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Formula and Cash Negotiated Fed Cattle Price Relationships

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We examine the dynamic relationships between formula and negotiated cash prices using new fed cattle price distribution data. We estimate vector autoregressive models to determine the relationship between weighted average prices and weighted variances for negotiated and formula prices of fed cattle. Formula prices respond to negotiated cash prices, but not vice versa. We also find that formula price variances are impacted by the previous week's weighted variance of negotiated cash prices. This study is the first to explore how negotiated cash and formula prices' weighted variances (live and dressed) can influence the weighted variance of both price series.

Key words: fed cattle price, formula pricing, market information, price discovery

Introduction

Around the mid-2000s, fed cattle sold using formula pricing replaced negotiated cash trades as the predominant method for cattle sales (Schroeder, Tonsor, and Coffey 2019; Adjemian et al. 2016). Negotiated cash prices are discovered through a negotiated bid-ask process between beef packers and cattle feeders on the day of the sale, while formula pricing of fed cattle is an advanced commitment to sell cattle with the base price being adjusted through carcass quality price premiums and discounts. Negotiated cash prices are often assumed to be used in setting the base price for the formula prices (Schroeter and Azzam 2004; Ji and Chung 2012; Lee, Ward, and Brorsen 2012; Coffey, Pendell, and Tonsor 2019; Brester, Swanser, and Crosby 2022). The steady decline in the volume of fed cattle sold via negotiated cash markets has been a concern among market participants for decades because of implications for price discovery (Koontz and Ward 2011; Matthews et al. 2015).

The Livestock Mandatory Price Reporting (LMR) Act of 1999 requires packers to report transactional data, such as average prices paid, twice per day to the United States (US) Department of Agriculture (USDA). The USDA then publishes these data in various forms. Under LMR, the identity of reporting packers and their proprietary transactions are confidential if certain criteria are not achieved.[1] These restrictions can lead to transactions not being reported and appear to bind more frequently with the declining number of negotiated cash sales. Recently, the "Spot Market"

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[1] More on the "3/70/20" guidelines followed in LMPR, which restricts data aggregation, can be found at USDA Agricultural Marketing Service (2023a).

bill (S.3693) and The Cattle Market Transparency Act of 2021 (S.4647) were reintroduced, which would require US beef processing plants to increase purchases of fed cattle through the negotiated cash market. Supporters of these policies claim an increase in negotiated cash sales would improve price discovery by reversing the thinning market (i.e., a market with declining trade volume).

Price discovery studies focused on fed cattle typically seek to determine what information forms the market prices and how this information is transmitted from one market to another. Several studies have examined price discovery across regions and price series like futures and live cattle prices (Bailey and Brorsen 1985, 1989; Schroeder and Goodwin 1990; Goodwin and Schroeder 1991; Coffey, Pendell, and Tonsor 2019); however, little empirical work exists on the relationship between negotiated cash and formula pricing and how much the negotiated cash price informs the formula price. Lee, Ward, and Brorsen (2012) used Granger causality to show directional relationships between fed cattle prices. They found that changes in the negotiated cash prices impacted formula prices from 2001 to 2010. However, the thinning of negotiated cash sales has caused some producers and other market participants to question if negotiated cash sales still inform the base price for formula pricing (Brester, Swanser, and Crosby 2022).

The information previously reported by the LMR included average prices (which are weighted by the volume of head, weight, and quality groups), minimum prices, and maximum prices for the day. Thus, market participants did not know the fed cattle price distribution, but only certain price intervals and empirical moments for formula and negotiated cash sales. Sales that are recorded at or near the minimum or maximum could have heavier weights in calculating the average price. The average price is not necessarily representative of the central tendency for skewed distributions and such problems are exacerbated in a thinning market. Studies have found that an increase in price dispersion could be due to a lack of information by buyers or sellers participating in the market. Price distributions are important when understanding market efficiency and price discovery (Stigler 1961; Garbade and Silber 1976; Grossman and Stiglitz 1980; Tomek 1980). Therefore, recent studies have demonstrated a need for more detailed data on the distribution of prices (Tonsor 2021; Boyer et al. 2023; Rogers et al. 2023; Schroeder, Tonsor, and Coffey 2023) to better understand price variability and market efficiency in the fed cattle market. Rogers et al. (2023) used a confidential formula base price and negotiated cash price series for fed cattle to explore price transparency, but to our knowledge, no study has explored if price variability in the negotiated cash market impacts the price variability in the formula market.

In August 2021, the USDA announced a new weekly market news report that would show US weekly cattle price distributions using price bins (LM_CT215). These new data show the price of cattle purchased at different levels of pricing within negotiated cash, net formula, net forward contract, and negotiated grid nets by two-dollar intervals. Figure 1 shows an example of how these weekly data are reported. These data allow for a novel analysis of how price variability is transmitted between negotiated cash prices and formula prices, as well as across weeks, providing insight into fed cattle market price discovery and the relationship between negotiated cash and formula prices.

