The World's Largest Open Access Agricultural & Applied Economics Digital Library

This document is discoverable and free to researchers across the globe due to the work of AgEcon Search.

Help ensure our sustainability.

Give to AgEcon Search

AgEcon Search
http://ageconsearch.umn.edu
aesearch@umn.edu

*Papers downloaded from **AgEcon Search** may be used for non-commercial purposes and personal study only. No other use, including posting to another Internet site, is permitted without permission from the copyright owner (not AgEcon Search), or as allowed under the provisions of Fair Use, U.S. Copyright Act, Title 17 U.S.C.*

NCCC - 134
APPLIED COMMODITY PRICE ANALYSIS, FORECASTING AND MARKET RISK MANAGEMENT

Correlations Go to One in a Crisis: Did the COVID 19 Market Crash Bring Cattle Futures and Equities Together?

by

Eli Mefford and Mindy Mallory

Suggested citation format:
Mefford, E. and M. Mallory. 2021. "Correlations Go to One in a Crisis: Did the COVID 19 Market Crash Bring Cattle Futures and Equities Together?" Proceedings of the NCCC-134 Conference on Applied Commodity Price Analysis, Forecasting, and Market Risk Management. [http://www.farmdoc.illinois.edu/nccc134].

Correlations Go to One in a Crisis: Did the COVID 19 Market Crash Bring Cattle Futures and Equities Together?

Eli Mefford and Mindy Mallory

Paper prepared for the NCCC-134 Conference on Applied Commodity Price Analysis, Forecasting, and Market Risk Management, 2021.

Copyright 2021 by Eli Mefford and Mindy Mallory. All rights reserved. Readers may make verbatim copies of this document for non-commercial purposes by any means, provided that this copyright notice appears on all such copies.

Eli Mefford is a master’s student and Mindy Mallory is Associate Professor and Clearing Corporation Chair in Food and Agricultural Marketing in the Department of Agricultural Economics at Purdue University

Correlations Go to One in a Crisis: Did the COVID 19 Market Crash Bring Cattle Futures and Equities Together?

We investigate the impacts of Covid-19 on cattle futures markets during the first half of 2020. This study focuses on cattle futures response to the equities crash in March of 2020 and the Covid-linked production delays at beef packing plants. We observe that the initial declines in cattle futures began prior to the onset of beef packing plant shutdowns. Analysis comparing live cattle contracts, feeder cattle contracts, and corn contracts to the E-Mini S&P 500 futures contract finds evidence that the S&P 500 had a significant impact on cattle prices during March of 2020. These results are an example of increased cross asset correlation during periods of financial distress.

Keywords: Covid-19, Cointegration, Vector Error Correction Models, Cattle Futures, Commodity Co-Movement

Introduction

The market adage "all correlations go to one in a crisis" refers to uniform financial market declines during periods of extreme volatility. This adage appeared to be true in March of 2020. Faced with unprecedented uncertainty at the onset of the Covid-19 pandemic, markets responded with sell offs across many asset classes. For example, the E-Mini S&P 500 futures contract finished March down 21% from the beginning of the year. Similarly, the nearby December Live Cattle and August Feeder Cattle contract, fell 23% and 16% respectively, over the same period. The decline in cattle futures prices was popularly attributed to the shutdown of beef packing plants due to Covid outbreaks among plant workers (Bradbury, 2020). The earliest plant shutdowns occurred at the end of March and continued through the spring (Reuters, 2020). Weekly cattle slaughter numbers declined throughout April and reached a yearly low during the first week of May (Knight and Davis, 2020). However, as seen in figure 1 many of the initial drops in cattle contracts came in mid-March, coincident with declines in global equities markets but prior to plant shutdowns. Research has shown that futures contracts making up the cattle crush spread which mimics the profitability of a cattle feedlot, offer good hedging effectiveness, and thus correlate with fundamentals in the cattle market more than to events in the broader financial markets (Fei et al. 2021; Power and Vendev 2010; Haigh and Holt, 2002). In this paper, we examine whether the extreme events of March 2020 briefly broke down correlation to cattle market fundamentals in the cattle market and increased correlation to broader financial markets.

To examine this question, we use five-minute intraday data to estimate vector error correction models (VECM) on the E-Mini S&P 500 futures contract (ES) and contracts making up the cattle crush spread: live cattle (LE), feeder cattle (GF), and corn (CZ). We examine the relationship among these contracts in four time periods: before March, during financial market turmoil in March, during the cattle processing plant shutdowns in April, and from May to July where cattle slaughter returned to 2019 levels (Knight & Davis, 2020). We suspect these periods to be important based on prices movements in figure 1, as well as important events in equity and cattle markets. Structural break tests on the cattle crush spread confirm specific break dates between the periods described. We find that cattle crush spreads and the ES contract were cointegrated between February and March of 2020, with many of the spreads continuing to show cointegration through April. Then cointegration with ES contracts disappears in the period from May through July. None of the spreads were cointegrated with the S&P 500 futures prior to March 2020.

