

Describing variation in formula base pricing of U.S. fed cattle: A hedonic approach

by

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A.A.S., North Carolina State University, 2016

B.S., North Carolina State University, 2019

A THESIS

submitted in partial fulfillment of the requirements for the degree

MASTER OF SCIENCE

Department of Agricultural Economics
College of Agriculture

KANSAS STATE UNIVERSITY
Manhattan, Kansas

2022

Approved by:

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This research was supported in part by the U.S. Department of Agriculture, Office of the Chief Economist and Agricultural Marketing Service. The findings and conclusions in this thesis are those of the author and should not be construed to represent any official USDA or U.S. Government determination or policy.

Abstract

The *Livestock Mandatory Reporting Act of 1999* (LMR) was enacted by Congress more than two decades ago and marked one of the largest enhancements to livestock market transparency in recent history. In the 20 years since, cattle and beef markets hardly resemble the predominantly cash negotiated and undifferentiated product that characterized the industry in the early 2000s. Due in part to changing consumer preferences, formula-based marketing agreements have proliferated in the fed cattle industry. USDA began publishing formula base price information in August 2021. However, considerable variation in the types of cattle marketed on formula has raised questions about the level of base price transparency that can be gleaned from current USDA formula base price reports. This study employs about six years of formula base price transactions under LMR to estimate hedonic models assessing the capability of existing data to describe variation in formula base prices. Results suggest omitted variable bias in the models due to constraints of available data. We offer suggestions for improved data collection which we expect would make hedonic modeling of base prices a more efficient mechanism for reporting useful and interpretable market information.

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Acknowledgements

First and foremost, I would like to express my deepest gratitude to my major professor Dr. Ted Schroeder for all of his patience, support, and guidance throughout this process. The opportunity to work with him is the primary reason I uprooted my family from North Carolina to move to Kansas. I will surely miss our afternoon chats over beers at Powercat's.

I would also like to thank Drs. Glynn Tonsor and Brian Coffey for their unwavering support as committee members. I could not have hoped for a better team of researchers to work with.

To my wife Camille, thank you for taking this journey with me and for your constant strength and optimism throughout the last year and a half. I could not have accomplished this without your support.

To my family back in North Carolina, thank you all for your constant encouragement and for enduring the 2–3-hour phone calls when I just needed to hear your voices.

Finally, to all the lifelong friends I've made here at Kansas State, everyone needs good friends to work through these types of challenges with, and you all have certainly been that for me.

Chapter 1 - Introduction

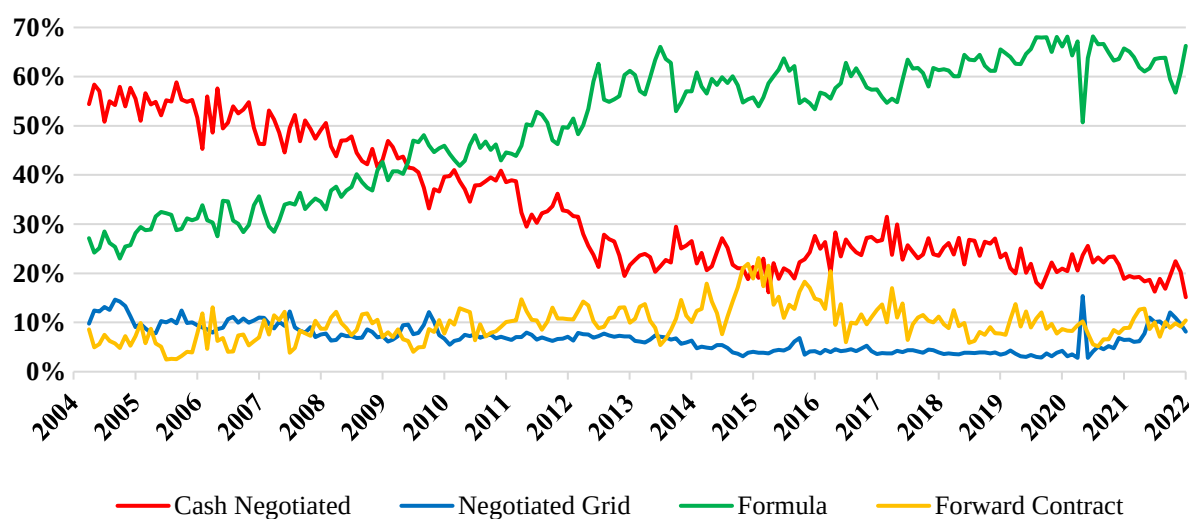
1.1 Topic Overview

Market transparency is pivotal to the functioning of efficient markets. Buyers and sellers incorporate all available market information to assess market conditions and discover market prices. One of the most important market transparency initiatives ever enacted by congress was the *Livestock Mandatory Reporting Act of 1999* (LMR). LMR requires qualifying meatpackers to report livestock prices, volumes, and other meat related pricing information to USDA twice each day. As such, livestock producers have ready access to dependable livestock market information regarding all cattle, boxed beef, swine, pork, and lamb purchases that are subject to reporting. In the time leading up to LMR, livestock prices were reported by meatpackers on a voluntary basis, and the primary method of marketing fed cattle was through cash negotiations. For cattle and beef specifically, the 1990s were a time of key structural changes as cattle feeders and meatpackers increasingly turned to alternative marketing agreements (AMA) and more value-oriented pricing systems. At the time of LMR enactment, cattle and beef were largely homogenous commodities. In the two decades that have followed, the fed cattle industry has been characterized by changing consumer demand, instigating unprecedented shifts toward product specialization and differentiation (Schulz et al. 2012).

AMAs provide important advantages to both cattle feeders and meatpackers. AMAs communicate consumer value signals more effectively than cash negotiated trade and enable meatpackers to organize production more efficiently to maximize capacity utilization rates reducing production costs per head (Bastian, Ritten & Nagler 2021; Schroeder, Coffey & Tonsor 2021A). Furthermore, AMAs reduce transaction costs and enable cattle feeders to manage risk more effectively (Peel et al. 2020). Because of the considerable economic benefits AMAs provide,

cattle producers have reduced participation in cash negotiated cattle trade (Peel et al. 2020). Consider Figure 1 which shows the evolution of prevailing fed cattle marketing methods used in the United States from 2004 through 2021. Traditional cash negotiated fed cattle trade has diminished to levels previously not seen in the U.S. and has been eclipsed by formula-based marketing agreements. Cash negotiated trades have precipitously declined from about 55% of transactions in 2004 to less than 20% at year-end 2021. Over the same time period, formula-based trade share more than doubled from about 27% in 2004 to over 60% by the end of 2021¹. While we discuss the issues associated with declines in spot market transactions in greater detail later, important to note is cash negotiated markets are being leveraged more than ever in formula agreements, even as spot transactions remain at historically low levels.

Figure 1. Percentage of Weekly Live Cattle Marketed by Transaction Types Nationally 2004-2021



Data Source: USDA AMS as archived by LMIC

Numbers are all live and dressed sales of steers, heifers, other fed cattle, cows and bulls reported in a given week for each transaction type.

¹ Any transaction not negotiated cash, negotiated grid, or forward contract is classified under the formula category. As such, formula traded cattle represent a widely varying number of cattle types (Schroeder, Coffey, Tonsor 2022).

1.2 Formula Base Pricing

An important aspect of formula contracts are the base transaction prices used to establish the agreement. Formula base prices are important to feeders because they are the price to which grid premiums and discounts are applied for over 60% of fed cattle. Formula based trade refers to all fed cattle transactions not including negotiated cash, negotiated grids, or forward contracts (Schroeder, Coffey & Tonsor 2021A). This means formula base prices are not negotiated daily or weekly, but rather the packer and feeder tie formula base prices to an externally discovered reference price (Ward, Feuz, & Schroeder 1999). Reference prices used in formula agreements vary by both source and market level and typically include: 1) a plant average base price (a price used for fed cattle purchased one or more weeks prior to the expected week of slaughter at the plant where the cattle will be slaughtered) (Schroeder, et al. 1997); 2) a USDA reported negotiated price for a given national or area cash market (Adjemian et al. 2016); 3) a live cattle futures price (Brester, Swanser & Crosby 2022); or 4) a wholesale beef price (Ward & Butcher 2003). Brester, Swanser, and Crosby (2022) suggest formula base prices tied to a live cattle futures price are rather similar to that of a cash negotiated price, as both prices likely incorporate the same available market information. While we do not dive into the respective advantages/disadvantages of any one reference price over another in this study, additional information can be obtained in Ward & Butcher (2003).² To address stakeholder concerns over insufficient market information regarding formula traded cattle, the Agricultural Marketing Service (AMS) introduced new market reports

² Ward, CE, Butcher, JE. 2003. "Formula Pricing Fed Cattle with Wholesale and Futures Markets." *Division of Agricultural Sciences and Natural Resources Oklahoma State University Extension*. AGECE-574. https://shareok.org/bitstream/handle/11244/49744/oksa_AGECE-0574_2004-03.pdf?sequence=1

in August 2021 including a daily and weekly statistical summary of formula base prices associated with formula contracts (Dennis 2021).

1.3 Problem Statement

Little is known about formula base prices and associated factors contributing to their variation across transactions or over a given week. Previous research reviewing base prices used in formula and grid pricing systems conclude base prices vary significantly and likely reference an undisclosed market source (Schroeder, Ward, Mintert & Peel 1997; Ward & Lee 1999; Ward, Feuz & Schroeder 1999; Peel et al. 2020). Research further suggests sources of formula base prices may potentially be thinly traded (negotiated cash base), endogenous to a specific plant (plant average base), and contribute little to price discovery in the current week due to elimination of the price negotiation phase in formula transactions (Schroeder et al. 1997; Ward, Feuz & Schroeder 1999; Peel et al. 2020). Additionally, the methods for which fed cattle market information and data are collected and reported have undergone little change since inception of LMR in 2001.³ In contrast, beef product branding and differentiation has brought about considerable change in how producers market cattle for slaughter (Schroeder, Coffey & Tonsor 2021). For these reasons, this study will use formula base transaction-level data to assess the capacity of existing LMR data collection and reporting methods to effectively describe formula base prices and their variation.

³ The Fed Cattle Exchange (FCE) online platform, beginning in 2016, was intended to facilitate additional cash negotiated trade and price discovery for the fed cattle industry. Though fed cattle trade appeared sustainable at the outset of FCE, trade has diminished as reservations still exist for packers and feeders to participate in online exchanges (Herbst 2018).

1.4 Research Significance

Understanding which observed factors drive variation in base price information is important to AMS as they determine ways to make base price reports useful and interpretable to decision makers using available data. Unexplained variation is equally important as it will illuminate whether collecting additional information from packers would be valuable to improve understanding of base price variation present to enhance market reporting. This study seeks to demonstrate how formula base price reporting could be modified to improve overall market efficiency through enhanced market transparency by devising new ways to synthesize and disseminate important cattle market information.

1.5 Objectives

The purpose of this study is to estimate the extent to which relevant factors statistically impact base price variation and to identify ways AMS might modify data collection and base price reporting to provide valuable and interpretable market information to an increasingly differentiated cattle and beef industry. We will demonstrate how hedonic modeling can be applied to existing transaction-level base price data collected under LMR to: 1) evaluate the level to which base price variation within a week is statistically explainable using available data; 2) quantify the extent to which specific formula transaction characteristics statistically impact base price; 3) analyze unexplained variation in base prices to illuminate the limitations of available data to explain base price variability. We further provide suggestions for additional data to be collected from packers to improve understanding of base price variation to make USDA reported prices more useful and interpretable to market participants.

Chapter 2 - Evolution of Livestock Mandatory Reporting

2.1 Background

USDA AMS began officially collecting livestock and other meat related price information from meatpackers through enactment of the *Agricultural Marketing Act of 1946* (Greene 2019; Maples & Burdine 2021). The *Agricultural Marketing Act of 1946*, which was in place for more than 50 years, laid the groundwork for livestock price reporting. Over that time, the livestock industry rapidly progressed and took strides to improve livestock market information under a voluntary system. Various changes and enhancements were made to market reporting in an effort to improve livestock market transparency (Maples & Burdine 2021).