This study examines the dynamic relationships between the average formula and negotiated cash prices (for live and dressed cattle) and price variances using these newly released distributional data. Specifically, we use vector autoregressive (VAR) models to explore the relationship between the weighted average price and a weighted average price variance between the two series. This study makes several contributions to the literature on cattle price relationships. First, this analysis addresses recent concerns about negotiated cash prices being associated with formula prices (Brester, Swanser, and Crosby 2022). This study is also the first to explore how negotiated cash and formula prices weighted variances (live and dressed) can influence the weighted variance of both price series. Lastly, the continuation of research on price discovery and market efficiency of fed cattle prices is continuously evolving, complex, and dynamic. It remains a key concern for market participants. This study builds on previous research and provides insight into the usefulness of more detailed data in assessing price discovery in the fed cattle markets.

LIVE BASIS DISTRIBUTION				
$2 Distribution Groups [1]	Negotiated	Formula Net	Forward Contract Net	Negotiated Grid Net
-30			159	
-28			80	
-26			80	
-24			68	
-22			35	
-14			291	
-12				144
-10		235		71
-8		2,582	19	901
-6	48	2,383	50	1,003
-4	12,827	1,001		1,220
-2	1,571	5,632		2,869
Live Wtd Avg	**$182.62**	**$185.25**	**$182.89**	**$185.25**
2	18,138	6,035		2,066
4	7,183	962	245	2,668
6	372	988	163	911
8	104		296	751
10			405	98
12			199	
16		236		
18		350	349	
20		349		
22		411		
24		36		
28		39		

Figure 1. Snapshot of Data Reported in USDA National Weekly Direct Beef Type Price Distribution (LM_CT215)

Data

This study uses data from a newly released USDA report National Weekly Direct Beef Type Price Distribution (LM_CT215) from August 10, 2021, to May 14, 2024. This report includes the weighted average price and head for live and dressed cattle that were sold negotiated cash, net formula, net forward contract, and negotiated grid net. The report also shows the volume of head sold, by two-dollar increments, which gives data to approximate a distribution. These data are reported weekly ending on a Monday; thus, prices are reported from Tuesday to Tuesday. The data are submitted by packers who meet the LMR threshold of 125,000 head harvested per year. We chose to only use negotiated cash and formula prices (live and dressed) in the analysis because these sale types account for 79% of all live fed cattle trades and 88% of all dressed fed cattle trades. In terms of volume of head sold, the data include 8,483,625 head sold live with negotiated cash sale, and 3,846,342 head sold live with formula. Dressed cattle volume was 3,131,878 head sold with negotiated cash, and 32,306,728 head sold with formula pricing. Most of the head accounted for in these data were traded formula (or 76%) with 89% of these trades being dressed. Most of the negotiated cash trades were live sales (73%).

In negotiated cash sales, cattle are delivered in 14 days or less after a price is agreed upon, while the delivery date of formula sales is 14 days or more after the price is agreed upon (Schroeter and Azzam 2004; Ward 2005; Ji and Chung 2012; Schroeder, Coffey, and Tonsor 2021).

Table 1. Summary Statistics of the Weekly Live and Dressed Fed Cattle Price from August 10, 2021, to May 14, 2024 (n = 145)

Price	Mean	Standard Deviation	Minimum	Maximum
Negotiated Cash Live	$158.29	20.92	$122.69	$189.63
Formula Live	$160.02	21.28	$123.24	$192.56
Negotiated Cash Dressed	$252.03	33.07	$195.20	$302.08
Formula Dressed	$253.03	33.20	$195.91	$302.15

Source USDA report National Weekly Direct Beef Type Price Distribution (LM_CT215)

Therefore, formula price and volumes are reported to LMR once the cattle have been harvested and all premiums and discounts applied. Negotiated cash transactions are reported once the trade is agreed to by the packer and producer since no premiums or discounts are applied to these prices.

Table 1 shows the summary statistics of the weighted average price of cattle sold during this period for the two types (formula and negotiated cash) and basis (live and dressed). Dressed cattle mean payment is based on carcass weight after slaughter (USDA Agricultural Marketing Service 2023b). Live cattle prices are for cattle purchased on a live basis where the purchaser pays the transportation costs. Live prices are lower than dressed price, which is expected based on additional implied costs. Formula prices were, on average, slightly higher than negotiated cash prices for both live and dressed cattle. The standard deviations for negotiated cash and formula prices were similar for both series.

Figures 2 and 3 show the negotiated cash and formula prices over time. Both price series are similar in the upward trend in prices over this period and they move relatively closely. Weighted variance is also shown for each price series. The weekly weighted variance was found by squaring the price deviations, which are in two-dollar increments (refer to figure 1), from the weekly weighted average price and summing across all price deviations from the weekly weighted average for each week. We then multiply by the head sold at each two-dollar price deviation by week. This is divided by the total head sold each week. This weekly weighted variance is mathematically defined as

$$PV_t = \sum_d^D (A_t - D_{td})^2 \times V_{td} \,/\, \sum_d^D V_{td} \tag{1}$$

where PV_t is the weekly price variance in time t ($t = 1,\ldots,T$); A_t is the weekly weighted average price (\$/cwt); D_{td} is the weekly price deviation from the weekly weighted average price (\$/cwt) for each two-dollar increment d; and V_{td} is the total head sold at each two-dollar increment from the weighted average price. This calculation returns a weekly weighted variance for each price series. The weekly weighted variance is the dependent variable in the variance model. Formula traded cattle had the highest weighted variance, compared to negotiated cash, with formula dressed being the highest. Rogers et al. (2023) also reported that formula prices have more variability than negotiated cash price series.

