

Price Discovery in Fed Cattle and Beef Markets: Does the Volume of Cash Trade Have an Impact?

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Executive Summary

The price discovery process is important for knowing the market value of fed cattle and to have fed cattle price discovery then fed cattle must be traded. And while in the past there was a modest relationship between the amount of price discovery that occurs and the volume of cash trade. In other words, when the volume of cash trade was reduced then the amount of price discovery that occurred in regional cash markets was also reduced. But now there is almost no relationship between price discovery and the volume of cash trade – this is since 2015. Mandating cash trade will not improve price discovery. And mandating cash trade will be costly along with having little to no price discovery benefits. An implied conclusion of this work is that the cattle feeding industry and the beef packing industry should pursue voluntary measures to monitor and maintain price discovery.

Introduction

The fed cattle market has experienced considerable unexpected volatility and variability over the 2019 through 2021 time period. These market events have created producer unrest which has generated policy proposals of considerable interest by legislators. Two of the most well-known are described as the “50/14” and “30/14” proposals. 50/14 would require that each business within the beef packing industry to procure 50% of each individual plant’s fed cattle needs each week for delivery within the 14 window that is associated with the negotiated cash market. The cash fed cattle market is typically a transaction agreed to this week for delivery this week but more likely next week. Thus, the implied 14-day window. (During times of very tight fed cattle numbers the USDA AMS defined the cash market as a trade today for delivery with 28 days. But the industry practically defines the cash market as a trade this week for delivery next week.) The 30/14 proposal is similar albeit the required cash purchases are 30% of individual plant needs.

Both proposals are substantially different than what is conducted today as business in regional fed cattle markets. Nationally, approximately 75-80% of fed cattle are marketed through alternatives to the cash market. These alternative marketing arrangements (AMAs) for fed cattle markets include formula arrangements and forward contracts and are part of the referred to 75-80% AMAs. Approximately 60-70% of fed cattle are marketed through formulas and approximately 10-20% are forward contracted. There are also some 100% packer owned fed cattle but these sources are minor. Approximately 20-30% of the fed cattle trade is through the negotiated cash market. This 20-30% includes the negotiated cash market and negotiated grid. A negotiated cash price is transparent, and the negotiated grid is bid-and-ask on the base price for a transaction where cattle are paid premiums and discounts for quality. Further, the negotiated prices can be a live weight price or a dressed weight price. However, the regional differences are substantial. None of the five main USDA AMS defined regions always trade 50% of the fed cattle through negotiated means. (The five regions are: Texas-Oklahoma-New Mexico,

Kansas, Colorado, Nebraska, and Iowa-Minnesota.) But regional markets in the upper Midwest come the closest. The Iowa-Minnesota region and the Nebraska region routinely trade around or greater than 50% in the negotiated cash market. However, the Colorado region, the Kansas region, and the reporting region that is Texas-Oklahoma-New Mexico do not. The further south and the further west in the USDA AMS price reporting region then the smaller the cash trade. In the TX-OK-NM region the cash trade can be less than 10% of the total animal marketings. Thus, the proposals will have the greatest impact on southern regions and enterprises that specialize in cattle feeding as opposed to the northern and eastern regions and enterprises where cattle feeding is part of the larger farming and animal production portfolio.

The auspices of both proposals, and much of the interest in legislative solutions, are improved price discovery. Specifically, the proposals state or imply that requiring more cash trade will improve price discovery in fed cattle markets. The context appears to also imply that the recent unexpected volatility and variability in fed cattle markets was caused by, and if not caused by then could be mitigated by, improved price discovery. Informal discussions with industry groups communicated a similar premise related to price levels and profitability of cattle enterprises upstream from packing enterprises. It is implied that improved prices and mitigation of market impacts could be obtained through increasing packer participating in cash market. And increasing packer participation requires legislation. The market experience during the 2019-2021 period was such that something had to be done and done through legislation. The reaction and proposals are reminiscent of experiences prior to the 2002 Farm Bill. The Johnson Amendment to that farm bill sought to prohibit or limit AMA use. This was the catalyst that produced legislation and funding that resulted in the 2007 USDA RTI Livestock and Meat Marketing Study (Muth et al. 2005 and Muth et al. 2007). That study was a comprehensive benefit/cost analysis of AMA use. The overall assessment revealed the extent and benefits to market participants of AMA use and therefore the costs associated with AMA prohibition. In addition to documenting the overall market impacts, these impacts were in part constructed from assessing the improved efficiency and improved quality associated with a market channel making use of AMAs (Muth et al. 2008). The benefits from AMA use were and continue to be substantial. The other costs associated with AMA use focused on access and the potential negative impacts on fed cattle price. Surveys and interviews found limited market access to be a non-issue. And the negative price impacts – called or likely associated with exercise of market power – were found to be modest. From a comprehensive perspective, costs associated with AMA use were found to be orders of magnitude lower than benefits. The benefits precipitate to consumers and producers – and mainly producers.