Moving into the 1970s, discussions regarding improvements to market price reporting were brought before multiple Congressional subcommittees (Maples & Burdine 2021). In 1979, the Subcommittee on Livestock and Grains of the Committee on Agriculture commenced discussions regarding mandatory price reporting⁴. Among other issues, these discussions included increased use of marketing agreements and their relative impact on declining cash negotiated trade (Committee on Agriculture 1979; Maples & Burdine 2021). In light of the growing popularity surrounding AMAs, the Congressional subcommittee encouraged market participants to “*substantially broaden the base of negotiated transactions*” (Committee on Agriculture 1979 pg. 70). The subcommittee additionally surmised mandatory price reporting was “*premature*” at that

⁴ Committee on Agriculture. 1979. “Price Movements in Cattle and Meat Markets, July-August 1979.” Hearing before the Subcommittee on Livestock and Grains of the Committee on Agriculture of the U.S. House of Representatives. 96th Congress, First Session. October 30. Serial No: 96-HH.

<https://onlinebooks.library.upenn.edu/webbin/book/lookupid?key=ha002948499>

point and could be avoided through “*voluntary cooperation of the [livestock] industry*” (Committee on Agriculture 1979 pg. 71).

By the 1990s, Greene (2019) affirms the livestock industry had witnessed substantial shifts towards greater concentration and vertical integration in meat packing and feeding. Coinciding with these structural changes in the livestock industry was a continued decline in cash negotiated transactions in favor of AMAs, namely formula-based cattle trade. Cattle and other livestock producers grew increasingly apprehensive about their ability to gauge fair market livestock prices as AMAs were not required to be reported under the voluntary system (Greene 2019). By 1999, calls for mandatory price reporting had reached a fever pitch. Congress acted by passing the *LMR Act of 1999* establishing mandatory price reporting for cattle, boxed beef, swine, pork and lamb purchases (Maples & Burdine 2021).

When LMR was reauthorized through September 2020 by way of the Agriculture Reauthorizations Act of 2015, Greene (2019) states the USDA was tasked with conducting a study that investigated evolutions in fed cattle marketing practices. The study additionally gauged the state of industry sentiments regarding those evolutions as well as their relative impact on LMR. Upon submission of the LMR study in April 2018, AMS determined the meatpacking industry had “become more concentrated and vertically integrated since LMR was established”, and the industry was, “responding to domestic and global consumer meat demand with product differentiation and a mix of new products that did not exist when LMR began” (Greene 2019 pg. 11). The report concluded that formulas and other AMAs had displaced negotiated trades as the preferred method for marketing fed cattle in the U.S. (Greene 2019; Agricultural Marketing Service 2018).

2.2 Current LMR Data Collection & Reporting Practices

USDA AMS uses what is referred to as the *LP-113: Live Cattle Daily Report*⁵ to collect all relevant price and related meat product data from meatpackers (Schroeder, Coffey & Tonsor 2022). Under the authority of LMR, qualifying meatpackers are required to submit all transaction information to USDA twice a day using the LP-113 form; once at 9:30 AM and again at 1:30 PM. Daily cattle reports are published each morning summarizing reported transactions from 1:30 PM of the previous day to 9:30 AM of the current day. The paramount objective of this study is to determine whether data collected under LMR from meatpackers using the LP-113 form is sufficient to describe base price variability over a given week.

Table 1 provides brief descriptions of transactions data currently collected in the LP-113 form. Qualifying meatpackers purchasing cattle provide a unique plant ID code, the date for which the transactions occurred, and the purchase method used (negotiated cash, negotiated grid, forward contract, or formula). Transaction characteristics include number of head, cattle class (steer, heifer, mixed steer/heifer, etc.), selling weight basis (live or dressed), delivery method (delivered or FOB feedlot), average weight of the pen, percentage Choice or higher, and average dressing percentage of the pen. The LP-113 form ensures all pricing and transaction data collected from meatpackers is submitted in a uniform fashion and is currently used to construct 44 daily and weekly cattle market reports by USDA⁶ (Schroeder, Coffey & Tonsor 2022).

⁵ <https://mpr.ams.usda.gov/mpr/manuals/help/lpFormInfo.htm?selItem=lp-113&formName=LS113&product=livestock>

⁶ <https://www.ams.usda.gov/sites/default/files/media/LMRCattleUserGuide.pdf>

Table 1. Data Collected by USDA from Qualifying Packers in LP-113 Live Cattle Daily Report

Data Field	Explanation	Data Field	Explanation
Plant Identification	ID, name, and location of plant purchasing cattle	Weight Premium	Average premium paid for weight
Reporting Date	Date of report	Quality Premium	Average premium paid for quality
Reporting Time	9:30 am or 1:30 pm	Yield Premium	Average premium paid for yield
Source	Domestic or Imported	Other Premium	Average premium paid for other
Purchase Type	Cash Neg.; Formula; Neg. Grid; Fwd. Contract	Weight Discount	Average discount paid for weight
Class	Steer; Heifer; Mixed S/H; Dairy S/H; Mixed S/H/Cow	Quality Discount	Average discount paid for quality
Selling Basis	Live or Dressed	Yield Discount	Average discount paid for yield
Selling Basis – Ship	FOB or Delivered	Other Discount	Average discount paid for other
Head Count	Number of head in the transaction	Packer Financing	Whether packer provided financing
Est. Avg. Weight	Average live animal/carcass weight	Delivery Location	Producer or Packer
Average Price	Live/dressed net (or base) price paid	Delivery Date	If set by Producer or Packer
% Choice or better	Percentage grading Choice or higher	Delivered	1-14 days or 15-30 days (neg. cash only)
Classification Code	Quality code for majority of the cattle in the lot		
Dressing %	Average dressing percentage		
Origin	Feedlot state		

Source: <https://mpr.ams.usda.gov/mpr/manuals/help/lrFormInfo.htm?selItem=lp-113&formName=LS113&product=livestock>

Table 2 shows a section of an example USDA daily formulated base purchases report. Formula base transactions are categorized by measures of percent Choice or higher, delivery method (delivered or FOB feedlot), cattle sex (Steer; Heifer; Mixed Steer/Heifer; Mixed Steer/Heifer/Cow; Dairybred Steer/Heifer), and selling weight basis (live or dressed). Percent Choice or higher measures are further broken down into four subcategories measuring percent Choice ranges from 0% - 80+%. Formula transactions are then summarized according to their percent Choice subcategory by number of head and relative weighted-average dressing percentages, weights, and base prices (note that “Avg Net Price” is actually the base price before premiums and discounts have been applied). Price and weight ranges simply identify the maximum and minimum base price and average weight observations in a specified percent Choice subcategory.

When LMR was implemented in early 2001, cattle and beef functioned predominantly as generic commodities with more than 60% of fed cattle being transacted through cash negotiations. The previous 20 years have seen the fed cattle industry take great strides to improve overall cattle quality and expand available beef product offerings through use of formula and other AMAs. Consequently, formula-based cattle trade encompasses a multitude of branded and specialized beef products that were absent from the marketplace when LMR began. Furthermore, formula agreements, which include any transaction not negotiated or forward contracted, accounted for over 65% of fed cattle transactions at year-end 2021. LMR data collection and reporting methods have remained mostly unaffected by these industry shifts and still reflect the homogeneous nature of the beef industry in the early 2000’s.

Table 2. Example of a Portion of USDA Slaughter Cattle Formulated Base Purchases Report⁷

 National Daily Direct Slaughter Cattle - Formulated Base Purchases - Summary Agricultural Marketing Service Livestock, Poultry, and Grain Market News March 15, 2022 LM_CT112 Email us with accessibility issues regarding this report.						
For Primarily Monday, 03/14/2022						
	Head Count	Week to Date	Same Day Week Ago	Same Period Last Week	Same Day Year Ago	Same Period Last Year
Formula Base:						
Dressed	132,400	132,400	130,294	130,294	121,335	121,335
Live	19,172	19,172	22,661	22,661	30,665	30,665
Total	151,572	151,572	152,955	152,955	152,000	152,000
FORMULA BASE						
	Head Count	Wtd Avg Dress Pct	Weight Range	Avg Wt	Price Range	Avg Net Price
STEERS LIVE FOB						
Over 80% Choice	7,463	62.9	1,325 - 1,600	1,486	137.94 - 160.00	139.81
65 - 80% Choice	5,462	63.2	1,290 - 1,600	1,403	135.94 - 140.94	139.34
35 - 65% Choice	28	63.5	1,300 - 1,300	1,300	138.00 - 138.00	138.00
0 - 35% Choice			-		-	
Total all grades	12,953	63.1	1,290 - 1,600	1,451	135.94 - 160.00	139.61
STEERS LIVE DELIVERED						
Over 80% Choice	78	62.8	1,550 - 1,550	1,550	141.35 - 141.35	141.35
65 - 80% Choice	280	62.8	1,450 - 1,450	1,450	140.85 - 140.85	140.85
35 - 65% Choice			-		-	
0 - 35% Choice			-		-	
Total all grades	358	62.8	1,450 - 1,550	1,472	140.85 - 141.35	140.96
STEERS DRESSED DELIVERED						
Over 80% Choice	17,120	63.5	819 - 1,046	963	216.38 - 255.58	220.96
65 - 80% Choice	9,834	63.7	750 - 1,005	889	215.53 - 225.00	219.63
35 - 65% Choice	1,211	63.9	756 - 887	829	216.38 - 222.44	220.17
0 - 35% Choice			-		-	
Total all grades	28,165	63.6	750 - 1,046	931	215.53 - 255.58	220.46

⁷ https://www.ams.usda.gov/mnreports/ams_3496.pdf

Chapter 3 - Literature Review

3.1 Introduction

Base prices associated with formula agreements and their relative variation within a week are not well understood. The various cattle types and volumes included in formula agreements make USDA reported weighted-average base price ranges difficult for cattle feeders to interpret. Past research has suggested using more advanced statistical modeling such as hedonics to report cattle prices and communicate more transparent value signals. In this chapter, we will review the following: 1) a synthesis of previously conducted research evaluating formula base prices; 2) recommended methods for improving usefulness and interpretability of formula base reports; and 3) the feasibility of hedonic modeling to describe and report base prices.

3.2 Formula Base Prices: A Synthesis of Published Literature

The use of formula and grid pricing systems in the fed cattle industry is not a novel concept. Consequently, neither are the concerns surrounding formula agreements and their relative impact on fed cattle market transparency. Previous research has primarily focused on the variation in formula and grid pricing after premiums and discounts have been applied, but paid special attention to variation in base prices (Ward & Lee 1999; Ward, Feuz & Schroeder 1999). Several other studies have discussed sources of base prices used in formula agreements and their relative impact on price discovery and fed cattle market information (Schroeder, Ward, Mintert & Peel 1997; Peel et al. 2020; Schroeder, Coffey & Tonsor 2021A). Little is known about base prices and base price variation either within a week or across time. However, base prices are immensely important to establish an initial price to which grid premiums and discounts are applied to arrive at a net price for more than 60% of fed cattle.

Changes in consumer preferences motivated meatpackers to communicate stronger value signals to cattle feeders, and formula marketing agreements have proven to provide exactly that. Formula contracts and associated grids used in the agreements differentiate cattle value per head and enable cattle feeders to secure higher prices for producing higher quality cattle (Schroeder, Coffey & Tonsor 2021A). While evaluating variation present in formula and grid pricing systems for fed cattle, Ward et al. (1999) noted formula pricing not only allows producers to secure higher prices for better quality, but there are also significant cost advantages associated with marketing agreements. One particular advantage is base prices in formula agreements are tied to an exogenous price, meaning buyers and sellers incur little to no cost of negotiation (Peel et al. 2020). Schroder et al. (1997) gauged fed cattle industry sentiments over the state of price discovery in the market through interviews with industry stakeholders and revealed several sources of base prices including a reported live/dressed cash negotiated price, a plant average base price where cattle are to be slaughtered, a live cattle futures price, or a wholesale beef price. As formula cattle trade continues to be the preferred method of marketing cattle, an often-voiced concern has been the relative impact on negotiated cash cattle markets.

