually across the production cycle (St-Pierre et al., 2003). However, heat abatement such as sprinkler use is generally low-cost and highly used across the industry, reducing signs of heat stress (Davis et al., 2022a).

3. Empirical Strategy

Several empirical and econometric challenges arise when trying to estimate the impact of welfare indicators on the grid values of fed cattle. First, without standardized definitions or goals for animal welfare, a wholistic assessment of animal welfare is not directly observable, so an index of indicators such as Open Mouth Breathing (OMB), poor mobility, or extensive bruising provides a proxy for individual factors decreasing animal well-being. These outcomes must align with observable data relevant to economic production decisions (Cryan, 1997). Thorough economic quantifications for animal welfare outcomes are often crude ranges or not researched extensively, especially in beef cattle. For example, the economic impacts on milk production yields and quality are found frequently in the literature (Hansen, 2023; Adamie et al., 2022), but these estimates have not been translated to fed beef cattle, particularly in the short final marketing stage. With the lack of economic studies on distinct, specific animal welfare concerns like carcass bruising loss, we must hypothesize that all possible welfare outcomes have the potential to impact fed cattle value. We must disconnect the compounding nature of multiple negative experiences that are often connected to the same observable outcomes, which may be impossible. The interconnectedness of stressors, outcomes, and meat quality thus presents challenges in dissecting what individual factors impact animal welfare concerns and final value most significantly.

Second, a consistent, appropriate valuation method must be used to account for the interactions of animal welfare outcomes and their impacts on final fed cattle performance outcomes. This valuation method must also consider the available observed data and what is currently quantifiable. Research on physical impacts (e.g., carcass bruising, lameness, heat stress) often does not extend to these defects' financial effects (e.g., trim loss amounts, slowing line movements, increased feed costs). Most research on beef cattle animal welfare outcomes reports about the overall industry loss of negative outcomes, but there is little research on the actual specific economic impact on lots or individually affected animals (Huertas et al., 2015; Kline et al., 2020). Economic impacts are most significant to the economic view of producers as profit-maximizers, so significant financial losses can incentivize non-regulatory investment into animal welfare management.

Finally, heterogeneity in the industry complicates the development of uniform data measures. Measuring and reporting of variables varies across companies, plants, and shifts. Identifying these differences is not always possible and presents difficulties in evaluating outcomes across different processing facilities. Disparities between plants may be as simple as differing weight categories or lairage layouts to as distinctive as recording half carcass meat traits rather than whole or slaughtering lots by arrival truck rather than altogether. This heterogeneity in overall plant practices can also be narrowed down to differences in management practices inside and outside the plant that may impact animal welfare outcomes within each plant. Some practices may come from company policies while others are shift training or variety in feedlot origin. To ensure the data captures this heterogeneity, it is crucial to collect data from differing companies, plants, shifts, and seasons to evaluate management differences that may confound animal welfare disparities across the industry.

4. Data

The empirical analysis combines data from three main sources: primary data at the slaughter-lot level collected from commercial packing plants, price data on market premiums and discounts for fed cattle, and secondary data sources that capture exogenous risk factors (e.g., climate).

4.1. Fed Cattle Slaughter Lots

The majority of our study variables are constructed from primary data on 637 slaughter lots of fed cattle collected from five federally inspected cattle processing facilities representing three beef processing companies over multiple trips from March 2021 to July 2022 (Davis et al., 2024). These lots represent over 87,220 head of individual cattle, for an average lot size of 137 head. The data collection strategy included repeat visits to the same facilities in different locations to capture seasonal and geographic variations in weather and climate, cattle and supply chain logistics, and market conditions. General lot characteristics, identifying factors, transportation data, and environmental conditions were recorded on-site. Overall, 53% of lots were exclusively steers rather than mixed or heifer lots. On average, lots traveled 150 miles from feedlot to processing with 36% being processed in the summer, the highest of any season, and the least in the fall at 13%. 56% of lots were processed during the first shift. The processing facilities provided additional records post-data collection, including meat carcass quality characteristics. Several slaughter lots in the primary dataset lacked meat quality information needed to calculate carcass values and were excluded from this research. Therefore, the empirical results reported here use data from 604 lots representing a total of 82,059 head.

4.2. Welfare Data

The primary data include researcher-scored variables related to animal welfare outcomes for the fed cattle. The team included students and faculty with extensive expertise and training in animal welfare topics. As documented in Davis et al., 2024, the team was trained through video and in-person training until all observers received a strong to almost perfect agreement inter-observer reliability to ensure data quality.

Specifically, the plant observed data includes transportation characteristics, temperature/humidity, animal characteristics, lairage factors, mobility, bruising prevalence, and signs of heat stress (See Appendix A, Table 2). Each of these affects a combination of animal welfare, plant efficiency, and product quality.

The bruising data qualitatively groups carcass bruising relative to a pack of cards: none, smaller than a pack, larger than a pack, or multiple bruises, consistent with the National Beef Quality Audit (NBQA) methodology (Davis et al., 2024). We do not know the location of bruising, which may affect the cost of these bruises if carcasses were bruised in the location of more valuable cuts of meat. However, bruising is most frequently found along the dorsal midline (spine) and rump which do not correlate to traditionally valuable meat cuts (Kline et al., 2020; SDSU Extension, 2022). Additionally, Kline et al., 2020, state that visual assessment of bruising may underestimate bruising losses as the bruise may extend much deeper under the surface; as our data is exclusively visually measured two-dimensionally, our bruising losses may undervalue the total effects of bruising on the final carcass value.

Mobility was observed during antemortem inspections when moving between lairage pens or to slaughter. A four-point scale created by the North American Meat Institute (NAMI) was used for scoring mobility. On this scale, 1 designated normal mobility with no apparent lameness and progressively worsens to 4 representing cattle that are extremely reluctant to move (NAMI, 2015*)*. Open mouth breathing (OMB) was also recorded during this antemortem evaluation. OMB is used as a measurement of heat stress and is considered an indicator of poor welfare. Open mouth breathing- where an animal exhibits increased respiration with a potentially protruding tongue and extended neck- is used as a metric for identifying animals suffering from heat stress and was observed during mobility scoring (Mader et al., 2006).

4.3. Other Control Variables

Other factors captured in the plant data include environmental and exogenous data including temperature, humidity, and seasonality. Management and handling vary across the industry, so there is potential for variation accounting from differing feedlot origin or processor plant of lots. To account for these factors, exogenous variables also include fixed effects such as plant and feedlot producer.

Additionally, some factors outside of the processor's control can impact animal welfare. Cattle characteristics including breed, genetics, or sex class which can predetermine tolerance to stressors and the likelihood of negative animal welfare outcomes. There are also management decisions in prior market segments which can affect cattle condition prior to arrival at the processing plant. Upon arrival at the plant, this prior condition impacts the animal's physical and mental condition, resulting in higher instances of negative outcomes. We evaluate these factors as fixed effects affecting carcass value since they are outside the management decisions of processing plants.

4.4. Cattle Prices and Premiums

We rely on a value-based pricing of carcass merits rather than live animal characteristics (Schroeder et al., 1998). Formula- based grid pricing rewards feedlot producers for marketing high quality animals, and thus may incentivize additional attention to animal welfare concerns, especially those tied to meat quality (Q) (Ward, Schroeder, & Fuez, 2017). Base prices for grid purchases can be derived from plant averages, cash market prices, or private negotiations, which may all not be reflective of true market conditions (Ward, Schroeder, & Fuez, 2017). To ensure proper representation of market conditions and accurate, uniform valuation of our sample cattle lots regardless of difficult private information negotiations, we tie the base price to wholesale beef market prices. Increased wholesale beef prices are directly tied to packer revenues and are thus a metric appropriate to analysis of packer managements decisions (Ward, Schroeder, & Fuez, 2017). Since we do not have lot- or animal-specific pricing data for our observed lots, our valuation is unable to pinpoint exactly who received the compensation. Rather, focusing on the final value of the meat produced allows us to explore economic impacts regardless of the recipient of revenue. The USDA Choice-to-Select carcass spread is another option for base pricing, but the National Weekly Direct Slaughter Cattle- Premiums and Discounts generally closely follows the boxed beef cutout values, and our carcass information does not contain the relative yield and quality grade for each individual carcass that is required for the Choice-to-Select valuation (Ward, Schroeder, & Fuez, 2017). Wholesale beef price data was collected from the Economic Research Service (ERS) historical monthly price spread series that provides monthly national averages for wholesale choice beef as the base grid price received for each lot of cattle observed in that month. Additionally, data from USDA Agricultural Marketing Service (AMS) National Weekly Direct Slaughter Cattle- Premiums and Discounts reviews were used as the premium and discount pricing sources for off-grid purchasing of beef. This report is published every Monday with a report of the average market wholesale beef prices in cents per hundredweight (cwt) for varying quality, yield, and weight of beef carcasses sold the previous week. Using both these data sources, we matched each observational trip with the prices and premiums/discounts for beef processed the same week as the observed slaughter lots from the plant data. Summary statistics of market variables used for the dependent variable calculation can be found in Table 1 of Appendix A. However, livestock grid values during the study period were historically high relative to historical average prices, so our grid values may be inflated. For a comparison of study and historical pricing averages, see Appendix A, Table 3.

5. Study Variables and Methods

5.1. Dependent Variable

The dependent variable is "fed carcass value per hundredweight" as observed at the lot level ($/cwt). It is defined as grid value per lot ($/lot) divided by dressed weight per lot (cwt/lot). Standardizing the value on a per hundred weight basis provides a comparable measure across lots of many different sizes. We construct the grid value per lot as "total gross value per lot" where gross value is total carcass chilled weight per lot multiplied by quality-adjusted market prices ($/cwt). As carcasses are chilled, water evaporation causes carcasses to lose two to five percent of their weight (Saner & Buseman, 2020). Therefore, total carcass chilled weight per lot is calculated by multiplying the average hot weight per head for each lot by the total number of cattle processed[1] and then multiplying by 96.5%. Construction of the gross value variable accounts for the proportion of cattle within each lot in each yield and quality grade category[2]. Quality-adjusted market prices are the wholesale beef price plus or minus premiums or discounts

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[1] Total carcass chilled weights include adjustments for lots graded as split carcasses when known

[2] $/cwt = (Wholesale Beef*(Avg Chill Weight*(Lot Size – D/D))– QG%*Discount – YG%*Discount – DC%*Discount)/(Total Dress Weight/100)

for quality and yield grade, including dark cutters when reported, for the week of data collection as reported by USDA ERS (2022) and USDA AMS (2022).

For example, lot 5011 was observed July 13, 2021. This lot contained 57 head, 1 of which was condemned in the antemortem inspection as a dead/downer. Thus, 56 carcasses were graded. The average hot weight of the lot was 899 pounds. After losing water weight during chilling, the average chill weight would be approximately 868 pounds per carcass. With a wholesale market beef price of $414/cwt in July of 2021, the base revenue for this lot would be $201,129.34. 13 of these carcasses graded prime, 42 graded choice, non were select, and 1 was a no roll and thus considered standard for this calculation (Beef Checkoff, n.d.). Thus, quality grading resulted in an additional $4,730 of grid value added to the base revenue to account for the $14.11/cwt premium for the 23% of the lot that graded premium minus 2% of cattle discounted at $32.57/cwt. Yield grades were more evenly distributed with 3 grading yield grade 1, 19 grading a 2 or 3, 12 as yield grad 4, and 3 as yield grade 5. With premiums of $3.69/cwt and $1.58/cwt for yield grades 1 and 2 respectively, combined with discounts of $11.23/cwt and $16.85/cwt discounts for yield grades 4 and 5, yield grading resulted in a $4,571 loss of grid value for lot 5011. Additionally, 1 carcass graded as a dark cutter and lost an additional $35.83/cwt for a total dark cutter discount of $289.74. Between all carcass characteristics, the lot had a final loss of $81.56 for a total grid value of $201,047.76. The lot had an average live weight of 1,384 pounds that had a dress yield of 65%, so the total dressed weight of the lot if it had not had any dead/downers would expect to be 51,277 pounds. So the total grid value divided by the expected dressed weight over 100 to adjust to a per hundredweight basis would result in a final lot grid value per hundredweight of $392.08.

As seen in Table 2, the average value of each lot was $415.29/cwt (±$2.82/cwt), slightly lower than the average wholesale beef price of $437.83/cwt seen over the data collection period. On average, over 20% of a lot graded lower than choice, and therefore was discounted below the wholesale beef price, resulting in a lower average value.

5.2. Explanatory Variables

The explanatory variables are organized according to the categories of factors affecting fed cattle values described in the conceptual framework (Tables 1 and 2). Quality Characteristics (denoted by Q in Equation 1) include carcass USDA quality and yield grading. Average quality and yield grade are calculated for consistency of lots of different sizes. To construct these variables, 5 is designated to the highest quality and yield grades- Prime and Grade 1 respectively- down to a 1 for the lowest quality and yield- Dark Cutter[3] and Yield Grade 5. Each numerical grade designation is multiplied by the proportion of the lot graded as the respective value and then divided by the total number of graded carcasses in the lot. A higher average quality or yield grade, therefore, signifies superior quality and yield. Welfare Characteristics (W) comprise varying forms of animal welfare measurement outcomes: bruising and mobility scores and heat stress. Since temperature and humidity compound to cause heat stress, a comprehensive Temperature Humidity Index[4] (THI) should be used to determine thresholds of when severe heat stress is possible and additional management for heat mitigation is needed (Gantner et al., 2011; UNL Beef 2014*)*. Transportation Characteristics (T) contain transport and lairage data like

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[3] Standard Quality includes Commercial and No Roll grades when reported. Dark Cutter includes Cutter, Canner, and Utility when reported.

[4] THI= Temp – (.55*(1-Humidity))*(Temp-58) (Schlatter 1987)

distance traveled, wait times to unload, and pen density. Market characteristics (M) capture all base and premium pricing data, as well as seasonality.