Methods

In what follows, we first examine properties of the time series data, in line with much of the existing literature on price transmission (von Cramon-Taubadel and Goodwin 2021). Of primary interest are stationarity and cointegration, which serve as building blocks for more complicated statistical models. The standard test for stationarity of a time series is the augmented Dickey-

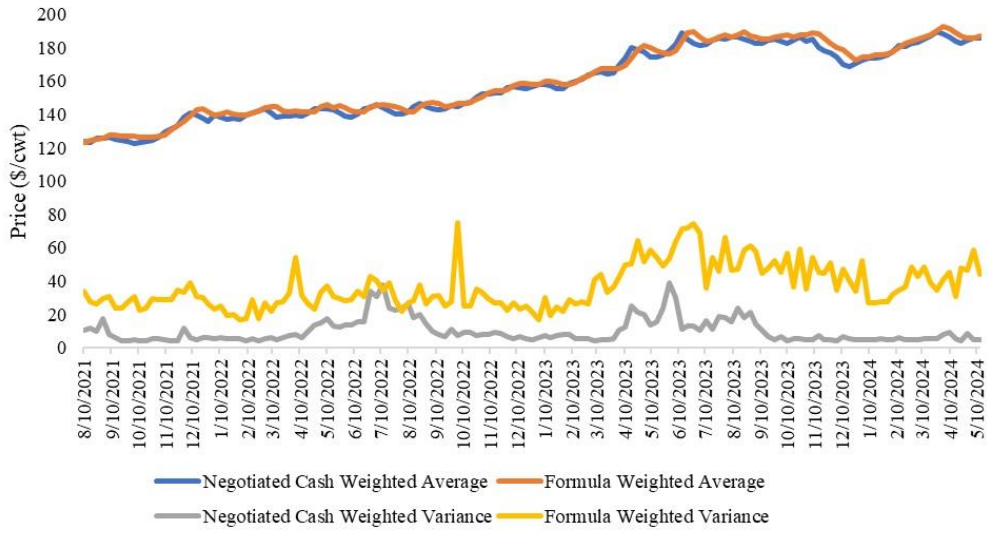


Figure 2. Weighted Average Price and Weighted variance ($/cwt) of Live Fed Cattle Prices Sold by Negotiated Cash and Formula Sales from August 10, 2021, to May 14, 2024.

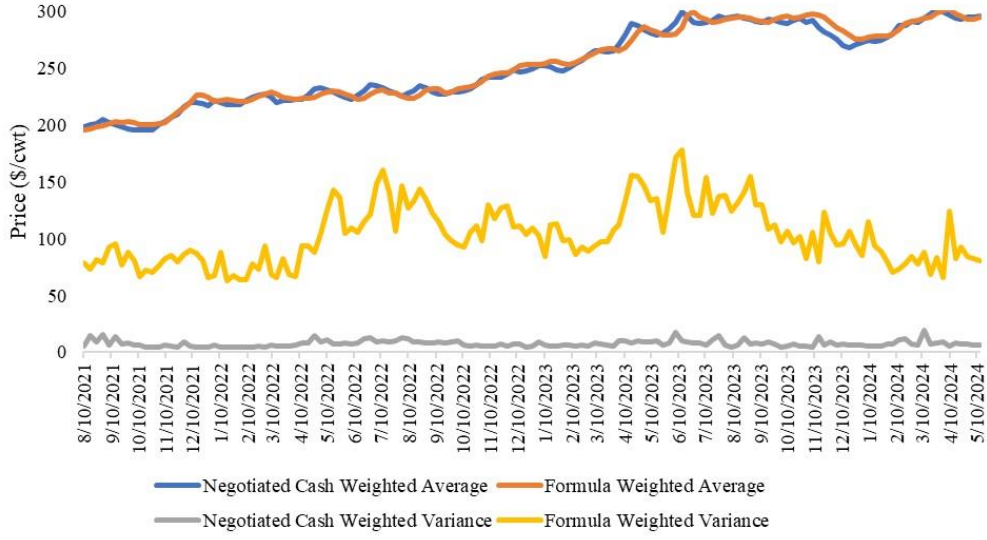


Figure 3. Weighted Average Price and Weighted variance ($/cwt) of Dressed Fed Cattle Prices Sold by Negotiated Cash and Formula Sales from August 10, 2021, to May 14, 2024.

Fuller test, which requires selection of the number of lags and can suffer from low power (Dickey and Fuller 1979; Schwert 2002). In addition to the augmented Dickey-Fuller test, we also implement the test developed by Ng and Perron (2001). Both augmented Dickey-Fuller test and Ng and Perron test results on the price series fail to reject the existence of a unit root for the weighted average price and weighted average variance. Therefore, we converted the price series to log-return process.[2] Returns were found to be stationary.

We subsequently conduct an analysis to determine if there is cointegration within the price series using the Johansen cointegration test (Johansen, 1991). Cointegration concerns the long-run relationship governing the variables. If the variables are cointegrated, then they can be described by

$$y_t = \alpha + \beta x_t + v_t \tag{2}$$

with $v_t = \phi v_{t-k} + \epsilon_t$, where y_t and x_t are the two potentially cointegrated variables.