Much of the research on Covid's impact on agriculture has examined production slowdowns. In March and April of 2020 prices weakened across the beef supply chain and production backlogs led to increased feed costs and increased weights of cattle at each stage of production. (Martinez et al, 2020). Research on packing plants have found that prices paid to farmers for livestock decreased while the retail prices of meat rose, improving the marketing margins of beef (Lusk et al, 2020). In turn, United States agriculture exports dropped significantly in April of 2020, with beef and other livestock products falling more than grain exports (Mallory, 2020). The focus of our study differs from previous work on the agriculture sector during Covid, as we examine the similarity in movements of the cattle crush spread and equities as opposed to the production delays caused by the pandemic.

This work builds on previous research on the impacts of economic events on commodity prices. For example, analysis of potential drivers of the wheat prices from 1990 to 2011, with a focus on spikes from 2008 to 2011, finds that wheat market fundamentals were the primary drivers of wheat prices as opposed co-movements with outside markets (Janzen et al, 2014). Similar results were found after examining cotton price spikes from 2008 to 2011 (Janzen et al, 2018). Research on commodity and equity co-movement finds that the correlation between the two assets has increased in recent decades, especially since the 2008 financial crisis (Delatte et al, 2013). Previous studies have also found that co-movement increases during times of financial distress (Buyuksahin et al, 2009; Girardi, 2015).

This study focuses on how a key hedging instrument, the cattle crush spread, behaved during the initial weeks of the Covid-19 crisis in the United States. We show that the initial drops in cattle futures, as well as much of the volatility in their prices, occurred prior to meat packing plant shutdowns. Through restriction tests on our VECM models we find that the ES contract had an influence on the movements of the cattle crush spread during the panic selling in March. Our finding of higher levels of commodity co-movement during the March stock market crash is consistent with previous studies of market co-movement during financial distress.

Figure 1: Graph of the Cattle Crush Spread Components and the E-Mini S&P 500 Futures Contract

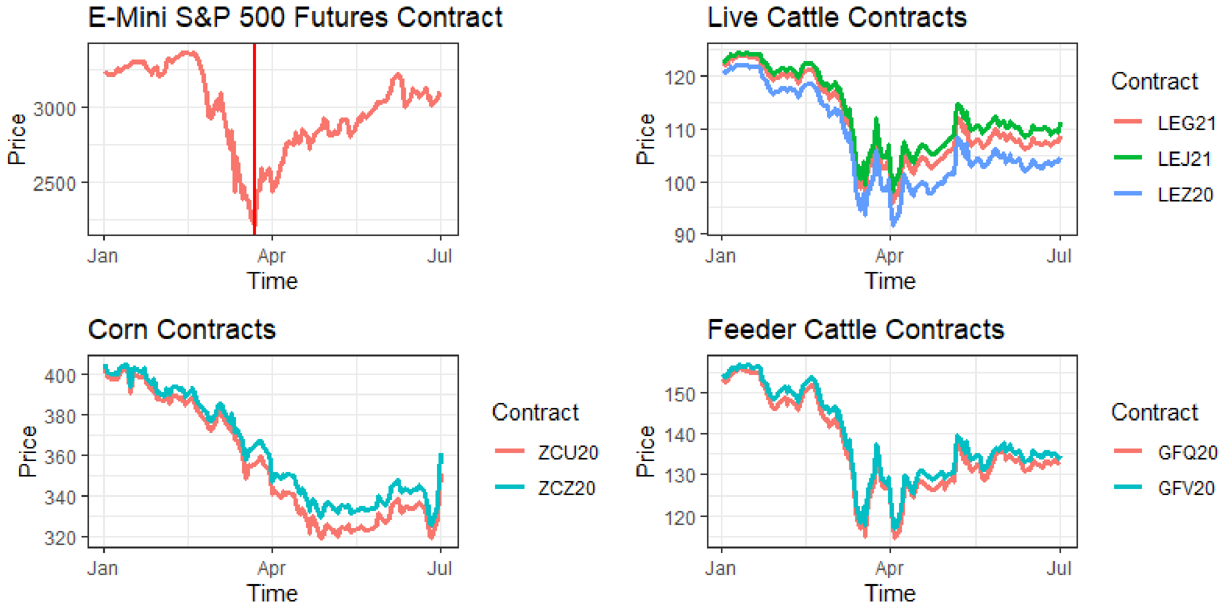


Figure 1 shows a rolling E-Mini S&P Futures contract, with the red line signifying the yearly low of the contract on 3/23. Clockwise from the ES, the next panel is of the three live cattle contracts included in our study: December 2020 (LEZ20) February 2021 (LEG21) and April 2021 (LEJ21). The bottom right panel shows the feeder cattle contracts: August 2020 (GFQ20) and October 2020 (GFV20). The final panel in the bottom left shows the two corn contracts in our analysis: September 2020 (ZCU20) and December 2020 (ZCZ20).

