Evaluating economic impacts of marketing agreements in a differentiated U.S. beef industry

by

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Abstract

Understanding the impact of value-based pricing methods on beef cattle quality, as well as differentiating the impact of high- and low-quality beef across the supply chain, has become increasingly important with the rise in high-quality cattle over the past decade. The shift towards alternative marketing agreements (AMAs) has heightened concerns over market transparency and price discovery, emphasizing the need to understand the long-term impact of these marketing methods on the industry.

This thesis first evaluates the influence of value-based pricing methods, specifically formula and negotiated grid pricing, on the percentage of cattle grading Choice and Prime. Using a quality index model, economic factors impacting cattle quality grading are evaluated. Findings indicate that increased use of AMAs has substantially shifted the quality dynamics of the beef industry, with a 0.94% increase in cattle grading Choice for every 1% increase in formula and grid priced cattle.

Building on these results, the economic impacts of supply shifts in high-quality beef are assessed across four levels of the beef supply chain – retail, wholesale, slaughter, farm – under scenarios of reduced formula and grid pricing. Since the dramatic improvement in beef quality and shift in fed cattle marketing methods, a study analyzing the impacts on a differentiated market has not been completed. This research uses an equilibrium displacement model to evaluate the impacts of a negative shock to high-quality wholesale beef supply resulting from an increased use of cash negotiated trade, as proposed policy in policy discussions. Findings indicate an increase in price and decrease quantity for high-quality wholesale and retail beef while price declines and quantity increases for low-quality wholesale and retail beef. Aggregate slaughter and feeder cattle producers experience declines in both price and quantity.

Findings from this study show a strong association between formula and grid pricing methods and high-quality beef production. Policies mandating increased cash-negotiated trade, which would diminish the use of formula and grid pricing, are shown to reduce demand for cattle from producers, ultimately leading to lower prices received by them. By adopting a heterogenous market perspective, this study highlights the differential impacts of AMAs, providing stakeholders with crucial insights into the valuation and policy implications of AMAs in the evolving beef industry.

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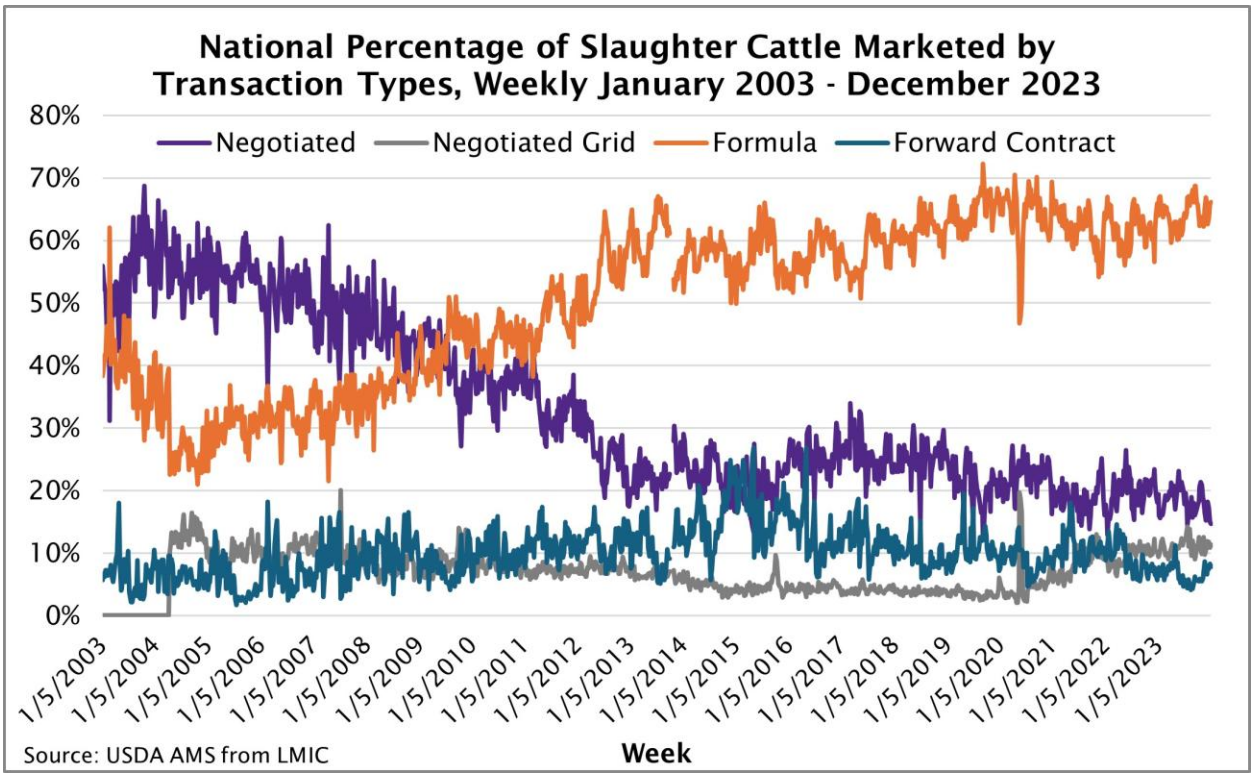
Dedication

This thesis is dedicated to my parents, Matthew and Stacey Doumit. Their unwavering love and support throughout my academic career have made this accomplishment possible. From instilling in me a strong work ethic to fostering a deep appreciation for the agricultural industry and the value of higher education, their influence has been immeasurable. They have supported me through some of life's most difficult decisions and encouraged me to continue pursuing my passions. Thank you for always being there for me and encouraging me to strive for nothing but my best.

Chapter 1 - Introduction

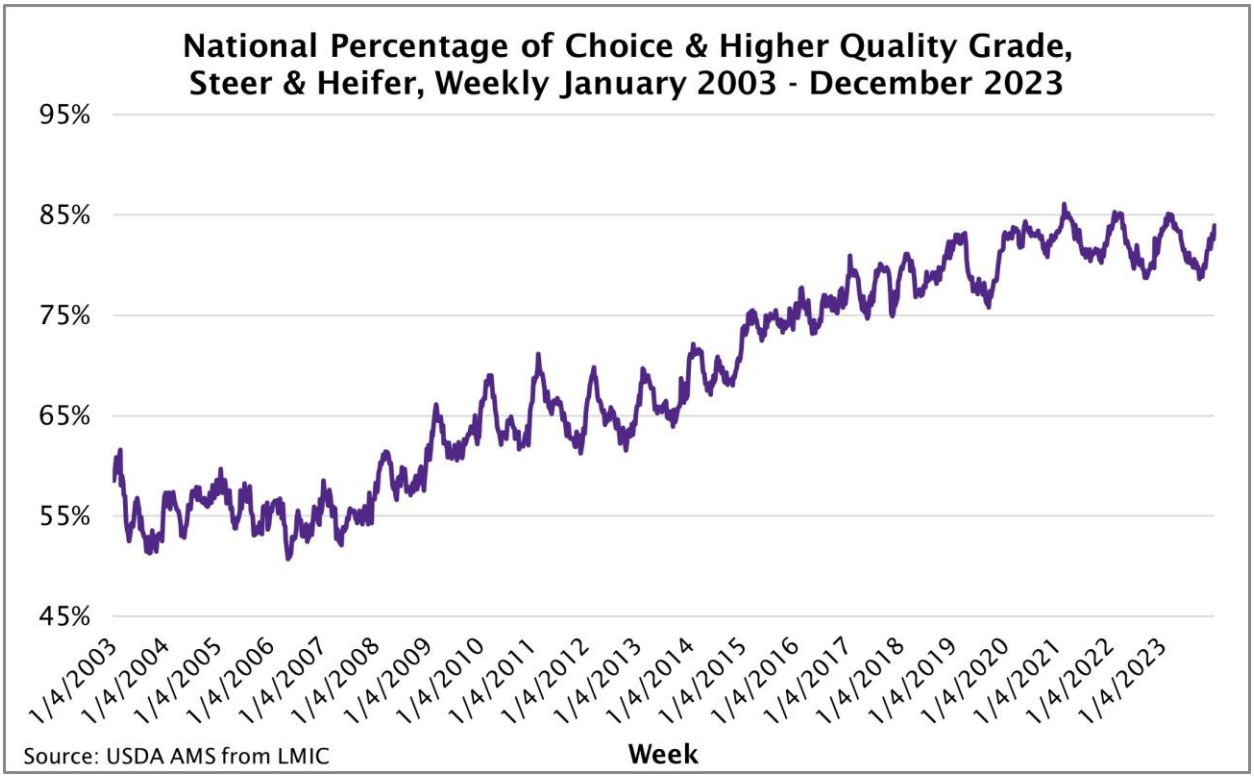
The quality and value of beef cattle have dramatically evolved over time. Over the past 15 years, fed cattle marketing methods have endured a major transformation from cash negotiated trade toward alternative marketing agreements (AMAs) despite increasing concerns over price discovery and market transparency. AMAs are alternatives to the cash market such as formula trade, forward contracts, or packer ownership (Taylor et al. 2007). In the early 2000s, about 55% of fed cattle were marketed through cash negotiated trade, with forward contracts and negotiated grid purchases accounting for roughly 20%, and formula trade making up the remaining 25%. By 2007, formula trade began to increase in the fed cattle market, reaching approximately 65% of transactions today, while cash negotiated trade dropped to below 20% (Figure 1.1).

Figure 1.1. National Percentage of Slaughter Cattle Marketed by Transaction Types (USDA AMS from LMIC)



As the industry transitioned towards using AMAs, the percentage of carcasses grading Choice and higher has increased by more than 30 percentage points from around 55% to 85% (Figure 1.2).

Figure 1.2. National Percentage of Choice and Prime Steers and Heifers (USDA AMS from LMIC)



Alongside this improvement in beef quality, consumer demand for high-quality products has also grown (Zimmerman and Schroeder 2013; Tatum 2015). In vertically connected industries such as the beef industry, primary suppliers are often not directly tied to primary demand activities. However, primary suppliers can realize economic value by supporting improvements in demand. McKendree et al. (2020) quantifies the impact of shifts in primary demand on producers across different levels of the industry, concluding that enhancements in retail and export demand benefit both feeder and fed cattle producers. Quantifying the economic implications of industry

investments driving these quality and demand trends across the beef supply chain is essential for marketing and policy decisions.

The primary objective of this study is to quantify the extent to which fed cattle marketing agreements and formula trade have contributed to improvements in cattle quality over time and to evaluate the economic implications of this association across market levels under various policy scenarios. To achieve this, a beef quality index model will be used to estimate how economic factors influence cattle quality grading distributions over time. This analysis will include measuring the effects of cost of gain in cattle feeding, heifer slaughter, marketing method shares, and seasonality on cattle quality distributions. Using the results from the quality index model to determine industry shifts in supply, impacts on prices, quantity, and farm revenue for both high- and low-quality cattle through an equilibrium displacement model (EDM) will be measured. This heterogeneous beef sector EDM will focus on beef cattle across four levels: retail, wholesale, slaughter (fed), and farm (feeder) cattle. The retail and wholesale levels will be further segregated by high quality (Choice, Branded, Prime) and low quality (Select) supply and demand functions.[1] This analysis will focus specifically on the influence of formula and grid pricing on cattle quality and estimate economic trade-offs under alternative pricing methods, assessing the broader impacts on cattle and beef markets.

While extensive research exists on the economic value of the premium and discount pricing structures, consumer demand for high-quality products, and policy implications for the aggregate beef industry, few studies have examined the industry in terms of disaggregated products. This research contributes to the literature by providing a quantitative analysis of the

[1] The "Standard" Quality Grade is omitted from this analysis to provide more accurate results. Standard is often grouped with "Ungraded" or "Other" carcasses.

relationship between AMAs and high-quality beef, an initial estimation of heterogenous beef quality elasticities, and a framework to understand implications across the beef marketing chain.