Finally, we construct an index of Negative Animal Welfare Outcomes (NAWO) to measure the interaction of the various animal welfare indicators. Negative animal welfare outcomes can directly or indirectly affect the dependent variable. Direct effects include adjustments to the total carcass chilled weight per lot for dead or downer animals. Indirect effects include NAWOs that do not directly reduce the quantity of meat yield but may contribute to lower quality grade scores. Generally, they include traditional animal welfare indicators, such as poor mobility, that are not directly observable in the gross revenue/net return of the lot. A slaughter lot with at least one poor animal welfare indicator is designated as having a NAWO. The thresholds for poor animal welfare are taken from industry standards or audit criteria. There are 7 possible negative animal welfare outcomes: mobility, bruising, lairage density, open mouth breathing, dark cutters, dead/downers, and truck waiting time. In their Recommended Animal Handling Guidelines and Audit Guide, the North American Meat Institute (NAMI) establishes an industry standard for optimal maximum truck waiting times of sixty minutes (NAMI, 2021). NAMI's audit guide also establishes minimum space allowances for lairage dependent on cattle weight. As little as 1.87 m^2 of space should be allotted for 1200-pound animals, and this area grows to 2.22 m^2 for 1600-pound animals, with varying allotments for animals between these extremes (NAMI, 2021). We conform to these industry guidelines for lairage density and truck waiting times so that any lot waiting longer than 60 minutes to unload or with a lairage density smaller than that recommended for their average live weight is deemed a negative animal welfare outcome. For mobility and bruising, the extremities of outcomes were considered a negative outcome; for mobility, that is the less than one percent of cattle in the data with irregular mobility- graded a 3 or 4 on the NAMI mobility scale. Bruising was much more prevalent in the data, so the fourth quartile of proportions of lots with multiple large bruises was deemed a NAWO. Finally, “outs” such as dark cutters and dead and downers where an entire carcass is lost or the presence of OMB (heat stress) are in themselves a negative animal welfare concern at any scale, so the presence of even one animal with these characteristics deem the lot as NAWO present for those three categories. These different individual outcomes are then aggregated into the count[5] of the total negative animal welfare outcomes as a comprehensive NAWO index ranging from one to seven possible negative outcomes. No single lot contained every possible NAWO. The most common individual NAWOs were bruising followed by dark cutting. In combination, 3.48% of lots experience bruising and dark cutting, the most common combination for those lots experiencing more than one NAWO. The single lot containing six NAWOs contains all possible individual NAWOs other than a truck waiting time longer than an hour.

There are significant differences across plants for many study variables. Fed carcass value is significantly different ($p<0.001$) between all plants except Plants 2 versus Plant 3, Plant 2 versus Plant 4, and Plant 3 versus Plant 4. The mobility NAWO, OMB NAWO, and dead/downer NAWO are largely consistent across plants. All other variables have one to four plants with similar averages and with no variable seeing differences over every plant combinations However, those plants with differences are highly significant ($p<0.001$).

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[5] If NAWO is treated as a binary explanatory variable (at least 1 possible NAWO present), no statistical significance is found.

5.3. Regression Models

The estimating equations evaluate the impact of NAWOs on fed cattle values. In total, we estimate six models that consist of each combination of two regression equations and three variable specifications. The two equations include: a simplified version that uses a single comprehensive NAWO index variable to capture the effects of compounding animal welfare outcomes on fed cattle values (Equation 2) and a second with disaggregated individual NAWO outcome variables (Equation 3). Both equations are estimated using three different variable specifications: an Ordinary Least Squares (OLS) regression with all variables in level terms (denoted Model A), a Log-Log OLS regression with the explanatory and all continuous explanatory variables log transformed (Model B), and a Log-Level OLS regression where the dependent variable is logged but explanatory variables are in level terms (Model C).

The regression equation for models with the NAWO index variable is:

$$\begin{aligned} Vhun = {} & \beta_0 + \beta_1 NAWO + \beta_2 AvgQlyGrade + \beta_3 AvgYGrade + \beta_4 Plant1 + \beta_5 Plant2 \\ & + \beta_6 Plant3 + \beta_7 Plant4 + \beta_8 Shift + \beta_9 Steers + \beta_{10} NumHead \\ & + \beta_{11} Distance + \beta_{12} THI + \beta_{13} NumHeadPerTruck + \epsilon \end{aligned} \tag{2}$$

We estimate Equation 2 three times in total for each of the variable specifications A, B, and C. The NAWO index includes the count of negative animal welfare outcomes for each slaughter lot, including irregular mobility, higher proportions of serious bruising, OMB, high lairage densities, and the presence of “outs”. Additionally, the regression equation accounts for differences in fixed effects of processor plants, shifts, and sex class. The equation also accounts for variation in lot size, distance traveled, THI, and number of head per truck that may independently correlate to animal welfare outcomes or producer returns.

We explore the individual effects of each negative animal welfare outcome by decomposing the aggregate NAWO index into individual outcomes with equation:

$$\begin{aligned} Vhun = {} & \beta_0 + \beta_1 NAWO\_mob + \beta_2 NAWO\_bruising + \beta_3 NAWO\_lden \\ & + \beta_4 NAWO\_OMB + \beta_5 NAWO\_darkcut + \beta_6 NAWO\_d/d \\ & + \beta_7 AvgQlyGrade + \beta_8 AvgYGrade + \beta_9 Plant1 + \beta_{10} Plant2 \\ & + \beta_{11} Plant3 + \beta_{12} Plant4 + \beta_{13} Shift + \beta_{14} Steers + \beta_{15} NumHead \\ & + \beta_{16} Distance + \beta_{17} THI + \beta_{18} NumHeadPerTruck + \epsilon \end{aligned} \tag{3}$$

We estimate Equation 3 three times in total for each of the variable specifications A, B, and C. This equation considers the effects of individual negatives outcomes beyond industry guidelines or average welfare results. It retains the fixed effects from the aggregate equation.

We performed regression diagnostics to examine the validity of regression assumptions, which involved testing for heteroskedasticity, non-normality, and multicollinearity (Gujarati & Porter, 2009). We tested for heteroskedasticity by performing a Breusch-Pagan test in STATA using the "hettest" command (UCLA, 2021). Heteroskedasticity biases the variances of the regression coefficients, causing the hypothesis tests to be unreliable. Next, normality is evaluated with a histogram of residuals and a Shapiro-Wilk W test- "swilk" in STATA (UCLA, 2021). Similar to homoskedasticity, normality of residuals is not required for unbiased estimated of the regression coefficients, but it ensures the hypothesis testing is valid (UCLA, 2021). Multicollinearity tests are conducted in STATA with "vif", the variance inflation factors (VIF) of each variable to ensure there is no near perfect relationship between explanatory variables that may alter significance of predictors (UCLA, 2021). Finally, variability in data values was also checked by examining the standard deviations of each variable.

6. Results and Discussion

We organize the results into three sections. First, we report and discuss the regression results for the comprehensive NAWO models. Second, we report and discuss the disaggregated NAWO model results. Last, we discuss connections between the results and policy implications.

6.1. Comprehensive NAWO model results

Table 3 reports estimated coefficients from all variable specifications for the comprehensive NAWO models (Equation 2)- level (a), log (b), and log-level (c) forms. We evaluated the results for their performance relative to standard regression assumptions. OLS regression produces unbiased coefficient estimates in the presence of non-constant variance but can lead to inaccurate inferences from inflated standard errors in the presence of heteroskedasticity. As all models failed tests for homoskedasticity assumptions, all parameter estimates are reported with robust standard errors. Both residual plots and the Shapiro-Wilk W Test also reject the assumption that the error term is normally distributed. All models' residual plots are equally skewed left, so no model better fits the normality assumption than another. Similar to heteroskedasticity, lack of normality in the residuals affects the minimum variance of OLS estimates, so more conservative robust standard errors should account for errors in hypothesis testing. All robust models have above a 0.45 R^2. Each variable for every model was also below the VIF threshold of 10, so there appears to be little concern for multicollinearity.

As expected, the presence of NAWOs results in a negative impact on carcass grid value. The comprehensive models in Table 3 evaluate the average impact of any of the possible NAWOs on net returns, so the effect is overall lower than the individual effects of the respective NAWO categories found in Table 4. On average, the presence of an additional NAWO results in an average \$2.69/cwt decrease in lot grid value in the level estimation specification (Model A), a 0.6% decrease in both the log-log and log-level specifications (Models B and C) ($p<.05$). Of the slaughter lots observed in this data set, 60% experienced a NAWO, but the average number of NAWOs experienced was only slightly more than 1. With 82,509 head in the study at an average chill weight of 843 pounds, that equates to 49,235 animals losing \$22.68 per carcass. Since our facilities process 1,200 to 5,000 head a day, assuming 60% of their cattle experience one NAWO and have the same average chilled weight as our study, that results in losses of \$16,330-\$34,020 per shift per day at these processing facilities, on average (Davis et al., 2024; Beef, 2022).

We observe statistically significant grid value effects on fed cattle grid value for plant, shift, and seasonal differences with results similar in sign across models with only slight differences in level of significance. As expected from Davis et al., 2024, there are significant differences between plants in each model. Due to varying management styles, incoming cattle, and geographic location, these plants have varying animal welfare outcomes which translates to the overall grid value of the carcasses coming out of the plants. These results are not sensitive to what plant is used as the reference category. These differences range from as low as a \$24.12/cwt higher value for slaughter lots processed in plant 4 over plant 5 to as high as \$58.34/cwt higher if lots were processed in plant 1 rather than plant 5 ($p<.01$). This ranges anywhere from 5.91% to 14.3% higher value for lots in plants 1-4 rather than plant 5 ($p<.01$). Additionally, shift 1 has a significantly higher average carcass value than shift 2 ($p<.01$). On average, shift 1 had a \$10.53 to \$10.94/cwt higher lot value. This corresponds to slightly more than a 2% increase in carcass grid value for lots processed in shift 1 over shift 2. Shift 2 may be predisposed to worse animal welfare outcomes as animals who travel further arrive later in the day, or there may be training differences between employees in different shifts. Spring and summer also significantly decrease fed cattle value over fall lots. On average, summer lots were more than $12/cwt lower in grid value than fall lots ($p<.01$). This is 1.38% to 3.17% decrease in value. Lots processed in the spring also saw decreases in value, but at a lower magnitude. Spring lots had $8.45-$9.31/cwt lower grid value, a more than 2% decrease from fall lots ($p<.05$). This is contrary to general cattle price seasonality where fall animals receive the lowest price. Our results may reflect heat increases that exacerbate other animal welfare concerns that reduce cattle value. With fall as the reference category, THI increases cause a statistically significant increase in carcass grid values. A unit increase in THI causes $1.57-$1.62/cwt increase in lot grid value, or approximately 0.38% increase. A 1% increase in THI causes a 16-17% increase in carcass value. Since fall typically sees the start of cold temperatures, this may result in positive THI effects that return climatic conditions to ideal temperatures. Thus, this result could be reliant on the season chosen as a reference category. Travel distance is also statistically significant in every model, but with very small positive impacts on grid value. As long travel distance should theoretically negatively impact animal welfare, there are most likely confounding factors that is causing this increase in carcass value for longer distances traveled.

Many lot characteristics were not statistically significant contrary to previous literature. Increases in lot size saw no significant impact on carcass value per hundredweight despite other research significance (Williams et al., 2012). Additionally, number of head per truck during transit also had no statistically significant impact on carcass grid value. Both average quality and yield grade were also statistically insignificant in impacting carcass grid value in the baseline models reported in Table 3. This is contrary to the calculation of grid pricing, which relies on superior quality and yield for higher cattle pay-offs. Lots containing only steers also had no significant difference in grid value from mixed or heifer lots. This is despite higher body mass and market price in steers as well as higher rates of bruising.

6.2. Disaggregated NAWO model results

Table 4 reports the Level-Level (A), Log-Log (B), and Log-Level (C) specifications of the disaggregated NAWO models (Equation 3). We observe that each type of NAWO does not impact carcass grid value equally in the disaggregated models found in Table 4. We see similar fixed effects results in the disaggregated models as the comprehensive models, but severe bruising is the only individually significant impactor of a lot's grid value. High proportions of multiple, large bruises result in a \$5.87/cwt reduction in lot value ($p<.05$). This correlates to a 1.44-1.61% decrease in value if a lot contains over 40% of carcasses with multiple large bruises ($p<.05$). This is higher than other literature that find anywhere from a \$1/fed animal to \$5/cwt decrease in carcass value depending on bruising severity (Grandin, 1995; LMAC, 2023). However, the location of the bruise can also increase bruising costs up to \$20/cwt as bruises in high value cuts result in a greater loss (Grandin, 1995). As our data do not include bruising location, our estimate of the impact of bruising on carcass value may be undervalued. As bruising presence has been increasing overall in the beef processing sector, as seen through the National Beef Quality Audits (NBQA), this significant reduction in value from heavily bruised carcasses further highlights the detrimental impacts of highly bruised fed cattle (Eastwood et al., 2017).

While the other six individual NAWO outcomes are not statistically significant impactors, this is likely due to the relative rarity of these outcomes in our data. The average number of NAWOs per lot was only 1.023 with a standard deviation of only 0.93, with bruising severity by far the most prevalent poor animal welfare outcome seen. Some of the other NAWOs, such as lairage density or OMB, would be difficult to quantify in lost value on a dollar basis. Even so, both outcomes were rare in the data as only 16.64% and 3.89% of lots were kept in lairage areas smaller than the NAMI recommended threshold for their average live weight or had at least one animal exhibiting OMB, respectively. Other NAWOs like mobility need additional research in the beef processing space specifically to better estimate the effects of how large numbers of mobility impaired cattle would impact line efficiency or induce rough handling that resulted in carcass impacts such as bruising. In our data, over 99% of cattle observed showed regular mobility or slight limps (scored 1 or 2), though, and thus would not have caused significant impacts to handling or efficiency.

The directly quantifiable NAWOs- dark cutters and dead/downers- are the most significant losses of lot grid value. However, these are both fortunately relatively rare occurrences in the observed lots. While a complete loss of revenue when present, only 1% of all lots contained a dead/downer. One would expect higher quality carcasses that are removed as dead/downers to have a higher impact on lot grid value, but the results are not sensitive to assumptions on the quality of the dead/downers removed from processing. Dark cutters were present in 27% of lots, but these severely discounted carcasses on average only comprised approximately 1.25% of the total lots in which they were present. The rarity of these outcomes could explain the lack of significant relation to carcass grid value.