Marketing cattle through formulas combines value-based grid pricing with a streamlined base price discovery system, reducing transaction costs for both buyers and sellers of fed cattle. As such, marketing cattle through cash negotiations has become comparatively inefficient for cattle feeders producing increasingly differentiated, and higher quality cattle. Consequently, there are strong disincentives for producers to participate in cash negotiated cattle trade (Peel 2021; Anderson, McKenzie, & Mitchell 2021; Coffey, Pendell & Tonsor 2019). This is concerning because many formulas reference a reported national or area cash negotiated price. Although cash negotiated cattle trade has maintained about 23% of trade share on average over the last decade,

fed cattle on formulas are tying base prices to historically low levels of underlying cash transactions that are likely not representative of the quality of cattle on formulas (Schroeder et al. 1997; Coffey, Pendell & Tonsor 2019; Anderson, McKenzie & Mitchell 2021).

Schroeder et al. (2021A) additionally explain that cash negotiated transaction prices are published by USDA the week a price is established, while formula base prices are not reported until cattle are delivered to the packer, which could take place as far as two weeks after a base price is agreed upon. As such, marketing agreements contribute little directly to price discovery in the current week. Price discovery concerns also exist for formulas referencing a plant average base price where cattle are to be slaughtered. Fluctuations in plant-average base prices are likely not reflective of broader fed cattle market conditions and rather assign value to cattle based on a subset of cattle slaughtered at a specific plant in recent weeks (Schroeder et al. 1997; Ward, Feuz & Schroeder 1999; Ward & Lee 1999). In the case of establishing a base through an alternative source (e.g., live cattle futures, boxed beef cutout), temporal concerns over a representative cattle price are mitigated, but these methods still contribute nothing to the current week's price discovery (Schroeder, Coffey & Tonsor 2021).

Although USDA has taken measures to provide supplemental market information by publishing statistical summaries of daily and weekly formula base transactions, formula purchase reports themselves may not be highly informative. Formula pricing is a broad term used to represent any fed cattle transaction not categorized into one of the other reporting methods (Schroeder, Coffey & Tonsor 2021). Consequently, over 60% of base transactions containing various volumes and program cattle types (e.g., breed specific, certified production method, etc.) fall into the formula category. Schroeder et al. (2021) claim because currently reported formula weighted-average prices represent such a wide variety of cattle types and transactions, USDA

reported price ranges likely make understanding where underlying price values exist a complex task.

Variation in formula and grid base prices have been estimated in the past. Ward et al. (1999) compared prices paid for fed cattle sold using live weight, dressed weight, and grid pricing. Transactions data from 11,703 carcasses produced from 71 pens of cattle marketed weekly during 1997 were analyzed. Grid pricing systems were the most discriminatory of cattle quality as they are more discerning in conveying pricing signals to cattle feeders. While the primary focus of the study was to quantify variation across premium and discount grids, Ward, Feuz, and Schroeder (1999) note base prices exhibited significant variation as well. Each plant average base price was assumed to be for Choice, Yield Grade 3 carcasses. Formula base prices tied to a plant average varied as much as \$2.17/cwt or over \$16/head, while base prices tied to a reported cash price varied \$2/cwt or about \$15/head (Ward, Feuz & Schroeder 1999; Ward & Lee 1999). Ward et al. (1999) point out variation in base prices tied to a plant average or reported cash price occur before variation in premium/discount grids, cattle quality, or other alternative base price sources have been accounted for (Ward & Lee 1999).

Given the level of product differentiation in beef and cattle that has taken place in the previous two decades, new questions have arisen regarding underlying base price values and what market information, whether available or unavailable to feeders, is driving base price variation. In a study quantifying profit determinants for fed cattle sold using grid pricing, McDonald and Schroeder (2003) claim feeder cattle prices and base prices used in grids had the greatest effect on cattle feeder profit per head in the two different grid structures analyzed (plant average base price versus USDA reported cash base). This suggests usefulness and interpretability of base purchase reports is vital for cattle feeders to maximize profitability. An important contribution of this study

is not only identifying factors driving formula base prices using existing data, but also demonstrating how hedonic modeling of LMR transactions data can be used to present base price information more succinctly than current USDA reported price ranges.

3.3 Methods for Improving Usefulness of Formula Base Purchase Reports

The goal of LMR is to provide timely and reliable fed cattle market information to decision makers. As previously noted, formula base purchase reports represent a widely varying number of cattle types and volumes, and weighted-average price ranges likely only provide minimal comprehension of base price values. Research has shown product specialization in cattle and beef associated with formula-based cattle trade has given rise to entirely new forms of market information that are likely not reflected in current USDA price reporting practices (Schroeder et al. 2021B). In this section we discuss several studies that have both pointed out, and proposed potential solutions for enhanced fed cattle market transparency given a predominating buyer and seller preference for formula-based trade.

Peel et al. (2020) discuss concerns about price discovery, competition, and potential impacts of market concentration in the fed cattle industry and potential legislative remedies being proposed to mitigate those concerns. Specifically mentioned were the use of formula agreements and how more detailed information about the types of formulas being used could enhance market transparency. Peel et al. (2020) explain that current reporting practices aggregate formula transactions into a single report. By identifying and reporting separate formula types by the base price used in the agreement, AMS could provide much more detailed formula cattle market information and facilitate additional forms of price discovery. Peel et al. (2020) point out LMR hog reports provide this level of formula transactions data currently and it has provided more

complete information about how different types of formulas used impact net price differences across time. Important to note is classifying specific formula types for reporting purposes would require less aggregation of formula transactions and could potentially preclude any reporting due to confidentiality constraints of the 3/70/20 rule⁸ (Peel et al. 2020). Maples and Burdine (2021) discuss this concern as it relates to thinning negotiated cash markets and impacts of market thinness on fed cattle market transparency. Cash negotiated and formula cattle trade have something of a common concern in that, as markets/categories of reportable trade become thinner/more specific, the risk of violating 3/70/20 increases. More specifically, as total formula trade volume becomes dispersed and classified according to the different types of formulas being used, the types of transactions required to be reported also become more specific. This ultimately leads to fewer transactions being classified into a given reporting category which leads to a higher likelihood of the 3/70/20 rule being binding (Maples & Burdine 2021).

Previous research has suggested the use of hedonic modeling to report fed cattle prices, but also notes that in order to maximize its effectiveness, additional price information is likely needed (Schroeder & Tonsor 2017; Schroeder, Coffey & Tonsor 2021B). Schroeder et al. (2021A) contend hedonic modeling of LMR transactions data could potentially enable improved pricing transparency while at the same time preserve confidentiality of reported information. This methodology would entail statistically summarizing reported pricing data, meaning actual reported prices would remain undisclosed. Schroeder et al. (2021A) indicate statistical modeling of reported transaction data is not as unconventional as it may seem. USDA has long reported cattle prices

⁸ The 3/70/20 rule requires the following conditions be met over the most recent 60- day period: (1) three reporting entities provide data at least 50% of the time, (2) no single entity provides more than 70% of the data for a report, (3) and no single entity is the sole reporting entity for an individual report more than 20% of the time.

Source: <https://www.ams.usda.gov/sites/default/files/LMRConfidentialityGuidelinePresentation.pdf>

by calculating a weighted-average price based on the number of head sold within a given set of transaction parameters⁹, and not publishing actual reported prices. What makes hedonic modeling of LMR formula base transactions especially preferable in this instance is while reported pricing information remains undisclosed, concerns over data confidentiality can also be alleviated. If a given hedonic variable falls below the reportable threshold, the variable can be aggregated over a larger time period/set of transactions to ensure confidentiality while not withholding valuable information (Schroeder et al. 2021A). In the case of formula base purchase reports, confidentiality can be preserved by aggregating across the types of base prices used in formula agreements (e.g., plant average, reported cash price, live cattle futures price, etc.) or by program cattle types (e.g., grass-fed, NHTC, etc.), while still providing cattle feeders more refined base price/value information.

3.4 Previous Empirical Uses of Hedonic Modeling to Describe Commodity Prices

Hedonic modeling has proven useful in identifying and capturing the underlying values associated with specific product attributes. Rosen (1974 pg. 34) defines a hedonic price as the *“implicit prices of attributes that are revealed to economic agents from observed transaction prices of differentiated products and the specific amounts of characteristics associated with them.”* As it applies to fed cattle, hedonic modeling of formula base transactions allows us the opportunity to specifically analyze determinants of base prices relative to available data, as well as an ability to quantify how much of base price variability is statistically explainable using that data.

⁹ USDA reports cattle prices by taking a head-weighted-average price based on cattle sex (steer, heifer, mixed steer/heifer, etc.), delivery method (delivered or FOB feedlot), selling weight basis (live or dressed), and percent Choice or higher classifications (See Table 2 above).

Previous research has demonstrated the effectiveness of hedonic modeling in identifying implicit prices of product attributes and describing variation in commodity prices. Love, Capps, and Williams (2010) conducted a study investigating how concentration in the meat packing industry and associated increases in economies of scale impacted prices cattle feeders received. Specifically analyzed was the economic importance of competing explanatory factors on prices paid by packers. Love et al. (2010) addressed this multivariate problem using hedonic modeling and obtained both fed cattle transactions and weekly plant-level packer costs and returns data from GIPSA. These data included 81% cash negotiated, 9% marketing agreements, 8% forward contracts, and 3% packer-fed transactions collected from 43 steer and heifer packing plants covering April 1992 to April 1993. Love et al. (2010) found yield grades, Select quality grade, breed, and average weight factors affected transaction prices. Schulz, Schroeder, and White (2012) used hedonic modeling to estimate how product attributes of retail beef steak affect prices by obtaining scanner data representing steak purchases in U.S. retail outlets from January 2004 through March 2009. The data contained 198,719 weekly aggregated sales observations as value of pounds sold by brand name, retail cut, quality grade, breed claim, organic production claim, religious processing claim, and presence of bone. Schulz et al. (2012) found numerous implicit values placed on specific product attributes were embedded in retail prices paid by consumers.

To specify statistically relevant factors impacting formula base prices using existing LMR data, we estimate sequentially the effects of purchasing packer, cattle origin, and pen attributes on formula base prices. Previous studies have used commodity transactions data to uncover relevant factors driving price variation. Brorsen, Grant, and Rister (1984) utilized four different hedonic price functions to estimate variation in rice prices. Sales records and grade sheets were obtained from several bid/acceptance rice markets in Texas for the 1981/82 marketing year and included a

total of 380 observations from one of these markets which was used in their analysis. Brorsen et al. (1984) estimated the level to which various rice transaction details impacted rice prices by sequentially incorporating all available rice quality grade and characteristic information across four hedonic price functions. Each equation contained a mill rice price, with equations 1 – 4 estimating price as a function of: 1) rice quality grades (1 – 6) only; 2) rice quality grades (1 – 6) plus rice yield measures; 3) rice quality characteristics only; and 4) all transaction information including rice quality grade, quality characteristics, and yield measures. Brorsen et al. (1984) determined all factors jointly combined offer a more powerful explanation of observed price variation than any set of factors individually, and rice buyers participating in the bid/acceptance market of interest used all available information relating to both grade and quality characteristics in determining their bid. The primary objective of this study is utilizing hedonic modeling to measure explanatory power of statistically relevant factors to describe base price variability. However, a valuable result of our analysis is additional insight into shortcomings of available data to explain base prices and potential modifications to LMR data collection protocols to make formula base reports more useful and interpretable to decision makers.

3.5 Hedonic Modeling to Report Commodity & Asset Prices

Markets are where information culminates into an asset (or commodity) price, and the most efficient of those markets incorporate all available information (Fama 1970). Improved data collection and novel market reporting practices may need to be considered if LMR is to properly incorporate all available cattle market information. Previous studies have demonstrated the use of hedonic modeling to measure the impact of specific cattle attributes on fed cattle prices. However, the feasibility of hedonic modeling to report fed cattle prices has not been assessed.