Chapter 2 - Background

2.1 Beef Supply Chain

The beef supply chain starts at cow-calf operations, where calves are raised into steers and heifers before being sent to backgrounding operations or feedlots. At feedlots, cattle are fed to reach harvest weight and then transported to packing plants for slaughter, chilling, and grading. Carcasses are then further processed into specific cuts, boxed, and distributed. Boxed beef from processors is then sold to retailers, food service outlets, distributors, exporters, or further processed before reaching the end consumer.

Through the late 1990s, the beef industry faced notable declines in domestic demand, attributed to shifting consumer preferences, demographic changes, and competitive pricing of other meats (Marsh 2003). Since then, the industry has made extensive efforts to revive consumer demand, primarily by improving beef quality. To achieve this, producers have invested in better aligning production practices with changing consumer expectations.

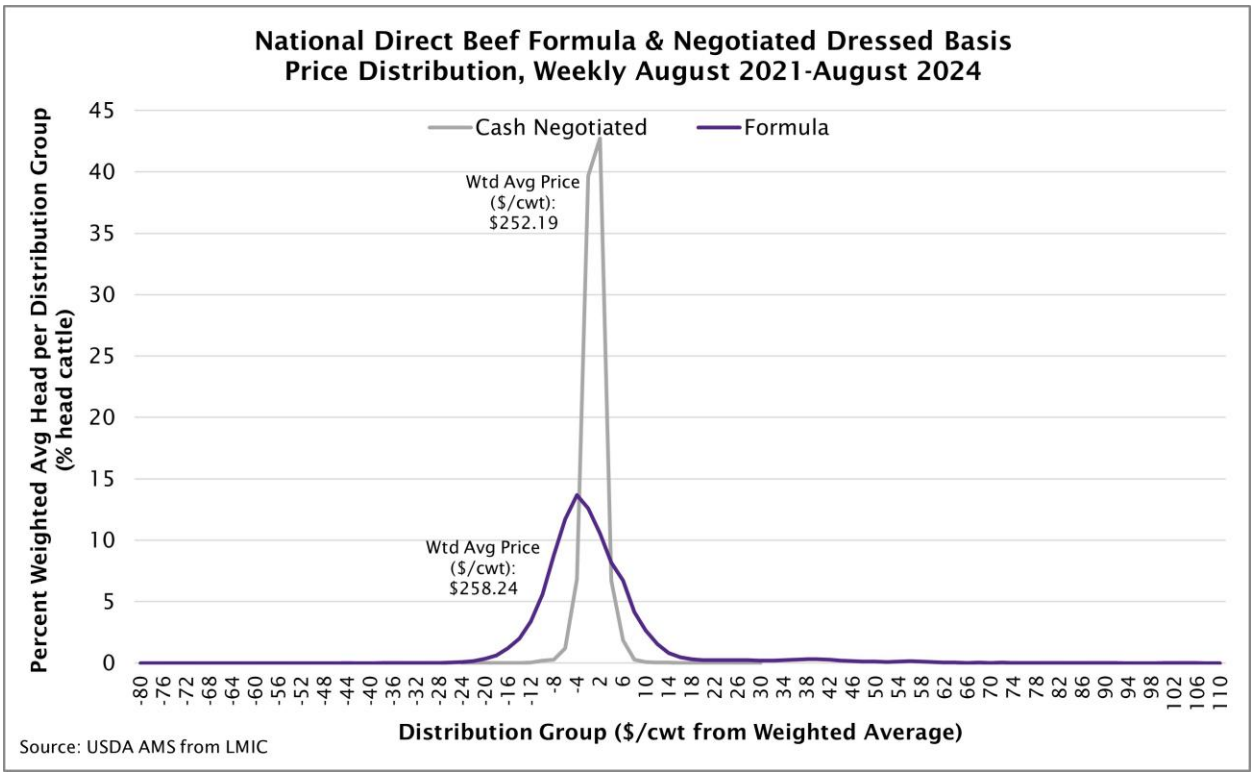
2.2 Economic Management Decisions

To better align with evolving consumer demands and improve supply chain coordination, meatpackers and cattle producers have adopted alternative marketing agreements. Although AMAs bring many direct benefits to both packers and producers, producing higher-quality cattle generally involves higher production costs. Enhancing quality generally requires longer feeding periods, feeding cattle to heavier finished weights, or specific genetic selection, all which raise production costs (May et al. 1992; Anderson and Trapp 1999). Opportunity costs are another crucial consideration when feeding cattle to heavier weights. Producers face increased price discounts for cattle with higher yield grades or heavier carcasses, limited ability to introduce new cattle into the production cycle resulting in missed revenue potential, and greater risks of

morbidity and mortality incidents (Horton et al. 2023). Producers are willing to incur these additional production and opportunity costs only if they are adequately compensated for the enhanced value their investments create.

AMAs support this dynamic by providing incentives for producers to deliver high-quality products consumers desire, offering value-based pricing based on carcass merit. This includes premiums or discounts for traits such as quality grade, yield grade, preferred weight, and branded programs. Value-based pricing of fed cattle has created notable variation in prices across transactions and is growing in importance as more grid transactions occur and a greater percentage of purchases consider animal, process, and carcass attributes (Schroeder, Coffey, and Tonsor 2023). Schroeder, Coffey, and Tonsor (2023) estimate frequency of quality, yield grade, weight, and other premiums and/or discounts for formula trade transactions all increased between 2016 and 2021. Quality and yield adjustments saw the largest increases going from 70% in 2016 to 80% in 2021 and 64% to 74%, respectively. As the frequency of premium and discounts occur in fed cattle pricing, so does the variation in net dressed prices. Figure 2.1 illustrates variation in the weekly weighted average distributions of net dressed prices for fed cattle sold through formula-based versus cash negotiated methods over the past three years.

Figure 2.1. National Direct Beef Formula and Negotiated Price Distribution, Dressed Basis (USDA AMS from LMIC)

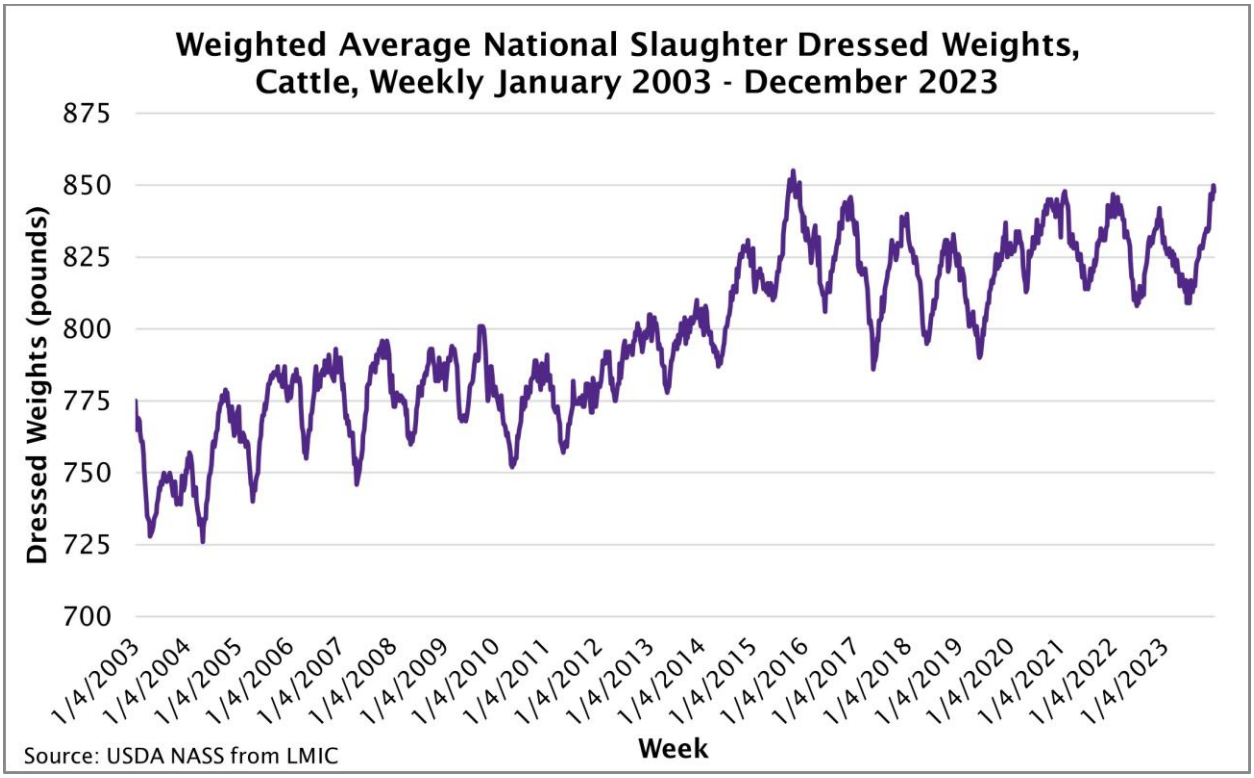


While 80% of fed cattle sold under cash negotiated pricing in a typical week receive a net dressed price within $2/cwt ($4/cwt range) of the weighted average price, formula priced cattle experience more variation with 80% of sales within $10/cwt ($20/cwt range) of the weighted average. This price variation is a direct result of premiums and discounts paid for varied cattle quality and other attributes in formula trade. As premium beef quality is incentivized, there has been a corresponding shift in cattle management practices.

Since the early 1990s, producers have shifted toward raising heavier cattle, consistent with feeding cattle longer. Cattle management is largely seasonally dependent based on many factors including cattle and feed prices, weather, and supply chain capacity. Despite seasonality, Figure 2.2 depicts a clear upward trend in dressed carcass weights since 2003 as heavier weights

and extended feeding periods correlate with higher marbling levels and quality grades (Owens and Gardner 2000).

Figure 2.2. National Slaughter Dressed Weights (USDA NASS from LMIC)



Packers have adapted by providing greater allowances for heavier carcasses, adjusting discount thresholds for Yield Grade 4 and above, and raising the upper weight discount level from 1,000 to 1,050 pounds in 2013 (Doumit and Schroeder 2023).

These economically driven cattle management changes have resulted in a steady increase in the percentage of U.S. fed cattle grading Choice and Prime, as shown in Figure 1.2. This trend, which has increased by over 30 percentage points since 2007 to current levels above 85%, underscores the association of carcass weights, quality grade, and use of formula pricing methods. Quantifying AMAs' specific impact on beef quality improvement is critical to understanding the value signals producers receive and informing ongoing industry and policy discussions.

2.3 Policy Discussions

Policy discussions around livestock markets have been active for decades and remain a focal point for industry stakeholders. In the mid-1990's, meat packing companies were consolidating and getting larger, leading to growing industry and Congress concerns over packer concentration. The ongoing concentration concerns and concerns over a lack of public disclosure regarding AMAs prompted Congress to pass the Livestock Mandatory Reporting Act of 1999 and USDA to implement the Livestock Mandatory Reporting program (LMR) in 2001 to provide product information readily understood by producers, improve price and supply reporting, and encourage competition in the marketplace (Mathews Jr. et al. 2015). Following implementation of LMR and reauthorization every five years since, negotiated cash trade has declined, raising concerns of market thinness and insufficient price discovery in the U.S. fed cattle industry (Anderson, Mitchell, and McKenzie 2022).