6.3. Robustness Checks

We estimate 3 extra regression equations to test the effect of varying plant records and variable specifications. First, we evaluate the effect of including plants that do not measure dark cutter prevalence. Plants 1 and 2 do not report dark cutters in their carcasses, so we remove their data and rerun the comprehensive and disaggregated model with only the remaining observations with all variables in level terms (See Appendix B). This robustness check has the most pronounced impact on our original findings. Without Plant 1 and 2 observations, the comprehensive level results remain largely consistent with our original regression estimation. On the other hand, two new individual NAWOs become significant at varying levels in the disaggregated equation. Bruising is no longer a significant loss to grid value in this equation. However, mobility causes over a $7 loss per hundredweight ($p<0.05$). Dark cutters also cause a statistically significant loss of $5.67/cwt ($p<0.1$). Additionally, the only fixed effects that are significant in these results are increases due to plant differences, average quality grade, THI ($p<0.001$), and lot size ($p<0.05$) while summer lots have a lower average value ($p<0.001$).

Next, we test the effect of adding lots with high proportions of mobility score 2 to the NAWO, Mobility variable. If most of a lot has normal mobility, a single score 3 or 4 for an animal may not significantly affect processing efficiency. However, a lot with significant amounts of even slightly impaired cattle may slow efficiency for the entire lot. To test high proportions of mobility score 2, we use the 4th quartile as the benchmark similar to the creation of the NAWO, Bruising variable. However, the 4th quartile of bruising score 2 proportions was only 10% of any given lot. Subsequently, this adjustment to the mobility NAWO metric results in disaggregated regression results with a highly significant NAWO, Mobility coefficient of over a $12 loss per hundredweight ($p<0.001$). This results in a comprehensive NAWO loss of $4.87/cwt ($p<0.001$). These values are very high given that mobility does not directly affect grid value. In comparison, bruising in both the original disaggregated regression estimation and this robustness check has results in a loss of around $6/cwt. Considering bruising is a direct impactor of grid value, it would be expected for bruising to cause the greatest loss, and this updated mobility metric has double the loss per hundredweight as bruising. Otherwise, all fixed effects remain relatively unchanged with the same significance as the original models.

7. Conclusion

Animal welfare concerns in the final marketing stage of fed cattle are diverse and multifaceted. The primary objective of this paper is the evaluate the impact of animal welfare outcomes on fed cattle carcass grid values, so we explore the magnitude to which negative animal welfare outcomes impact final fed cattle grid value at a lot level. As expected, the presence of negative animal welfare outcomes reduces beef carcass grid values. Overall, experiencing a negative animal welfare outcome causes an average $2.69/cwt decrease in final fed cattle value. However, severe bruising is the only individually significant NAWO and causes over $5 in grid value loss.

Specifically, severe carcass bruising compounds meat trimming and quality downgrades into the most substantial reduction in carcass value when each possible NAWO is evaluated individually. As the prevalence of carcass bruising is increasing throughout the industry in recent years, it is crucial to continue to examine the economic impacts and possible management factors of such carcass defects (Eastwood et al., 2017). Direct carcass effects such as bruising are shown to cause up to $35 million in losses due to trimming or carcass downgrades, yet there is little data or homogeneous management on the weight of bruise trims, especially in fed cattle body masses (Gallo et al., 1999; Lee et al., 2017; Huertas et al., 2015).

However, there exist some limitations in our approach to evaluating animal welfare's economic effects. Our research did not report the location of bruising and thus potentially undervalued the severity of bruising impacts on carcass value as bruises as high value cuts may exponentially increase meat value of trim losses (Grandin, 1995). Thus, further research is necessary to better quantify the direct revenue impacts of carcass bruising. Our grid values overall may be inflated as livestock grid values during the study period were historically high relative to historical average prices. We expect the monetary values associated with NAWOs to be less when livestock prices are lower. If prices remain elevated, supply chain firms may benefit from greater investments in best animal welfare management practices to reduce these higher impacts of negative outcomes. Research is also needed to evaluate if and how outcomes such as high levels of impaired mobility, large proportions of heat stress, or other not directly quantifiable outcomes impact line efficiency and thus increase processing costs rather than decrease revenue. The combination of direct carcass value decreases and production cost increases or efficiency losses could compound into producer profit impacts beyond the grid carcass value effects evaluated in this paper. Additionally, despite focusing on outcomes observable in the final marketing stage, the causes of these outcomes may span across supply chain segments, and we cannot attribute the causes of each NAWO to a specific segment. Management changes would thus have to occur throughout the beef supply chain to reduce overall negative animal welfare even if revenue is affected specifically at final processing. Furthermore, lots with low grid value may also be profitable to packers or other supply chain firms if they were obtained at a low cost. Without access to confidential purchasing transactions, there is no way to identify the profit levels of the final carcass values because lower quality and welfare lots may have been obtained at lower initial costs. We do not know the live cost of the cattle, and many producers may have contracts for lower than market live cattle prices if they know the quality of the cattle received is routinely poor.

Overall, this research can direct policy or industry initiatives towards areas that will make the most impact under economic restraints. The rarity of poor animal welfare outcomes in this data displays the advancements in animal welfare management in the beef processing industry. Every five years, the Beef Quality Assurance (BQA) program conducts the National Beef Quality Audit (NBQA) to assess progress in cattle well-being and product quality across the beef industry and track production issues that affect consumer demand for beef (BQA, 2024). In beef processing specifically, the North American Meat Institute (NAMI) also houses the Humane Handling Guidelines and Audit Guide for meat processors (NAMI, 2021). These guidelines go beyond regulatory requirements for transport, holding, and slaughter processes to promote animal welfare practices (NAMI, 2023a). Both NBQA and NAMI show historical improvements in animal welfare management and reduction of most negative outcomes across the beef industry and show industry commitment to animal welfare investments. As the beef industry continues to invest in animal welfare management, however, the cost of improvements will be high compared to the relative benefit. Continuing to partake in overarching, comprehensive animal welfare research, combined with improved quantification of losses in product value and production efficiency, provides the opportunity to homogenize industry standards and pinpoint where further management investments should focus.

Table 1. Study Variables

Variables	Code Name	Unit	Description
Dependent Variable			
Lot Grid Value	Vhun	$/cwt	Lot grid value per hundredweight
Lot Characteristics (L)			
Lot Size	NumHead	Head/Lot	Number of head in lot (in 100s)
Sex Class	STEERS	Binary	Lot was purely steers (1=yes, 0=no)
Quality Characteristics (Q)			
Average Quality Grade	AvgQlyGr	Weighted Average	Average quality grade of lot (5=prime, 1=DC)
Average Yield Grade	AvgYGr	Weighted Average	Average yield grade of lot (5=YG1, 1=YG5)
Transportation Characteristics (T)			
Transportation distance	Distance	Miles	Distance from feedlot to slaughter plant (in 100 mi)
Number Head per Truck	NumHeadPerTruck	Head	Average head per truck during transportation
Temperature Humidity Index	THI	Degree F	Max combined measurement of temperature and relative humidity during time in pen
Season			
Spring	season1	Binary	Lot observed in spring (1 = yes, 0 = no)
Summer	season2	Binary	Lot observed in summer (1 = yes, 0 = no)
Fall[#]	season3	Binary	Lot observed in fall (1 = yes, 0 = no)
Winter	season4	Binary	Lot observed in winter (1 = yes, 0 = no)
Plants			
Plant 1	plant1	Binary	Lot processed at Plant 1 (1=yes, 0=no)
Plant 2	plant2	Binary	Lot processed at Plant 2 (1=yes, 0=no)
Plant 3	plant3	Binary	Lot processed at Plant 3 (1=yes, 0=no)
Plant 4	plant4	Binary	Lot processed at Plant 4 (1=yes, 0=no)
Plant 5[#]	plant5	Binary	Lot processed at Plant 5 (1=yes, 0=no)
Shift	SHIFT	Binary	Lot processed during Shift 1 (1=yes, 0=no)
Welfare Characteristics (W)			
Amount of NAWOs	NAWO	Count	How many NAWOs are present in the lot (0-7)
NAWO, Mobility	NAWO_mob	Binary	At least 1 animal in the lot had mobility score 3 or 4 (1=yes, 0=no)
NAWO, Bruising	NAWO_bruising	Binary	Over 45% of the lot has multiple large bruises (1=yes, 0=no)
NAWO, Lairage Density	NAWO_lden	Binary	The lot had less than 2.04 m^2 of lairage space (1=yes, 0=no)
NAWO, OMB	NAWO_OMB	Binary	At least 1 animal in the lot displayed OMB (1=yes, 0=no)
NAWO, Dark Cutters	NAWO_dc	Binary	At least 1 animal in the lot categorized as a Dark Cutter (1=yes, 0=no)
NAWO, Dead/Downers	NAWO_dd	Binary	At least 1 dead/downer animal was present in the lot (1=yes, 0=no)
NAWO, Truck Waiting Times	NAWO_wait	Binary	Trucks waited on average over 60 min to be unloaded (1=yes, 0=no)

Notes: [#] Variable will serve as reference category, so dropped from econometric model.
[$]Includes No Roll, Commercial, and Standard quality beef
[@]Includes Cutter, Canner, Utility, LGD, and Dark Cutter quality beef

Table 2. Study Variable Descriptive Statistics

Variable	N[*]	Mean	SD	Min	Max
Dependent Variables					
Lot Grid Value	604	415.29	35.41	336.88	479.50
Lot Characteristics (L)					
Lot Size	604	1.36	0.946	.01	9.29
Sex Class	604	0.535	0.499	0	1
Quality Characteristics (Q)					
Avg. Quality Grade	604	3.85	0.261	3.00	5.00
Avg, Yield Grade	604	3.23	0.504	1.00	5.00
Welfare Characteristics (W)					
Count of NAWOs	604	1.06	1.14	0	6
NAWO, Bruising	604	0.267	0.443	0	1
NAWO, Mobility	604	0.164	0.371	0	1
NAWO, Lairage Density	604	0.159	0.366	0	1
NAWO, Truck Wait Time	604	0.144	0.351	0	1
NAWO, OMB	604	0.040	0.196	0	1
NAWO, Dead/Downer	604	0.012	0.107	0	1
NAWO, Dark Cutter	604	0.272	0.445	0	1
Transportation Characteristics (T)					
Distance	604	1.52	2.11	0	13.33
THI	593	60.22	14.05	18.84	81.70
Season					
Spring	604	0.253	0.435	0	1
Summer	604	0.368	0.483	0	1
Fall[#]	604	0.129	0.336	0	1
Winter	604	0.250	0.433	0	1
Plant					
Plant 1	604	0.185	0.389	0	1
Plant 2	604	0.219	0.414	0	1
Plant 3	604	0.184	0.388	0	1
Plant 4	604	0.235	0.424	0	1
Plant 5[#]	604	0.177	0.382	0	1
Shift	604	0.563	0.496	0	1

Notes: [*]Observations at a lot level
[#] Variable will serve as reference category so dropped from econometric model.

Table 3. Comprehensive Regression Results

	Comprehensive NAWO		
	Level-Level A	Log-Log B	Log-Level C
Intercept	248.2***	5.161***	5.620***
	(31.43)	(0.128)	(0.0751)
Welfare Characteristics (W)			
NAWO	-2.693**	-0.0056*	-0.0064**
	(1.299)	(0.0032)	(0.0031)
Lot Characteristics (L)			
Plant 1	58.34***	0.143***	0.137***
	(3.961)	(0.0109)	(0.0097)
Plant 2	47.22***	0.113***	0.114***
	(2.871)	(0.0109)	(0.0069)
Plant 3	44.10***	0.110***	0.106***
	(4.656)	(0.0123)	(0.0111)
Plant 4	24.12***	0.0690***	0.0592***
	(3.458)	(0.011)	(0.0083)
Spring	-8.454**	-0.0213**	-0.0233**
	(3.793)	(0.0093)	(0.0092)
Summer	-12.64***	-0.0161*	-0.0317***
	(3.666)	(0.0095)	(0.0087)
Winter	0.0834	-0.003	-0.00008
	(3.346)	(0.0113)	(0.008)
Shift	10.97***	0.0204***	0.026***
	(2.876)	(0.0066)	(0.0069)
Sex Class	-1.081	-0.0064	-0.0024
	(2.286)	(0.0057)	(0.0055)
Lot Size$	0.788	-0.0056	0.0018
	(1.270)	(0.0047)	(0.0031)
Transportation Characteristics (T)			
Travel Distance$	0.709**	0.005*	0.0017**
	(0.337)	(0.0027)	(0.0008)
Number of Head per Truck$	0.191	0.0068	0.0004
	(0.181)	(0.0124)	(0.0004)
THI$	1.624***	0.170***	0.0039***
	(0.140)	(0.0188)	(0.0003)
Quality Characteristics (Q)			
Average Quality Grade$	8.409	0.0592	0.0221
	(5.698)	(0.0542)	(0.0135)
Average Yield Grade$	-1.002	-0.0067	-0.0015
	(2.670)	(0.0216)	(0.0064)
N	593	567	593
R^2	0.465	0.451	0.456
F@	64.08	28.19	64.04
Prob > F	<0.0001	<0.0001	<0.0001

Notes: Robust standard errors in parentheses
$ Variable log-transformed in estimation method (b)
*** p<0.01, ** p<0.05, * p<0.1
@ Model a & c: F(16, 576); Model b: F(16, 550)