Visual Analysis of the Spread

Figure 1 displays the futures contracts that make up the cattle crush spread. The cattle and corn futures contracts experience a slow decline before the crash in late March, similar to the S&P 500. Packing plants began to shut down during the beginning of April which coincides with the second steep drop in the cattle prices on April second (Reuters, 2020). Feeder cattle and live cattle futures quickly rebounded after this drop, while corn futures took until early summer before picking back up. Then cattle futures rose through the rest of the April even though cattle slaughter was declining throughout April, reaching its lowest level in the first week of May (Knight & Davis, 2020). Rising cattle prices through April seems to suggest the cattle markets were not merely pricing off of the beef processing plant shutdowns, since cattle prices were beginning their recover during the worst of the production bottlenecks. Since live cattle futures contracts represent the prices of cattle ready for slaughter and slaughter rates were declining during April, live cattle futures prices would have been falling in step with slaughter plant closures as there was decreased demand for cattle ready to be slaughtered and inelastic supply (Martinez et al., 2020**)**. Further, feedlots who would be struggling to sell their finished cattle would in turn slow purchases of feeder calves to restock the feedlot so feeder cattle prices should also have been declining (Martinez et al., 2020**)**. Despite the bearish situation cattle contracts rose steadily through April into May. Never again reaching their March or early April lows.

Data

This study examines the E-Mini S&P 500 futures contract, as well as the live cattle, feeder cattle and corn futures contracts from the Chicago Mercantile Exchange and the Chicago Board of Trade. Live cattle, feeder cattle, and corn contracts make up cattle crush spread. Our study period runs from January 1st, 2020, to July 1st, 2020. July 1st is approximately the time when cattle slaughter numbers returned to their 2019 levels (Knight & Davis, 2020). We use contract expirations that that traded over our entire study period: December 2020, February 2021, and April 2021 live cattle contracts; August 2020 and October 2020 feeder cattle contracts; and September 2020 and December 2020 corn contracts. For the ES series we use the rolling nearby series with volume-based rolls and back adjusted prices at the contract rollovers. Although corn and ES contracts have overnight trading hours, all prices in our analysis are between 8:30 a.m. – 1:05 p.m., when live and feeder cattle contracts are traded. All analysis was performed with 5-minute data to capture intraday volatility.

Methodology

Our analysis proceeds as follows. First, we construct 8-4-2 cattle crush spreads using live cattle, feeder cattle, and corn futures contract prices constructed so that the expirations of the constituent futures contracts of the spread mimic the production timeline of a typical feedlot bringing in 750 lb calves and feeding them to 1250 lbs. The 8-4-2 spread is widely used in the industry as the proper spread for feedlot hedging. This gives us a single series for each spread expiration, and we conduct a structural break tests to determine the subperiods used in the rest of the analysis. Next, we conduct cointegration tests on each expiration of the cattle crush spread and the nearby ES contract during each subperiod. Then when cointegration is found, we fit a VECM model for each cattle crush spread expiration and the nearby ES contract and test a restriction setting to zero the coefficient on the ES contract in the cointegrating relationship.

Identifying Subperiods with Structural Break Tests on the 8-4-2 Cattle Crush Spread

The 8-4-2 cattle crush spread represents a gross profit equation for feedlots represented by live cattle revenue minus feeder cattle and corn costs (Steiner, 2014). This represents 8 live cattle contracts, 4 feeder cattle contracts and 2 corn contracts. This combination can hedge approximately 266 calves entering feed lots at 750 lbs, marketed as live cattle at 1,250 lbs and fed 10,678 bushels of corn. The total is then divided by 266 to give the result on a per calve basis.

$$Cattle\ Crush\ Spread\ Spread\ = \tag{1}$$

$$\frac{(Live\ Cattle\ \$ * 8 * 400) - (Feeder\ Cattle\ \$ * 4 * 500) - (Corn\ \$ * 2 * 5000)}{266}$$

We chose feeder cattle contract expirations such that the feeder cattle contract expires between four and six months before the live cattle contract to allow for adequate time for the feeders to reach finished weight. Corn futures contracts are included in the spread to account for feeding costs. Finishing rations are about 75% corn and are purchased closer to the feeder cattle contact expiration. Since several expirations of the cattle spread were trading at the time of the March 2020 COVID-19 crisis, we refer to the spreads based on the expiration of their live cattle contract. The spreads we examined are December 2020, February 2021, and April 2021. The spreads we consider in this study are shown in table 1. These spreads were chosen because each constituent contract was trading during the date range we analyzed, January 1st, 2020 to July 1st, 2020.