The recent Cattle Price Discovery and Transparency Acts represent industry and federal responses to market participants' concerns. Reintroduced in February 2023, these acts propose greater transparency through the implementation of a cattle contract library and additional public reports on base prices for cattle transactions from the United States Department of Agriculture (USDA). The Acts also seek to address market thinness by establishing a minimum regional threshold for negotiated cash purchases, commonly referred to as "regional minimums" (Dennis and Lubben 2022). Responses have already been implemented since the first introduction of these acts, but a substantial amount of concern over requiring regional minimums continues.

In 2024, the USDA Agricultural Marketing Service (AMS) issued an Advance Notice of Proposed Rulemaking (ANPR) to solicit public feedback on possible interventions to develop new benchmarks as AMA base prices and approaches to trading when using benchmarks.

Feedback is requested on a proposed set of regulatory options including a 50% cap on the use of a regional cash negotiated benchmark, limitations on meat packers' exclusivity agreements, prohibitions to prevent meat packers from engaging in certain trade practices allowing them to manipulate base prices and to prevent them from delaying the pick-up of purchased live cattle, and written documentation requirements to assess contributions to price discovery (USDA AMS 2024). The USDA's interest in these interventions appears to stem from long-standing concerns over the thin nature of the fed cattle market. These efforts aim to address potential negative price effects of AMAs on the spot market and perceived preferential behavior for producers marketing cattle under AMAs.

Since 2020, numerous legislative measures have targeted market transparency and price discovery including three Senate bills, three House bills, and a voluntary industry proposal, each focusing on defining an implementing regional minimums to support price transparency.[2] Dennis and Lubben (2022) provide an in-depth performance and sensitivity analysis of each of these policy initiatives, emphasizing the importance of preserving industry progress in aligning beef production with consumer preferences if regional minimums were implemented. If enforced, regional minimums will ultimately reduce the percentage of cattle marketed with AMAs, which could hinder the supply chain for high-quality cattle and raise industry costs.

Regional minimums are just one proposed solution to several concerns over beef cattle market issues. Peel et al. (2020) provides a comprehensive review regarding the nature of these concerns and proposed recommendations for the National Cattlemen's Beef Association and industry leaders. While most research confirms a relatively small percentage of effective cash

[2] S.B. 4647, S.B. 543, S.B. 3229; H.R. 8557, H.R. 3766, H.R. 5992; National Cattlemen's Beef Association 75% Plan

trades are sufficient to ensuring price discovery, the economic advantages of AMAs and concentrated industry structure concerns are largely separate from price discovery issues (Peel et al. 2020). Understanding and illustrating the tradeoffs of marketing methods' effects on the industry over time is crucial for addressing strategies to support producer adoption of value-based practices.

2.4 Literature Review

Consumer demand is central to this research. From the mid-1970s to the late 1990s, beef demand fell by approximately 50%. Several experts attributed the loss of market share to a production approach focused on quantity over quality (Johnson and Ward 2006; Schroeder, Marsh, and Mintert 2000; Marsh 2003). In an effort to improve demand and revenue, the industry introduced grid pricing in 1991 to incentivize high-quality products and strengthen price signals along the supply chain (Fausti et al. 2010). Brester and Schroeder (1995) used a nonlinear Rotterdam model to estimate the impacts of brand and generic meat advertising on demand. They concluded that branded beef and poultry advertising increased overall meat demand and prompted substitution between commodities. In recent years, as beef has become more expensive, consumers have shown a greater willingness to pay a premium to achieve a more desirable eating experience (Tatum 2015; Tonsor 2024).

Extensive research has explored how grid and formula pricing adds value. Grid pricing literature extensively discusses the effectiveness of grid pricing to transmit quality-related market signals to producers (Schroeder and Graff 2000; McDonald and Schroeder 2003; Johnson and Ward 2006; Fausti et al. 2015). Koontz (2021) analyzes improvements in efficiencies, coordination, communication, and a cost and benefit analysis due to AMAs. An economic model simulating market interactions to estimate market-wide impacts of AMAs is used – specifically a

25% reduction in AMAs in the cattle and beef industry. Findings show the impact is a minimum of $10 per head for the packer and $25 per head for the cattle feeding industry due to increased processing costs, marketing costs, and decreased efficiency. This translates to industry-wide costs of potentially over $2.5 billion per year with much of the impact being borne on cow-calf producers.

As products have become increasingly differentiated, literature on heterogenous products has expanded, though studies examining market-wide effects remain limited. Aggregating products as single commodities can hide structural differences in both supply and demand for differentiated products (Brester 1996). Demand functions generally differ for different cuts of beef not only due to the differences from a consumption perspective, but in the case of ground beef and table cuts, they are generally produced by a different type of beef animal. Studies have revealed the importance of disaggregation in beef cuts as the own-price demand elasticity for ground beef is much more elastic than the elasticity for table cut beef (Brester 1996; Brester and Wohlgenant 1991; Eales and Unnevehr 1988). Beef has also been disaggregated into categories of differentiated products and quality grade (Zimmerman and Schroeder 2013; Lusk et al. 2001; Tonsor, Lusk, and Schroeder 2018). Lusk et al. (2001) estimates wholesale demand for pork, chicken, and quality differentiated beef. Their results indicate that meat retailers have more elastic demand for lower quality beef, while seasonal analysis shows demand for both Choice and Select beef becomes highly price inelastic during the summer months. Ultimately, disaggregation allows for a more precise analysis of supply and demand relationships between differentiated products (Cashin 1991).

Chapter 3 - Impact of Marketing Agreements on Beef Cattle Quality

3.1 Previous Research

The GIPSA Livestock and Meat Marketing Study conducted by Research Triangle Institute (RTI) International (2007) studied factors motivating the use of various fed and beef marketing practices, including AMAs. The RTI team conducted surveys across the beef supply chain, including 29 large beef packing plants, and gained transaction level proprietary data. This data covered 572,000 lots (100 head/lot), representing approximately 85% of fed cattle slaughtered during October 2002 through March 2005. Using this data, the RTI study determined 86% of the total marketing volume was dominated by cash trade and marketing agreements, representing 57% and 29% respectively. Auction barns and brokers, forward contracts, and packer-owned agreements made up the remining transactions. The conclusions from this study showed 60% of direct trade cattle and 63% of marketing agreement cattle graded Choice or higher.

In a follow-up study to the RTI analysis, Liu et al. (2009), used the transaction level data collected to estimate the impact of AMAs on beef quality using Tobit models. The Liu et al. study determined the highest quality cattle were those purchased from auction barns; however, auction barns represented a very small portion of the transactions. They determined cattle purchased using AMAs realized about 2% more Prime and Choice cattle compared to direct trade.

As part of the analysis, Liu et al, constructed a quality index representing a composite measure of a quality-adjusted average market value of a lot of cattle. They regressed the quality index as a function of AMA purchases controlling for seasonality and fixed effects of slaughter plants. In this study, the quality index is a calculated average market value of a lot of cattle

determined by the percentages of cattle in the lot classified by quality grade and type of cattle and average market prices for the respective classification. The difference in the quality index shown by the regression coefficient estimates is interpreted as the difference in average market values between the respective variable and direct trade. This study concluded that cattle procured through marketing agreements improved the quality index $0.57/cwt compared to direct trade, signifying that the average market value of cattle marketed through marketing agreements is $0.57/cwt higher than cattle marketed through direct trade. They determined carcasses weight basis valuation with grid provided better price signals to producers and tighter vertical coordination using AMAs which ultimately help improve beef quality.

Extending Liu. et al., Schroeder, Tonsor, and Coffey (2021) constructed a similar model using current and publicly available data from 2004 to 2020. This model regressed a modified quality index representing the value-weighted percentage of beef grading Prime and Choice on marketing methods of formula and grid, forward, and packer owned, a steer/corn ratio, cattle on feed, and included seasonality measures. Results showed the steer/corn ratio, used as a measure of net returns, increased the quality index while cattle on feed had a negative effect. The formula combined with grid pricing and forward pricing variables had a positive effect on the quality index while packer owned decreased quality. Specifically, as formula and grid cattle pricing increased by one percentage point, the quality index increased by 0.62 percentage points. All variables were statistically significant ($p<0.05$) with the exception of cattle on feed.

3.2 Beef Quality Index Model

The Schroeder, Tonsor, and Coffey model was adapted to further quantify the relationship between AMA use and high-quality fed cattle. Utilizing a similar value-weighted quality index of the percentage of cattle grading Choice and Prime, the model was estimated

using similar variables and monthly data from January 2003 through December 2023. The estimated model is outlined in Equation 3.1.[3]

$$QGIndex_t = \beta_0 + \beta_1 CostofGain_t + \beta_2 HeiferSlaughter_t + \beta_3 Formula\&Grid_t + \beta_4 Forward_t + \beta_5 QTR1 + \beta_6 QTR1 + \beta_7 QTR3 + e_t \quad (3.1)$$

The quality grade index, used as the dependent variable in this model, explores the relationship between cattle quality and AMAs. The index is a calculated value-weighted index of the highest quality fed cattle, Choice and Prime, relative to all graded beef using data from USDA Agricultural Marketing Service (AMS) and is expressed as a percentage. Prime cattle are weighted higher than Choice because Prime cattle receive a premium relative to Choice and Prime cattle are generally more costly to produce. Specifically, the quality index is calculated as specified in Equation 3.2.

$$QGIndex_t = \left[\frac{(Prime\ Cattle * Relative\ Prime\ Premium) + Choice\ Cattle}{Prime\ Cattle + Choice\ Cattle + Select\ Cattle + Other\ Cattle}\right] * 100 \quad (3.2)$$

The Prime, Choice, Select, and Other Cattle values in Equation 3.2 are the number of head assigned each respective quality grade each month while the *Relative Prime Premium* is a calculated value using the average monthly USDA AMS National Choice Dressed Steer and Heifer Prices and National Prime Premium as shown by Equation 3.3.

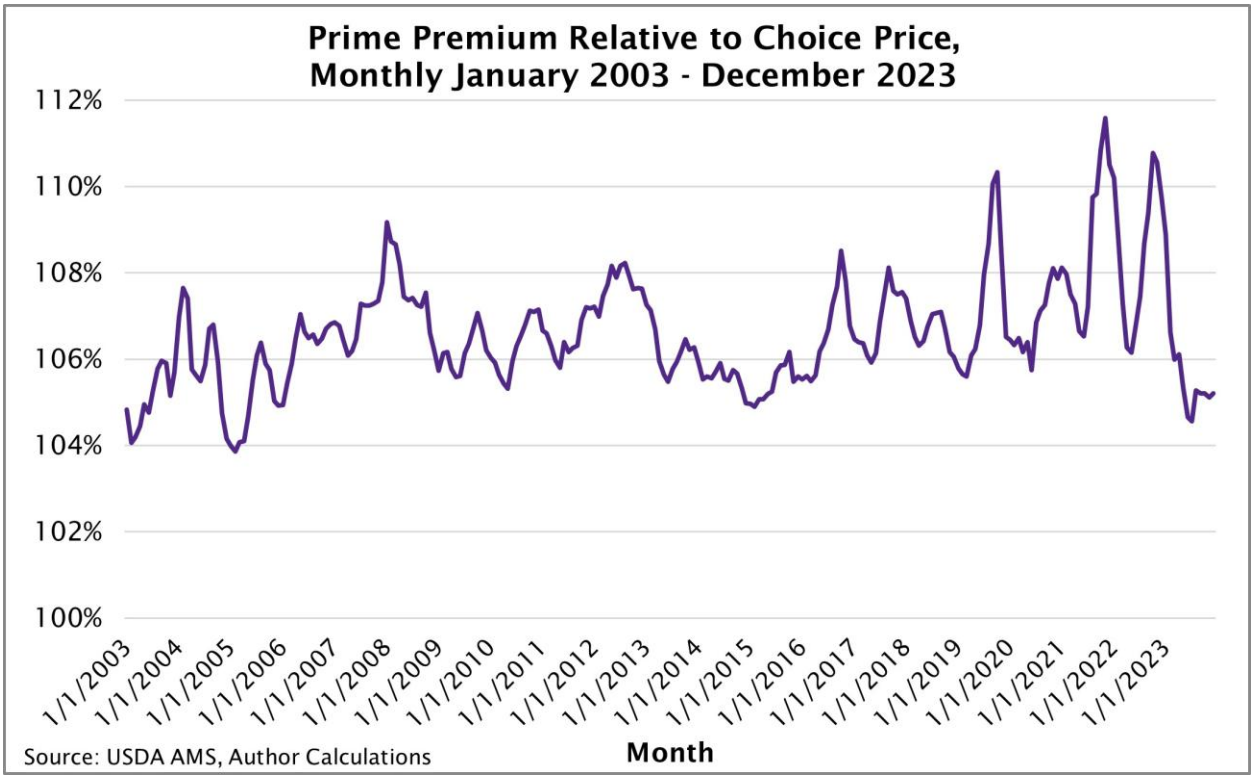
$$Relative\ Prime\ Premium = \frac{Prime\ Premium + Choice\ Dressed\ Price}{Choice\ Dressed\ Price} \quad (3.3)$$