Table 4. Disaggregated Regression Results

	Disaggregated NAWO		
	Level-Level A	Log-Log B	Log-Level C
Intercept	251.1***	5.194***	5.626***
	(31.43)	(0.132)	(0.0772)
Welfare Characteristics (W)			
NAWO, Mobility	-3.881	-0.0082	-0.0096
	(2.914)	(0.0073)	(0.0069)
NAWO, Bruising	-5.868**	-0.0161**	-0.0144**
	(2.623)	(0.0066)	(0.0062)
NAWO, Lairage	0.573	0.0031	0.0015
	(3.271)	(0.0081)	(0.0077)
NAWO, OMB	2.458	0.0095	0.0056
	(6.069)	(0.0162)	(0.0147)
NAWO, Dark Cutter	-4.322	-0.0113	-0.0101
	(3.261)	(0.0081)	(0.0077)
NAWO, Dead/Downers	9.041	0.0208	0.0231
	(8.793)	(0.0251)	(0.0212)
NAWO, Wait Time	-2.506	-0.0026	-0.0053
	(4.008)	(0.0099)	(0.0095)
Lot Characteristics (L)			
Plant 1	58.34***	0.136***	0.132***
	(4.406)	(0.0114)	(0.0108)
Plant 2	47.22***	0.106***	0.109***
	(3.118)	(0.0083)	(0.0074)
Plant 3	44.10***	0.105***	0.103***
	(5.005)	(0.0124)	(0.0119)
Plant 4	24.12***	0.0676***	0.0591***
	(3.789)	(0.0097)	(0.0091)
Summer	-12.11***	-0.0138	-0.0301***
	(3.720)	(0.0086)	(0.0088)
Spring	-9.314**	-0.0239**	-0.0256***
	(3.930)	(0.0098)	(0.0095)
Winter	-0.842	-0.0064	-0.0030
	(3.493)	(0.0085)	(0.0083)
Shift	10.53***	0.0202***	0.0248***
	(2.944)	(0.0072)	(0.0071)
Sex Class	-1.274	-0.0064	-0.0028
	(2.309)	(0.0057)	(0.0056)
Lot Size$	0.306	-0.0059	0.0006
	(1.361)	(0.0047)	(0.0033)
Transportation Characteristics (T)			
Travel Distance$	0.765**	0.0053*	0.0018**
	(0.353)	(0.0030)	(0.0008)
Number of Head per Truck$	0.156	0.0071	0.0004
	(0.181)	(0.0131)	(0.0004)
THI$	1.569***	0.16***	0.0037***
	(0.145)	(0.0189)	(0.0004)
Quality Characteristics (Q)			
Average Quality Grade$	8.488	0.0559	0.0224
	(5.875)	(0.0537)	(0.0139)
Average Yield Grade$	-0.473	-0.0017	-0.0002

	(2.701)	(0.0176)	(0.0064)
N	593	567	593
R^2	0.470	0.457	0.462
$F^{@}$	48.57	45.06	48.61
Prob > F	<0.0001	<0.0001	<0.0001

Notes: Robust standard errors in parentheses
$ Variable log-transformed in estimation method (b)
*** p<0.01, ** p<0.05, * p<0.1
@ Model a & c: F(22, 570); Model b: F(22, 544)

REFERENCES

Adamie, B., Uehleke, R., Hansson, H., Mußhoff, O., & Hüttel, S., (2022). Dairy cow welfare measures: Can production economic data help? *Sustainable Production and Consumption*, Volume 32, 2022, Pages 296-305, ISSN 2352-5509, https://doi.org/10.1016/j.spc.2022.04.032.

Agricultural Marketing Service, United States Department of Agriculture. (2021-2022). Carcass Beef Grades and Standards. https://www.ams.usda.gov/grades-standards/carcass-beef-grades-and-standards

Agricultural Marketing Service, United States Department of Agriculture. (2021-2022). *National Weekly Direct Slaughter Cattle- Premiums and Discounts*. https://mymarketnews.ams.usda.gov/viewReport/2565

Ahmed, H., Alvåsen, K., Berg, C., Hansson, H., Hultgren, J., Röcklinsberg, H., & Emanuelson, U. (2020). Assessing economic consequences of improved animal welfare in Swedish cattle fattening operations using a stochastic partial budgeting approach. *Livestock Science*, Volume 232, 2020, 103920, ISSN 1871-1413, https://doi.org/10.1016/j.livsci.2020.103920.

Ahmed, H., Emanuelson, U., Alvåsen, K., Berg, C., Hultgren, J., Rocklinsberg, H., & Hansson, H. (2023). Animal welfare efforts and farm economic outcomes: Evidence from Swedish beef production. *Agricultural and Resource Economics Review, 52*(3), 498-519. doi:10.1017/age.2023.8

BEEF. (2022). Beef packing capacity update. *Informa PLC*. https://www.beefmagazine.com/cattle-market-outlook/beef-packing-capacity-update#:~:text=In%202021%2C%20the%20United%20States,about%205%2C000%20head%20per%20day.

Beef Checkoff. (n.d.). Understanding Beef Quality Grades. *Washington Beef*. https://www.wabeef.org/Media/WABEEF2019/Docs/understanding_beef_quality_grades.pdf

BQA. (2024). National Beef Quality Audits. *Beef Quality Assurance*. https://www.bqa.org/resources/national-beef-quality-audits

Bruijnis, MRN, Hogeveen, H, & Stassen, EN. (2013). Measures to improve dairy cow foot health: consequences for farmer income and dairy cow welfare. *Animal*. 2013;7(1):167-175. doi:10.1017/S1751731112001383

CFR. (1979). Humane Slaughter of Livestock. 9 CFR Part 313. *Code of Federal Regulations*. https://www.law.cornell.edu/cfr/text/9/part-313

CFR. (2016). Ante-mortem inspection on premises of official establishments. 9 CFR 309.1-2. *Code of Federal Regulations.* https://www.law.cornell.edu/cfr/text/9/309.1

Charban, D. (2018). Beef Quality Grades & Effects of Bruising. *Arrowquip*, Livestock Handling. https://arrowquip.com/blog/livestock-handling/the-detrimental-effects-of-bruising/

Cryan, R. (1997). Animal welfare: ends and means. *University of Florida*. http://archive.org/details/animalwelfareend00crya

Davis, M.K., Engle, T.E., Cadaret, C.N., Cramer, M.C., Bigler, L.J., Wanger, J.J., & Edwards-Callaway, L.N. (2022a). Characterizing heat mitigation strategies utilized by beef processors in the United States. *Translational Animal Science*. 6:txab231. doi:10.1093/tas/txab231.

Davis, M., Sullivan, P., Bretón, J., Dean, L., & Edwards-Callaway, L. (2022b). Investigating the impact of pre-slaughter management factors on indicators of fed beef cattle welfare – a scoping review. *Frontiers in Animal Science.* 3. doi: 10.3389/fanim.2022.1073849

Davis, M.K., Sullivan, P.A., Hess, A.M., Nair, M.N., Mooney, D.F., & Edwards-Callaway, L.N. (2024). Benchmarking current preslaughter management factors, welfare indicators, and meat quality outcomes at commercial fed cattle processing facilities in the United States. *Translational Animal Science*, 8.

Dudley, H. (2017). Lameness in the US Cattle Industry. *NC State Extension*, Beef.

Economic Research Service, United States Department of Agriculture. (2023). *Historical monthly price spread data for beef, pork, broilers* [Data set]. https://www.ers.usda.gov/data-products/meat-price-spreads/

Eastwood, L. C., Boykin, C. A., Harris, M. K., Arnold, A. N., Hale, D. S., Kerth, C. R., et al. (2017). National beef quality audit-2016: Transportation, mobility, and harvest-floor assessments of targeted characteristics that affect quality and value of cattle, carcasses, and by-products. *Translational Animal Science*. 1, 229–238. doi: 10.2527/ tas2017.0029

Edwardes, F., van der Voort, M., Halasa, T., Holzhauer, M., & Hogeveen, H. (2022). Simulating the mechanics behind sub-optimal mobility and the associated economic losses in dairy production, *Preventive Veterinary Medicine*, Volume 199, 2022, 105551, ISSN 0167-5877, https://doi.org/10.1016/j.prevetmed.2021.105551.

Edwards-Callaway, L. & Calvo-Lorenzo, M. (2020). Animal welfare in the U.S. slaughter industry—a focus on fed cattle, *Journal of Animal Science*, Volume 98, Issue 4, April 2020, skaa040, https://doi.org/10.1093/jas/skaa040

Feuz, R., Norwood, B.F., & Ramanathan, R. (2020). The Spillover Effect of Marketing Discolored Beef on Consumer Preferences for Nondiscolored Beef. *Journal of Agricultural and Applied Economics* (2020), 52, 160-176. doi 10.1017/aae.2019.39

Gantner, V., Mijić, P., Kuterovac, K., Solić, D., & Gantner, R. (2011). Temperature-humidity index values and their significance on the daily production of dairy cattle. *Mljekarstvo*. 61:56-63. https://www.researchgate.net/publication/50392071_Temperature-humidity_index_values_and_their_significance_on_the_daily_production_of_dairy_cattle

Grandin, T. (1995). Reducing Bruising in Cattle. *Beef Cattle Handbook*. Extension Beef Cattle Resource Committee. BCH-4410. Available: https://www.iowabeefcenter.org/bch/ReducingBruising.pdf

Grandin, T. (2007). *Livestock Handling and Transport*. doi: 10.1079/9780851994093.0409

Grethe, H. (2017). The Economics of Farm Animal Welfare. *Annual Review of Resource Economics,* 2017, Vol. 9 (2017), pp 75-94. https://www.jstor.org/stable/10.2307/26773549

Gujarati, D., & Porter, D. (2009). *Basic Econometrics* (Fifth). McGraw-Hill.

Hale, D., Goodson, K., & Savell, J. (2013). USDA Beef Quality and Yield Grades. *Texas A&M Meat Science.* https://meat.tamu.edu/beefgrading/

Hansen, BG. (2023). Animal welfare and farm economy-exploring the relationship between dairy animal welfare indicators and economic efficiency. *Preventative Veterinary Medicine*. Dec 2023;221:106058. doi: 10.1016/j.prevetmed.2023.106058.

Huertas, S. M., van Eerdenburg, F., Gil, A., & Piaggio, J. (2015). Prevalence of carcass bruises as an indicator of welfare in beef cattle and the relation to the economic impact. *Veterinary Medicine and Science*, 1(1), 9-15. doi: 10.1002/vms3.2

Kline, H. et al. (2020). From unloading to trimming: studying bruising in individual slaughter cattle. *Translational Animal Science* 2020. 4:1-9. doi:10.1093/tas/txaa165

LiveCorp and Meat and Livestock Australia. (2023). Veterinary Handbook for Cattle, Sheep and Goats. *LiveCorp and Meat and Livestock Australia.* https://www.veterinaryhandbook.com.au/ContentSection.aspx?id=51

LMAC. (2023). Reduce Carcass Bruising Costs. *Livestock Markets Association of Canada.* https://lmacmarkets.com/reduce-carcass-bruising-costs/

MacDonald, J., Ollinger, M., Nelson, K., & Handy, C. (2000). Consolidation in U.S. Meatpacking. *United States Department of Agriculture, Economic Research Service*. Agricultural Economic Report 785. https://www.ers.usda.gov/publications/pub-details/?pubid=41120

Mader, T. L., Davis, M. S., & Brown-Brandl, T. (2006). Environmental factors influencing heat stress in feedlot cattle. *Journal of Animal Science. 84:712-719*. doi:10.2527/2006.843712x.

Meadows, L. (2013). What's Your Beef- Prime, Choice, or Select? *United States Department of Agriculture*. https://www.usda.gov/media/blog/2013/01/28/whats-your-beef-prime-choice-or-select

Miller, M. (n.d.). Dark, Firm, and Dry Beef. *Beef Research*. https://www.beefresearch.org/resources/product-quality/fact-sheets/dark-firm-and-dry-beef#

Morris, R. (2013). Demystifying USDA Beef Grades. *modern farmer*. https://modernfarmer.com/2013/10/demystifying-usda-meat-grades/

NAMI. (2015). North American Meat Institute Scoring System. https://www.youtube.com/watch?v=QislfHCvkpg

NAMI. (2021). North American Meat Institute. Recommended Animal Handling Guidelines & Audit Guide: A Systematic Approach to Animal Welfare. *North American Meat Institute*. https://animalhandling.org/sites/default/files/forms/Animal_Handling_Guide012021.pdf

NAMI. (2023a). NAMI Animal Handling Guidelines and Audit. *North American Meat Institute.* https://www.meatinstitute.org/Animal_Welfare/Guidelines_and_Audits

Nardone, A., Ronchi, B., Lacetera, N., Ranieri, M.S., & Bernabucci, U. (2010). Effects of climate changes on animal production and sustainability of livestock systems. *Livestock Science.* 130:57–69. doi:10.1016/j.livsci.2010.02.011.

O'Connor, A.H., Bokkers, E.A.M., de Boer, I.J.M., Hogeveen, H., Sayers, R., Byrne, N., Ruelle, E., & Shalloo, L. (2020). Associating mobility scores with production and reproductive performance in pasture-based dairy cows, *Journal of Dairy Science*, Volume 103, Issue 10, 2020, Pages 9238-9249, ISSN 0022-0302, https://doi.org/10.3168/jds.2019-17103.

Park, Rachel M., Margaret Foster, & Courtney L. Daigle. (2020). A Scoping Review: The Impact of Housing Systems and Environmental Features on Beef Cattle Welfare. *Animals* 10, no. 4: 565. https://doi.org/10.3390/ani10040565

Ponnampalam, E. N., Hopkins, D.L., Bruce, H., Li, D., Baldi, G., & Bekhit, A.E. (2017). Causes and Contributing Factors to "Dark Cutting" Meat: Current Trends and Future Directions: A Review. *Comprehensive Reviews in Food Science and Food Safety*. 16:400–430. doi:10.1111/1541-4337.12258

Public Law. 107–171, title X, §10305, May 13, 2002, 116 Stat. 493. Enforcement of Humane Methods of Slaughter Act of 1958. *U.S. Code, Title 7.*

https://www.govinfo.gov/content/pkg/USCODE-2021-title7/html/USCODE-2021-title7-chap48-sec1901.htm

Radunz, Amy. (2012). Live Cattle Evaluation for Carcass Traits and Grid Marketing Basics. *UW Extension Wisconsin Beef Information Center*. http://fyi.uwex.edu/wbic/

Saner, R. & Buseman, B. (2020). How Many Pounds of Meat Can We Expect From A Beef Animal? *University of Nebraska- Lincoln Institute of Agriculture and Natural Resources BEEF.* https://beef.unl.edu/beefwatch/2020/how-many-pounds-meat-can-we-expect-beef-animal#:~:text=In%20summary%2C%20the%20amount%20of,will%20be%20approximately%20840%20pounds.

Schlatter, T.W. (1987). Temperature-humidity index. In: Climatology. *Encyclopedia of Earth Science*, Springer, Boston, MA. https://doi.org/10.1007/0-387-30749-4_176

Schroeder, T., Minter, J., Brzle, F., & Grunewald, O. (1988). Factors Affecting Feeder Cattle Price Differentials. *Western Journal of Agricultural Economics*, 13(1), 71–81. http://www.jstor.org/stable/40987944.