The variables are cointegrated if the error correction term meets certain conditions. The basic idea is that the variables must move together in the long-run if they are cointegrated, but they can diverge in the short-run. In our analysis, this concept is particularly relevant when examining the relationship between negotiated and formula prices. We anticipate a cointegrating association in the pricing of the negotiated cash and formula cattle markets. This expectation is based on the belief that if cash prices form the foundation for formula pricing, significant and sustained deviations between the two are unlikely. Such disparities would typically prompt arbitrage activities, leading to a market correction that realigns the formula prices with the cash prices. The Johansen tests indicated that the price series are cointegrated. Consequently, our analysis shifts to examining the short-term dynamics of these prices and variances.

The short-run dynamics of the cash and formula prices and their variances are assessed through VAR[3]. The basic VAR is given by

$$y_t = C + \beta_1 y_{t-1} + \cdots + \beta_p y_{t-p} + \epsilon_t \tag{3}$$

where y_t is a vector for the variables of interest (returns for the two-price and their variances) and the VAR itself is of order p, which is determined based on goodness-of-fit as well as the empirical features of the dataset. The error terms, ϵ_t, are mean zero, have a covariance matrix that is positive semi-definite, and there is no serial correlation. The parameters of the VAR describe how past shocks to variables are transmitted to contemporaneous values of those same variables.

Because the VAR is a potentially complicated system of multiple equations, the impacts of shocks to the variables are best assessed using impulse response functions. Impulse response functions can be plotted to visually portray the impact of a single shock through the VAR system. We consider orthogonal impulse responses. The orthogonal impulse response is generated by decomposing the variance-covariance matrix of the VAR and allows for the investigation of contemporaneous shocks or impulses. Error bands around the impulse responses are generated using bootstrapping. Our analysis estimates the VAR based on the returns from two different price series and their variances. By doing this, we gain insight into the immediate reactions of the price series when subjected to shocks from the other variables in the system.

[2] This was done after the weighted average variance was calculated as discussed in the data section.

[3] We also considered the suitability of a Threshold VAR model and selected its optimal threshold using the Akaike Information Criterion (AIC). However, our findings revealed that the chosen optimal threshold was excessively high, in most cases, resulting in noisy impulse response calculations for the high regime due to limited observations. Moreover, the lower-regime outcomes closely resembled those of the simple VAR model. Consequently, we opted to employ the simple VAR model for our analysis.

Table 2. Estimated Parameters for Weekly Weighted Average Fed Cattle Price by Formula and Negotiated Cash Sales and by Dressed and Live from August 10, 2021, to May 14, 2024 (n = 145)

Parameter	Live		Dressed	
	Negotiated Cash	Formula	Negotiated Cash	Formula
Intercept	0.002*	0.000	0.002*	0.000
NC_{t-1}	0.373***	0.440***	0.496***	0.474***
FM_{t-1}	0.267	0.256**	-0.384	0.148
NC_{t-2}	-0.117	0.221***	0.169	0.366***
FM_{t-2}	-0.211	-0.223**	0.171	0.152*
NC_{t-3}	-0.236*	0.071	-0.185	-0.151*
FM_{t-3}	0.176	-0.017	-0.003	-0.074

Note: Single, double, and triple asterisks (*, **, and ***) represent significance at the 5%, 1%, and 0.1% levels. NC denotes negotiated cash price and FM denotes formula prices.

Results

Table 2 shows estimated parameters for the average fed cattle price series. Cattle traded via live negotiated cash price were positively impacted by last week's live negotiated cash price (0.1% level) and negatively impacted by the live negotiated cash prices from three periods ago (5% level). Lee, Ward, and Brorsen (2012) found negotiated cash prices of fed cattle were not impacted by formula pricing, which aligns with our findings. Dressed negotiated cash cattle sales were also positively impacted by last week's dressed negotiated cash price (0.1% level). For both price series, the previous week's prices had a positive impact on the price.

Live formula prices were significantly impacted by all previous week's live prices. The previous two weeks' live negotiated cash price positively impacted the live formula price (0.1% level). That is, a higher live negotiated cash price in the previous two weeks had a positive impact on the live formula price in the given week. Interestingly, the previous week's live formula had a positive impact in the given week's formula price (0.1% level), but the two-week lag (1% level) price negatively impacted the live formula price in the given week. The live formula price was not impacted by the prices three periods ago. The dressed formula price this week was also positively impacted by the previous weeks dressed negotiated cash price and the dressed negotiated cash price from two weeks prior (0.1% level). The dressed negotiated price from three weeks prior negatively impacts the dressed formula price in the current week (5% level). Dressed cattle formula prices in previous weeks do not impact this week's dressed formula price, which is different from the live cattle formula prices. As noted in the data section, most of the cattle represented in these data were sold using formula pricing as dressed. Therefore, the results for the dressed formula prices likely are more reflective of formula price impacts than the live formula prices.

Lee, Ward, and Brorsen (2012) found that negotiated cash prices impacted formula prices from 2001 to 2010. While the negotiated cash market has gotten thinner, these prices still influence the formula price today. This suggests the formula market is still relying on negotiated cash prices as a base price, and that the directional change of negotiated cash price for two weeks prior to the given week results in the same directional impact on formula prices. Formula prices are not just impacted by cash prices from two weeks ago, but also by the previous week and three-week lagged price (for dressed cattle), which matches with reporting lags in the data and the structure of the sales (Schroeter and Azzam 2004; Ward 2005; Ji and Chung 2012; Schroeder, Coffey, and Tonsor 2021).