Past research has demonstrated how hedonic modeling can be applied to report other agricultural commodity prices. Brown et al. (1995) developed a new objective approach for estimating and reporting cotton prices referred to as the *Daily Price Estimation System* (DPES). The objectives of the DPES are to provide an objective and accurate tool to facilitate reporting of cotton prices, premiums, and discounts. Brown et al. (1995 pg. 410) describe DPES more specifically as a “*computer-automated system for receiving and statistically analyzing sales data*”, which then “*estimates prices using an econometric model developed from hedonic price research and transmits the results to market participants.*” Hedonic modeling has also been used in other sectors to analyze and report prices. The FNC Residential Price Index (Dorsey et al. 2010), Multi-Family House Price Index of the Bureau of Economic Analysis (de Leeuw 1993), and the Census Bureau’s Single-Family House Price Indexes all utilize a hedonic pricing approach. Furthermore, Moulton (2001) explained that the Bureau of Labor Statistics (BLS) has conducted research in hedonic modeling since the 1970’s. BLS officially began using hedonic pricing indexes in 1987 to present housing rental, and homeowners’ equivalent rental prices and has since used hedonics to make quality-adjustments to the Consumer Price Index for various consumer products and assets (Lane, Randolph & Berenson 1988; Kokoski 1993; Leigey & Shepler 1999; Brown 2004). An important contribution of this study is assessing the feasibility of hedonic modeling to report formula base prices using data collected under LMR using the LP-113 form.

3.6 Summary

Formula based cattle trade has been a net positive for the fed cattle industry. Meatpackers and cattle feeders have forged marketing agreements to better organize production along the supply chain and communicate consumer value signals, maximize packer capacity utilization rates, and

secure higher prices for producing higher quality cattle. However, often unknown sources of base prices used in formula agreements along with variation in base transactions present across formulas suggests a more refined understanding of base price information could be ascertained.

Although statistical modeling of commodity and retail transactions data is a multivariate and complex endeavor, several published studies have demonstrated how hedonic modeling can be applied to estimate drivers of price variability and identify implicit values associated with an underlying transaction price. This indicates hedonic modeling of formula base transactions collected under LMR can facilitate the objectives of this study by not only quantifying the level of base price variability explained by available data, but can also provide model goodness-of-fit statistics that enable us to draw conclusions about other potential sources of base price value that remain uncollected and unreported.

Chapter 4 - Data & Methods

4.1 Formula Base Transactions Data & Modeling Procedures

To accomplish the objectives of this study of determining whether market transparency can be enhanced through use of hedonic modeling and whether data currently being collected by AMS from packers is sufficient to explain factors driving weekly price variation, transactions data were obtained from USDA AMS. The transactions data spans the time period of January 4, 2016 – October 22, 2021, and consists of data collected under LMR using the LP-113 form. Our analysis focuses only on base prices paid for formula purchases so as to emphasize transactions that reference an exogenous price and eliminate any base price that may have been negotiated. Forward contracts were also excluded from our analysis due to the fact they are entered into at various times leading to significant temporal variation in forward contract prices and a misrepresentation of weekly fed cattle prices in our hedonic models (Schroeder et al. 2021A).

Filters were applied to better organize relevant transactions data and eliminate outliers that may bias analysis. In price reporting, USDA identifies transactions that are excluded from the slaughter cattle formulated base purchase reports and removes transactions that involve less than 11 head. Also removed from our data were trades including: cows; non-domestic origin; dairy bred cattle (Ward, Feuz & Schroeder 1999; Ward & Lee 1999); dressed price <\$40/cwt or dressed price >\$320/cwt; dressing percentage¹⁰ <50% or dressing percentage >70%; live weight <800lbs. or live weight >2200 lbs.; dressed weight <500 lbs. or dressed weight >1400 lbs.; and head counts >5,000.

¹⁰ Dressing percentage is the hanging hot carcass weight divided by the live animal weight, in a given transaction.

As a means of creating more uniformity in the data, live cattle prices and weights were adjusted to a dressed basis. Live weights were multiplied by the dressing percentage reported in each transaction and live animal prices were divided by the dressing percentage reported in each transaction (e.g., live price = \$150/cwt & dressing percentage = 60%; $(150/.6) = \underline{\$250/\text{dressed cwt}}$) (Ward, Feuz & Schroeder 1999). To address impacts of irregularities of transaction prices, formula base price observations were grouped according to the week the transaction took place. Any base price falling outside the range of ± 2.5 median absolute deviations around the corresponding weekly median base price was removed (Leys et al. 2013; Bina, Schroeder & Tonsor, 2022). Additional information regarding median absolute deviations for outlier detection can be found in (Leys et al. 2013).¹¹ The above filters led to the removal of 29,279 observations, leaving the final dataset used in our analysis with 527,148 formula base transactions spanning a total of 303 weeks, or just under six years.

Hedonic models used in our analysis include only data currently collected and reported by AMS from qualifying meatpackers. The primary focus of this study was to estimate the level to which existing data collected in the LP-113 form can explain formula base price variation at a point in time. However, an additional point of emphasis in this study was to identify data that could potentially enhance fed cattle market transparency. To assess whether collecting additional information from meatpackers could improve model price predictions, model errors were closely evaluated. Results indicate pen attributes as reported contribute minimally to observed variation in base prices and potentially important formula transaction information is likely omitted in our

¹¹ Leys, C, Ley, C, Klein, O, Bernard, P, and Licata, L. 2013. “Detecting Outliers: Do Not Use Standard Deviation Around the Mean, Use Absolute Deviation Around the Median.” *Journal of Experimental Social Psychology* 49(4): pgs. 764-766. <https://www.sciencedirect.com/science/article/abs/pii/S0022103113000668>

data. Some key market information that would be beneficial to include in our models relate to certain fed cattle production and verification/certification systems (grass-fed, organic, NHTC, export certified, etc.) as well as breed specific programs (Certified Angus Beef, Wagyu, etc.) associated with the transaction. Additionally, more detailed information about the source of base prices used in formula agreements (cash negotiated, futures price, wholesale beef price, etc.) could enable a more in-depth analysis of how formula base prices vary simply based on the reference price used in the agreement. We elaborate more later about new sources of base price information that could potentially be collected from packers, but a key takeaway here is model goodness-of-fit statistics suggest hedonic price functions used in our analysis are likely suffering from model specification concerns due to constraints of available data.

To achieve our objectives of determining whether 1) existing LMR formula base transactions data is able to effectively describe variation in base price, and 2) whether certain transaction characteristics are more statistically impactful on base price variation than others, three separate hedonic equations were used. Hedonic models were constructed so as to sequentially incorporate specific variable groups associated with formula base transactions and are developed as follows:

$$(1) \textit{Formula Base Price}_{it} = f(\textit{Plant}, \varepsilon)$$

$$(2) \textit{Formula Base Price}_{it} = f(\textit{Plant}, \textit{Origin}, \varepsilon)$$

$$(3) \textit{Formula Base Price}_{it} = f(\textit{Plant}, \textit{Origin}, \textit{Quality}, \textit{Head}, \textit{Dressing}, \\ \textit{Weight}, \textit{Cattle Sex}, \textit{Delivery}, \textit{Weight Basis}, \varepsilon)$$

Where (i) refers to an individual formula base transaction, (t) refers to a single week for which the transaction occurred, and (ε) is the error term. Model variable definitions for hedonic equations (1) – (3) are provided in Table 3. Formula base price is modeled first as a function of the plant where cattle were purchased and slaughtered only. This allows us to isolate effects of purchasing plant on base price variation and evaluate goodness-of-fit statistics to assess the level of variation explained by plant effects alone. Our second hedonic equation models base price as a function of both purchasing plant and cattle state of origin. Plant effects are likely embedded somewhat in state of origin effects, however, the reason for including the two separately is to assess average base price differences in fed cattle producing states where at least a single LMR reporting plant is located and states where no such packing plants are currently established. Cattle producing states which contain no LMR reporting plants will further be referred to as “remote states.” Formula base price is modeled in the third hedonic equation as a function of purchasing plant, cattle state of origin, and pen attributes¹², incorporating all available formula base transaction data currently collected under LMR. Given that formula base prices are tied to an externally discovered price, we do not expect pen attributes to be economically important drivers of base price variability. We include pen attributes in our analysis because these data are used to describe base price variation in existing LMR price reports. Binary weekday variables are included to account for base price variation across days during the week with one weekday as the default.

Hedonic equations (1) - (3) were estimated using ordinary least squares modeling (OLS) and were run separately for each of the 303 weeks contained in our dataset. Weekly models had

¹² Pen attributes data includes quality (percent Choice or higher), number of head, average dressed weight, delivery method (delivered or FOB feedlot), cattle sex (steer, heifer, or mixed steer/heifer), and selling weight basis (live or dressed).

an average of about 1740 formula base transactions per week. By incorporating formula base transaction characteristics related to purchasing plant, cattle state of origin, and lot attributes sequentially from equation (1) to (3), we are able to evaluate changes in the level of price variability that is explained to assess the degree of statistical relevance associated with a specific variable group. To analyze the output for each hedonic equation over the 303 weeks contained in our data, an average coefficient estimate and standard deviation was calculated for each of the independent variables included in the corresponding model (i.e., equation (1) includes 31 independent binary plant variables with one as default; when equation (1) is estimated weekly, there are 30 plant variables with 303 coefficient estimates per plant, one for each week the model was estimated). Model explanatory power was assessed using goodness-of-fit statistics of R-Squared and Root Mean Square Error (RMSE). Maximum, minimum, and average goodness-of-fit statistics for equations (1) – (3) were also calculated for each of the 303 weekly models. To test for joint significance of variable groups included in our hedonic models, equation (3), which incorporates all available formula transaction characteristics data, is used as the unrestricted model. F-tests for elimination were conducted to determine whether global significance is impacted by eliminating variable groups in equations (1) and (2).

Table 3. Independent Variables Used in Weekly Hedonic Models

Independent Variable	Description
<u>Price</u>	
<i>Base Price</i>	Price paid on a dressed basis (\$/cwt)
<u>Quality</u>	
<i>Choice</i>	Percentage grading Choice or higher (%)
<u>Head</u>	
<i>Head50</i>	Binary variable=1 if lot size is ≤ 50
<i>Head100</i>	Binary variable=1 if $50 < \text{lot size} \leq 100$
<i>Head100+</i>	Binary variable=1 if lot size is > 100 (default)
<u>Dressing</u>	
<i>Dressing</i>	Dressing percentage of cattle carcass (%)
<u>Weight</u>	
<i>Weight1</i>	Binary variable=1 if average dressed weight ≤ 800 lbs.
<i>Weight2</i>	Binary variable=1 if $800 \text{ lbs.} < \text{average dressed weight} \leq 900 \text{ lbs.}$ (default)
<i>Weight3</i>	Binary variable=1 if average dressed weight > 900 lbs.
<u>Cattle Sex</u>	
<i>Steer</i>	Binary variable=1 if sex=steer (default)
<i>Heifer</i>	Binary variable=1 if sex=heifer
<i>Mixed</i>	Binary variable=1 if sex= mixed steer/heifer
<u>Delivery</u>	
<i>Delivered</i>	Binary variable=1 if cattle delivered to plant (default)
<i>FOB</i>	Binary variable=1 if cattle purchased FOB feedlot
<u>Weight Basis</u>	
<i>Dressed</i>	Binary variable=1 if cattle purchased on dressed weight basis (default)
<i>Live</i>	Binary variable=1 if cattle purchased on a live weight basis
<u>Origin</u>	
<i>State_K</i>	Set of binary variables=1 for each cattle state of origin (TX as default)
<u>Plant</u>	
<i>Plant_J</i>	Set of binary variables=1 for each plant J purchasing cattle (one as default)
<u>Weekday</u>	
<i>Monday, etc.</i>	Set of binary variables=1 for each day of the week (Monday as default)

Although formula base prices are estimated on a state-by-state basis in this study, to present summary statistics of our data in a more simplified fashion, we have categorized cattle states of origin by region. Described in Table 4 are cattle region classifications used to summarize our data, and closely resemble region classifications used for LMR formulated base purchase reports¹³. Regions incorporating more than three states are typically a function of comparatively thinner fed cattle trade volumes. Thinly traded regions aggregate transactions across a larger number of states in order to maintain a reportable level of trade without violating 3/70/20 confidentiality guidelines. Figure 4-1 depicts fed cattle producing regions as a percentage of total head marketed on a formula, purchased between 2016 and October 2021. TX-OK-NM, KS, NE, and CO (about 75% of the 5-Area market¹⁴) account for 88% of formula base transactions over the near six year period contained in our dataset. IA-MN-MO, western states, and north central states make up just over 11% of formula base transactions, while eastern corn belt, northeastern, and southeastern states jointly equate to less than 1% of formula base transactions.