Schroeder, T. C., & Graff, J. L. (2000). Estimated Value of Increased Pricing Accuracy for Fed Cattle. *Review of Agricultural Economics*, *22*(1), 89–101. http://www.jstor.org/stable/1349931.

Schroder, T. C., Ward, C. E., Mintert, J., & Peel, D. S. (1998). Beef Industry Price Discovery: A Look Ahead. *Research Institute on Livestock Pricing,* Virginia Tech. http://purl.umn.edu/232524.

St-Pierre, N.R., Cobanov, B., & Schnitkey, G. (2003). Economic Losses from Heat Stress by US Livestock Industries. *Journal of Dairy Science*, 86, Supplement, June 2003, E52-E77. https://doi.org/10.3168/jds.S0022-0302(03)74040-5

South Dakota State University Department of Animal Science. *Beef Grading.* https://www.sdstate.edu/agriculture-food-environmental-sciences/animal-science/beef-grading#:~:text=Yield%20grade%20is%20an%20estimate,is%20also%20known%20as%20cutability.&text=Yield%20grade%20is%20based%20on,pelvic%20fat%2C%20and%20ribeye%20area

Sullivan, P., Davis, M., Bretón, J., & Edwards-Callaway, L. (2022). Investigating the impact of pre-slaughter management factors on meat quality outcomes in cattle raised for beef: A scoping review. *Frontiers in Animal Science.* 3. doi: 10.3389/fanim.2022.1073849

Summer, A., Lora, I., Formaggioni, P., & Gottardo, F. (2019). Impact of heat stress on milk and meat production. *Animal Frontiers.* 9:39–46. doi:10.1093/af/vfy026.

Texas A&M AgriLife Extension. (n.d.). Understanding USDA Beef Quality Grades. *Texas A&M University*. https://meat.tamu.edu/files/2018/10/Understanding-USDA-beef-quality-grades.pdf

Tucker, C.B., Coetzee, J.F., Stookey, J.M., Thomson, D.U., Grandin, T., & Schwartzkopf-Genswein, K.S. (2015). Beef cattle welfare in the USA: identification of priorities for future research. *Animal Health Research Reviews*. 2015;16(2):107-124. doi:10.1017/S1466252315000171

UCLA. (2021). Regression with STATA Chapter 2- Regression Diagnostics. *UCLA Advanced Research Computing*, Statistical Methods and Data Analytics. https://stats.oarc.ucla.edu/stata/webbooks/reg/chapter2/stata-webbooksregressionwith-statachapter-2-regression-diagnostics/

Underwood, K. R., Tong, J., Zhu, M. J., Shen, Q. W., Means, W. J., Ford, S. P., Paisley, S. I., Hess, B. W., & Du, M. (2007). Relationship between Kinase Phosphorylation, Muscle Fiber Typing, and Glycogen Accumulation in Longissimus Muscle of Beef Cattle with High and Low Intramuscular Fat. *Journal of Agricultural and Food Chemistry*. 55:9698–9703. doi:10.1021/jf071573z

UNL Beef. (2014). Handling Cattle through High Heat Humidity Indexes. *UNL Beef*. https://beef.unl.edu/handling-cattle-through-high-heat-humidity-indexes#:~:text=Plan%20to%20handle%20cattle%20before,lower%20back%20to%20normal%20temperature.

Ward, C. E., Schroeder, T. C., & Feuz, D. M. (2017). Grid Pricing of Fed Cattle: Base Prices and Premiums-Discounts. *Oklahoma State University Extension*. https://extension.okstate.edu/fact-sheets/grid-pricing-of-fed-cattle-base-prices-and-premiums-discounts.html

Warriss, P.D. (1990). The handling of cattle pre-slaughter and its effects on carcass and meat quality. *Applied Animal Behaviour Science,* 28 (1990) 171-186. doi: 0168-1591/90/$03.50

Wigham, E., Butterworth, A., & Wotton, S. (2018). Assessing cattle welfare at slaughter – Why is it important and what challenges are faced?, *Meat Science*, Volume 145, 2018, Pages 171-177, ISSN 0309-1740, https://doi.org/10.1016/j.meatsci.2018.06.010.

Williams, G. S., Raper, K. C., DeVuyst, E. A., Peel, D., & McKinney, D. (2012). Determinants of Price Differentials in Oklahoma Value-Added Feeder Cattle Auctions. *Journal of Agricultural and Resource Economics*, *37*(1), 114–127. http://www.jstor.org/stable/23243052

Zimmerman, L. Schroeder, T., Dhuyvetter, K., Olson, K., Stokka, G., Seeger, J., & Grotelueschen, D. (2012). The Effect of Value-Added Management on Calf Prices at

Superior Livestock Auction Video Markets. *Journal of Agricultural and Resource Economics*, 37(1): 128-143. https://www.jstor.org/stable/23243053

ESSAY 2: HETEROGENEOUS MOTIVES FOR ANIMAL WELFARE IMPROVEMENTS IN BEEF SUPPLY CHAINS

Synopsis

Animal welfare management has broad implications for the organization of livestock supply chains, including changing regulatory, market, and private industry requirements for producing animal products. This essay discusses the heterogeneous motives behind animal welfare management and treatment of animal welfare as an extra-market good. Animal welfare improvements are a conscious management decision impacting the various strategic goals of business. Beyond simple profit motives, we explore societal and consumer expectations, corporate responsibility, and access to differentiated markets. We adopt a conceptual framework that highlights trade-offs between animal welfare improvements and relative profit to explore the motives which may incentivize supply chain firms to invest beyond the economic and regulatory requirements of animal welfare standards. In this essay, we combine previous literature in subsets of these fields into an over-arching discussion of the opportunities and challenges beyond private profit that supply chains may face when deciding how to manage animal welfare outcomes.

Keywords: motives, market access, animal welfare management, consumer expectations

JEL Codes: Q18, Q13, L15, L21, L22,

1. Introduction

In recent decades, consumers have driven improvements in farm animal welfare by demanding improvements in production welfare that go beyond the basic legal obligations of companies. This surge in consumer demand has caused advancements in animal welfare science and monitoring which are constantly adapting the welfare landscape and desired outcomes. However, a complication in any meat production animal welfare research is the ethical debate on meat consumption. Only 39% of consumers express concern for the welfare of meat animals compared to 73% of other animal products (Alonso et al., 2020). This reluctance to relate meat to live animals establishes a barrier to animal welfare research and management initiatives specific to the meat industry, including beef production (Christensen & Sandøe, 2019). Combined with the growing global demand for meat products, encouraging animal welfare management decisions that require substantial capital investments requires additional incentives beyond simple profit maximization. Companies have an opportunity to embrace the growing consumer demand for meat products and overall animal welfare and capitalize on it through various avenues.

Animal welfare, despite its growing worldwide demand, has no uniform definition or standard. The specifications for "good" and "bad" animal welfare and how to manage animals for the best welfare outcomes vary across personal opinions and company stances. Most often, expectations of animal welfare are defined by the 1965 "Five Freedoms": freedom from hunger, malnutrition, and thirst, freedom from fear and distress, freedom from physical discomfort, freedom from pain, injury and disease, and freedom to express normal patterns of behavior (WOAH, 2023). Animal welfare is therefore generally considered all-encompassing of a physical and mental effects of handling concerns (AVMA, 2023). As the longest meat animal production cycle, beef cattle face unique animal welfare challenges. The United States Department of Agriculture (USDA) Food Safety and Inspection Service (FSIS) establishes four main benefits of humane handling of finished cattle: preventing needless suffering of animals, ensuring safe working conditions for employees, improving meat product quality, and minimizing financial losses to slaughter establishments (Public Law 107-171, 2002). But what incentivizes cattle processors to adopt best management practices for these benefits? What trade-offs do supply chains face when investing in improved animal welfare? Do firms have motives beyond simple profit maximization for promoting their animal welfare management?

The philosophical and political implications of rising animal welfare demand have been extensively analyzed. After these fields established a clear desire for animal welfare improvements, economists have more recently begun researching the practical implications of consumer preferences for agricultural producers (Alonso et al., 2020; Kehlbacher et al., 2012; Jensen, 2006). However, there are varying motivations and approaches to integrating animal welfare concerns into farm animal production. European markets are generally further developed regarding animal welfare research, regulations, and labeling programs (Christensen et al., 2019; Klink-Lehmann et al., 2000; Verbeke & Viaene, 2000). As American consumer information and purchasing habits differ from the European markets, it is crucial to advance the United States' knowledge of consumer expectations for their food, and how beef supply chains can evolve to meet these food chain demands.

We aim to apply the broader studies of animal welfare to the unique issues of American beef supply. We will explore the differing motivations and strategies firms utilize when evaluating their investment into animal welfare. Specifically, we adopt a conceptual framework that explores varying market conditions behind animal welfare investments. Finally, we analyze the multitude of approaches companies or governments may utilize to capture animal welfare demand in the market depending on their management goals. These market strategies show animal welfare improvements as a conscious management decision impacting the way firms organize and conduct business.

In this paper, we begin with an overview of current animal welfare initiatives in the beef supply chain. Next, the conceptual framework explores the economic rationale that incentivizes improved animal welfare throughout supply chains. Then, we explore the various avenues which supply chains may utilize to justify their animal welfare investment in different market conditions. Finally, we discuss the advantages of market versus regulatory approaches in incentivizing animal welfare management.

2. Animal Welfare in Beef Supply Chains

The intricacies of the beef supply chain cause distinctive challenges to adopting widespread animal welfare improvements compared to more vertically integrated production systems. American fed cattle- animals raised specifically for the purpose of becoming meat- pass through at least 3 stages of production in their lifetime: cow-calf operations, feedlots, and processors (ERS, 2023). Calves are born on cow-calf operations where they remain on pasture for 3-7 months before being weaned (ERS, 2023). While some animals may be retained for herd replacement, the remaining enter the beef supply chain. At this point, weaned calves either graze in stocker programs or are backgrounded on grain for 3-4 more months before being finished in a feedlot (ERS, 2023). Feedlots aim to produce high-quality, high-value beef by feeding a high protein grain diet for the last 90 to 300 days of the cattle's lifespan (ERS, 2023). Finally, cattle are sent to processing plants where they are slaughtered, dressed, and graded to be sold to beef consumers. Animal welfare of fed cattle is thus reliant on the management decisions of each of these supply chain segment operators, including the transportation companies that move cattle between segments. Therefore, the supply chain must incentivize improvements at all levels, not just one segment.

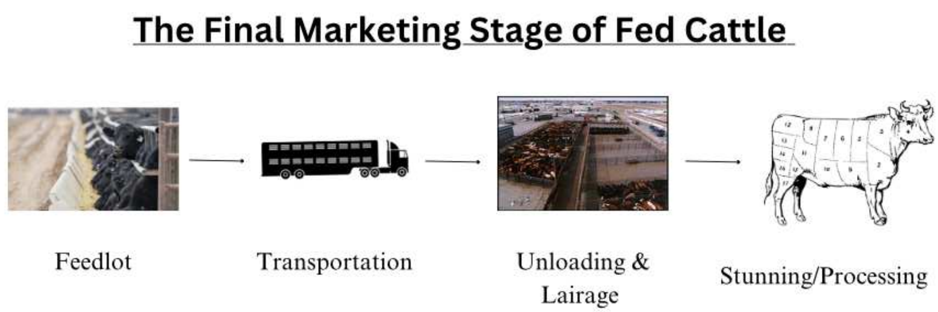

Figure 1. Graphic depiction of the final marketing stage of the cattle cycle. Activities include loading at feedlots, transport to processing facility, unloading and lairage (holding), through stunning and processing

There are some basic animal welfare regulations for beef cattle, but they are far from all-encompassing of the multitudes of stressors cattle phase in their lifespan. For example, the final marketing stage of cattle is the shortest portion of beef cattle's life span, lasting a few hours to a few days at most, but is a time in which they are consistently faced with new, unique stressors. This portion of the cattle lifespan involves loading onto trucks at feedlots, transport to processing facilities, unloading, lairage, handling, and slaughter (Davis et al., 2022). Thus, the final market stage connects two of the three major portions of the cattle supply chain (excluding only cow-calf ranches) and is subject to the animal welfare management of many supply chain actors. Cattle in this setting frequently enter novel environments, are mixed with unfamiliar herds and handlers, and face temporary food and water deprivation, and are thus more likely to become agitated. The welfare of cattle in this production stage are faced with management from at least three different companies with differing goals and systems. Minimum American animal welfare regulations in this production stage include the 28 Hour Transit Law and the Humane Methods of Livestock Slaughter Act (HMSA) of 1978 (FSIS, 2022). Additional national guidance can be found through USDA resources like the FSIS Compliance Guide for a Systematic Approach to the Humane Handline of Livestock (FSIS, 2022). Summaries of enforcement activities and violations are also reported quarterly by FSIS and the Public Health Information System's (PHIS) Humane Handling Activities Tracking System (HATS) (FSIS, 2022). As there is a lack of uniform standards for animal welfare, the field of animal welfare is also constantly adapting to new research that creates moving objectives for companies to target, so these regulations may be outdated from current best management practices.

Industry standards and private audits set benchmarks for companies to adapt to increasing animal welfare requirements in the market and hopefully incentivize homogeneity across industry investments. The meat sector was the first in animal agriculture to begin self-auditing animal welfare guidelines, and cattle producers across the industry can participate in pre-existing programs to enhance their performance guidelines (NAMI, 2023b). Beef check off funding is used to finance the Beef Quality Assurance (BQA) program that provides systematic reviews of cattle well-being and product quality on firms across the supply chain to encourage best management practices that benefit both cattle and producers (BQA, 2024b). Every five years, BQA conducts the National Beef Quality Audit (NBQA) to assess progress across the industry and track production issues that affect consumer demand for beef (BQA, 2024a). In beef processing specifically, the North American Meat Institute (NAMI) houses the Humane Handling Guidelines and Audit Guide for meat processors (NAMI, 2021). These guidelines go beyond regulatory requirements for transport, holding, and slaughter processes to promote animal welfare practices (NAMI, 2023a). NAMI also partners with third-party labeling and certification programs to support industry stakeholders in animal welfare standard development (NAMI, 2023b). Both NBQA and NAMI show historical improvements in animal welfare management across the beef and meat industry at large and show industry commitment to animal welfare investments. Both regulatory and industry initiatives show animal welfare improvements as a conscious management decision rather than a by-product. Animal welfare can thus be considered as an extra-market good that is demanded and supplied but not sold and purchased.