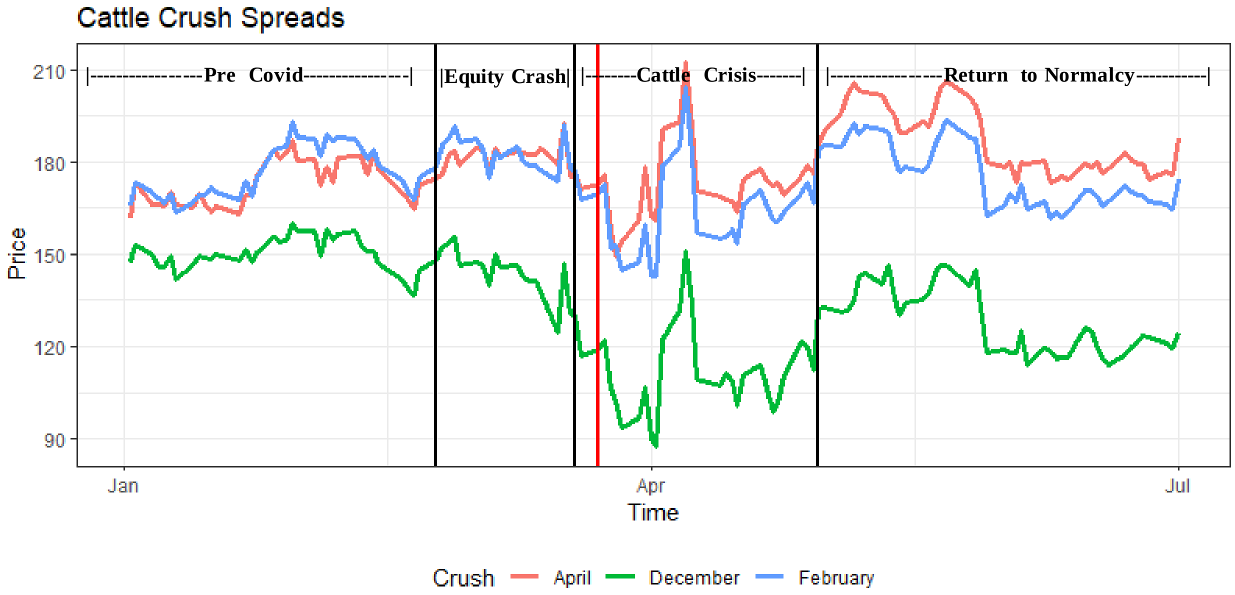
Table 1**:** Cattle Crush Spreads and their Constituent Contracts

Name of Spread	Live Cattle Contract	Feder Cattle Contract	Corn Contract	ES Contract
December Spread	December (LEZ 2020)	August (GFQ 2020)	September (ZCZ 2020)	Nearby
February Spread	February (LEG 2021)	August (GFQ 2020)	September (ZCU 2020)	Nearby
April Spread	April (LEJ 2021)	October (GFV 2020)	December (ZCZ 2020)	Nearby

We test for structural breaks on each cattle crush spread to divide the January to July period into four subperiods to examine the evolution in the relationship between the cattle crush spread contracts and ES-Mini S&P 500 contract. We use the structural break tests described in Bai and Perron (2003), Bai (1997), and Zeileis et al. (2003). Each spread has similar structural break dates, so we pick the mode date to establish subperiods. The time periods are displayed in figure 2 and are defined as follows: January 1st to February 23rd, February 24th to March 18th, March 19th to April 29th and then April 30th to July 1st.

The first time period is "pre-Covid," in that while Covid had already begun to spread in the United States it was not until March when the World Health Organization declared Covid to be a pandemic (AJMC, 2020**)**. The second time period is labeled "equity crash". The initial declines in equities and cattle markets occurred during the February to March period. It is important to notice that the March 19th breakpoint is very close to the bottom of the ES contract on March 23rd (figure 2). The third time period is labeled "cattle crisis". March and April included the bulk of the plant shutdowns. Finally, the fourth period is labeled "return to normalcy". Cattle slaughter numbers returned to 2019 levels in the April to July period (Knight & Davis, 2020) and equity markets began an impressive recovery from the March lows during this time period. Our primary focus is on the differences in the relationship between the cattle crush spread contracts and the ES contract between the February to March and March to April periods.

Figure 2: Graph of Cattle Crush Spread Breakpoints



Note: Breakpoints occurred at February 23rd, March 19th, and April 30th, shown as vertical black lines. The lines define the periods Pre Covid, Equity Crash, Cattle Crisis, and Return to Normalcy.

Determine Existence of Cointegration and Estimate VECM Models on Each Cattle Spread Expiration and in Each Subperiod

After determining that all prices are non-stationarity (found in tables 5-7 in the Appendix), cointegration tests are conducted on the three agricultural contracts of each spread and the ES contact over the whole study period and across all four subperiods (Johansen, 1988; Johansen and Juselius, 1990). We would expect the cattle crush spreads to be cointegrated because they are used in a production process and if the feeder cattle contract increase (decrease) then we would expect the live cattle contract to in turn rise (fall) a similar magnitude. The ES is not traditionally a part of this relationship, and we use the cointegration tests on our subperiods to determine the degree to which prices in the cattle spread moved in concert alongside the ES during the most volatile times of the crisis.