Table 3. Estimated Parameters for Weekly Weighted Variance Fed Cattle Price by Formula and Negotiated Cash Sales and by Dressed and Live from August 10, 2021, to May 14, 2024 (n = 145)

	Live		Dressed	
Parameter	**Negotiated Cash**	**Formula**	**Negotiated Cash**	**Formula**
Intercept	-0.002	0.009	-0.008	-0.001
NC_{t-1}	-0.189*	0.128*	-0.573***	0.088*
FM_{t-1}	-0.028	-0.622***	0.286	-0.486***
NC_{t-2}	-0.037	0.063	-0.436***	0.094*
FM_{t-2}	-0.180	-0.199*	0.008	-0.158
NC_{t-3}	-0.024	0.051	-0.240**	0.036
FM_{t-3}	-0.019	-0.077	0.155	-0.109

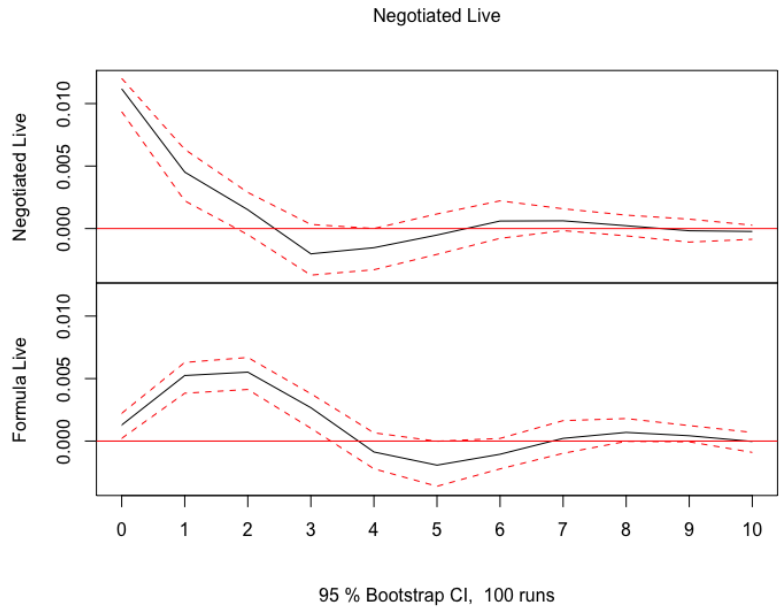
Note: Single, double, and triple asterisks (*, **, and ***) represent significance at the 5%, 1%, and 0.1% levels. NC denotes negotiated cash price and FM denotes formula prices.

Figure 4 shows the impulse response function for the live weighted average negotiated cash and formula prices. The figures show that a shock to negotiated cash prices results in formula prices increasing for two weeks and then the prices begin declining. For three weeks, a positive shock to live negotiated cash prices increases formula prices. However, a positive shock in live formula prices has no impact on the live negotiated cash prices. A similar pattern is found for dressed cattle prices in Figure 5. A positive shock to dressed negotiated cash prices effects dressed formula prices to increase for two weeks before returning to normal levels, and a shock to formula price has no significant impact on negotiated cash prices.

Table 3 presents the outcomes of the weighted variance model. It indicates that for live negotiated cash prices, constituting 73% of all negotiated cash transactions, the weighted variance in the specified week was only negatively impacted by the previous week's weighted variances (5% level). Regarding dressed negotiated cash prices, the weighted variance in a given period is impacted by the weighted variance in the previous three weeks. All three coefficients were negative (1% level) meaning a higher weighted variance in the previous weeks reduces the weighted variances for these prices in the given week. Additionally, the analysis reveals that the variability in formula prices does not affect the variance in negotiated cash prices for both live and dressed categories.

The analysis of live formula prices' variances demonstrates that changes in the previous week's weighted variance of live negotiated cash prices negatively affect the current week's weighted variance in live formula prices (0.1% level). This implies that greater variance in live negotiated cash prices leads to a decrease in the variation of live formula prices in the subsequent week. The weighted variance two weeks prior for live formula prices was also had a similar effect on the given weeks weighted variance of live formula prices. Interestingly, the weighted variance of live negotiated cash prices in the prior period positively impacts the weighted variance of the live formula price (5% level), meaning more variance in the negotiated cash live prices results in more variance in the live formula price.