3. Conceptual Framework

3.1. Animal Welfare as an Economic Good

Figure 2 explores the societal costs and benefits of improving animal welfare (W). Social and technical processes work together in a market-based approach to co-determine supply and demand. There is a constant rebalancing of the appropriate level of animal welfare as the classification of animal welfare adapts to new views and research (Buller & Roe, 2012; Lusk, 2011). Costs [C(W)] include the investments supply chain firms must make to improve animal welfare as well as the lost revenue from producing animals at lower welfare levels where negative welfare outcomes may negatively impact product quality and quantity. As seen by the convexity of the function, as supply chains continue to invest in W towards the maximum well-being state, the cost associated with marginal improvements begins to rapidly increase.

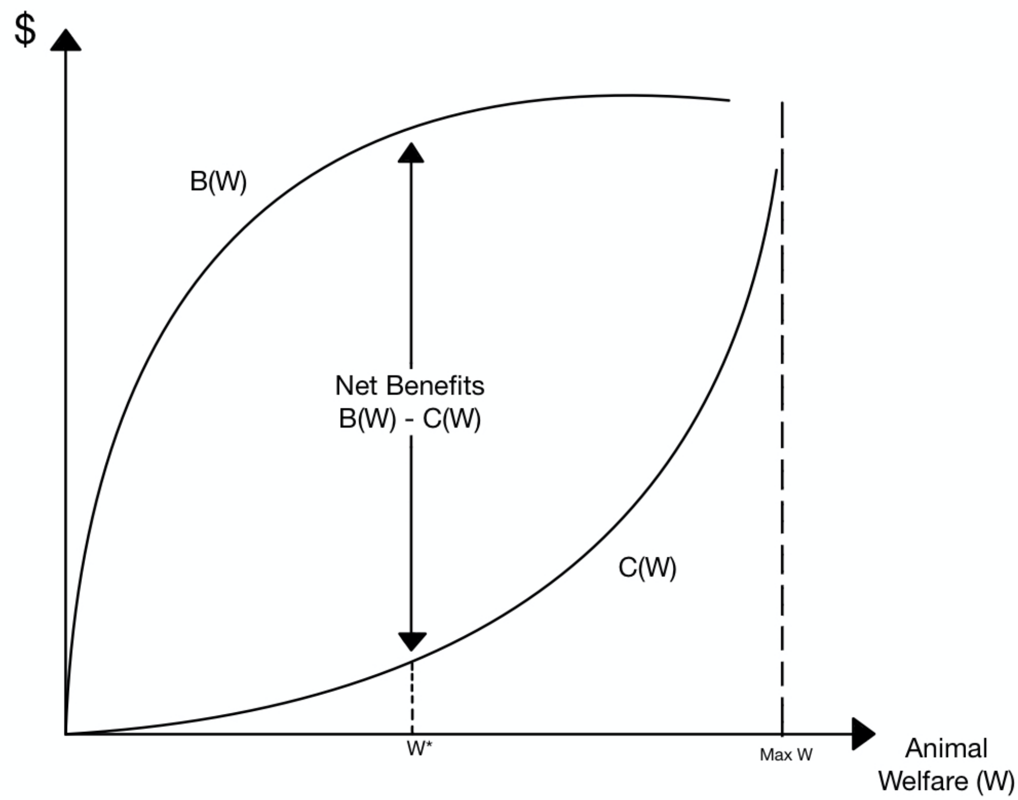

Figure 2: Total Costs and Benefits of Animal Welfare
(adapted from Keohane & Olmstead, 2016)

Opposingly, benefits [B(W)] include societal approvement or more available welfare certified products. This is a concave function where each marginal improvement in welfare provides slightly less benefit than the prior unit. Consumers in recent decades have continuously demanded higher standards of animal welfare. However, the wide range of familiarization with food animal production causes highly heterogeneous demand for animal welfare. Some consumers may have no desire for improved animal welfare so long as food is provided and cost effective. On the other end of the spectrum, some consumers will not consume animal products regardless of the production system and level of animal welfare. "Compassionate carnivores"- consumers who eat meat but are still concerned with animal well-being- are the spread between the two extremes and categorize most American consumers (Lusk, 2011). Since there are groups of consumers who are concerned with animal welfare, negative animal welfare outcomes can be viewed as an externality of meat consumption. The market price of meat does not take this disutility into account, so there may be more meat produced than a society with large consideration of animal well-being would prefer (Lusk, 2011). Since some consumers who may never consume beef have existence value for high levels of animals in a reduced state of welfare (Lusk, 2011). Compassionate consumers and vegetarians/vegans thus both benefit from animal welfare investments (Lusk, 2011).

Animal welfare is primarily classified by the "state of the animal" in the science literature. Consumers who demand improved animal welfare outcomes must have knowledge of livestock systems to coalesce market demand with realistic, cost-effective compliance efforts in the production space. However, consumers are often detached from the food system and may hold expectations that are disconnected from the current practicalities of animal welfare and production implications of desired adaptations. Consumers' disconnect from the food system results in limited understanding of what traits and management choices are associated with extremely high levels of improved animal welfare (Alonso, González-Montaña, & Lomillos, 2020; Denver et al., 2017). The maximum net benefit is where the marginal cost and benefit of a marginal improvement in welfare are equal (W^*), and it becomes inefficient to invest past this point as the high cost of improvement is not reciprocated by an appropriately high marginal benefit from consumers. Lack of a sufficient price premium for high levels of animal welfare may undermine consumer driven initiatives to improve animal welfare management as the cost of highly improved systems is often too high for the marginal rate at which consumers' willingness to pay (WTP) increases (Kehlbacher et al., 2012). While consumers may state their concern and WTP for animal welfare in studies, practical sales may be different from their stated preferences (Alonso, González-Montaña, & Lomillos, 2020).

3.2. Improving Animal Welfare

The framework for this paper focuses on the trade-off of animal welfare management efforts and relative profit maximization and is based upon work used previously to explore the heterogeneous motivations behind farmer stewardship behaviors. Within Figure 3 (adapted from Chouinard et al., 2008), we see three varying indifference curves corresponding to a production possibility frontier (PPF) representing the profit versus animal welfare trade-offs in a traditional, undifferentiated beef market (PPF^U). I_1 is a purely profit-driven supply chain: these firms are indifferent to the management of animal welfare [e(W)] if their indifference curve is perfectly horizontal. At the y-value that the PPF maximizes, there is still some level of animal welfare management required because in low production levels, there is a positive relationship between productivity and animal welfare as poor animal welfare potentially decreases yield, quality, and thus profit (McInerney, 2004; Dawkins, 2017). This increased animal welfare for profit maximization still differs from an animal welfare maximization framework (Cryan, 1997). But in the traditional beef market, this product is uniform to all beef in the market (disregarding quality or breed certifications), so they do not have incentive to advance animal welfare beyond the rational profit-maximizing level in this undifferentiated market.

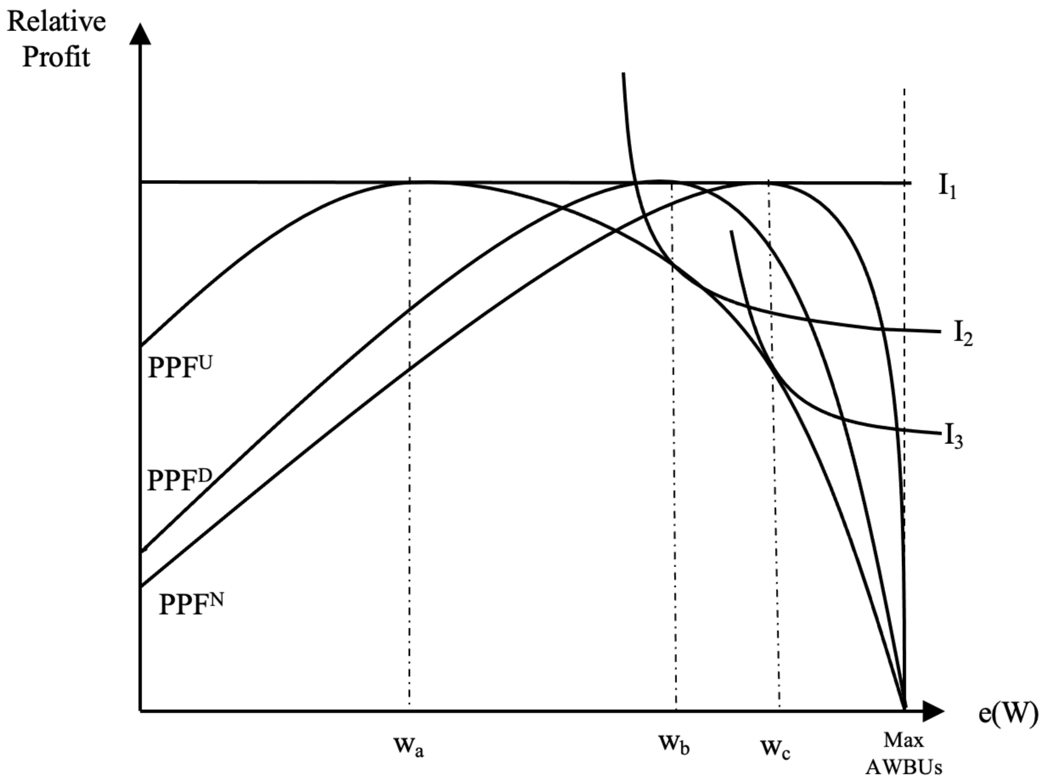

Figure 3: Production Possibilities Frontiers for Supply Chain Profit and Indifference Curves

However, there may be reasons that a business would choose to trade short-run profits in exchange for improved animal welfare in intensive production systems (McInerney, 2004)- these are represented by I_2 and I_3. Realistically, this is a spectrum with varying levels of trade-off between profit and welfare. Some supply chains invest beyond the profit maximizing optimal levels of animal welfare because they expect to receive a premium in the market by engaging in behavior society deems as desirable. Improved animal welfare in this space contributes to corporate social responsibility (CSR) initiatives and provides opportunities for higher prices (Christensen & Sandøe, 2019; Dawkins, 2017). However, firms must make the conscious management decision to increase their investments into animal welfare and forgo short term profits, but companies expect to see returns in the long run, such as increased market power or product competition through what others may view as "ethical" improvements of their production systems. Ultimately, distinct animal welfare strategies will unify producers at varying production segments into distinct supply chains as each segment will work with other segment firms that have the same strategic animal welfare goals. If each production segment invests in animal welfare management, it will carry on throughout the supply chain as the interconnected producers meet the standards of the next level purchaser. For example, a retailer with welfare labeling will purchase from a processor who has strong animal welfare CSR who likely partners with feedlots with positive animal welfare who received feeder calves from ranches with improved animal welfare management.

Since I_2 and I_3 firms already operate past the marginal cost/benefit equilibrium with their advanced investments, they fall into the scenario discussed in Figure 2, where the high cost is not reciprocated by an equal benefit on PPF^U. With each successive investment into animal welfare, the marginal cost of animal welfare improvements past the relative profit maximization of I_2 and I_3, respectively, become higher. A supply chain with indifference curve I_2 invests slightly more in animal welfare than a pure profit-maximizer, but not to the point of drastically increased animal well-being. The improvement from w_A to w_B may be utilized through animal welfare labeling to horizontally differentiate their product from other supply chains. These firms give up some small-run profit in hopes that their long-term returns will maximize their potential profits through production of a differentiated product. By differentiating their product or gaining access to a specialized market- moving to PPF^D or PPF^N- supply chains hope to combat any benefit/cost imbalances by gaining more benefit from consumers with higher WTP for animal welfare. The I_3 supply chain moves to w_C through large investments in animal welfare that move them much closer to the maximum animal well-being. These firms are past the net benefit maximum from

Figure 2, and so each marginal improvement comes at great costs. However, these supply chains most likely have access to the most exclusive programs and specialized markets and will capture more positive public perception even from those consumers who do not purchase meat products. In the long-term, these firms hope to capture the highest price premiums and specialized market share in return for their high levels of investment. Supply chain firms at any of these investment levels may, however, utilize multiple avenues to promote their animal welfare goals and management.

4. Drivers of Improved Animal Welfare in Beef Supply Chains

IFC Good Practice Note "Animal Welfare in Livestock Operations" states that "Higher animal welfare standards are increasingly seen to be a prerequisite to enhancing business efficiency and profitability, satisfying international markets and meeting consumer expectations" (Alonso et al., 2020). Each of these prerequisites is a unique motivator and strategy for firms to showcase their investment in animal welfare initiatives. Used independently or in conjunction, simple profitability, corporate behavior, and specialized market access provide supply chains with opportunities for product differentiation and increasing market power.

4.1. Simple Profitability

As discussed previously, producers must manage animal welfare to a basic amount or risk impacting production results, such as carcass bruising or downer cattle. Therefore, as we move from the origin to w_a in Figure 3, we see increases in both relative profit and animal welfare. Beyond that threshold, animal welfare investments can be costly and time ineffective.

Improved animal welfare increases farm animal production profits by decreasing animal mortality, improving animal health which decreases veterinary costs, and improves final product quality (Dawkins, 2017). Thus, there is some level of positive animal welfare needed for firm profit maximization (w_A in Figure 3). Animal welfare management is thus necessary to even the most basic functions of business- garnering a profit. As seen in the first chapter of this thesis, animal welfare outcomes in the final marketing stage are not identically quantifiable and have differing impacts on final meat carcass valuation. Profitability is a crucial factor for animal welfare considerations, and those animal welfare outcomes that cause significant production losses are likely to face the most management intervention. Some welfare concerns are easier and more cost-efficient to address then others, such as heat stress. Without heat abatement, losses in growth and deaths caused by heat stress are estimated at $282 million per year annually (St-Pierre et al., 2003). However, heat abatement such as sprinkler use is generally low-cost and highly used across the industry, reducing signs and impacts of heat stress (St-Pierre et al., 2003). Other animal welfare concerns, such as transport truck redesign which may reduce bruising level would be very expensive with costs likely surpassing the benefit it provides.