If the series are found to be cointegrated, we fit a VECM to model these relationships, as shown below. The VECM includes an error correction term (ECT) (inside the parenthesis) with β terms that capture the relationship the series maintained. The α term precedes the ECT for each variable and determines how quickly prices return to equilibrium. The gamma coefficients capture how lagged 5-minute returns of each variable affects the current price. Likelihood ratio Restriction tests are run on the ES β in each VECM equation to determine if it belongs in the VECM (Johansen, 1991).

$$\begin{bmatrix}\Delta GF_t\\ \Delta LE_t\\ \Delta ZC_t\\ \Delta ES_{\ t}\end{bmatrix} = \begin{bmatrix}\gamma_0^{GF}\\ \gamma_0^{LE}\\ \gamma_0^{ZC}\\ \gamma_0^{ES}\end{bmatrix} + \begin{bmatrix}a_1\\ a_2\\ a_3\\ a_4\end{bmatrix}[\beta_0 + \beta_1 GF_{t-1} + \beta_2 LE_{t-1} + \beta_3 ZC_{t-1} + \beta_4 ES_{t-1}] + \tag{2}$$

$$\begin{bmatrix}\gamma_1^{GF} & \gamma_2^{GF}\\ \gamma_1^{LE} & \gamma_2^{LE}\\ \gamma_1^{ZC} & \gamma_2^{ZC}\\ \gamma_1^{ES} & \gamma_2^{ES}\end{bmatrix}\begin{bmatrix}\Delta GF_{t-1}\\ \Delta LE_{t-1}\\ \Delta ZC_{t-1}\\ \Delta ES_{t-1}\end{bmatrix} + \begin{bmatrix}\gamma_3^{GF} & \gamma_4^{GF}\\ \gamma_3^{LE} & \gamma_4^{LE}\\ \gamma_3^{ZC} & \gamma_4^{ZC}\\ \gamma_3^{ES} & \gamma_4^{ES}\end{bmatrix}\begin{bmatrix}\Delta GF_{t-2}\\ \Delta LE_{t-2}\\ \Delta ZC_{t-2}\\ \Delta ES_{t-2}\end{bmatrix} + \begin{bmatrix}\gamma_5^{GF} & \gamma_6^{GF}\\ \gamma_5^{LE} & \gamma_6^{LE}\\ \gamma_5^{ZC} & \gamma_6^{ZC}\\ \gamma_5^{ES} & \gamma_6^{ES}\end{bmatrix}\begin{bmatrix}\Delta GF_{t-3}\\ \Delta LE_{t-3}\\ \Delta ZC_{t-3}\\ \Delta ES_{t-3}\end{bmatrix} +$$

$$\begin{bmatrix}\vartheta_t^{GF}\\ \vartheta_t^{LE}\\ \vartheta_t^{ZC}\\ \vartheta_t^{ES}\end{bmatrix}$$

Results

Results of cointegration testing are shown in table 2. All combinations of spreads and the S&P futures contract we analyze are cointegrated at a 5% significance level over the whole-time period of the study. The February and April spreads are cointegrated during the pre-Covid period. Interestingly, even as cattle slaughter returned to previous levels, none of the spreads are cointegrated during Return to Normalcy period.

The two periods of primary interest, Equity Crash and Cattle Crisis, exhibit strong evidence of cointegration. All three spreads are cointegrated at the 5% significance level or greater during the market crash period. The Cattle Crisis period contained some of the most severe production delays for beef packing plants. The April and February spreads are cointegrated to at least 5% significance level over this time. The December spread is cointegrated at the 10% significance level in this period as well.

Table 2: Cointegration Among Cattle Crush Spread Constituents and S&P 500

Spread	Full Sample	Pre-Covid	Equity Crash	Cattle Crisis	Return to Normalcy
December Spread	**		**	*	
February Spread	***	**	***	***	
April Spread	**	**	***	**	

Note: Null = series is not cointegrated; * - Significant at the 10% level; ** - Significant at the 5% level; *** - Significant at the 1% level. Subperiod definitions: Pre-Covid, 1/01/2020-2/23/2020; Equity Crash, 2/24/2020-3/18/2020; Cattle Crisis, 3/19/2020-4/29/2020; Return to Normalcy, 4/30/2020-7/01/2020.

The strong cointegration of these spreads relative to the Pre-Covid period and the Return to Normalcy periods suggests that these markets experienced increased correlation and co-movement during the Equity Crash and Cattle Crisis periods. This provides evidence supporting our correlation hypothesis. We examine this further by fitting VECM models to the subperiods in which ES, GF, LE, and ZC are cointegrated.

Table 3 displays the β vector results from the VECMs of the cointegrated subperiods. There is a constant relationship between the feeder cattle (GF) β and the live cattle (LE) β across each period. This is unsurprising as the live cattle contract is composed of finished feeder calves, so if the price of one contract were to change, the other would likely move in the same direction in response. While small in magnitude, the ES β's are consistent across each period. Due to the natural cointegration between the prices in the cattle crush spread, we should check whether the ES is really a part of the equilibrium relationship by testing a restriction of $\beta_{ES} = 0$. We indicate when β_{ES} is significantly different from zero by showing those estimates in bold in table 3. We find statistically significant β_{ES} in three instances: the β_{ES} for the February spread in the Equity Crisis subperiod, the β_{ES} for the April spread in the Equity Crisis subperiod, and the β_{ES} for the April spread in the full sample. The results of these tests confirm that the ES contract had a significant impact on the cattle crush spread during the market declines in late February and March of 2020, but in none of the other subperiods considered aside from the full sample. This evidence of spillover from broader financial markets into cattle markets supports our visual analysis of figure 1, as well as the results of our cointegration tests where each spread was cointegration at least the 5% significance level during the Equity Crisis subperiod.