Similarly, for dressed formula prices, it was observed that changes in the previous week's weighted variance of dressed negotiated cash price had a positive effect on the current week's weighted variance of dressed formula prices (5%% level). For dressed formula price, the two-week prior weighted variance of dressed negotiated cash prices also had a positive effect on the current week's weighted variance of dressed formula prices (5% level). These findings suggest that the market conveys more than just average price effects from week to week. Specifically, the results indicate that the weighted variance in formula prices is influenced by the variance changes



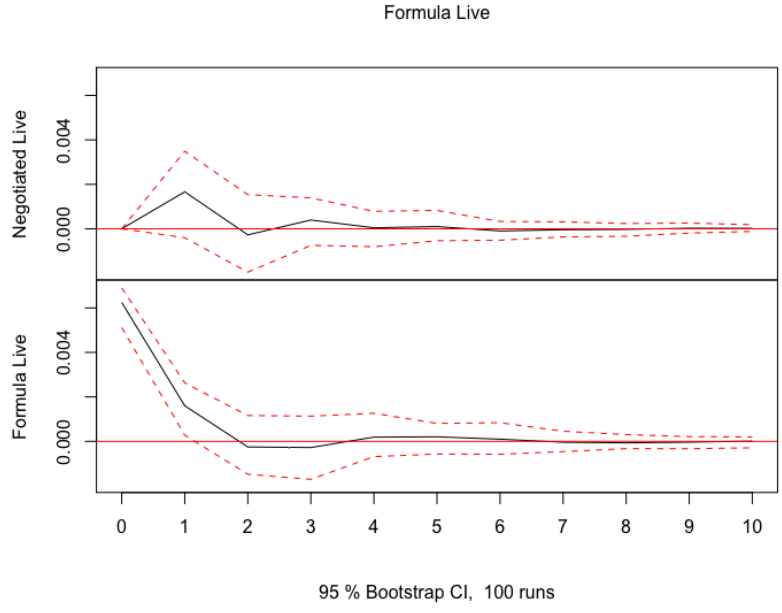


Figure 4. Impulse response to the shock from Negotiated live (above) and Formula live (below) Weighted Average Price

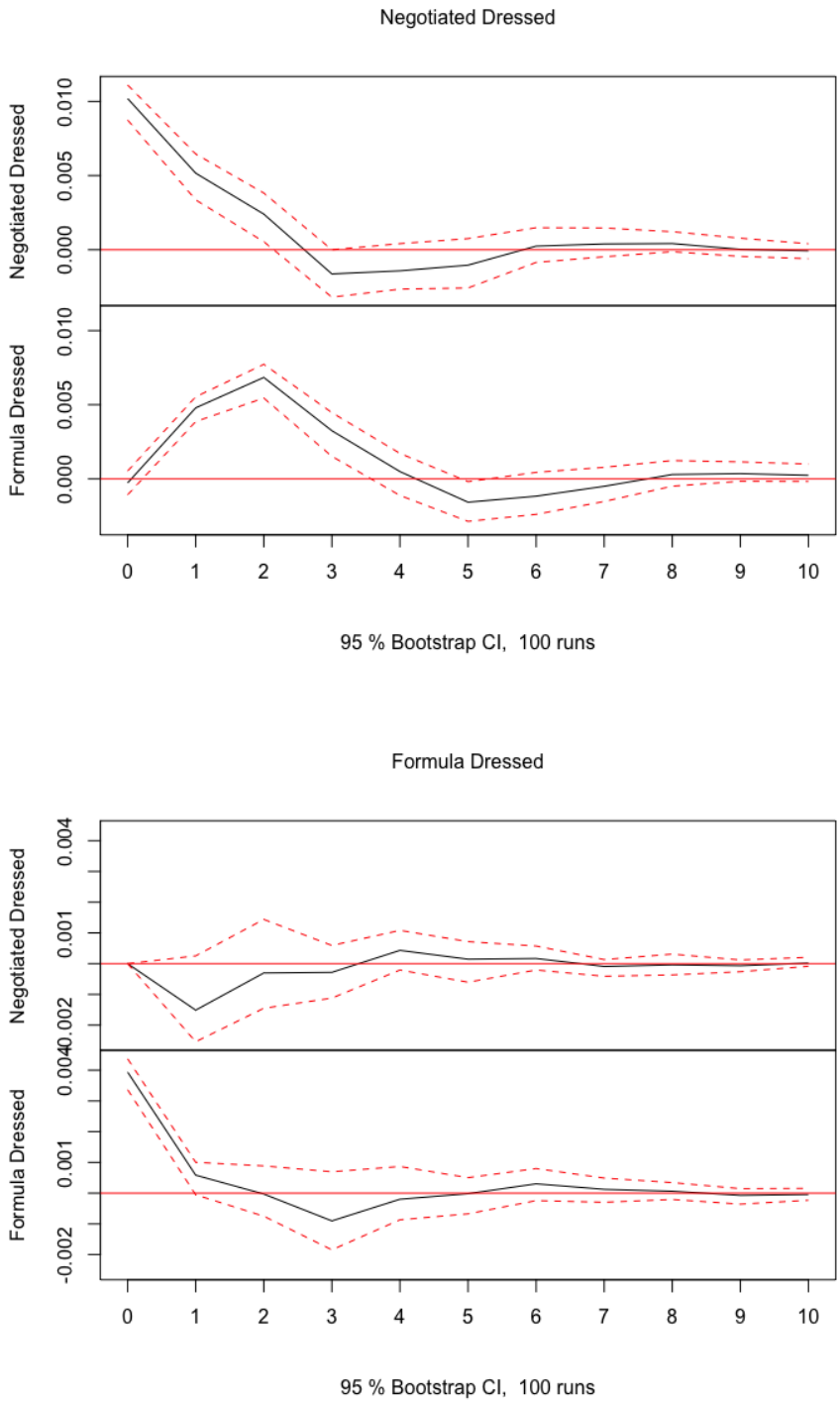


Figure 5. Impulse response to the shock from Negotiated Dressed (above) and Formula Dressed (below) Weighted Average Price

in negotiated cash prices and more variance in the negotiated cash prices results in more variance in formula pricing.