Finding the balance between marginal costs and benefits of animal welfare management is a crucial factor in future investment in animal welfare management. Since many low-cost methods-like sprinklers- are already being implemented across the industry, beef production is likely approaching a point where high-cost investments are the next possible improvements. Eventually, the industry will reach a ceiling where profit motives alone will prove ineffective at incentivizing animal welfare progression because of this boundary in marginal cost-benefit analyses.

Those firms who go above and beyond the basic legal and societal requirements for animal welfare also face the opportunity to receive a potential price premium that increases their own production welfare in exchange for those increased investments in animal welfare management systems. This can be done through multiple avenues of product marketing.

4.2. Access to Differentiated Markets

The food chain adapts to consumer preferences and the potential for product and brand segmentation by creating differentiated markets (Buller & Roe, 2012). This can be seen as a movement from w_a to w_b in Figure 3 with hopes that the firm will see long-term returns from their increased investments. Choosing which market condition to operate in is crucial to strategically managing animal welfare investments. One such market opportunity arises through global cohesion of animal welfare requirements. Some regions like the European Union (EU) or California are committed to raising animal welfare requirements which develops sanitary and phytosanitary (SPS) nontariff barriers to trade (European Commission, 2022; CDFA, 2024). Developing global uniform standards aligns these regulations and could increase trade between regions since exporting countries must align to higher regulations in importing regions (Chambers et al., 2001). Many private and non-governmental organization (NGO) entities have begun certification programs that hope to align international market standards. The International Organization for Standardization (ISO) is an NGO of 170 member countries including the U.S. that develops global standards for trade products, including beef animal welfare (ISO, n.d.). Their animal welfare initiatives cover rearing, transportation, and slaughter of production animals, and USDA AMS also certifies American producers to ISO standards that are accepted in all member countries (ISO, 2021; AWIC, n.d.). While all beef welfare programs in the United

States are currently voluntary, there is potential that regions and governments with long-term animal welfare goals- such as part of the EU Farm to Fork Strategy- will implement higher regulatory requirements; participating in voluntary improvements now can serve as a proactive investment in animal welfare as we continue to see growth in global requirements for animal welfare.

Beyond governmental approaches, private labeling programs have also grown to include globally traded goods. Whole Foods- which only sells meat certified to 100 animal welfare standards- created the Global Animal Partnership (GAP) as a non-profit labeling and certification program that now spans five continents (GAP, n.d.; Whole Foods, 2024). GAP also partners with NAMI to conduct processor certification and align its standards with industry guidelines. Uniquely, the GAP label is a ranked system with varying tiers of certification. Ranked systems capture varying willingness to pay for consumer preferences regarding animal welfare and capture levels of price premiums for different advancement levels of systems. A ranked program that continues to be voluntary also allows supply chains to differentiate their homogeneous products from competitors and choose what level of animal welfare improvement best fits their production system and capital investment potential. Certification by global programs allows firms to benefit from increased animal welfare investments by selling in markets that have higher regulations.

4.3. Strategic Corporate Behavior

Resolving information asymmetry between producers who carefully manage animal welfare and consumers who may be disconnected from their food system is crucial to supply chain success (Alonso et al., 2020; Christensen & Sandøe, 2019). As societal expectations continue to change, it is crucial to maintain positive public images to stay economically viable (Alonso et al., 2020). Improving animal welfare management even slightly past the basic requirements for production allows supply chains to highlight their investments and promote their products in the marketplace. Consumers expect ethical and philosophical improvements to their products that go beyond the economic and legal requirements, such as movement from w_b to w_c in Figure 3, and CSR aims to inform consumers on corresponding management investments.

Corporate Social Responsibility allows firms to promote their product over their competitors by appealing to consumers' ethical and philosophical desires. CSR is a management strategy where companies integrate social and environmental concerns into their business and interactions with stakeholders (UNIDO, 2023). de Olde et al., 2019, observes the trend that "Producers and retailers are increasingly engaging in CSR initiatives in order to show their commitment to sustainability issues such as animal welfare." Firms who utilize corporate behavior do not have to gain access to specialized, controlled markets, but they can sell in the same markets and promote their products through labeling, reductions in sales selections, differing product pricing, and increasing visibility and knowledge of animal-welfare-friendly products (Christensen & Sandøe, 2019). Many beef packing companies have developed animal welfare statements and management teams to display a commitment to improving animal welfare initiatives. In fact, three of the four controlling beef processing firms have animal welfare platforms and website pages dedicated to their continued investment in the advancement of animal welfare in the industry. By upholding their CSR statements on animal welfare, supply chains may be able to gain more revenue in the market and retain a greater proportion of beef consumers by capitalizing on their increased WTP for improved animal welfare products. These initiatives may also appeal to consumers who never consume meat, thus improving their public perception across the food chain.

Animal welfare labeling also captures higher, varying WTP for different consumers and increases consumer welfare by reducing information asymmetry. Consumers are typically removed from the systems that produce their food. Animal welfare labeling differentiates meat products based on credence attributes- those food characteristic that buyers cannot identify through appearance or experience at the time of purchase (Schrobback et al., 2023). Labeling gives consumers a direct connection to the production systems in place for the products they purchase by informing them of the management activities that produced their beef. When participating in labeling programs, firms make the distinct decision to prioritize their animal welfare improvements in a way that is visible to the entire supply chain. Currently, all American labeling systems are voluntary and conducted through third-party audits. While run by private auditors, labels like Certified Humane or American Humane Certified are recognized by the USDA and may even be trained by USDA Agricultural Marketing Service (AMS) auditors (AWIC, n.d.). Federally regulated or recognized programs add an additional level of reliability for consumers to be informed of the production systems and animal welfare management practices in those businesses from which they purchase by increasing transparency and confidence (Alonso et al., 2020). Participation in audit certifications improves company standing through accreditations that horizontally differentiate products from their competitors. By upholding slightly higher animal welfare levels than their competitors- or their competitors' public image- supply chains may horizontally differentiate their products from competing firms, gaining more revenue and retaining a greater proportion of beef consumers by capitalizing on their increased WTP for improved animal welfare products. These principles appear to be contributing to a societal goal, but they aim to gain further revenues or market access through a "do good" appearance. Additionally, this increased personal business standard moves the private cost and supply of welfare closer to the socially optimal level developed by consumer demand for animal welfare, mitigating a potential market failure.

Entirely new markets have been created to cater to adapting demands for higher animal welfare. For example, major meat buyers have a Hazard Analysis Critical Control Point (HACCP) audit of which companies like McDonald's and Wendy's take part (Wigham et al., 2018). USDA AMS provides auditing and accreditation directly for HACCP in addition to working with private certification auditors (AWIC, n.d.). These rigorous welfare standards go beyond legislation requirements, and a packer company could leverage their own commitment to improving welfare management through audits like these to gain that consumer's share of the market. This increases that producer's welfare by capturing a new share of the market. Packer companies with increased levels of animal welfare can advertise available carcasses to wholesalers and companies that have preferences for improved welfare products through programs like HACCP. These supply chain adaptations display animal welfare not as a side-effect of food production, but a unique outcome firms can include in their production management decisions (Buller & Roe, 2012).

5. Discussion

Policies could include anything for federally regulated animal welfare labeling programs to actual mandates on animal welfare management and improvements. Firstly, federal regulation of animal welfare requires extensive government oversight. Specifically with beef cattle, a traceability system would need to be developed to track animals and their welfare as they move through the supply chain and pass to different producers. Although the USDA Food Safety and Inspection Service (FSIS) and AMS already conduct producer inspections and certifications, any additional regulatory requirements would require additional employees and training to oversee the new requirements. From where would the costs of these traceability, trainings, and employees be sourced? Would firms have to pay for their own certification and auditing? Otherwise, extensive public funds must be raised in some fashion to finance animal welfare monitoring.

Secondly, regulatory pressures increase costs across the supply chain, making it more difficult for supply chains to garner a price premium for animal welfare. Some firms would likely still be beyond the regulatory requirements, but with overall increases in supply costs, combined with current beef prices at an all-time high and expected to continue to rise in the coming years, the additional WTP for beef from consumers is likely a slim margin (Shan, 2023). Market adjustments allow the supply chain to adjust to an equilibrium of animal welfare levels that provides specialized price premiums for producers and caters to the spectrum of consumer preferences for animal welfare products. Consumers receive more societal benefit from animal welfare investments and specialized products because they can tailor their buying practices to their heterogeneous preferences. However, higher income consumers are the most likely to pay for animal welfare-friendly products because they can pay higher price premiums (Clark et al., 2017; Lagerkvist & Hess, 2010). As demand for animal welfare increases, specialized products and markets may be inaccessible to low-income consumers regardless of their preferences for animal welfare levels. If animal welfare regulations increase, the price of beef is likely to rise to accommodate for increased management costs, but that could be detrimental to low-income consumers who cannot afford animal welfare premiums. Any policy initiatives must account for the equity of the program, and with the extreme costs involved in instituting beef welfare monitoring, it is likely to create high prices that could prevent purchase of any beef products regardless of animal welfare levels.

Additionally, with the time involved in beginning to implement any regulatory changes and corresponding agency changes, regulatory approaches will often lag the cutting-edge research of animal welfare as it continues to develop and adapt. By allowing market strategies to drive animal welfare improvements, producers and consumers alike can adjust to novel information in real time (Lusk, 2011). Yet even market approaches may require investments to sustain effectiveness. Despite repeated studies that consumers will pay price premiums for improved animal welfare products, their actual buying decisions may not reflect this (Denver & Christensen, 2017; Kehlbacher et al., 2012). Especially when firms reach extremely high levels of animal welfare, their costs may not be reciprocated with an equal price premium because many consumers are not aware of the differences between different levels of animal welfare investments (Kehlbacher et al., 2012). Policy initiatives could choose to continue enhancing market approaches by aiding private initiatives and programs that are able to adjust quickly to new information. National guidance and cooperation with third-party audits provide reliability in animal welfare programs while avoiding some of the difficulties in instituting nationalized regulatory requirements. With widespread federal assistance, consumers could be educated on the available programs and associated management levels to ensure their WTP is based on accurate information that reflects the investments of the supply chain.

We focus on market approaches to animal welfare management because there are many difficulties with regulatory approaches to animal welfare investments in the beef supply chain. By allowing the market to determine the appropriate level of animal welfare provision, consumers and supply chain actors can amend their practices in timely response to the latest information and opinions. Consumer WTP drives the demand for animal welfare. Management practices and business actions drive the supply of animal welfare. So, those supply chains with extensive resources who choose to invest in animal welfare innovations (e.g., practices or infrastructure that lead to improved animal well-being states) have the potential for the highest potential price premiums from high-demanding consumers, but that investment may not be returned in practical sales. Each sector of the beef supply chain becomes more consolidated with larger operations (ERS, 2023). Firms further downstream of the supply chain thus interact with more upstream firms to acquire cattle and may have more resources to invest in management initiatives. For example, with high market power concentration in cattle processing, investments in animal welfare in this production stage impact millions of beef cattle. These large packer corporations have access to capital and resources needed to make large scale animal welfare improvements, making it a prime focus for animal welfare management investments rather than other production systems that would require interactions between thousands of small-scale actors such as cow-calf ranches or feedlots. However, to improve animal welfare across the entire beef supply chain, firms at all stages of supply must make investments into animal welfare management. Since processors acquire cattle from upstream sources, their purchasing decisions can incentivize management changes in their suppliers. Increased personal business standards consistent with consumer WTP for improvements move the private demand and wider industry supply of welfare closer to the socially optimal level, mitigating a market failure.

Overall, supply chain actors have many opportunities to capitalize on increased animal welfare demands. By prioritizing their animal welfare improvements, supply chains are dedicating conscious management decisions on welfare that guide their business operations and their ultimate strategic goals. While animal welfare improvements increase input and management costs, beef supply chains can differentiate their product from competitors, gain access to new markets, and improve their public perception. Consumers are the ultimate driver of animal welfare investments that go beyond regulatory and economic requirements. Animal welfare labeling and dedicated markets capture the spectrum of preferences for animal welfare by providing programs that garner a price premium for specialized products with advanced animal welfare investments- such as the movement to extreme w_C in Figure 2. As animal welfare demand continues to grow across the food supply chain, it is crucial to react to changes in consumer behavior while also proactively adapting to the anticipation of changing production requirements. By combining any number of the approaches discussed in this paper, beef supply chains have the opportunity to combat the growing societal concern about meat production in a way that promotes their investments being repaid in the long run.

REFERENCES

Alonso, M., González-Montaña, J., & Lomillos, J. (2020). Consumers' Concerns and Perceptions of Farm Animal Welfare. *Animals* 2020, *10,* 385. doi:10.3390/ani10030385.

American Humane Certified. (2017). Beef Cattle Animal Welfare Standards Audit Tool. *American Humane Farm Program*. https://www.americanhumane.org/app/uploads/2021/08/Beef-Cattle-Audit-Tool-1.pdf

AVMA. (2023). Animal welfare: What is it? *American Veterinary Medical Association.* https://www.avma.org/resources/animal-health-welfare/animal-welfare-what-it

Animal Welfare Information Center (AWIC). (n.d.). Animal Welfare Audit and Certification Programs. *USDA National Agricultural Library.* https://www.nal.usda.gov/animal-health-and-welfare/animal-welfare-audit-and-certification-programs

BQA. (2024a). National Beef Quality Audits. *Beef Quality Assurance*. https://www.bqa.org/resources/national-beef-quality-audits

BQA. (2024b). What is BQA? *Beef Quality Assurance*. https://www.bqa.org/about-us/bqa-and-the-cattle-industry

Buller, H. & Roe, E. (2012). Commodifying animal welfare. *Animal Welfare*, 21(S1), 131-135. doi: 10.7120/096272812X13345905674042.

CDFA. (2024). Animal Care Program. *California Department of Food & Ag*. https://www.cdfa.ca.gov/AHFSS/AnimalCare/

Chambers, P., Grandin, T., Heinz, G., & Srisuvan, T. (2001). Guidelines for humane handling, transport and slaughter of livestock. *Food and Agriculture Organization of the United Nations Regional Office for Asia and the Pacific*. https://www.fao.org/3/x6909e/x6909e.pdf

Chouinard, H. H., Paterson, T., Wandschneider, P. R., & Ohler, A. M. (2008). Will Farmers Trade Profits for Stewardship? Heterogeneous Motivations for Farm Practice Selection. *Land Economics*, *84*(1), 66–82. http://www.jstor.org/stable/27647806.