Table 3: VECM β Terms

Spread	Constant	GF	LE	ZC	ES
December					
Full Sample	-4.37	1	-1.24	0.03	-0.003
Equity Crash	10.96	1	-1.33	-0.002	-0.002
Cattle Crisis	12.08	1	-1.62	0.05	0.002
February					
Full Sample	13.89	1	-1.37	0.03	-0.003
Pre Covid	96.04	1	-2.3	0.1	-0.002
Equity Crash	26.38	1	-1.32	-0.01	**-0.004**
Cattle Crisis	57.77	1	-1.64	-0.02	-0.003
April					
Full Sample	-44.54	1	-0.89	0.11	**-0.01**
Pre Covid	96.85	1	-2.17	0.07	-0.003
Equity Crash	-14.1	1	-1.52	0.17	**-0.01**
Cattle Crisis	55.61	1	-1.72	0.001	-0.001

Note: **Bold – s**ignifies statistically different from zero result in restriction tests on the ES coefficients.

Table 4 contains the α's for the VECM equations. The α determines the speed at which the error correction term pushes prices back to equilibrium. If an α is found to be significant in an equation of the VECM model, then that price is contributing to pushing the group back into equilibrium. Overall, it appears that the feeder cattle α is often significant meaning that feeder cattle contracts will move to maintain the cattle crush spread's equilibrium. Some of the ES α's are found to be significant which is unexpected, as we would not expect the ES to have a large role in maintaining the cattle crush spread. An interesting finding from the estimated α's is that some of the feeder cattle α's are not significant for the February to March period. We interpret this as a breakdown in the typical cointegration relation among the cattle series, and it provides further evidence of the correlation hypothesis.

Table 4: VECM α Terms

Spread	GF	LE	ZC	ES
December				
Full Sample	-0.02***	-0.004	0.002	0.16
	(0.004)	(0.003)	(0.006)	(0.1)
Equity Crash	-0.04	0.03	0.05	2.06*
	(0.03)	(0.02)	(0.03)	(0.93)
Cattle Crisis	-0.04**	-0.04**	-0.01	-0.45*
	(0.01)	(0.01)	(0.01)	(0.23)
February				
Full Sample	-0.02***	-0.004	-0.002	0.13
	(0.01)	(0.003)	(0.008)	(0.11)
Pre Covid	-0.02	0.02*	-0.05	-0.42
	(0.01)	(0.01)	(0.03)	(0.22)
Equity Crash	-0.07	0.03	0.05	2.4*
	(0.04)	(0.02)	(0.04)	(1.14)
Cattle Crisis	-0.05**	-0.01	-0.001	-0.31
	(0.02)	(0.01)	(0.02)	(0.29)
April				
Full Sample	-0.01***	-0.004***	-0.01**	-0.06
	(0.002)	(0.001)	(0.003)	(0.04)
Pre Covid	-0.13	0.07	-0.16	-0.25
	(0.07)	(0.05)	(0.16)	(1.26)
Equity Crash	-0.15*	0.07	0.01	4.29
	(0.07)	(0.05)	(0.07)	(2.21)
Cattle Crisis	-0.04	-0.02	0.02	-0.28
	(0.02)	(0.02)	(0.03)	(0.42)

Note: Null = α is not significant; * - Significant at the 10% level; ** - Significant at the 5% level; *** - Significant at the 1% level.

Conclusion

We examined the relationship between components of the cattle crush spread at all expirations actively traded during the first half of 2020 and ES (E-mini S&P 500). We found that the ES formed an equilibrium relationship with the cattle crush spread components during both the equity crash and cattle crisis sub-periods for all cattle crush spreads considered. During the pre-Covid period, the February and April cattle crush spread components were cointegrated with the nearby ES contract, but the December cattle crush spread was not. Results from restriction tests on the β_{ES} coefficients suggest that cattle futures responded to changes in the S&P 500 during the equities crash in March 2020. The statistical tests support what is depicted in figure 1. Figure one shows cattle futures decline alongside the ES contract beginning in February before their first severe drop on March 19th, just two trading days before the ES contracts yearly low on March 23rd. Cattle futures then experience large fluctuations in March but appear to normalize as April progresses even amidst declining cattle slaughter rates. Our study is consistent with prior findings of commodity and equity co-movement during periods of financial stress.