Between 2003 and 2023, the actual USDA AMS National Prime Premium average value is $12/cwt, but has seen premiums as high as $25.73/cwt and as low as $5.07/cwt. The average *Relative Prime Premium* over the 20-year time period is 1.0658 indicating cattle grading Prime

[3] The subscript *t* refers to month and *e* is a random error term.

realize 106.58% of the Choice cattle value. The *Relative Prime Premium* over time is depicted in Figure 3.1.

Figure 3.1. Prime Cattle Premium Relative to Choice Price (USDA AMS, Author Calculations)



The variation observed is largely due to seasonal trends where the Prime premium is typically highest in the fall months of October and November and lowest in May and June. Additionally, there is greater variation over the past five years as average premiums have seen new highs. Including relative price information in this model is important to show the value of premiums have adapted with changes in the beef industry.

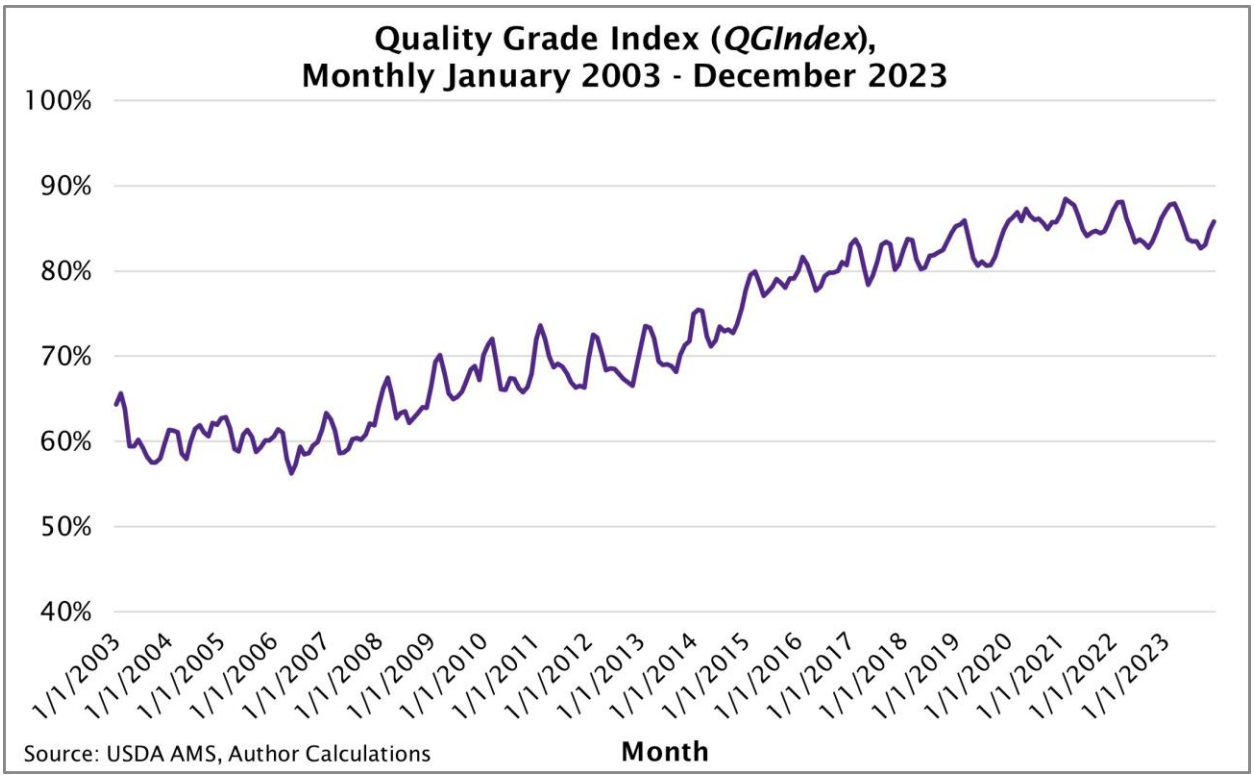
Summary statistics of the data used in the regression are reported in *Table 3.1*.

Table 3.1. Summary Statistics of Monthly Data Used in the Regression Model Explaining the Quality Grade Index, January 2003-December 2023

Variable	*Mean*	*Std. Dev.*	*Minimum*	*Maximum*
QGIndex (%)	72.89	9.80	56.23	88.49
Cost of Gain ($/cwt)	85.37	23.97	50.09	149.02
Heifer Slaughter (%)	29.33	2.02	22.95	34.78
Formula & Grid Pricing (%)	57.23	12.09	32.56	78.35
Forward Pricing (%)	9.99	3.74	2.47	23.60
Placement Weight (lbs)	795.65	37.01	705.62	876.60

The average value of *QGIndex* is 72.89 with a range from 56, seen in 2006, to 88.5, observed in 2021. A comparison of the *QGIndex* in Figure 3.2 to the percentage of cattle grading Choice and Prime in Figure 1.2 illustrates a consistent positive trend and seasonality.

Figure 3.2. Quality Grade Index (USDA AMS, Author Calculations)



CostofGain is the cost incurred to increase the weight of a steer, sensitive to changes in feed conversions and corn, alfalfa, and other feed ingredient prices, in dollars per hundredweight of cattle gain. This data is sourced from the Kansas State University *Focus on Feedlot* newsletter and reported by the Livestock Marketing Information Center (LMIC). When producers experience higher feed prices, it's expected cattle will be on feed for fewer days, resulting in reduced cattle harvest weights, and ultimately cattle quality. It is expected the coefficient on *CostofGain* would be negative as the cost of feeding cattle increases, cattle would be sent to slaughter quicker, resulting in lower quality grades.

The *HeiferSlaughter* variable is the percentage of federally inspected cattle slaughtered that are heifers calculated using USDA National Agricultural Statistics Service (NASS) data as reported by LMIC. *HeiferSlaughter* is representative of the cyclical nature of the beef cow herd.

Figure 3.3. Heifer Slaughter as a Percentage of Total Cattle Slaughter (USDA NASS from LMIC)

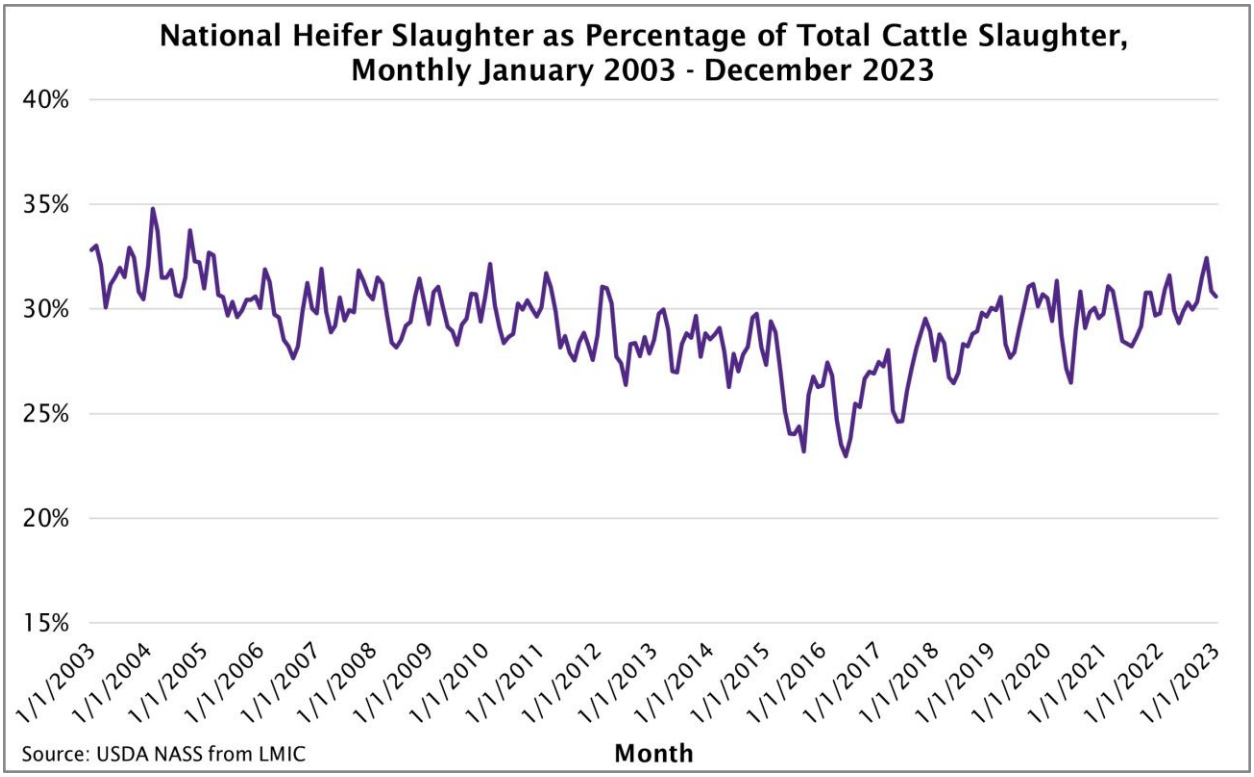


Figure 3.3 shows as producers retain a greater number of replacement heifers in expansion years, there's a corresponding decline in the percentage of heifers in fed cattle production. Heifers tend to have a marbling advantage over steers, so it's expected as *HeiferSlaughter* increases, so would *QGIndex* (Boykin et al. 2017; Moore et al. 2012). In 2006, the low in *HeiferSlaughter* corresponds with the low in percentage of cattle grading Choice and Prime (Figure 3.3, Figure 1.2). However, as we've seen an increase in high-quality cattle over the most recent cattle cycle, overall beef cow inventory has declined in comparison to previous cycles and so has heifer slaughter. This suggests over the past decade, there have been more influential factors impacting high-quality beef. *HeiferSlaughter* also contributes to explaining the seasonality seen in *QGIndex* as they both generally experience lows over the summer months and highs throughout the winter.