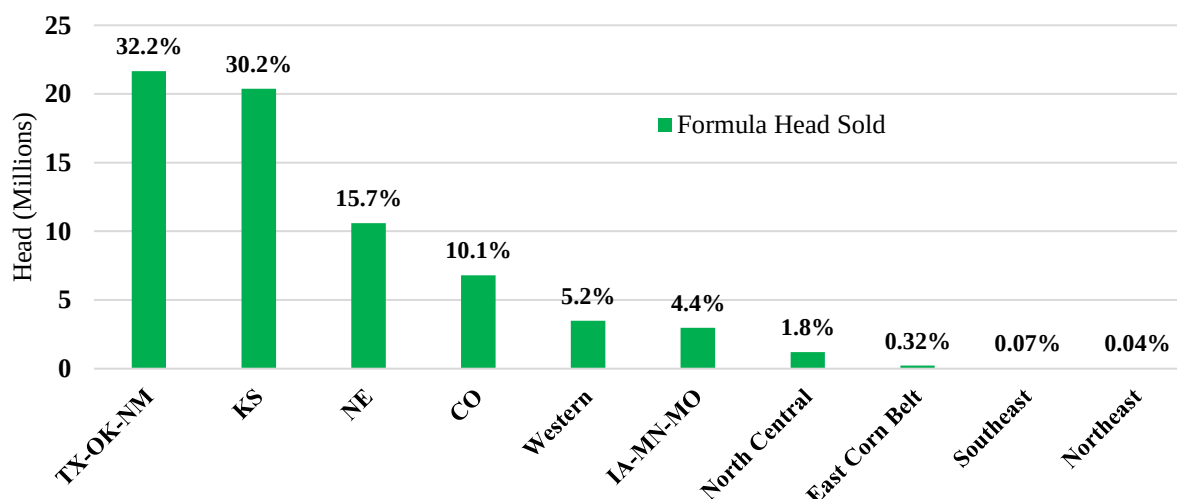
Table 4. Description of Fed Cattle Regions of Origin

Region Name	Region Description
National	<i>(38 total states represented)</i>
KS, NE, CO	<i>(represented as individual states)</i>
TX-OK-NM	<i>TX-OK-NM</i>
Western Corn Belt	<i>IA-MN-MO</i>
North Central States	<i>MT-ND-SD-WY</i>
Eastern Corn Belt	<i>IL-IN-KY-MI-WI</i>
Western States	<i>AZ-CA-ID-NV-OR-UT-WA</i>
Southeastern States	<i>AL-AR-FL-GA-MS-NC-SC-TN-VA</i>
Northeastern States	<i>CT-DE-MA-MD-ME-NH-NJ-NY-OH-PA-RI-WV-VT</i>

¹³ https://www.ams.usda.gov/mnreports/ams_3496.pdf (see page 4)

¹⁴ The 5-Area market encompasses five fed cattle producing regions that include the following states: TX, OK, NM, KS, NE, CO, IA, and MN.

Figure 2. Cattle Region of Origin as Percentage of Total Head Marketed on Formula, 2016-2021



Summary statistics of dressed steers and heifers marketed on formula between 2016 and October 2021 are also presented in Table 5. The national weighted-average formula base price was \$184.95/cwt with a standard deviation of \$14.87/cwt. Regional average base prices were highest compared to the national average in the northeastern and southeastern states which also are the two most thinly traded markets in our dataset. Northeastern and southeastern states, because of their relatively low fed cattle trade volume, likely do not reflect broader fed cattle market conditions. Outside of the northeast and southeast, regional average base prices remain within a range of \$1.45/cwt of the national average base price. Due to the infrequent and inconsistent nature of formula base transactions in thinly traded states of origin, coefficient estimates vary considerably, and often times misrepresent the level of base price variation present in a given week. As such, we provide model statistics only for the top ten fed cattle producing states (out of 38 total included in our models) for cattle marketed on formula. The top ten states represent approximately 96% of total formula head sold from 2016 to 2021.

Table 5. Formula Base Transactions Summary Statistics for Dressed Steers and Heifers
Marketed on Formula, 2016-2021

Cattle Region	Statistic	Wtd. Mean¹⁵	Max¹⁶	Min	Std. Deviation
National	Head	127.87	4982	11	103.78
	Dressed Weight (lbs.)	860.4	1380.0	503.8	68.3
	Percent Choice or Higher (%)	76.5	100	0	13.2
	Dressed Base Price (\$/cwt)	\$184.95	\$199.81	\$169.33	\$14.87
TX-OK-NM	Head	140.37	1300	11	87.00
	Dressed Weight (lbs.)	840.2	1350	503.8	69.4
	Percent Choice or Higher (%)	68.7	100	0	13.9
	Dressed Base Price (\$/cwt)	\$184.77	\$199.73	\$169.20	\$15.06
KS	Head	120.04	3021	11	78.49
	Dressed Weight (lbs.)	862.4	1375.0	535.8	64.4
	Percent Choice or Higher (%)	79.3	100	0	10.2
	Dressed Base Price (\$/cwt)	\$185.02	\$197.98	\$168.50	\$14.67
NE	Head	146.7	4982	11	152.11
	Dressed Weight (lbs.)	884.4	1375.0	561.9	65.7
	Percent Choice or Higher (%)	82.7	100	0	11.5
	Dressed Base Price (\$/cwt)	\$186.10	\$201.28	\$170.00	\$14.99
CO	Head	170.71	2183	11	131.38
	Dressed Weight (lbs.)	872.8	1127.1	591.4	67.4
	Percent Choice or Higher (%)	79.2	100	0	12.0
	Dressed Base Price (\$/cwt)	\$186.21	\$201.45	\$170.00	\$14.97
IA-MN-MO	Head	80.43	1400	11	72.01
	Dressed Weight (lbs.)	891.0	1380.0	545.0	69.1
	Percent Choice or Higher (%)	83.7	100	0	10.6
	Dressed Base Price (\$/cwt)	\$185.64	\$200.13	\$169.62	\$14.65
East Corn Belt	Head	43.33	324	11	25.29
	Dressed Weight (lbs.)	874.2	1019.3	652.3	65.7
	Percent Choice or Higher (%)	90.7	100	0	7.0
	Dressed Base Price (\$/cwt)	\$185.08	\$199.82	\$169.00	\$14.65
Western States	Head	107.47	2917	11	126.62
	Dressed Weight (lbs.)	848.9	1325	523.7	74.6
	Percent Choice or Higher (%)	73.8	100	0	11.9
	Dressed Base Price (\$/cwt)	\$185.95	\$200.76	\$170.86	\$14.59
N. Central States	Head	81.32	1064	11	73.74
	Dressed Weight (lbs.)	869.9	1231.0	613.7	61.2
	Percent Choice or Higher (%)	86.9	100	0	10.3
	Dressed Base Price (\$/cwt)	\$184.92	\$200.01	\$169.66	\$14.73
Northeast States	Head	54.29	332	11	39.32
	Dressed Weight (lbs.)	865.3	992.0	654.2	54.1
	Percent Choice or Higher (%)	84.4	100	0	9.3
	Dressed Base Price (\$/cwt)	\$187.05	\$201.70	\$172.96	\$13.67
Southeast States	Head	40.47	280	11	21.05
	Dressed Weight (lbs.)	806.6	1070.0	562.0	66.4
	Percent Choice or Higher (%)	80.5	95.0	0	5.0
	Dressed Base Price (\$/cwt)	\$187.98	\$205.67	\$171.70	\$15.93

¹⁵ Weighted Mean refers to a head-weighted-average dressed weight, % Choice or higher, and dressed base price.

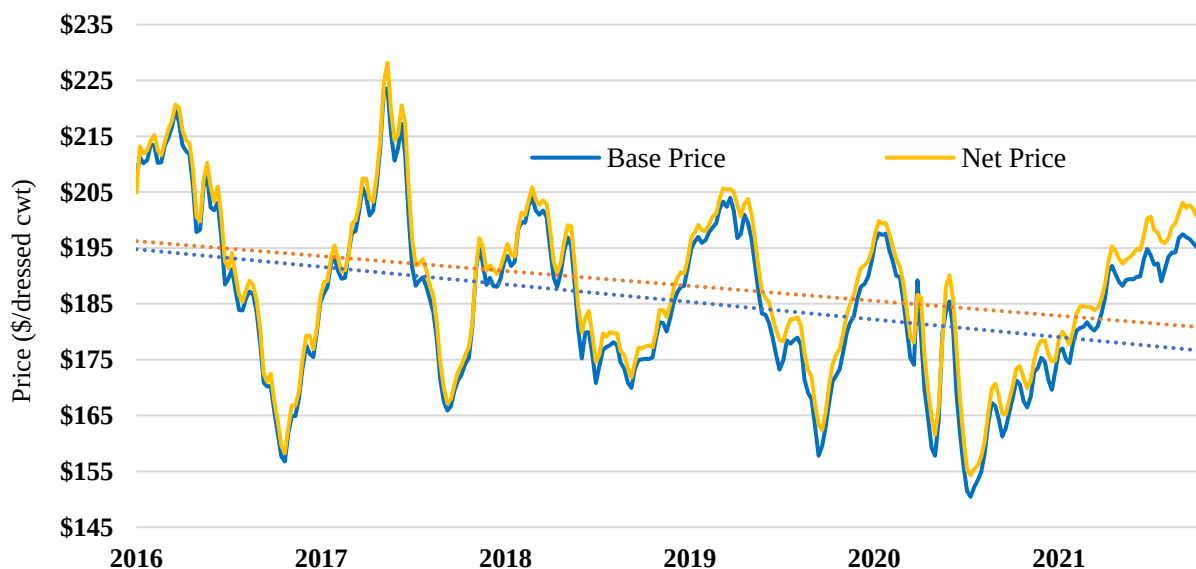
¹⁶ Min/Max national/regional price values are presented at the 15th and 85th percentiles.

Figure 3 illustrates the evolving relationship between formula base and net prices spanning the period of January 2016 through October 2021 contained in our dataset. Formula net prices were obtained from Livestock Market Information Center (LMIC) which provides a weekly statistical summary of formula net dressed steer and heifer transactions going back to April 2001. Included in the archived LMIC reports are weekly aggregated formula head counts, weighted-average dressed weights, and weighted-average dressed net prices. Beginning in 2016, formula base and net prices follow one another closely, maintaining a weighted-average base to net price differential of about \$2/cwt over the 2016 marketing year. This trend continues through 2018 as base to net price differentials average about \$2.17/cwt over the first three years in our dataset. Entering the latter half of 2020 and into 2021, the fed cattle industry continued to evolve and adapt to market uncertainty and substantial volatility in cattle prices due to massive supply shocks brought on by the COVID-19 pandemic (Lusk, Tonsor & Schulz 2020). The difference between formula base and net prices during 2020 through 2021 averaged about \$3.86/cwt, while in 2021 alone (through October 22) the weighted-average formula base to net price differential was about \$4.51/cwt.