Figure 6 displays the impulse response function related to the adjusted weighted variance of both negotiated cash and formula live prices. The figure illustrates that a positive shock in the weighted variance of negotiated cash prices leads to an increase (for one week) in the weighted variance of live formula prices, while simultaneously causing a decline in the variance of negotiated cash prices. Conversely, a positive shock in the weighted variance of live formula prices appears to have no effect on the weighted variance of live negotiated cash prices, yet it does result in a decrease in the variance of formula prices.

Figure 7 shows similar shocks, but for dressed weighted variance prices. A positive shock in the weighted variance of negotiated cash prices has a negative effect on the weighted variance of negotiated cash prices after approximately two weeks. However, it does not influence the weighted variance of formula prices. Conversely, a disturbance in the weighted variance of formula prices does not affect the weighted variance of negotiated cash prices, but it does have an impact on the variance of formula prices. These findings indicate that price variability is more significantly transmitted from negotiated cash prices to formula prices when the product is sold live rather than dressed.

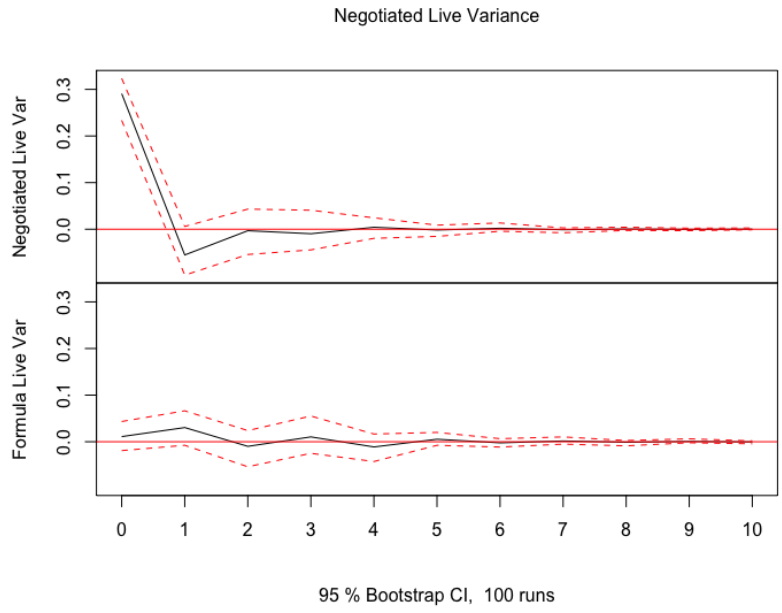
Conclusions

A key question for researchers and market participants is whether the thinning of cash-negotiated sales has influenced price discovery in the fed cattle market. Several studies have analyzed the relationship between the cash negotiated sale and formula pricing and how this relationship might change with different market information. We take a unique approach to understand how the fed cattle prices interact with each other. This approach is possible due to the improved information on prices that is now being collected by USDA. Specifically, we estimate VAR models to determine the relationship between weighted average price and weighted variance for negotiated and formula prices of fed cattle. We use newly available distributional data to examine dynamic relationships between formula and negotiated cash prices.

Results show that the negotiated cash price impacts the setting of formula prices; this observation is in-line with anecdotal evidence. As expected, the impact is from lagged negotiated prices to formula prices. This effect has important implications around concerns that the negotiated cash market is too thin and does not provide marketing information for formula prices. The negotiated cash price is strongly impacted by its own previous week's prices, while formula prices are impacted by both the previous week's negotiated cash and formula prices. The live formula price variances are also impacted by the previous week's weighted variance of negotiated cash prices. Thus, there was no evidence to support the conclusion that negotiated cash price variance is being transmitted to formula price variability.

This study is the first to explore how negotiated cash and formula prices' weighted variances (live and dressed) can influence the weighted variance of both price series. Studies have shown the relationship between the average price of these two-price series but not the price variances. This paper also has limitations. It should be noted that this study was conducted during a timeframe when fed cattle prices were steadily increasing to prices not seen in the past 10 years. The results could differ in times of declining prices during the cattle cycle. Also, the data are observed during a period when processing capacity is relatively limited (Martinez et al. 2023) and the industry has experienced a herd liquidation.

Thus, future research with this new dataset should analyze how prices interact and/or change during steady to lower prices. Also, the data do not provide any information about the quality or characteristics of the cattle sold as well as the associated changes in weekly quality premium and discounts. That means we cannot control for various quality grades and locations, which is another major limitation of the study. Furthermore, the interaction of these two-price series and their