The key variables of interest in this model are *Formula&Grid* and *Forward*, representing AMAs, specifically, the percentage of cattle purchased by reporting packers categorized as formula plus negotiated grid, and the percentage of cattle purchased by reporting packers categorized as forward pricing. These data are from the USDA AMS as reported by LMIC. Given that formula and negotiated grid pricing provide incentives to producers based on carcass traits, specifically quality traits, it's expected more *Formula&Grid* would increase the *QGIndex*.

While increasing beef quality generally requires increased production costs, formula and negotiated grid pricing provides producers value-based incentives to compensate for increases in cost. It can be inferred that while factors such as an improvement in beef genetics, specifically marbling expected progeny differences (EPDs), and heavier carcass weights ultimately improve quality grade, these factors are a direct result of the incentives provided to producers for their higher quality cattle. Figure 1.1 depicts an increase in formula pricing methods of around 40 percentage points since 2005, and when combined with negotiated grid pricing, these pricing

methods currently make up roughly 75% of fed cattle marketing. This sizable impact of formula and grid pricing on the industry over time would be expected to have a large effect on high quality cattle production comparatively.

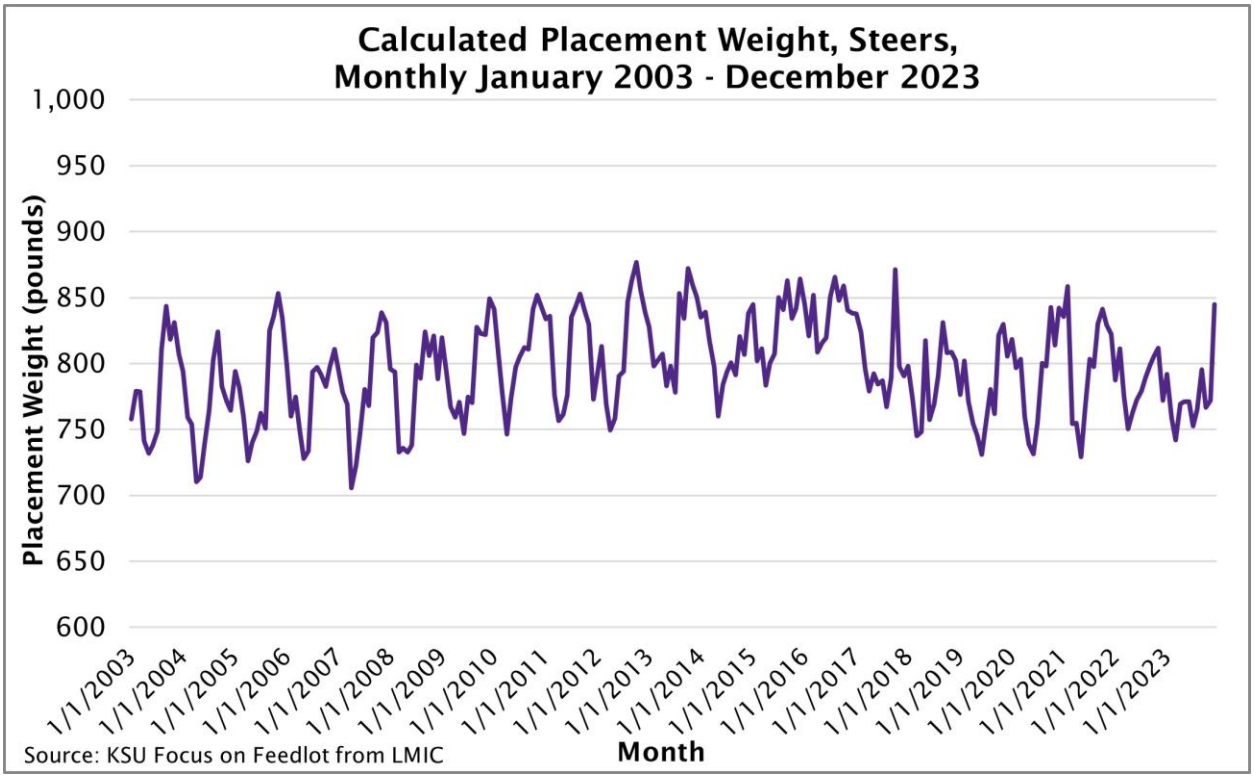
Forward contract trade is an agreement of purchasing cattle in advance of slaughter where the base price is established referencing the CME Live Cattle Futures contract (USDA AMS 2020). Forward pricing is another form of an Alternative Marketing Agreement and would likely be expected to increase *QGIndex* as premiums and discounts can be offered similarly to formula and negotiated grid pricing methods to determine the final net price. However, forward contract pricing does not use value-based pricing as consistently as formula and grid pricing, indicating a difference in the magnitude of the effect on *QGIndex* comparatively.

QTR1, *QTR2*, and *QTR3* are quarterly dummy variables for each respective quarter using *QTR4* as the default. Seasonality is an important factor in this model due to higher quality grades being easier to realize in mild weather. In an effort to further describe the seasonality in the model, a second model was developed using *PlacementWeight* instead of the quarterly dummy variables. The second model is outlined in *Equation 4.*

$$QGIndex_t = \beta_0 + \beta_1 CostofGain_t + \beta_2 HeiferSlaughter_t + \beta_3 Formula\&Grid_t + \beta_4 Forward_t + \beta_5 PlacementWeight_t + e_t \quad (3.4)$$

PlacementWeight is the calculated initial weight of a steer at the time it was placed in the feedlot using data from a sample of feedlots in Kansas. These weights correspond with the initial weights of the cattle that were slaughtered during respective month, so the variable does not require a lag. This initial weight is reported in the Kansas State University *Focus on Feedlot* newsletter and sourced from the LMIC. The seasonal nature of placement weights is clearly shown in Figure 3.4.

Figure 3.4. Calculated Steer Placement Weight (KSU Focus on Feedlot from LMIC)



When comparing Figure 3.4 to Figure 3.2, there's observed similarity in the seasonality of the data, observing highs at the beginning and end of a year and lows throughout the summer months. Using *PlacementWeights* instead of quarterly dummy variables is intended to better capture the seasonality seen throughout beef production. In addition to seasonality, *PlacementWeight* indicates the growth stage at which cattle are being placed in feedlots. Generally, when cattle are placed on feed later, at heavier weights, producers capitalize on minimizing the period of time cattle are on feed while reaching heavier carcass weights, leading to a corresponding increase in quality grade.

3.3 Results and Conclusions

The use of AMAs to explain beef quality grade is investigated in this section. The model was estimated adjusting for first-order autoregressive errors and estimates for Model 1, using

quarterly dummy variables to explain seasonality and Model 2, using placement weights to describe seasonality, and Model 3, including all variables, are reported in Table 3.2.

Table 3.2. Regression Models for Beef Quality Index Model

Independent Variable	*Model 1*	*Model 2*	*Model 3*
Intercept	9.937 (5.633)	13.185 (7.779)	34.276** (11.079)
Cost of Gain	-0.128** (0.015)	-0.129** (0.016)	-0.124** (0.015)
Heifer Slaughter	0.598** (0.160)	0.900** (0.151)	0.4184* (0.173)
Formula & Grid Pricing	0.939** (0.032)	0.937** (0.033)	0.934** (0.031)
Forward Pricing	0.224** (0.078)	0.448** (0.075)	0.247** (0.078)
QTR 1	2.814** (0.648)		2.231** (0.681)
QTR 2	0.699 (0.680)		-1.065 (0.966)
QTR 3	-1.972** (0.704)		-2.581** (0.737)
Placement Weight		-0.017* (0.007)	-0.023* (0.009)
R^2	0.8684	0.8484	0.8718
$\bar{R}^2$	0.8646	0.8453	0.8676
RMSE	3.606	3.855	3.566
Lagged Error	0.779**	0.780**	0.759**
Observations	252	252	252
F-value for QTR 1, QTR 2, QTR 3	14.78**		
F-value for Placement Weight		6.37*	
F-value for Placement Weight, QTR 1, QTR 2, QTR 3			12.95**

Note: Standard errors are in parenthesis
*denotes significance at 5% level
**denotes significance at 1% level

The overall R^2 of the first model is 0.868 implying 86.8% of the variation in the high-quality cattle index is explained by the independent variables. All of the parameter estimates are statistically different from zero ($p<0.05$), with the exception of *QTR 2,* and coefficients had the expected signs. Model two has an overall R^2 of 0.848, parameter estimates are all statistically significant ($p<0.05$), and anticipated parameter signs as well. The third model has an R^2 of 0.872 and again, all parameter estimates are statistically significant ($p<0.05$) with anticipated parameter signs. The reported F-value is 14.78 for the quarterly dummy variables and 12.95 for both the quarterly dummy variables and placement weight variable, while the reported F-value of 6.37 for the placement weight variable indicating the statistical significance of each seasonality representation in the respective models. In terms of magnitude, the F-value for the quarterly dummy variables is more than twice the F-value for placement weights. This suggests that the quarterly dummy variables have a relatively stronger impact on the model's explanatory power compared to the placement weight variable. Additionally, recognizing the larger R^2 and smaller RMSE indicates a better fit of models one and three to the data.

Going forward, focus will be on the results given from model one. Given the results were accurate and similar across all models, outcomes from model one are advantageous in terms of simplicity, focus on core variables that are consistently significant across all models, and to avoid multicollinearity and redundancy. In model two, it's evident the coefficients on *Heifer Slaughter* and *Forward Pricing* deviate substantially from the other model results which indicate *Placement Weight* could capture information related to other production factors that might overlap with the variables whose results change.

The primary focus of this study is the relationship between AMAs and fed cattle quality grade index over time. As formula and grid priced cattle increase by one percentage point, the

quality index increases by 0.94 percentage points. Another way to interpret this relationship is that as cattle purchased through formula and grid pricing methods increases from 50% to 60%, the percentage of cattle grading Choice increases from 50% to 59.4% assuming no change in the percentage of cattle grading Prime. Although this relationship cannot be attributed to being completely causal, formula and grid cattle are generally purchased using premium and discount incentives, indicating at least somewhat of a causal relationship.

Cattle priced using forward contracting are also associated with increasing quality grade, but the magnitude of the impact is much smaller than that of formula and grid priced cattle. This is expected largely because forward pricing does not use value-based pricing methods as consistently as formula and grid priced cattle. The first model used shows that as forward pricing cattle increase by one percentage point, the quality index increases by 0.22 percentage points, indicating forward contracting has a relatively small influence on changing quality grade over time.

3.3.1 Comparative Analysis

Comparing this model to the Schroeder, Tonsor, Coffey study, there's a similar statistical significance of the overall model, but a greater impact of the formula and grid pricing parameter using our methods. The primary differences between the quality index model used in this study and the Schroeder, Tonsor, Coffey study are omitting the cattle on feed variable which was statistically insignificant ($p>0.05$) and had a very small magnitude impact and omitting the packer owned variable. Not including packer owned cattle in this model is largely because they used to represent about 10% of the industry in the early 2000s, but more recently represent less than 3%. While the variable was statistically significant ($p<0.05$) in the previous study, logically the magnitude of the economic impact on the model here would be relatively minor.

Additionally, in this study the cost of gain variable was used instead of the steer/corn ratio used in the prior model. This is to incorporate the variable cost of feeding cattle in a more straightforward manner; however, it does not include the relationship of cost of feed with fed cattle prices.

In the prior study, the coefficient on the formula and grid pricing parameter was only 0.62 compared to this study's value of 0.94 indicating formula and grid pricing has a much larger impact using this model. The sample of data in this study includes 252 observations from 2003-2023, while the prior study was 193 observations from 2004-2020 which explains a portion of the magnitude differences in the formula and grid pricing parameter as the percentage of cattle marketed through formula and grid pricing methods has continued to increase since 2020. However, when running this model over the same 2004-2020 time-period, the formula and grid pricing coefficient was 0.87 compared to 0.94 over the entire time period. This indicates the use of different control variables, and not different time period, is the primary explanation for the greater impact of the formula and grid pricing parameter.