Figure 4 illustrates variability present in formula base prices during the week of Monday June 14, 2021, to Friday June 18, 2021. This week was chosen specifically to represent the average, or ‘typical’ week as it relates to the distribution of base price differentials around the weekly weighted-average base price. As previously mentioned in our description of model variables, a binary weekday variable is included to account for day-to-day variation in base prices within a given week time period. In the case of Figure 4-3, weekday variables all rounded to zero indicating formula base prices during this week remained relatively consistent. Additionally, the average number of observations in weekly models was about 1740 observations, while the week

of June 14 – 18, 2021 had over 1900 observations. Nearly 70% of formula base prices fell within $\pm \$1/\text{cwt}$ of the week's weighted-average base price, and about 84% fell within $\pm \$2/\text{cwt}$ of weekly mean base price. Only about 6% of formula base prices were more than $\$2/\text{cwt}$ under the weighted-average mean, while about 9% achieved base prices greater than $\$2/\text{cwt}$ above the weekly mean. This suggests formula base prices in a conventional week do not vary significantly. Furthermore, from a price reporting perspective, this data substantiates previous suggestions made by researchers claiming reporting cattle prices at the 15th and 85th percentiles as low and high price values in reported price ranges may be more representative of current cattle market conditions, as opposed to reporting absolute minimum and maximum cattle price observations as is done by USDA AMS currently (Schroeder, Coffey & Tonsor, 2021B).

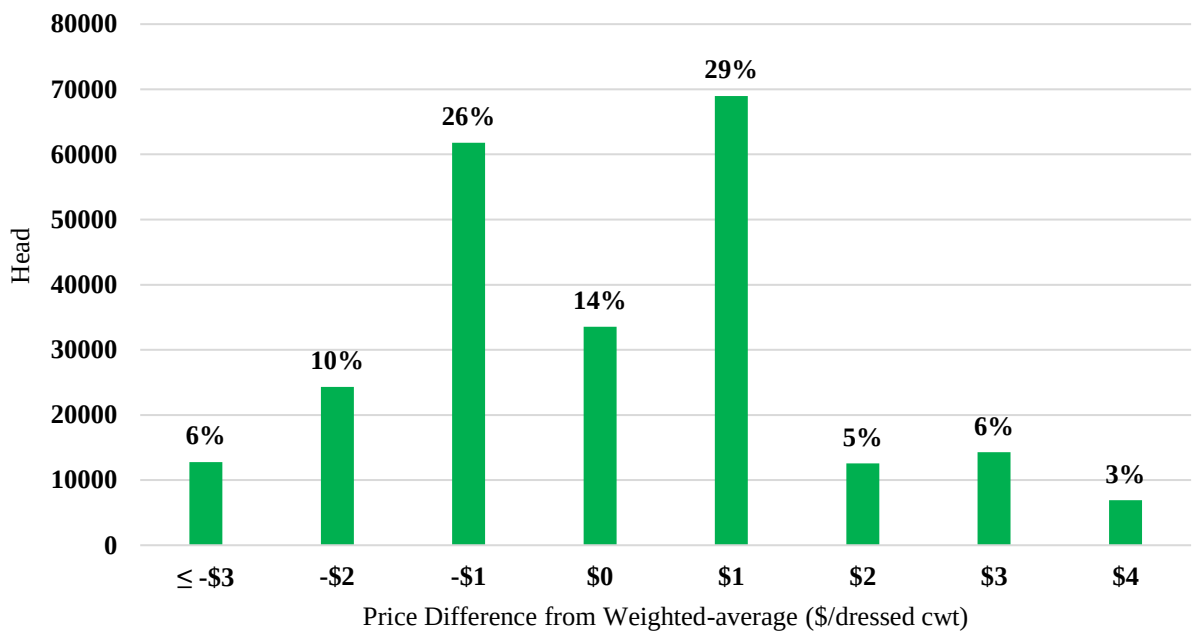
Figure 3. Comparison of Weekly Weighted-Average Base and Net Prices for Dressed Steers and Heifers Marketed on Formula, 2016-2021



Data Source: USDA AMS as archived by LMIC

Formula net prices are all dressed sales of steers and heifers reported in a given week for each formula transaction, 2016 - 2021.

Figure 4. Distribution of Dressed Formula Base Cattle Prices, Week of June 14-18, 2021 (Wtd. Avg. Base Price: \$189.95/cwt)



Chapter 5 - Results

5.1 Goodness-of-Fit Summary Statistics

Weekly model goodness-of-fit summary statistics are presented in Table 6. Modeling base price as a function of fixed plant effects alone explains 53% of base price variation on average while measures of RMSE indicate model predictions of base price deviate from observed sample values by \$1.87/cwt on average. Including cattle state of origin in weekly models contributes little to model explanatory power. Fixed origin effects explain an additional 2.1% of base price variation relative to effects of purchasing packer, and RMSE values decline only by \$0.04/cwt. Importance of fixed plant effects in describing price variability become more pronounced when they are removed entirely from equation (2). R-squared measures decline to just 0.30 while there is a marked increase in RMSE values from \$1.83/cwt on average, to \$2.31/cwt (over 25% increase). Equation (3) models price as a function of purchasing plant, cattle state of origin, and pen attributes, and as results indicate, yields the best results comparatively. Incorporating all available formula base transactions data in weekly hedonic models explains 59% of base price variation on average, while RMSE values suggest base price predictions deviate about \$1.76/cwt from actual reported base prices on average. When fixed plant effects are removed from equation (3), a story similar to that of equation (2) is observed. The average adjusted R-squared term drops from 0.59 to 0.41, while the average RMSE value increases from \$1.76/cwt to \$2.11/cwt (a nearly 20% increase). F-tests of joint significance of variables eliminated from the unrestricted model (equation (3)) indicate each variable group included in weekly hedonic models contains at least one independent variable that is statistically significant in describing base price variation. F-statistics and associated p-values for models removing either plant effects, cattle origin effects, and/or pen attributes relative to the unrestricted model were statistically significant at the 99%

confidence level. While we elaborate further in the following section, our findings provide valuable evidence to suggest key market information related to formula base purchases is not currently being collected under LMR.

Table 6. Average Weekly Model Goodness-of-Fit Summary Statistics for Formula Base Transactions (303 Total Weeks), 2016-2021

Variable Groups	Hedonic Equation	Variables Included	Adj. R-Squared	RMSE (\$/cwt)
(A) = Plant	(1)	$P = f(A)$	0.53	1.87
(B) = State of Origin	(2)	$P = f(A + B)$	0.55	1.83
(C) = Pen Attributes	(2) excl. plant	$P = f(B)$	0.30	2.31
	(3)	$P = f(A + B + C)$	0.59	1.76
	(3) excl. plant	$P = f(B + C)$	0.41	2.11

5.2 Fixed LMR Plant Effects

Summary statistics for fixed plant effects in weekly hedonic models are presented in Table 7. LMR plant coefficient estimates were combined to produce a distribution of base price differentials for 30 LMR plants across 303 weeks compared to the default plant (i.e., a distribution of base price differentials across time, not within a week). This step was taken for each of the three hedonic equations, extracting a range of base price differentials at the 15th and 85th percentiles as well as the standard deviation of estimates around the mean. Presenting base price variation on the basis of purchasing plant at the 15th and 85th percentiles provides a more representative depiction of the typical variation over time. This step additionally protects the confidentiality of individual base prices at the absolute minimum and maximum values. In estimating equation (1),

formula base prices paid by plants had differential range of \$6.50/cwt. Across the three hedonic equations, the 15th and 85th percentile range of base price differentials was about \$6.76/cwt. An important observation to note is the implication of including fixed state of origin and pen attribute effects in equations (2) and (3). LMR plant estimates at the 15th and 85th percentiles indicate as additional variables are included in the model, estimations of base price become less precise. The standard deviation of plant estimates increase by more than 20% from equation (1) to (2), and by about 15% from equation (1) to (3). This result brings us back to the argument for more detailed information regarding the types of reference prices being used in formula agreements (Peel et al. 2020). The type of formula used in a given transaction is omitted in our data, yet this information is likely strongly correlated with base prices paid by plants, and an important factor in describing variation in formula base prices within a week or across time. As such, hedonic models used in our analysis are likely miss-specified due omitted relevant variables. This leads to omitted variable bias in our model estimations and an overstatement of the effects of purchasing plant on variation in base prices. This is further evidenced by the fact standard deviations of plant estimates actually exceed the value of base price differentials at the 15th and 85th percentiles across equations (1) – (3). Relatively large measures of standard deviation imply substantial variation in plant estimates over time (Schroeder, Coffey & Tonsor 2022). This will be a recurring theme throughout our analysis as presence of omitted variable bias is made abundantly clear.

Table 7. Formula Base Coefficient Comparisons for Fixed LMR Processing Plant Effects in Weekly Models (Equations (1), (2), and (3); 15th/85th Percentiles and Standard Deviations are for 30 Plants Across 303 Weeks; One Plant as Default)

Hedonic Equation	15 th Percentile	85 th Percentile	Std Deviation
(1) Plant	-2.96	3.54	3.81
(2) Plant, Origin	-3.87	3.17	4.60
(3) Plant, Origin, Lot Attributes	-3.60	3.15	4.38

5.3 Fixed Cattle State of Origin Effects

Average coefficient estimates and standard deviations for cattle state of origin effects in weekly models are provided in Table 8 and Figure 5. Fixed origin effects exhibit a similar downward shift to that of plant effects when pen attribute variables are included from equation (2) to (3). Weekly average base prices paid on the basis of cattle state of origin compared to Texas ranged from \$1.33/cwt in equation (2), to \$1.25/cwt in equation (3). Northwestern states such as Washington, Oregon, and Idaho saw average base prices \$0.65/cwt, \$0.63/cwt, and \$0.53/cwt lower respectively across equations (2) and (3). This result likely reflects underlying variation in reference prices used from state-to-state. Nebraska and Iowa cattle received average base prices \$0.62/cwt and \$0.39/cwt higher respectively across equations (2) and (3), while base prices in Colorado and South Dakota averaged \$0.20/cwt and \$0.29/cwt higher in equation (2) only.

Presence of an LMR reporting plant in state of origin does not appear to substantially impact average base prices. Although plant estimates of base prices paid relative to the default are likely magnified, they remain within a range of about \$6.76/cwt across equations (1) – (3). This suggests base prices paid by plants do not exhibit any concerning level of variation and thus demonstrate no state/region-based biases. Furthermore, state of origin estimates provide no

evidence to suggest states containing at least one LMR reporting plant maintain any price advantages over remote states, especially considering the variation in estimates over time. Differences in average base prices cattle feeders received state-to-state are more likely a function of external reference prices used in the agreement, variation in local market fundamentals, and specific characteristics contained in a given transaction (live/dressed, delivered/FOB feedlot, etc.).