Christensen, T., Denver, S., & Sandøe, P. (2019). How best to improve farm animal welfare? Four main approaches view from an economic perspective. *Animal Welfare*, *28*(1), 95-106. doi:10.7219/09627286.28.1.095.

Clark, B., Stewart, G.B., Panzone, L.A., Kyriazakis, I., & Frewer, L.J. (2017). Citizens, consumers, and farm animal welfare: A meta-analysis of willingness-to-pay studies. *Food Policy*, Vol. 68, April 2017, Pages 112-127. https://doi.org/10.1016/j.foodpol.2017.01.006

Code of Federal Regulations. (1979). Humane Slaughter of Livestock. https://www.law.cornell.edu/cfr/text/9/part-313

Cryan, R. (1997). Animal welfare: ends and means. *University of Florida*. https://archive.org/details/animalwelfareend00crya

Dawkins, M. S. (2017). Animal welfare and efficient farming: is conflict inevitable? *Animal Production Science* 57: 201-208. https://doi.org/10.1071/AN15383.

de Olde, E.M. & Valentino, V. (2019). The Moral Complexity of Agriculture: A Challenge for Corporate Social Responsibility. *Journal of Agricultural and Environmental Ethics*, 32, 413–430 (2019). https://doi.org/10.1007/s10806-019-09782-3.

Denver, S., Sandøe, Pe., & Christensen, T. (2017). Consumer preferences for pig welfare – Can the market accommodate more than one level of welfare pork?. *Meat Science,* 129. doi:10.1016/j.meatsci.2017.02.018.

Edwards-Callaway, L. & Calvo-Lorenzo, M. (2020). Animal welfare in the U.S. slaughter industry—a focus on fed cattle, *Journal of Animal Science*, Volume 98, Issue 4, April 2020, skaa040, https://doi.org/10.1093/jas/skaa040

European Commission. (2022). Animal welfare labelling. *European Commission, Food Safety*. https://food.ec.europa.eu/animals/animal-welfare/other-aspects-animal-welfare/animal-welfare-labelling_en#:~:text=Current%20EU%20system,%2C%20barn%2C%20etc.).

ERS. (2023). Sector at a Glance. *U.S. Department of Agriculture, Economic Research Service.* https://www.ers.usda.gov/topics/animal-products/cattle-beef/sector-at-a-glance/

Food Safety and Inspection Service. (2022). Humane Handling. *United States Department of Agriculture Food Safety and Inspection Service*. https://www.fsis.usda.gov/inspection/compliance-guidance/humane-handling

GAP. (n.d.). Our History. *Global Animal Partnership*. https://globalanimalpartnership.org/about/history/

ISO. (2021). ISO/TS 34700:2016, Animal Welfare Management. *International Organization for Standardization.* https://www.iso.org/standard/64749.html

ISO. (n.d.). What we do. *International Organization for Standardization.* https://www.iso.org/what-we-do.html

Jensen, H. (2006). Consumer Issues and Demand. *Choices*, 21(3), 165-169. https://www.choicesmagazine.org/2006-3/animal/2006-3-09.htm

Kehlbacher, A., Bennett, R., & Balcombe, K. (2012). Measuring the consumer benefits of improving farm animal welfare to inform welfare labelling. *Food Policy*, 37(6), 627-633. https://doi.org/10.1016/j.foodpol.2012.07.002

Keohane, N.O. & Olmstead, S.M. (2016). Markets and the Environment, Second Edition. *Island Press*.

Klink-Lehmann, J., Tatic, M., Weingarten, N., & Hartmann, M. (2023). Sustainability trade-offs in animal husbandry: consumers' choice when they can't have it all. *Q Open,* Volume 3, Issue 2, 2023, qoad025, https://doi.org/10.1093/qopen/qoad025

Lagerkvist, C.J. & Hess, S. (2010). A meta-analysis of consumer willingness to pay for farm animal welfare. *European Review of Agricultural Economics*, Vol. 38, Issue 1, March 2011, Pages 55-78. https://doi.org/10.1093/erae/jbq043

Lusk, J.L. (2011). The market for animal welfare. *Agriculture and Human Values,* **28**, 561–575 (2011). https://doi.org/10.1007/s10460-011-9318-x.

Lusk, J. L. & Norwood, F. B. (2011). Animal Welfare Economics. *Applied Economic Perspectives and Policy*, *33*(4), 463–483. http://www.jstor.org/stable/41336220.

McInerney, J. (2004). Animal Welfare, Economics and Policy. *Farm & Animal Health Economics Division of Defra.* https://www.researchgate.net/publication/294462122_Animal_welfare_economics_and_policy

McKendree, M.G.S., Croney, C.C., & Widmar, N.J.O. (2014). Effects of demographic factors and information sources on United States consumer perceptions of animal welfare. *Journal of Animal Science*, Vol. 92, Issue 7, July 2014, Pages 3161-3173. https://doi.org/10.2527/jas.2014-6874

NAMI. (2021). North American Meat Institute. Recommended Animal Handling Guidelines & Audit Guide: A Systematic Approach to Animal Welfare. North American Meat Institute. https://animalhandling.org/sites/default/files/forms/Animal_Handling_Guide012021.pdf

NAMI. (2023a). NAMI Animal Handling Guidelines and Audit. *North American Meat Institute.* https://www.meatinstitute.org/Animal_Welfare/Guidelines_and_Audits

NAMI. (2023b). Our Partnership. *North American Meat Institute.* https://meatinstitute.org/Partnership

Public Law. 107–171, title X, §10305, May 13, 2002, 116 Stat. 493. (2002). Enforcement of Humane Methods of Slaughter Act of 1958. *U.S. Code, Title 7.* https://www.govinfo.gov/content/pkg/USCODE-2021-title7/html/USCODE-2021-title7-chap48-sec1901.htm

Schrobback, P., Zhang, A., Loechel, B., Ricketts, K., & Ingham, A. (2023). Food Credence Attributes: A Conceptual Framework of Supply Chain Stakeholders, Their Motives, and Mechanisms to Address Information Asymmetry. *Foods,* 2023, 12(3):538. https://doi.org/10.3390/foods12030538

Shan, L.Y. (2023). Beef prices are at record highs- how much pricier will your steak get? *CNBC*. https://www.cnbc.com/2023/10/25/beef-prices-are-at-record-highs-and-your-steak-is-becoming-pricier.html

St-Pierre, N.R., Cobanov, B., & Schnitkey, G. (2003). Economic Losses from Heat Stress by US Livestock Industries. *Journal of Dairy Science*, 86, Supplement, June 2003, E52-E77. https://doi.org/10.3168/jds.S0022-0302(03)74040-5

Sullivan, S. P. (2013). Empowering Market Regulation of Agricultural Animal Welfare through Product Labeling. *Animal Law Review, Lewis & Clark Law School*, 19 Animal L. 391 (2013).

United Nations Industrial Development Organization. (2023). What is CSR? Available: https://www.unido.org/our-focus/advancing-economic-competitiveness/competitive-trade-capacities-and-corporate-responsibility/corporate-social-responsibility-market-integration/whatcsr#:~:text=Corporate%20Social%20Responsibility%20is%20a,and%20interactions%20with%20their%20stakeholders.

Verbeke, W. & Vianene, J. (2000). Ethical Challenges for Livestock Production: Meeting Consumer Concerns about Meat Safety and Animal Welfare. *Journal of Agricultural and Environmental Ethics*, 12, 141-151, 2000. https://sean-sullivan.com/media/papers/2013_emraaw.pdf

Whole Foods Market. (2024). Meat Department. *Whole Foods Market IP, Inc.* https://www.wholefoodsmarket.com/departments/meat

Wigham, E., Butterworth, A., & Wotton, S. (2018). Assessing cattle welfare at slaughter- Why is it important and what challenges are faced? Meat Science 145 (2018) 171-177. https://doi.org/10.1016/j.meatsci.2018.06.010

WOAH. (2023). Animal Welfare. *World Organization for Animal Health*. https://www.woah.org/en/what-we-do/animal-health-and-welfare/animal-welfare/

Appendix A. Supplemental Tables

Table A1. Summary of Variables Used For Value Construction

Variable	N	Mean	SD	Min	Max
Market Characteristics (M)					
Price/lb	604	4.35	.371	3.56	4.87
Premium, Price	604	17.04	3.98	12.68	24.11
Discount, Select	604	-17.14	6.33	-28.58	-7.67
Discount, Standard	604	-31.61	2.76	-37.93	-27.86
Discount, Dark Cutter	604	-35.52	.603	-35.83	-33.75
Premium, Yield Grade 1	604	3.63	.055	3.58	3.69
Premium, Yield Grade 2	604	1.58	0	1.58	1.58
Discount, Yield Grade 4	604	-11.23	0	-11.23	-11.23
Discount Yield Grade 5	604	-16.82	.100	-16.85	-16.46
Lot Characteristics (L)					
Avg. Live Weight	604	1372.38	123.68	797.00	1690.00
Avg. Hot Weight	604	874.0321	84.89	665.00	1490.00
Avg. Chill Weight	604	843.441	81.92	641.73	1437.85
Dress Yield	604	63.5718	1.48	57.90	67.7
Quality Characteristics (Q)					
Premium	604	0.087	0.111	0	1
Choice	604	0.708	0.138	0	1
Select	604	0.187	0.156	0	1
Standard	604	0.014	0.022	0	0.219
Dark Cutter	604	0.013	0.037	0	0.564
Yield Grade 1	604	0.064	0.084	0	1
Yield Grade 2	604	0.327	0.175	0	0.803
Yield Grade 3	604	0.423	0.145	0	0.875
Yield Grade 4	604	0.145	0.120	0	0.542
Yield Grade 5	604	0.041	0.096	0	1

Table A2. Summary of Variables Used For NAWO Construction

Variable	N	Mean	SD	Min	Max
Welfare Characteristics (W)					
No Bruises	581	0.323	0.227	0	1
Multiple Small Bruises	581	0.147	0.094	0	0.467
Multiple Large Bruises	581	0.316	0.182	0	0.925
1 Small Bruise	581	0.121	0.075	0	0.500
1 Large Bruise	581	0.093	0.060	0	0.429
Mobility 1	585	0.917	0.090	0	1
Mobility 2	585	0.079	0.082	0	1
Mobility 3	585	0.003	0.015	0	0.250
Mobility 4	585	0.00002	0.0005	0	0.013
Dead/Downer	585	0.0003	0.004	0	0.103
OMB	593	0.0006	0.003	0	0.035
Transportation Characteristics (T)					
Stocking Density (M)	580	3.06	2.03	0.560	31.68
Quality Characteristics (Q)					
Dark Cutter	604	0.0125	0.037	0	0.564

Table A3. Mean Historical vs Study Period Prices

Variable	Study Period [@] (March 2021- July 2022)	Historical (Jan. 2004- Dec. 2019)
Wholesale Beef Price[*]	434.67	281.20
Premium, Price	17.04	12.07
Discount, Select	-17.14	-8.40
Discount, Standard	-31.61	-25.46
Discount, Dark Cutter	-35.52	-36.54
Premium, Yield Grade 1	3.63	5.43
Premium, Yield Grade 2	1.58	2.42
Discount, Yield Grade 4	-11.23	-9.80
Discount Yield Grade 5	-16.82	-14.96

Notes: All prices reported per hundredweight ($/cwt)

[*]Wholesale Beef Price is an average of monthly ERS "Historical monthly price spread data for beef, pork, broiler" estimates over the respective time periods.

All Quality and Yield Grade Premiums/Discounts are averages of weekly AMS "National Weekly Direct Slaughter Cattle- Premiums and Discounts" estimates over the respective time periods.

[@]Study period estimates are calculated based on USDA estimates in the months/weeks lots in this study were observed rather than over the entire 17-month period.

Appendix B. Robustness Check Model Results

	Comprehensive Level	Disaggregated Level
Intercept	240.363***	251.2569***
	(40.2484)	(41.4005)
Welfare Characteristics (W)		
NAWO	-2.8402*	
	(1.5295)	
NAWO, Mobility		-7.1755**
		(3.5639)
NAWO, Bruising		-1.4790
		(3.1347)
NAWO, Lairage		1.2688
		(4.4248)
NAWO, OMB		5.5355
		(8.6822)
NAWO, Dark Cutter		-5.6723*
		(3.2397)
NAWO, Dead/Downers		2.8635
		(12.0804)
NAWO, Wait Time		-2.6197
		(4.4391)
Lot Characteristics (L)		
Plant 3	27.7245***	26.4464***
	(6.1110)	(6.7912)
Plant 4	19.7361***	20.5041***
	(3.6607)	(4.0163)
Summer	-23.3034***	-23.4234***
	(4.9637)	(5.1969)
Spring	-5.2145	-6.2839
	(4.5864)	(4.8146)
Winter	-3.9732	-4.6351
	(3.6304)	(3.9471)
Shift	-4.6944	-5.2092
	(4.3007)	(4.5828)
Sex Class	-2.9347	-3.7832
	(2.8108)	(2,8451)
Lot Size[$]	2.8616**	3.3963**
	(1.3524)	(1.5894)
Transportation Characteristics (T)		
Travel Distance[$]	0.2930	0.5114
	(0.3820)	(0.4193)
Number of Head per Truck[$]	0.2780	0.2242
	(0.3820)	(0.2499)
THI[$]	1.3463***	1.3204***
	(0.1559)	(0.1680)
Quality Characteristics (Q)		
Average Quality Grade[$]	15.6790*	13.8806*
	(8.1559)	(8.3711)
Average Yield Grade[$]	3.6516	3.6496
	(3.3448)	(3.3988)
N	350	350
R^2	0.4030	0.4130
F[@]	21.36	14.89

Prob > F	<0.0001	<0.0001

Notes: Robust standard errors in parentheses
$ Variable log-transformed in estimation method (b)
*** p<0.01, ** p<0.05, * p<0.1
@ Comprehensive: F(14, 335); Disaggregated: F(20, 329)