3.3.2 Discussion and Implications

Implications of this analysis are primarily centered around the control variables used and autocorrelation in the model. Future research could determine more effective control variables, especially those representing seasonality, and potentially identify control variables not considered in this study. This model indicates positive autocorrelation, with a lagged error of 0.78, which could result in biased parameter estimates, inefficient estimation, and model misspecification.

This paper provides valuable insight into the increasing impact of AMA usage on the quality of beef. The US beef cattle industry continues to evolve to meet changing consumer

demand by incentivizing greater investments in beef production. As the industry evolves, concerns continue to rise over cattle marketing implications. This study specifically quantifies the extent to which fed cattle marketing agreements and formula trade have contributed to improved cattle quality, contributing to the conversation to increase understanding and mitigate concerns.

Chapter 4 will utilize results from this study to measure price and quantity effects of value-based marketing on producers of high- and low-quality beef and on consumers. Quantifying the direct impact of the increase in high quality beef through value-based pricing methods would advance understanding of current and prospective policy decisions that impact producers and consumers across all levels of the beef supply chain.

Chapter 4 - Economic Impacts of Incentivizing Quality in the U.S. Beef Cattle Industry

4.1 Previous Research

A general structural model of supply and demand relationships in the beef industry provides the framework for developing an equilibrium displacement model. First developed by Muth (1964) to develop reduced forms for proportional displacements from equilibrium supply and demand of a product dependent on two factors of production, EDMs are now widely used for analyzing market impacts of technology adoption and policy changes as exogenous shocks to markets (Schroeder and Tonsor 2011; Pendell et al. 2010; Balagtas and Kim 2007; Lusk and Norwood 2005; Brester, Marsh, and Atwood 2004; Wohlgenant 1993).

While many EDMs have been developed to address impacts on the beef industry (RTI International 2007; Lusk and Norwood 2005) and more broadly, the meat industry (Pendell et al. 2010; Pendell and Schroeder 2007; Brester, Marsh, and Atwood 2004; Schroeder and Tonsor 2011), very few have been developed for heterogeneous products across a multi-sector supply chain. A homogeneous good model will fail to account for the different effects for policy-induced shifts in the distribution of quality (James and Alston 2002).

James and Alston (2002) introduce an approach to modeling quality, linking quality changes to tax policies, to increase understanding of how policies influence quality. In the model they developed, quality variation is incorporated in an EDM where the quantity is available in two qualities, simplifying the nature of heterogeneity in agricultural products. Analyzing quality responses to tax policies in the Australian wine industry, their model relates the qualities in consumption and production so therefore the quantity demanded and supplied of each quality depends on its own price and the price of the other quality.

Applying this concept to the beef industry, Lusk and Norwood (2005) combine the product-differentiated James and Alston model and the marketing channel model of Wohlgenant (1993) to analyze how generic promotion and research affects beef quality. This model develops primary supply and demand equations following James and Alston and incorporates aggregate beef exogeneous supply and demand shocks at the farm and retail levels, respectively. Their results clearly demonstrate the importance of accounting for heterogeneity in the beef industry, especially as the beef sector is increasingly differentiated by quality across all levels of the marketing chain. They suggest if beef is treated as a homogenous commodity in some circumstances, it would provide poor indicators of changes in price premiums and quantity associated with an exogenous shock.

In a report quantifying the economic impacts of a hypothetical foot-and-mouth disease outbreak, Pendell and Schroeder (2007) develop an EDM of the U.S. beef, pork and poultry industry integrating trade. In the case of a foot-and-mouth disease outbreak, trade is one of the main issues considered due to animal movement bans and border closings, so their model specifies structural supply and demand for the U.S., other states, and Kansas while considering international trade.

4.2 Structural Model

An economic model is used to assess how the improvement in beef quality associated with use of AMAs impacts US beef producers and consumers. The model estimates changes in cattle and beef prices, quantities exchanged, and producer and consumer surplus under a variety of policy scenarios.

To quantify the economic implications of a shock to U.S. beef supply, a partial equilibrium analysis is employed. In this study, the multimarket equilibrium displacement model

is developed by integrating theory from the product differentiated model of James and Alston (2002), the model integrating trade of Pendell and Schroeder (2007), the simulation model of the U.S. meat industry of Pendell et al. (2010), and the heterogeneous beef quality model of Lusk and Norwood (2005). The structural model comprises horizontally linked high- and low-quality beef demands at the retail level and wholesale level as well as vertical linkages between the farm, wholesale, slaughter, and retail sectors of the heterogeneous beef industry. The beef industry is modeled as a series of primary and derived demand and supply relationships considering four sectors: retail (consumer), wholesale (packer/processor), slaughter (cattle feeding), and farm (feeder cattle). Simplifying the model to focus specifically on the domestic beef market, international trade and competitive meat industries are not incorporated in the model. The following is a structural demand and supply model for the product-differentiated US beef sector with multiple marketing levels:[4]

Retail Beef Sector:

(4.1) Retail high-quality beef demand: $\boldsymbol{Q_H^{rd} = f_1(P_H^{rd}, P_L^{rd}, Z_H^{rd}, Z_L^{rd})}$

(4.2) Retail low-quality beef demand: $\boldsymbol{Q_L^{rd} = f_2(P_L^{rd}, P_H^{rd}, Z_H^{rd}, Z_L^{rd})}$

(4.3) Retail high-quality beef supply: $\boldsymbol{Q_H^{rs} = f_3(P_H^{rs}, Q_B^{ws}, W_H^{rs}, W_L^{rs})}$

(4.4) Retail low-quality beef supply: $\boldsymbol{Q_L^{rs} = f_4(P_L^{rs}, Q_B^{ws}, W_H^{rs}, W_L^{rs})}$

Wholesale Beef Sector:

(4.5) Wholesale high-quality beef demand: $\boldsymbol{Q_H^{wd} = f_5(P_H^{wd}, Q_B^{rd}, Z_H^{wd}, Z_L^{wd})}$

(4.6) Wholesale low-quality beef demand: $\boldsymbol{Q_L^{wd} = f_6(P_L^{wd}, Q_B^{rd}, Z_L^{wd}, Z_L^{wd})}$

(4.7) Wholesale high-quality beef supply: $\boldsymbol{Q_H^{ws} = f_7(P_H^{ws}, Q_B^{ss}, W_H^{ws}, W_L^{ws})}$

[4] Error terms have been omitted

(4.8) Wholesale low-quality beef supply: $\boldsymbol{Q_L^{ws} = f_8(P_L^{ws}, Q_B^{ss}, W_H^{ws}, W_L^{ws})}$

(4.9) Total wholesale beef demand: $\boldsymbol{Q_B^{wd} = Q_H^{wd} + Q_L^{wd}}$

(4.10) Total wholesale beef supply: $\boldsymbol{Q_B^{ws} = Q_H^{ws} + Q_L^{ws}}$

Slaughter Cattle Sector:

(4.11) Total slaughter cattle demand: $\boldsymbol{Q_B^{sd} = f_9(P_B^{sd}, Q_B^{wd}, Z_B^{sd})}$

(4.12) Total slaughter cattle supply: $\boldsymbol{Q_B^{ss} = f_{10}(P_B^{ss}, Q_B^{fs}, W_B^{ss})}$

Feeder Cattle Sector:

(4.13) Total feeder cattle demand: $\boldsymbol{Q_B^{fd} = f_{11}(P_B^{fd}, Q_B^{sd}, Z_B^{fd})}$

(4.14) Total feeder cattle supply: $\boldsymbol{Q_B^{fs} = f_{12}(P_B^{fs}, W_B^{fs})}$,

where each of the endogenous price (P) and quantity (Q) variables and exogenous demand (Z) and supply (W) shifters are presented in the form $\boldsymbol{X_k^{ij}}$. In each case, the superscript i represents marketing level (i.e., r = retail, s = wholesale, s = slaughter (feeding), and f = feeder (farm)) and superscript j indicates a demand (d) or supply (s) function. The subscript k indicates beef quality level (i.e., H = high-quality, L = low-quality, B = total beef).[5] Consistent with Wohlgenant (1993), market levels are linked by downstream quantity variables in the demand equations and upstream quantity variables in the supply equations. Equations (4.9) and (4.10) are incorporated to allow for market clearing at the wholesale level. Market clearing conditions imply $\boldsymbol{X_k^{id} = X_k^{is} = X_k^i}$.

High- and low-quality retail beef primary demand, equations (4.1) and (4.2), follow James and Alston (2002) because the two qualities are related in consumption, the quantity demanded depends on its own price and the price of the other quality. Quality specific exogenous

[5] In this study, high-quality beef is Prime, Branded, and Choice and low-quality is Select.

shocks are included in wholesale and retail supply and demand equations (4.1)-(4.8) following theory suggested by Lusk and Norwood (2005). Equations (4.9) and (4.10) which allow for market clearing follow Pendell and Schroeder (2007) market clearing conditions for total supply and demand at each marketing level. Finally, farm and slaughter supply and demand equations (4.11)-(4.14) follow Pendell et al. (2010).

4.3 Equilibrium Displacement Model

4.3.1 Model Specification

An EDM is a linear estimation of unknown supply and demand functions. The model's accuracy is determined from the initial equilibrium and degree of non-linearity of true supply and demand functions. If the deviations from the initial equilibrium are relatively small, then the linear approximation of unknown supply and demand curves are relatively accurate measures of true supply and demand functions (Wohlgenant 1993).

To illustrate this EDM framework, totally differentiating equations (4.1) through (4.14) and converting to elasticity form results in the following equilibrium displacement of the heterogeneous US beef market:

Retail Beef Sector:

(4.15) $$\boldsymbol{EQ_H^r = \eta_H^r EP_H^r + \eta_{HL}^r EP_L^r - Ez_H^r \eta_H^r - Ez_L^r \eta_{HL}^r}$$

(4.16) $$\boldsymbol{EQ_L^r = \eta_L^r EP_L^r + \eta_{LH}^r EP_H^r - Ez_H^r \eta_{LH}^r - Ez_L^r \eta_{LL}^r}$$

(4.17) $$\boldsymbol{EQ_H^r = \varepsilon_H^r EP_H^r + \gamma_B^{wr} EQ_H^w + Ew_H^r \varepsilon_H^r + Ew_L^r \varepsilon_{HL}^r}$$

(4.18) $$\boldsymbol{EQ_L^r = \varepsilon_L^r EP_L^r + \gamma_B^{wr} EQ_L^w + Ew_H^r \varepsilon_{LH}^r + Ew_L^r \varepsilon_L^r}$$

Wholesale Beef Sector:

(4.19) $$\boldsymbol{EQ_H^w = \eta_H^w EP_H^w + \tau_B^{rw} EQ_H^r - Ez_H^w \eta_H^w - Ez_L^w \eta_{HL}}$$

(4.20) $$\boldsymbol{EQ_L^w = \eta_L^w EP_L^w + \tau_b^{rw} EQ_L^r - Ez_L^w \eta_{LH}^w - Ez_L^w \eta_{LL}^w}$$

(4.21) $$EQ_H^w = \varepsilon_H^w EP_H^w + \gamma_B^{sw}(Q_H^s/Q_B^s)EQ_B^s + Ew_H^w\varepsilon_H^w + Ew_L^w\varepsilon_{HL}^w$$

(4.22) $$EQ_L^w = \varepsilon_L^w EP_L^w + \gamma_B^{sw}(Q_L^s/Q_B^s)EQ_B^s + Ew_H^w\varepsilon_{LH}^w + Ew_L^w\varepsilon_L^w$$

(4.23) $$EQ_B^w = (Q_H^w/Q_B^w)EQ_H^w + (Q_L^w/Q_B^w)EQ_L^w$$

Slaughter Cattle Sector:

(4.24) $$EQ_B^s = \eta_B^s EP_B^s + \tau_B^{ws} EQ_B^w + Ez_B^s$$

(4.25) $$EQ_B^s = \varepsilon_B^s EP_B^s + \gamma_B^{fs} EQ_B^f + Ew_B^s$$

Feeder Cattle Sector:

(4.26) $$EQ_B^f = \eta_B^f EP_B^f + \tau_B^{sf} EQ_B^s + Ez_B^f$$

(4.27) $$EQ_B^f = \varepsilon_B^f EP_B^f + Ew_B^f.$$

The term *E* represents a relative or percentage change operator (i.e., $EQ_B^r = dQ_B^r/Q_B^r = dlnQ_B^r$).