Table 8. Formula Base Coefficient Comparisons for Fixed State of Origin Effects in Weekly Models (Equations (2) and (3); Averages and Standard Deviations across 303 weeks; TX = default)

State of Origin	(2) Plant, Origin		(3) Plant, Origin, Pen Attributes	
	Avg Coefficient Estimate	Standard Deviation	Avg Coefficient Estimate	Standard Deviation
KS	-0.13	0.83	-0.23	0.74
TX	BASE	BASE	BASE	BASE
NE	0.74	1.18	0.49	1.04
CO	0.20	1.27	-0.01	1.11
OK	-0.28	0.82	-0.32	0.72
IA	0.58	1.21	0.20	1.05
ID	-0.44	2.46	-0.61	2.21
SD	0.29	1.46	-0.15	1.26
OR	-0.59	2.82	-0.67	2.69
WA	-0.53	2.98	-0.76	2.78

Figure 5. Average Variation in Formula Base Prices Across Top 10 Fed Cattle States by Head Marketed on Formula, 2016-2021 (Equations (2) and (3); Average coefficient estimates across 303 weeks; TX = default)

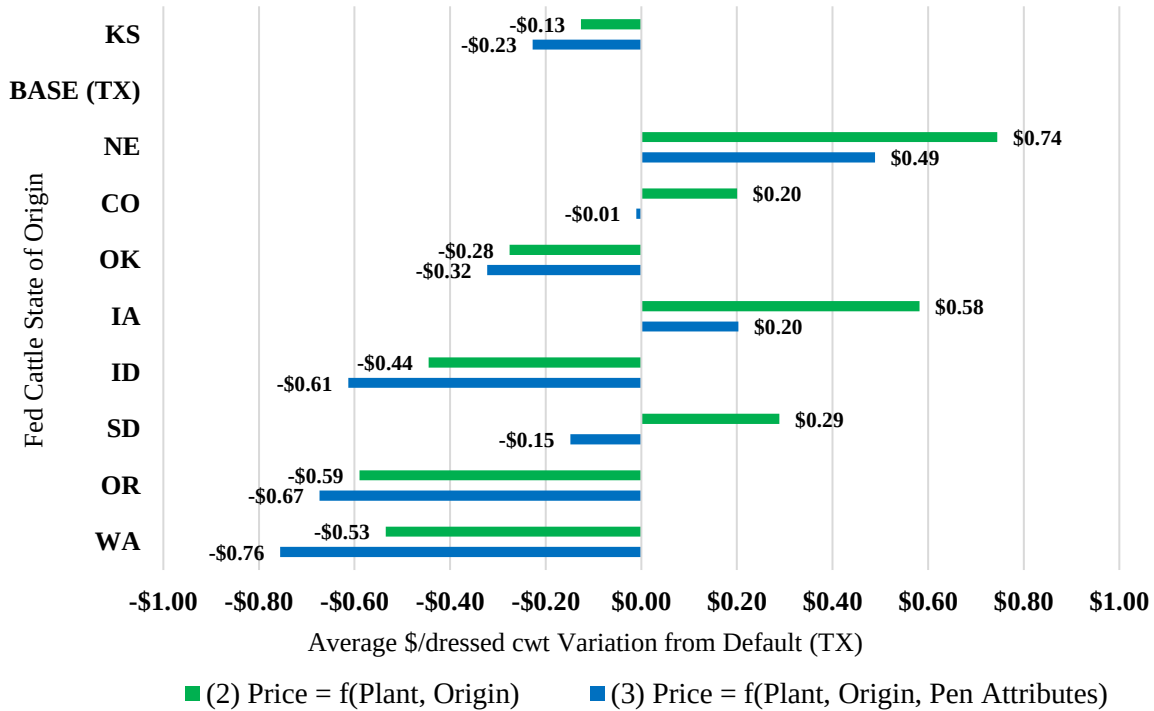
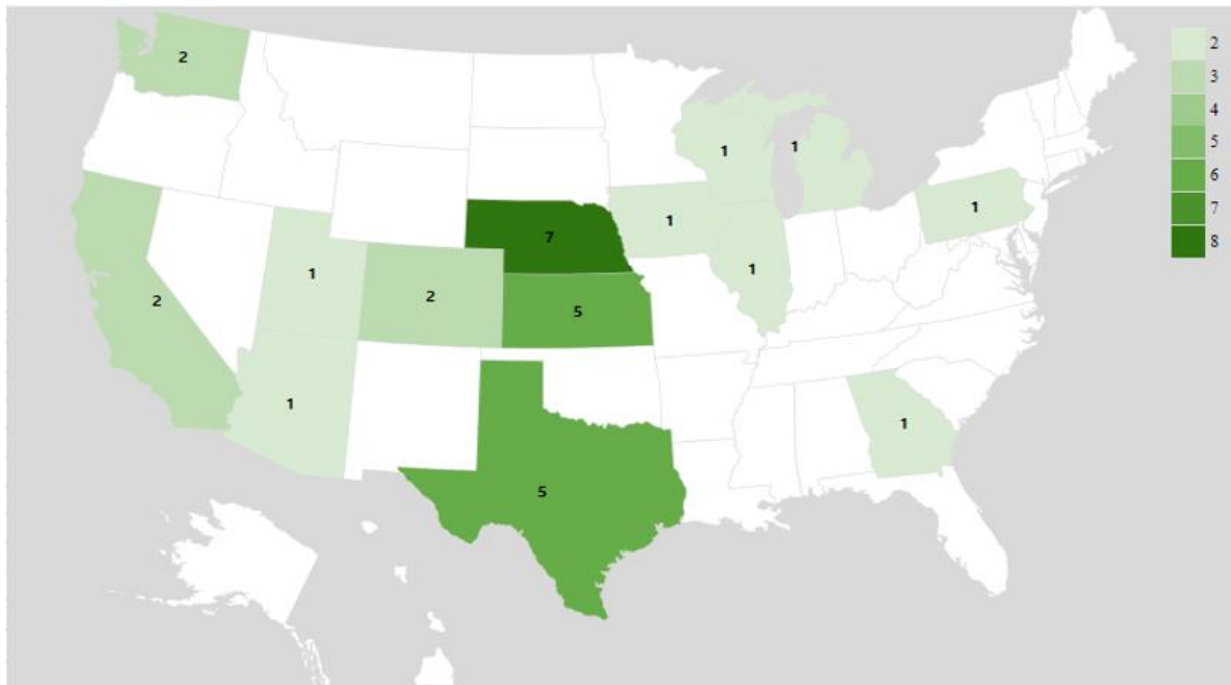


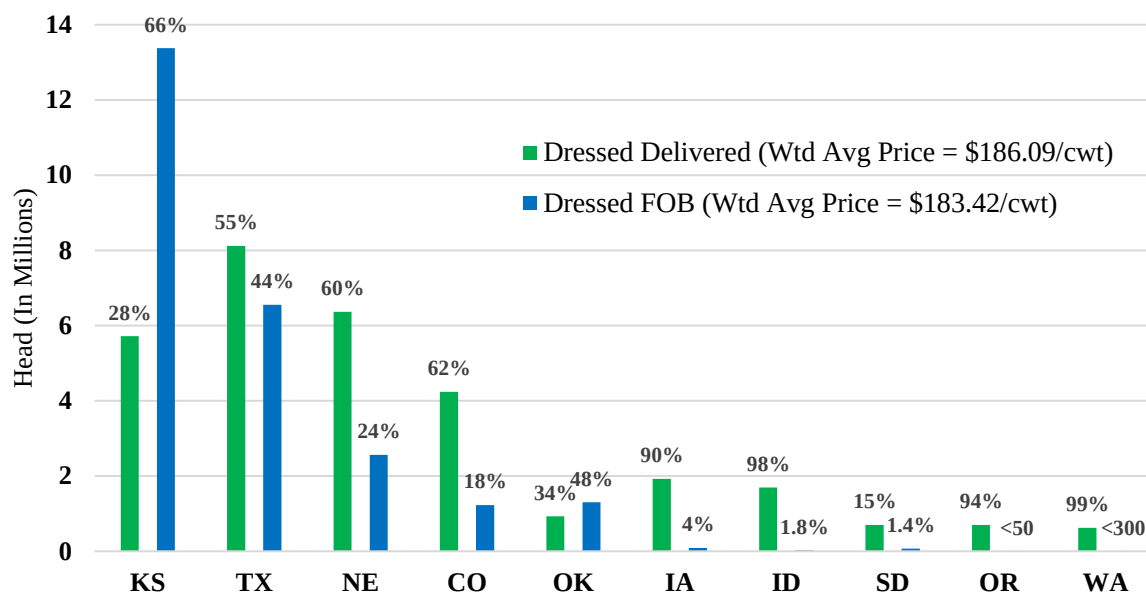
Figure 6. LMR Plant Locations Reporting Formula Base Prices Per U.S. State



One observable, and economically important aspect of the transaction appears to be related to weight basis and delivery method of cattle committed for slaughter. For example, Kansas formula cattle received base prices about \$0.18/cwt less than Texas formula cattle on average across equations (2) and (3). Both of these states have five LMR reporting plants and have maintained similar cattle quality over time. One difference we see from Figure 7 is Kansas demonstrated a proclivity for dressed FOB feedlot transactions (over 65% of total formula transactions from 2016 – 2021; more than double that of TX dressed FOB transactions) which secured lower base prices on average. This is not to say that weight basis and delivery method alone explain the coefficient estimates for Kansas formula cattle, it is simply one contributing factor evidenced in our data. Results of pen attribute effects substantiate this finding, which we discuss in more detail in the following section.

Fixed state of origin effects, similar to fixed plant effects, likely misrepresent the true relationship between state of origin and formula base price variation due to biased coefficient estimates resulting from omitted relevant variables. Table 8 further illustrates standard deviations of coefficient estimates for origin effects surpass the value of average coefficient estimates in every case. Evidence suggests multiple factors are attributable to the variation in average base prices paid across cattle producing states; some of which are observable, while others remain unclear.

Figure 7. Top 10 Fed Cattle Producing States as Percentage of Total Head Marketed on Formula by Dressed Delivered and FOB Transactions, 2016-2021



5.4 Pen Attribute Effects

Average coefficient estimates and standard deviations for effects of pen attributes in weekly hedonic models are provided in Table 9. Percentage Choice measures had little impact on average base prices received in a given week, but do demonstrate a positive relationship with base price. Standard deviations of percent Choice estimates suggest this outcome is typical for formula base transactions in our model. A unit increase in dressing percentage was associated with a decrease in average base prices of \$0.25/cwt. Both measures of percent Choice and dressing percentage in our data evoke additional questions about the source of this information. Dressing percentage and percent Choice grading are likely not known at the time a base price is established. While we cannot be certain as to where these data points originate from, reported percent Choice and dressing percentage in a given formula transaction could be associated with a plant average base price, a reported USDA cash price, or derived from another unknown source.

Table 9 further demonstrates that formula base transactions designated as FOB feedlot saw base prices \$0.33/cwt lower than formula cattle who were delivered to the plant on average. However, standard deviations indicate substantial variation in FOB coefficient estimates over time. Binary head count variables compared to head counts of 100+ received base prices of \$0.05/cwt ($\text{head} \leq 50$) and \$0.10/cwt ($50 < \text{head} \leq 100$) lower on average. Binary weight estimates suggest formula base prices are mostly unaffected by average weight of the pen. The 800 – 900 lb. default (containing more than 55% of formula transactions from 2016-2021) received base prices \$0.06/cwt lower than average weights of less than 800 lbs., and \$0.10/cwt lower than average weights greater than 900 lbs. Mixed steer/heifer lots received base prices \$0.39/cwt higher than steer only lots on average. Steer and heifer specific lots exhibit little difference with heifers receiving only \$0.01/cwt higher than steers on average, but standard deviations of heifer estimates suggest this result tends to vary week-to-week. Coefficient estimates for mixed steer/heifer lots did not align with expectations as steer only lots were presumed to be favored. This result may also reflect differences in how formula cattle are transacted regionally (Schroeder, Coffey & Tonsor 2022). Estimates for live versus dressed cattle are difficult to interpret given the level of variation that occurs in live coefficients across time. The average coefficient estimate for live-weight transactions suggests that, on a \$/dressed cwt basis, formula base prices for live and dressed cattle only marginally differ on average (\$0.001/cwt). Again, live prices are adjusted to a dressed basis, the importance being we have a basis for comparison to observe variation across both live and dressed transactions. Measures of standard deviation for live-weight estimates indicate base prices for live and dressed cattle can vary significantly in any given week. We suspect this result reflects regional standards/preferences for specific delivery methods and likely varies from state-to-state.

Table 9. Formula Base Coefficient Comparisons for Pen Attributes in Weekly Hedonic Models (Equation (3); Averages and Standard Deviations across 303 weeks)

Variable	Avg Coefficient Estimate (\$/cwt)	Standard Deviation
Choice	0.006	0.011
Dressing	-0.25	0.21
FOB	-0.33	0.68
Head50	-0.05	0.33
Head100	-0.10	0.20
Weight1	0.06	0.21
Weight3	0.10	0.33
Heifer	0.01	0.24
Mixed	0.39	0.25
Live	-0.001	1.48

5.5 Simulated Hedonic Formulated Base Purchase Report

To demonstrate how hedonic modeling can be applied to provide a weekly summary of formula base prices, a simulated formula base purchase report for a week in September 2021, is presented in Table 10. To construct the report, formula base transactions for this week were estimated using hedonic equation (3), replacing binary *state* of origin variables with binary *region* of origin variables as defined in Table 4 above. This step was taken in order to provide market information for cattle feeders in states that fall outside of the top 10 cattle producing states as ranked by the number of head marketed on formula. Hedonic regression results for the aforementioned week have an adjusted R-squared of 0.80 and an RMSE value of \$1.54/cwt. A head-weighted-average base price was calculated for formula base transactions including TX-OK-NM steers, 80% Choice, dressed, and delivered to the packer (the reference pen). Base price

differentials are simply the coefficient estimate associated with a given transaction characteristic compared to the default. The coefficient estimate is added to/subtracted from the weighted-average base price to produce a specific attribute-adjusted base price.