Our study has some limitations. Studying cattle markets during the Covid-19 crisis is unique in that the same force that caused the market crash also had serious and immediate implications for the beef supply chain. While in previous economic crises the shock events typically did not directly impact agriculture supply chains. Therefore, it is impossible to identify whether the cattle crush contracts became cointegrated with ES contracts because there were simply financial market volatility spillovers, which is the idea behind the saying that all correlations go to one in a crisis, or whether market participants accurately predicted problems in the beef supply chain that led to price reaction in those markets predating the actual processing facility closures. Our view is that it is more likely that the cattle markets were experiencing increased correlation with equity markets during the period of increased (downside) volatility. However, our research cannot prove or disprove this directly; it is an important topic for future research.

This research also has implications for policy. We cannot provide an answer to whether the cattle cointegration with ES markets was due to increased correlation during a period of volatility, or whether it was due to a group of informed traders correctly anticipating trouble with the cattle market. However, detailed trading records that are available to regulators would shed light on this question. This information could shed light on why cattle prices fell prior to plant closures. There is a possibility that informed market participants, such as large agribusiness companies, anticipated the plant shutdowns in March and acted preemptively. Most information in USDA reports are collected and released with the intention of providing fundamental market information to the public and to prevent an outsized advantage from information gained through business handling the spot commodity. Covid 19 falls in the category of unexpected shocks to supply or demand that are extremely rare (like, for example, the fire at the Tyson's Holcomb, KS), and policy makers could consider whether there should be requirements for reporting the public such material market information before placing trades. This would be similar in sprit to the Export Sales reporting system implemented after the 1970's purchases of large amounts of U.S. grain (Schmitz 2003).

Bibliography

AJMC. (n.d.) A Timeline of Covid-19 Developments in 2020. *American Journal of Managed Care*. https://www.ajmc.com/view/a-timeline-of-covid19-developments-in-2020

Bai, J. (1997), Estimation of a Change Point in Multiple Regression Models, *Review of Economics and Statistics*, **79**, 551-563.

Bai, J., & Perron, P. (2003), Computation and Analysis of Multiple Structural Change Models, *Journal of Applied Econometrics*, **18**, 1-22.

Bradbury, S. (31 Mar. 2020), More than 800 Greeley Meat Packing Plant Workers Call off as Coronavirus Is Confirmed among Employees, *Denver Post*. https://www.denverpost.com/2020/03/31/jbs-meat-plant-greeley-colorado-coronavirus/

Büyüksahin, B., Haigh, M. S., & Robe, M. A. (2009). Commodities and Equities: Ever a "Market of One"? *The Journal of Alternater Investments*, Winter 2010, 12 (3) 76-95. DOI: https://doi.org/10.3905/JAI.2010.12.3.076

Delatte, A. L., & Lopez, C. (2013). Commodity and equity markets: Some stylized facts from a copula approach. *Journal of Banking and Finance*, *37*(12), 5346–5356. https://doi.org/10.1016/j.jbankfin.2013.06.012

Fei, C., Vedenov, D., Stevens, R., & Anderson, D. (2021). Single-Commodity versus Joint Hedging in Cattle Feeding Cycle: Is Joint Hedging Always Essential? *Journal of Agricultural and Resource Economics*. Forthcoming. doi: 10.22004/ag.econ.304776.

Girardi, D. (2015). Financialization of food. Modelling the time-varying relation between agricultural prices and stock market dynamics. *International Review of Applied Economics*, *29*(4), 482–505. https://doi.org/10.1080/02692171.2015.1016406

Haigh, M., & Holt, M. (2002). Crack Spread Hedging: Accounting for Time-Varying Volatility Spillovers in the Energy Futures Markets. *Journal of Applied Econometrics*. 17(3): 269–289. doi: 10.1002/jae.628.

Janzen, J., Carter, C. A., Smith, A., & Adjemian, M. (2014). Deconstructing Wheat Price Spikes: A Model of Supply and Demand, Financial Speculation, and Commodity Price Comovement. *SSRN Electronic Journal*, 2014. *DOI.org (Crossref)*, doi:10.2139/ssrn.2502922.

Janzen, J. P., Smith, A., & Carter, C. A. (2018). Commodity Price Comovement and Financial Speculation: The Case of Cotton. *American Journal of Agricultural Economics*, *100*(1), 264–285. https://doi.org/10.1093/ajae/aax052

Johansen, S. (1988), Statistical Analysis of Cointegration Vectors, *Journal of Economic Dynamics and Control*, 12, 231-254.

Johansen, S. (1991). Estimation and Hypothesis Testing of Cointegration Vectors in Gaussian Vector Autoregressive Models. *Econometrica, 59*(6), 1551-1580. doi:10.2307/2938278

Johansen, S. & Juselius, K. (1990), Maximum Likelihood Estimation and Inference on Cointegration – with Applications to the Demand for Money, *Oxford Bulletin of Economics and Statistics,* 52,2, 169—220.