The heterogeneous beef market is completely characterized at the retail, wholesale, slaughter, and farm levels in equations (4.15) though (4.27). The elasticity form of the model can be expressed in matrix notation as:

(4.28) $$\boldsymbol{AY = X},$$

where *A* is a 13 x 13 nonsingular matrix of elasticities, *Y* is a 13 x 1 vector of changes in the endogenous price and quantity variables, and *X* is a 13 x 1 vector of percent changes in the exogenous supply and demand shocks. Changes in the endogenous variables (*Y*) caused by changes in the supply of quality-differentiated beef associated with a shift in alternative marketing agreement use under different policy scenarios (*X*) are calculated by solving equation (4.28) as:

(4.29) $$\boldsymbol{Y = A^{-1}X}.$$

Definitions and estimates for all model parameters can be found in Tables A.1 and A.2 in the Appendix.

4.3.2 Elasticity Estimates

Solutions for *Y* in equation (4.29) require elasticity estimates for the elements of *A*. There are several methods to obtain elasticities, which include borrowing from previous literature, estimating, using economic intuition, and basing them on economic theories. Aggregate elasticity estimates in this study are obtained from existing literature while elasticities of quality-differentiated beef are not always able to be found in previous studies.

Following model development of James and Alston (2002) and Johnson et al. (2005), under the approach associated with Armington (1969), retail own- and cross-price demand elasticities and wholesale own- and cross-price supply elasticities are derived for high- and low-quality beef. Under the assumption that low- and high-quality varieties comprise a weakly separable group, the elasticities of demand for the individual commodities with respect to individual prices are given by:

(4.30) $\eta_H^r = S_H\eta_B^r - S_L\sigma,$

(4.31) $\eta_{HL}^r = S_L(\eta_B^r + \sigma),$

(4.32) $\eta_L^r = S_L\eta_B^r - S_H\sigma,$

(4.33) $\eta_{LH}^r = S_H(\eta_B^r + \sigma),$

where notation follows that in equations (4.1)-(4.27) above, S_i denotes the expenditure share for *i* beef quality level, η_B^r denotes the overall beef retail own-price demand elasticity, and σ represents the elasticity of substitution between high- and low-quality beef. Adding up conditions require that $S_H + S_L = 1$.

Similarly, own- and cross-price elasticities of supply are given by:

(4.34) $\varepsilon_H^w = S_H\varepsilon_B^w - S_L\tau,$

(4.35) $\varepsilon_{HL}^w = S_L(\varepsilon_B^w + \tau),$

(4.36) $\varepsilon_L^W = S_L \varepsilon_B^W - S_H \tau,$

(4.37) $\varepsilon_{LH}^W = S_H(\varepsilon_B^W + \tau),$

where parameter definitions follow the same notation. τ denotes the elasticity of transformation in production between high- and low-quality beef and is analogous to the elasticity of substitution on the demand side.

Following Lusk and Norwood (2005), the expenditure shares were determined using data from the Livestock Marketing Information Center (LMIC). During 2023, data indicates that roughly 180,000 boxed beef loads were Choice, Branded, and Prime while nearly 40,000 graded Select. Over the same time period, the weighted average price of Choice and better beef was $300.27/cwt and the price of Select boxed beef averaged $275.79/cwt. These data imply the revenue/cost shares of high- and low-quality beef were roughly 83% and 17% respectively in 2023. Because no comparable data exists at the retail level, these expenditure shares were used in both the wholesale and retail level elasticity estimates.

Limited previous estimates exist to determine the elasticity of substitution at the retail or wholesale level, so applying framework from McFadden (1978) and Lusk and Norwood (2005), the elasticity of substitution is determined by regressing the log ratio of the quantity of the two goods against a constant and the log ratio of the prices of the two goods. No data exists to determine these estimates at the retail level, so using wholesale boxed beef prices and quantities, this framework was applied to a weekly data set of 1041 observations from 2004 to 2023 and found:

(4.38) $$log(Q_H^{BXB}/Q_L^{BXB}) = \underset{(0.01)}{0.43} + \underset{(0.45)}{0.55}\, log(P_L^{BXB}/P_H^{BXB})$$

$$R^2 = 0.0014$$

where Q_i^{BXB} are total weekly boxed beef load volumes (40,000-pound loads) and P_i^{BXB} are weekly weighted average boxed beef prices ($/cwt) for *i* quality level, and numbers in parenthesis below coefficient estimates are the standard errors. These estimates imply the elasticity of substitution between high- and low-quality beef is about 0.55. Because these data are at the wholesale level and substitutability is likely higher at the retail level, it is assumed that the elasticity of substitution between high- and low-quality beef was 1 in estimating own- and cross-price demand elasticities through equations (4.30)-(4.33) while -0.55 is used as the elasticity of transformation at the wholesale level.[6]

To determine wholesale demand elasticities, the relationship between the retail and derived demand elasticities is assumed to be linear. Under this assumption, Asche et al. (2002) define the own-price elasticity for input *a*, E_a, as:

$$E_a = \eta E_T \tag{4.39}$$

where E_T is the elasticity of price transmission. The elasticity of price transmission is the elasticity of consumer price with respect to the input price and means the relationship between retail and derived demand elasticities are proportional and generally not equal (Asche et al. 2002). Based on the ratio of wholesale to retail demand elasticities estimated in previous literature, the elasticity of price transmission from the retail to wholesale level is estimated to be 0.65 in the short-run and 0.80 in the long-run (Pendell et al. 2010; RTI International 2007). Using this estimation with equation (4.39), approximate wholesale elasticities of demand for high- and low-quality beef can be quantified.

Using similar methodology, differentiated elasticities of supply at the retail level derived from the estimated wholesale supply elasticities can be calculated. The ratio of retail to

[6] This estimate is consistent with estimates by Lusk and Norwood (2005).

wholesale aggregate beef supply is inferred to be approximately 1.30 for both the long and short run based on estimates from previous literature (Pendell et al. 2010; Brester, Marsh, and Atwood 2004). Retail elasticities of supply for high- and low-quality beef can be derived using this estimation and the previously estimated wholesale supply elasticities.

These estimates are all consistent with the assumption that derived demand is more inelastic than primary demand while derived supply is more elastic than primary supply. The variable definitions and estimates used to determine elasticities in equations (4.30) through (4.39) can be found in Table A.3 in the Appendix.

4.3.3 Market Shifts

To quantify the economic impacts of shifts in high-quality beef due to a reduction in cattle marketed through formula and grid pricing, two scenarios are considered. Each scenario includes different cash pricing requirements, commonly suggested through the regional minimum policy suggestions, requiring a percentage of cattle to be purchased using cash negotiated pricing. Two shifts were considered reflective of 30% and 50% cash pricing requirements to follow specific proposed policy recommendations.[7]

Because of the inverse relationship the industry has experienced with cash negotiated pricing and formula trade, these shifts assume that for every percentage increase in required cash negotiated trade, there is an equal and opposite impact on cattle traded under formula pricing methods. Under that assumption, the shock on differentiated beef supply can be quantified using results from the beef quality index model outlined in Chapter 3. Each shift is representative of the impact on beef quality directly influenced by marketing methods. The specific shocks are quantified by multiplying the coefficient of the formula and grid pricing variable from model one

[7] H.R. 8489

by the percentage decrease in formula and grid pricing the industry would experience if 30% or 50% of fed cattle marketing transactions were required to be cash negotiated.

All proposed bills regarding regional minimum policies require the meat processing plants to meet the regional minimum purchases (Dennis and Lubben 2022). In this model, the shifts are implemented at the high-quality wholesale beef level. Although the shock is a shift in supply and the supply of beef theoretically can't be altered at that stage in the supply chain, the shift is reflective of a shift in quality which generally can be altered throughout the cattle feeding process.

In 2023, 18.21% of fed cattle marketing transactions were negotiated cash. If these transactions were required to increase 11.79 percentage points to the recommended 30% requirement, it is assumed the percentage of cattle marketed through formula and grid pricing would decrease by 11.79 percentage points. At the recommended 50% negotiated cash requirement, it is assumed formula and grid pricing would then decrease by 31.79 percentage points. Multiplying 11.79 and 31.79 by the coefficient of the formula and grid pricing variable from model one in Chapter 3, 0.939, to determine the shift in high-quality beef due to a requirement in cash negotiated trade, the shocks of -11.07% and -29.85% are considered at the high-quality wholesale supply level.

4.3 Results and Conclusions

Short- and long-run percentage changes in beef prices and quantities resulting from the different levels of suggested regional minimum policies are presented in Table 4.1.

Table 4.1. Percentage Changes from Varying Levels of Required Cash Negotiated Trade

	30% Cash Trade [a]		*50% Cash Trade* [b]	
Endogenous Variables	*Short Run*	*Long Run*	*Short Run*	*Long Run*
Price				
Retail high-quality beef	3.470	0.194	9.356	0.524
Retail low-quality beef	-0.300	-0.503	-0.810	-1.356
Wholesale high-quality beef	4.255	1.050	11.474	2.830
Wholesale low-quality beef	-0.454	-1.077	-1.224	-2.903
Slaughter cattle	-2.550	-0.038	-6.876	-0.104
Feeder cattle	-4.710	-0.175	-12.700	-0.471
Quantity				
Retail high-quality beef	-2.005	-0.267	-5.406	-0.719
Retail low-quality beef	1.765	0.601	4.760	1.622
Wholesale high-quality beef	-3.569	-1.042	-9.624	-2.810
Wholesale low-quality beef	2.024	1.320	5.459	3.559
Wholesale beef	-2.561	-0.617	-6.906	-1.663
Slaughter cattle	-1.772	-0.652	-4.777	-1.757
Feeder cattle	-1.036	-0.493	-2.794	-1.328

Note: Percentage changes are based upon average 2023 prices and quantities for cattle and beef
[a]11.07% decline in high-quality wholesale beef supply
[b]29.85% decline in high-quality wholesale beef supply

Due to the linearity of the model, the changes in equilibrium price and quantity respond proportionally to different shocks in the market. Quantities for retail and wholesale high-quality beef decline while low-quality retail and wholesale beef increase. Prices for high-quality retail beef increase in each shock scenario while low-quality retail prices decline. At the 30% required cash level, these values are a 3.47% increase for high-quality beef and 0.30% decline for low-quality in the short run. These results are theoretically consistent with a decrease in high-quality beef supply at the wholesale level. With a decline in the supply of high-quality beef at the wholesale level but no shift in aggregate beef produced, it is expected the supply of the

horizontally related quantity of low-quality beef at the wholesale would increase. The model results indicate there is an aggregate decline in wholesale beef of 2.56% given the shock to high-quality wholesale beef supply. Similarly, the derived supply function at the retail level is then shifted due to less product being supplied with an observed decline in the quantity of high-quality retail beef and increase in the quantity of low-quality retail beef. The decline in high-quality beef supply at the wholesale level also impacts slaughter and farm level demand as less product is required downstream. The decrease in demand for cattle causes prices and quantities to both decline at the slaughter and farm levels. At the 30% required cash negotiated level in the short run, slaughter cattle price and quantity decline by 2.55% and 1.72% respectively, while feeder cattle prices and quantity decline by 4.71% and 1.04% respectively.