Utilizing hedonic modeling to report formula base prices shows promise to improve upon currently reported weighted-average prices under LMR. Actual reported base price information is not being presented as a weighted-average base price is calculated by identifying only those transactions meeting the base pen criteria. Hedonic modeling of reported formula base prices also facilitates additional pricing transparency as producers are able to identify specific attributes associated with their respective herds to better understand how those attributes impact base prices in a given week. Furthermore, reporting base prices on the basis of region enables producers to gain additional insight into base price variability in differing cattle regions relative to the TX-OK-NM default.

Table 10. Simulated Formula Base Purchases Weekly Summary Using Hedonic Equation (3) for a Week in September 2021 (Equation (3); \$/dressed cwt)

<u>Transaction Variable</u>	<u>Base Price (\$/cwt)</u>	<u>Price Differential (\$/cwt)</u>	<u>Transaction Variable</u>	<u>Base Price (\$/cwt)</u>	<u>Price Differential (\$/cwt)</u>
% Choice			Lot Size		
90% or Higher	\$196.36	\$0.18	Head ≤ 50	\$195.92	(\$0.26)
80% or Higher	\$196.18	BASE	50 < Head ≤ 100	\$195.81	(\$0.37)
70% or Higher	\$196.00	(\$0.18)	Head > 100	\$196.18	BASE
60% or Higher	\$195.82	(\$0.36)	Average Weight		
50% or Higher	\$195.64	(\$0.54)	Weight < 800#	\$196.00	(\$0.18)
40% or Higher	\$195.46	(\$0.72)	800# ≤ Weight ≤ 900#	\$196.18	BASE
30% or Higher	\$195.28	(\$0.90)	Weight > 900#	\$196.59	\$0.41
Cattle Sex			Cattle Region		
Steer	\$196.18	BASE	TX-OK-NM	\$196.18	BASE
Heifer	\$196.16	(\$0.02)	KS	\$196.48	\$0.30
Mixed S/H	\$196.11	(\$0.07)	NE	\$197.43	\$1.25
Delivery Method			CO	\$196.92	\$0.74
Delivered	\$196.18	BASE	IA-MN-MO	\$197.20	\$1.02
FOB Feedlot	\$196.05	(\$0.13)	Eastern Corn Belt	\$196.23	\$0.05
Weight Basis			North Central	\$196.68	\$0.50
Live	\$196.30	\$0.12	Western	\$194.40	(\$1.78)
Dressed	\$196.18	BASE	Northeastern	\$193.58	(\$2.60)
			Southeastern	N/A	N/A

A comparison of estimated and actual distributions of formula base prices for the above week in September 2021 are provided in Figure 8. Binary weekday variables indicate that base prices moved higher by about \$0.54/cwt over the course of the week. To account for within-week variation, individual weekday coefficient estimates were used to adjust the corresponding weekday's price observations to the relative Monday price (the default weekday)¹⁷. The actual distribution of base prices for this week ranged from -\$9/cwt to \$7/cwt. Base prices less than or equal to -\$5/cwt below, as well as those between \$1-\$2/cwt, \$3-\$4/cwt, and \$6-\$7/cwt above the week's weighted-average base price were aggregated to maintain confidentiality of formula base transactions data. The estimated distribution of base prices using equation (3) with binary region of origin variables (opposed to binary state of origin variables used in the above analysis) had a range of about -\$4/cwt to \$2/cwt. The estimated range of weekly base prices was calculated by summing the largest price differences from the weighted-average price of the base pen for each transaction parameter (percent Choice or higher, cattle sex, etc.)¹⁸. The estimated range of base prices provided in Table 10 represent just over 70% of the week's formula base transactions. Base prices between \$3/cwt and \$7/cwt above the weighted-average base price represent about 27% of the week's formula base transactions, yet they are not accurately captured in Table 10. This result

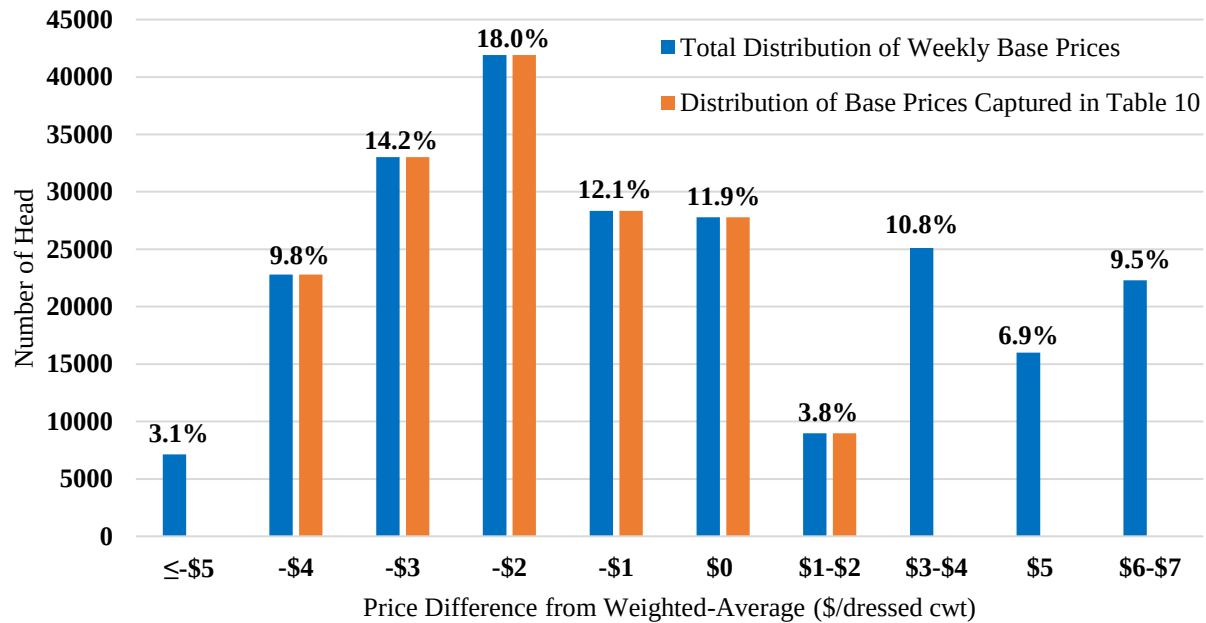
¹⁷ Ex. Binary weekday coefficient estimate for Tuesday = +1/cwt; This means that base prices moved \$1/cwt higher from Monday to Tuesday; Therefore, all base price observations that occurred on Tuesday are reduced by \$1/cwt to put Tuesday prices in terms of Monday prices.

¹⁸ Minimum base price for Table 10 is 30% Choice or higher, Mixed S/H, Dressed, FOB Feedlot, 50 < Head ≤ 100, Avg. Weight < 800#, Northeast Region = \$191.93/cwt; about \$4.25/cwt less than weighted-average price of the base pen.

Maximum base price for Table 10 is 90% Choice or higher, Steers, Live, Delivered, Head > 100, Avg. Weight > 900#, Nebraska Region = \$198.14/cwt; about \$1.96/cwt higher than the weighted-average price of the base pen.

further suggests that important fed cattle market information is likely omitted in our simulated formula base purchase report.

Figure 8. Comparison of Estimated and Actual Distribution of Formula Base Prices for a Week in September 2021 (Equation (3); Wtd. Avg. Base Price: \$196.93/cwt)



Chapter 6 - Conclusions

6.1 Summary of Results

Transparency, and the timely distribution of dependable market information are foundational characteristics of an efficient market. As market information evolves, so too should the mechanism through which that information is disseminated. LMR was implemented over 20 years ago to provide buyers and sellers of livestock in the United States with accessible and reliable market information. In the 20 years since LMR enactment, cattle and beef in particular have evolved from functioning as homogenous commodities to offering an expansive array of specialized and differentiated beef products. Increased use of formula marketing agreements over time have facilitated these industry shifts by effectively aligning the profitability of the cattle feeder with the demands of the end consumer. Consequently, new and different types of market information contained in formula agreements are also more expansive. LMR data collection and reporting practices for formula transactions still largely reflect an undifferentiated, and predominantly cash negotiated commodity.

Employing just under six years of formula base transactions data collected under LMR using the LP-113 form, this study illustrated how hedonic modeling can be applied to not only enhance fed cattle market transparency, but also to provide more useful and interpretable market information to decision makers extending beyond what currently reported weighted-average price ranges can provide. Results of this modeling exercise identify several economically important factors describing variation in base prices. Plant effects alone describe more than 50% of variation in base prices while fixed origin and pen attribute effects contribute little to model explanatory power. Coefficient estimates of LMR plant effects at the 15th and 85th percentiles indicate formula base prices paid by plants in the typical week do not substantially differ. Fixed origin effects

exhibit important differences in formula base prices paid from state-to-state in a given week and are likely underpinned by regional variation in reference prices, cattle quality, and transaction characteristics. Pen attribute estimates identify certain implicit base price values related to selling weight basis (live/dressed), delivery method (delivered/FOB feedlot), and sex of the pen (steer/heifer/mixed), though variation in estimates precludes determining the nature these relationships over time.

Results additionally reveal key weaknesses associated with current LMR data collection and reporting for formula base transactions. Existing data collected under LMR is inadequate and necessitates additional forms of market information that more accurately depict the type of cattle marketed on formula. Hedonic models used in our analysis likely suffer from omitted variable bias due to constraints of available data. We suspect omitted relevant variables represented in our error term (ε) are correlated with at least one, if not all of the independent variable groups included in our analysis (i.e., Zero-conditional mean assumption is violated; $E[\varepsilon | \text{Plant, Origin, Pen Attributes}] \neq 0$). This implies relative impacts of other confounding factors on base price variation are being attributed to independent variables included in our models, overstating their effects. Constraints of available data render average coefficient estimates of various formula transaction characteristics biased and unreliable.

Based on the results of our analyses, we suggest USDA AMS add new fields to the LP-113 form to capture the following formula base transaction data from qualifying beef packers :

- 1) The source of base prices being referenced in formula agreements (USDA national/area market cash price, plant average price, live cattle futures price, or wholesale beef price)
- 2) Formula base transactions that include:

- a. Cattle qualifying for specialty breed/branding programs (CAB, Wagyu, etc.)
- b. Cattle qualifying for specialty production programs (All Natural, NHTC, Grass-fed, etc.)
- c. Cattle that are process verified, age verified, or export certified

The source of base prices used in formula agreements likely vary across plants and cattle producing regions/states. This information is critical to obtaining a greater understanding of formula base prices and their associated variation both within a week, and across time. Access to base price source data will also facilitate future research analyzing how sources of base price impact differences in formula net prices across time (Peel et al. 2020; Schroeder, Coffey & Tonsor 2022). Data related to specific cattle programs are meant to supplement current pen attributes given factors such as expected quality and average weight may be impacted by the nature of the program (e.g., Grass-fed cattle may also be lighter weight on average; higher quality expectations associated with CAB). Important to identify here is whether premiums associated with various program cattle are even remotely realized in formula base prices, or if they are accounted for solely in the associated grid used in the agreement.

If the above formula base transaction data were to be collected from qualifying meatpackers moving forward, we expect it would provide important benefits to buyers and sellers of formula cattle in the long term. Plants purchasing formula cattle likely already collect these data and would therefore incur little to no additional cost to report this information (Schroeder, Coffey & Tonsor 2022). Furthermore, this study has demonstrated that, given the level of variation in the types of cattle marketed on formula, formula base price reports could be modified to provide a more refined understanding of variation in base prices within a week or across time. Whether or

not hedonic modeling is used to report formula base prices, the recommended formula base transaction data would improve overall formula cattle market transparency and facilitate additional forms of formula base price discovery by providing specific sources of base prices being used in formula agreements.

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