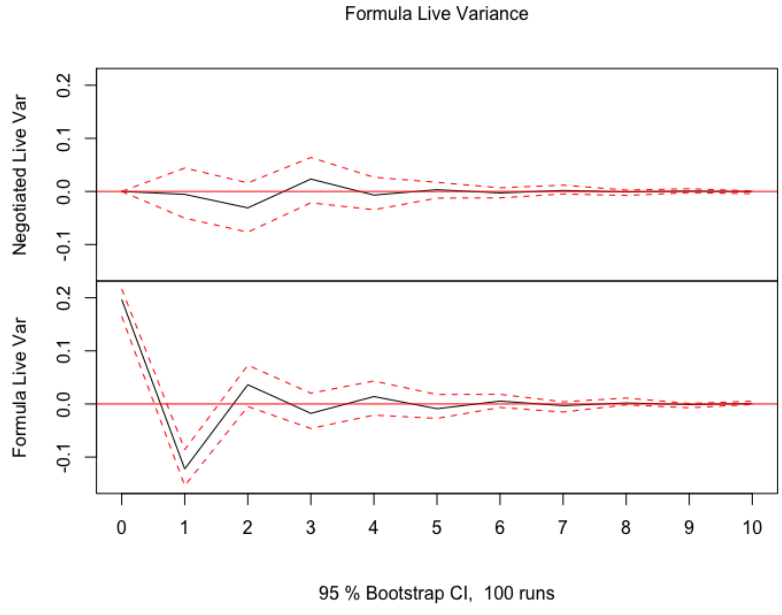


Figure 6. Impulse response to the shock from Negotiated Live Weighted Variance (above) and Formula live Weighted Variance (below).

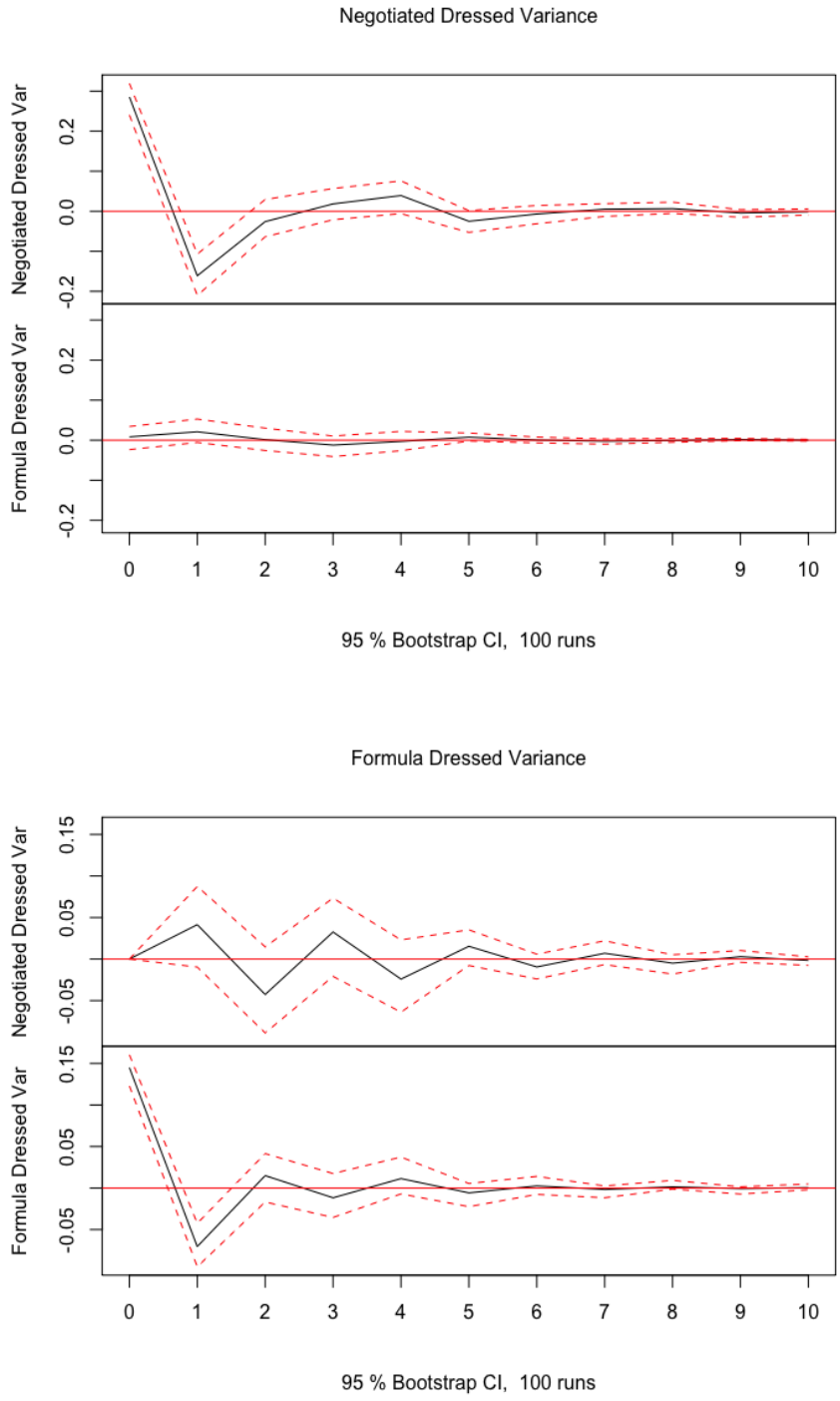


Figure 7. Impulse response to the shock from Negotiated Dressed Weighted Variance (above) and Formula Dressed Weighted Variance (below).

weighted variance with the differing quality of wholesale box beef prices would be interesting to explore in future research. This could give insight into how beef quality might be connected to sales methods. Such information would be helpful to estimate more precise price distributions for fed cattle.

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