The changes in prices and quantity discussed reflect a theoretical average on producers and consumers within the respective sectors. Producers and consumers who utilize different pricing methods may experience varied effects under these scenarios. For instance, since the policies would be implemented at the packer level, a scenario where the packer fulfills minimum cash purchase requirements from some producers while allowing others to exclusively market with formula pricing would lead to different outcomes. Producers utilizing only formula pricing methods could benefit more significantly, as they are more likely to meet the packer's demands for specific carcass attributes, potentially leading to higher prices received. These impacts are especially pronounced at the non-differentiated slaughter cattle level, likely resulting in underestimated effects on those producers, as this is the level where marking methods directly vary.

4.3.1 Discussion and Implications

The parameters used in the model are an important implication of the research. Developing more specific elasticities for differing beef quality and substitution between products could further develop this study and future industry research. Additionally, elasticities can evolve over time and a limitation of using modeling like an equilibrium displacement model is that the parameters don't have the ability to vary over time. In an increasingly differentiated market, heterogenous product analysis will continue to be of great importance and parameters may be altered as the industry evolves.

This model also doesn't currently account for competing meat supply and demand factors, or for international trade. Omitting these markets could limit the ability of using this model framework for future studies by not capturing the full impact of policies with trade implications. Additionally, the price sensitivity in the model currently is only reflective of domestic price responses and does not account for price changes in substitutable products.

The model framework in this analysis focuses on differentiated products at the retail and wholesale levels, primarily due to the availability of product-specific data. The quality index model analysis in Chapter 3 is centered around fed cattle marketings, which occur at the slaughter cattle level. However, the results from that analysis are applied to the wholesale level in this model due to the equilibrium displacement model framework's inability to quality-differentiate at the slaughter cattle level. This approach is justified, as packers would be responsible for implementing the policy scenarios. As data collection continues to improve and the ability to differentiate cattle before the wholesale beef process becomes increasingly significant, it will be vital to expand differentiation across the entire marketing chain. Additionally, these results do not consider potential benefits from increased negotiated cash

usage, such as reduced price variation risks often associated with formula and grid pricing methods.

Welfare measurements were not included in this analysis due to the difficulty of measuring these impacts in multiple markets. These calculations are more complex because changes in prices of one market affect prices and quantity consumed and produced in another, especially under this model where there are horizontal links in both consumption and production. Applications of simplistic producer and consumer welfare equations could result in double counting welfare gains or losses if summed across the two goods (Lusk and Tonsor 2021).

This paper offers valuable insights into the impact of AMA usage across different quality levels. By quantifying the effects of reduced formula trade, and subsequent decrease in high-quality beef production, it enhances understanding of how current and ongoing policy decisions substantially affect producers and consumers throughout the beef supply chain.

Chapter 5 - Discussion and Conclusions

Fed cattle marketing methods and the differentiated beef industry continue to attract considerable industry among industry participants and policymakers. Despite ongoing debates regarding price discovery and transparency, and whether there should be a required amount of cash negotiated trade, few analyses have considered the economic impacts of these policies. An essential part of these conversations is the association AMAs have with quality grade, and what impact policies like those would have if high-quality beef production was no longer incentivized.

The purpose of this thesis was to quantify the association between fed cattle marketing methods and high-quality beef, develop model framework for a quality-differentiated beef industry, and provide initial estimates of heterogenous-beef supply and demand elasticities. The quantifiable analysis of the association between fed cattle marketing methods and high-quality beef shows for every 1% increase in formula and grid pricing methods used, high-quality beef increases by 0.94%, indicating a very strong relationship.

Model framework was developed for the domestic beef industry, differentiating by quality at the retail and wholesale levels. The analysis also provides initial estimates of heterogenous beef supply and demand elasticities. Combining the quality index analysis results with the equilibrium displacement model framework, industry shifts in prices and quantities are estimated under 30% and 50% required cash trade policies, depicting the effect of shifts in high-quality beef due to a reduction in cattle marketed through formula and grid pricing. Under these policy scenarios, results indicate high-quality wholesale beef producers would receive higher prices with a decline in quantity while retail consumers would be required to pay more. Alternatively, low-quality wholesale producers would receive lower prices with an increase in quantity while low-quality retail beef consumers would pay less for beef while quantities

increased. Cattle producers would experience an overall decline in product demand resulting in lower prices received.

This thesis emphasizes the continued importance of considering a differentiated industry to fully capture the impacts of policy changes. The analysis contributes new insights into market dynamics by providing quality-differentiated elasticity estimates and modeling a heterogenous beef industry. Adopting a heterogenous market perspective, this study highlights the differential effects of AMAs, offering stakeholders critical insights into the valuation and policy implications within the evolving beef industry.

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Appendix A - Equilibrium Displacement Model Parameters

Appendix Table A.1. Elasticity Definitions, Estimates, and Sources for the Equilibrium Displacement Model

Symbol	*Definition*	*Estimate*	
		Short Run	*Long Run*
η_H^r	Own-price elasticity of demand for high-quality retail beef	-0.57[a]	-1.14[a]
η_{HL}^r	Cross-price elasticity of demand for high-quality retail beef with respect to the price of low-quality retail beef	0.09[a]	
η_L^r	Own-price elasticity of demand for low-quality retail beef	-0.91[a]	-1.03[a]
η_{LH}^r	Cross-price elasticity of demand for low-quality retail beef with respect to the price of high-quality retail beef	0.43[a]	
ε_H^r	Own-price elasticity of supply for high-quality retail beef	0.42[a]	3.83[a]
ε_L^r	Own-price elasticity of supply for low-quality retail beef	0.66[a]	1.35[a]
η_H^w	Own-price elasticity of demand for high-quality wholesale beef	-0.37[a]	-0.74[a]
η_L^w	Own-price elasticity of demand for low-quality wholesale beef	-0.59[a]	-0.67[a]
ε_H^w	Own-price elasticity of supply for high-quality wholesale beef	0.33[a]	2.95[a]
ε_{HL}^w	Cross-price elasticity of supply for high-quality wholesale beef with respect to the price of low-quality wholesale beef	-0.05[a]	
ε_L^w	Own-price elasticity of supply for low-quality wholesale beef	0.51[a]	1.04[a]
ε_{LH}^w	Cross-price elasticity of supply for low-quality wholesale beef with respect to the price of high-quality wholesale beef	-0.23[a]	
η_B^s	Own-price elasticity of demand for slaughter cattle	-0.40[c]	-0.53[c]
ε_B^s	Own-price elasticity of supply for slaughter cattle	0.26[b]	3.24[b]
η_B^f	Own-price elasticity of demand for feeder cattle	-0.14[c]	-0.75[c]
ε_B^f	Own-price elasticity of supply for feeder cattle	0.22[b]	2.82[b]

Appendix Table A.1. Elasticity Definitions, Estimates, and Sources for the Equilibrium Displacement Model (continued)

Symbol	*Definition*	*Estimate*	
		Short Run	*Long Run*
γ_B^{wr}	Percentage change in retail beef supply given a 1% change in wholesale beef supply	0.970 [a]	
τ_B^{rw}	Percentage change in wholesale beef demand given a 1% change in retail beef demand	0.995[b]	
γ_B^{sw}	Percentage change in wholesale beef supply given a 1% change in slaughter cattle supply	0.909[b]	
τ_B^{ws}	Percentage change in slaughter cattle demand given a 1% change in wholesale beef demand	1.090[b]	
γ_B^{fs}	Percentage change in slaughter cattle supply given a 1% change in feeder cattle supply	1.070[b]	
τ_B^{sf}	Percentage change in feeder cattle demand given a 1% change in slaughter cattle demand	0.957[b]	

[a]Author calculation, [b]Pendell et. al. (2010), [c]GIPSA RTI Meat Marketing Study (2007)

Appendix Table A.2. Variable Definitions and Estimates for the Structural Equilibrium Displacement Model, 2023 (Livestock Marketing Information Center)

Symbol	*Definition*	*Mean*
Q_H^r	Quantity (consumption) of high-quality retail beef, billions pounds (retail weight)	15.95[a]
Q_L^r	Quantity (consumption) of low-quality retail beef, billions pounds (retail weight)	3.08[a]
P_H^r	Price of high-quality retail beef, cents per pound	812.17[a]
P_L^r	Price of low-quality retail beef, cents per pound	746.04[a]
Q_H^w	Quantity of high-quality wholesale beef, billions pounds (carcass weight)	22.11[a]
Q_L^w	Quantity of low-quality wholesale beef, billions pounds (carcass weight)	4.86[a]
P_H^w	Price of high-quality wholesale beef, cents per pound	300.27 [a]
P_L^w	Price of low-quality wholesale beef, cents per pound	275.79
Q_H^s	Quantity of high-quality beef obtained from slaughter cattle, billions pounds (live weight)	36.75 [a]
Q_L^s	Quantity of low-quality beef obtained from slaughter cattle, billions pounds (live weight)	8.08
Q_B^s	Quantity of beef obtained from slaughter cattle, billions pounds (live weight)	44.83
P_B^s	Price of slaughter cattle, $/cwt (live weight)	175.53
Q_B^f	Quantity of beef obtained from feeder cattle, billions pounds (live weight)	31.16
P_B^f	Price of feeder cattle, $/cwt	221.88
z_j^i	Demand shifters in the *i*th market level for the *j*th quality level	
w_j^i	Supply shifters in the *i*th market level for the *j*th quality level	

[a]Author Calculation, [b]Variables without means are inputs to the model and do not have data values

Appendix Table A.3. Variable Definitions, Estimates, and Sources for Elasticity Estimation

Symbol	*Definition*	*Estimate*	
		Short Run	*Long Run*
S_H	Expenditure share of high-quality beef, 2023	0.83[a]	
S_L	Expenditure share of low-quality beef, 2023	0.17[a]	
η_B^r	Own-price elasticity of demand for retail beef	-0.48[c]	-1.17[b]
σ	Elasticity of substitution between high- and low-quality beef	1.00[d]	
ε_B^w	Own-price elasticity of supply for wholesale beef	0.28[b]	3.43[b]
τ	Elasticity of transformation between high- and low-quality beef	-0.55[a]	
Q_H^{BXB}	Total weekly high-quality boxed beef load volume (40,000 pounds), Mean, 2004-2023	993.19[a]	
Q_L^{BXB}	Total weekly low-quality boxed beef load volume (40,000 pounds), Mean, 2004-2023	1181.16[a]	
P_H^{BXB}	Weighted average weekly high-quality boxed beef price ($/cwt), 2004-2023	201.09[a]	
P_L^{BXB}	Weighted average weekly low-quality boxed beef price ($/cwt), 2004-2023	188.22[a]	
E_T^d	Price transmission elasticity of retail to wholesale demand	0.65[a]	
E_T^s	Price transmission elasticity of wholesale to retail supply	1.30[a]	

[a]Author Calculation, [b]Pendell et. al. (2010), [c]Tonsor, Lusk, and Schroeder (2018), [d]Author Estimate