Knight, R., & Davis, C. (2020). *Livestock, Dairy, and Poultry Outlook: Beef/Cattle*. USDA ERS. https://www.ers.usda.gov/webdocs/outlooks/98651/ldp-m-312.pdf?v=1559, 3-7

Lusk, J. L., Tonsor, G. T., & Schulz, L. L. (2020). Beef and Pork Marketing Margins and Price Spreads during COVID -19. *Applied Economic Perspectives and Policy*, *43*(1), 4–23. https://doi.org/10.1002/aepp.13101

Mallory, M. L. (2020). "Impact of COVID-19 on Medium-Term Export Prospects for Soybeans, Corn, Beef, Pork, and Poultry." *Applied Economic Perspectives and Policy*. https://doi.org/10.1002/aepp.13113

Martinez, C. C., Maples, J. G., & Benavidez, J. (2020). Beef Cattle Markets and COVID-19. *Applied Economic Perspectives and Policy*, *43*(1), 304–314. https://doi.org/10.1002/aepp.13080

Power, G.J., & Vedenov, D. (2010). Dealing with Downside Risk in a Multi-Commodity Setting: A Case for a 'Texas Hedge'?" *Journal of Futures Markets*. 30(3): 290–304. https://doi.org/10.1002/fut.20411

Reuters Staff.(13 Apr 2020). Factbox: Spread of coronavirus closes North American meat plants. *Reuters*. https://www.reuters.com/article/us-health-coronavirus-meat-factbox/factbox-spread-of-coronavirus-closes-north-american-meat-plants-idUSKCN21V09W

Schmitz, A. "The Economics of World Wheat Markets." (2003): 285-286.

Steiner, L. (2014) The Cattle Crush and Reverse Crush: An Industry Hedging Tool and a Financial Investment Opportunity. *CME.* https://www.cmegroup.com/education/files/the-cattle-crush-and-reverse-crush.pdf

Zeileis A., Kleiber C., Krämer W., & Hornik K. (2003), Testing and Dating of Structural Changes in Practice, *Computational Statistics and Data Analysis*, **44**, 109-123. doi:10.1016/S0167-9473(03)00030-6.

Appendix:

Table 5: December Spread Stationary Test Results

statistic	p.value	parameter	method	alternative
-1.393437	0.8352694	18	Augmented Dickey-Fuller Test	stationary
-5.471198	0.8046467	11	Phillips-Perron Unit Root Test	stationary
33.835129	0.01	11	KPSS Test for Level Stationarity	unit root
-1.753134	0.6829172	18	Augmented Dickey-Fuller Test	stationary
-6.829112	0.7289505	11	Phillips-Perron Unit Root Test	stationary
30.586947	0.01	11	KPSS Test for Level Stationarity	unit root
-0.425215	0.9853091	27	Augmented Dickey-Fuller Test	stationary
-3.48099	0.9126588	15	Phillips-Perron Unit Root Test	stationary
115.8758	0.01	15	KPSS Test for Level Stationarity	unit root
-2.557856	0.3405211	46	Augmented Dickey-Fuller Test	stationary
-11.49423	0.4746023	22	Phillips-Perron Unit Root Test	stationary
345.70673	0.01	22	KPSS Test for Level Stationarity	unit root

Table 6: February Spread Stationary Test Results

statistic	p.value	parameter	method	alternative
-1.610967	0.7431077	17	Augmented Dickey-Fuller Test	stationary
-6.455613	0.7497467	10	Phillips-Perron Unit Root Test	stationary
20.76482	0.01	10	KPSS Test for Level Stationarity	unit root
-1.753134	0.6829172	18	Augmented Dickey-Fuller Test	stationary
-6.829112	0.7289505	11	Phillips-Perron Unit Root Test	stationary
30.586947	0.01	11	KPSS Test for Level Stationarity	unit root
-0.425215	0.9853091	27	Augmented Dickey-Fuller Test	stationary
-3.48099	0.9126588	15	Phillips-Perron Unit Root Test	stationary
115.8758	0.01	15	KPSS Test for Level Stationarity	unit root
-2.557856	0.3405211	46	Augmented Dickey-Fuller Test	stationary
-11.49423	0.4746023	22	Phillips-Perron Unit Root Test	stationary
345.70673	0.01	22	KPSS Test for Level Stationarity	unit root

Table 7: April Spread Stationary Results

statistic	p.value	parameter	method	alternative
-4.297549	0.01	25	Augmented Dickey-Fuller Test	stationary
-27.24253	0.016328	14	Phillips-Perron Unit Root Test	stationary
57.913279	0.01	14	KPSS Test for Level Stationarity	unit root
-2.911746	0.1920942	21	Augmented Dickey-Fuller Test	stationary
-12.37265	0.4201293	12	Phillips-Perron Unit Root Test	stationary
8.105555	0.01	12	KPSS Test for Level Stationarity	unit root
-1.408411	0.8302007	34	Augmented Dickey-Fuller Test	stationary
-3.373871	0.9175847	18	Phillips-Perron Unit Root Test	stationary
64.4846	0.01	18	KPSS Test for Level Stationarity	unit root
-2.557856	0.3405211	46	Augmented Dickey-Fuller Test	stationary
-11.49423	0.4746023	22	Phillips-Perron Unit Root Test	stationary
345.70673	0.01	22	KPSS Test for Level Stationarity	unit root