One of the shortcomings of the USDA RTI LMMS is that it did not – but nor was it tasked with – examining questions regarding price discovery. There were no concerns expressed at that time about the quantity or quality of price discovery in fed cattle markets. In the sample period of the RTI Study the largest use of AMAs was about 40% of plant needs. During that sample period the national use of AMAs over a weekly time interval was averaged about 25%. AMA use was not as common or substantial as it has been since the study period. But the changes in AMA use over time since the study should not be a surprise. AMAs are overwhelmingly beneficial both to the individual that use them and to the marketplace. Producer and consumer surplus – measures of economic wellbeing – are improved by not limiting AMA use and by the market adoption of use to the extent individual market participants wish.

However, the thorough adoption of AMAs and especially in some regions give rise to the next economic question. How thin is too thin? AMAs have economic merit and are clearly beneficial. The cattle

feeding industry has continued to adopt them. But the largest portion of AMAs – formula transactions – have prices based on what has become the residual negotiated cash trade. Further, even forward contract transactions need or require information on cash-futures basis and thus need cash market price information. How small can the negotiated cash market shrink to and maintain effective price discovery? This is the reasonable next question. Before proceeding to an analysis of that question some preliminary information needs to be communicated. These are the next several sections of this report. First, price discovery versus price determination concepts is discussed. The proposed policies are focused on price discovery, and price discovery is an appropriate question when the cash market is thinning, but price determination is the relevant topic for concerns about market outcomes. Second, the use and examples of formula trade require discussion. It is straightforward to show that formula use, or AMA use, does not change the supply and demand balance in a marketplace and therefore is unlikely to impact price determination. Third, how is price discovery measured? Answering the question of, “How thin is too thin?” requires objective measures of price discovery. These measures will be outlined. The fourth section of this report will communicate relations between objective measures of price discovery and the volumes of negotiated cash trade in the different regional cash markets.

Price Determination and Price Discovery

Price determination and price discovery are two important concepts to market economists – and to market participants. Prices are determined by supply and demand. Examining markets from a price determination perspective brings the power of those tools – supply and demand – to understanding price levels and adjustments within any market. But the economic tools of supply and demand do not administer prices. Individuals in marketplaces – especially agricultural and food product markets – bid and ask and discover prices. Price discovery is the human process of doing work in markets to conduct business. People discover price through interacting in the marketplace. Prices are discovered and products change hands. Price determination summarizes the process, but price discovery is the actual work. Examples of both are worthwhile.

Suppose the current fed cattle price is \$120/cwt and that it is expected that supplies will decrease by 4% and that demand will increase by 2%. We can use the own price elasticity of demand to determine the likely extent of the price adjustment. If the own price elasticity is $-0.85 = \frac{\% \Delta Q}{\% \Delta P}$. The entire percent change in quantity will be consumed and price adjust to clear the market. The percent change in price is $+4.7\% (= -4\% / -0.85)$. Next, an increase in demand is like a decrease in supply from the perspective of price. Combining the change in supply with the change in demand creates the net quantity impacting price. A 4% decrease in supply and a 2% increase in demand is like a 6% decline in supply in terms of its impact on price. Combining the supply and demand information suggests a $+7.0\% (= -6\% / -0.85)$ change in price. Increasing \$120/cwt by 7% results in a new equilibrium price of \$128.40/cwt. This is an example of price determination.

The tools in this example cleanly and concisely summarize the impacts in the marketplace. Reductions in the quantity supplied in a marketplace will result prices increasing. But this analysis is what happens on average as measured over time by the own-price elasticity. There is no market administrator that adjusts the price higher. And this exercise is not to say that \$128.40/cwt is the right or the correct price. But given the starting place and the known likely changes to supply and demand then the resulting price is similar to what has happened historically in the past in this market. These tools summarize the

market impacts in a succinct manner. But the tools summarize and are not the mechanism whereby price changes.

It is the market participants in the actual trade of fed cattle that cause prices to change. This is price discovery. As supplies decrease and demand increases then beef prices will increase. Packers will also have some additional excess capacity. Sellers of fed cattle will ask for higher prices and buyers of fed cattle will likely be willing to pay higher prices. With smaller supplies and higher beef prices then packer margins increase, and packers will be more willing to bid higher for cattle. This willingness is reinforced by fewer animals being available. Packers will have to bid more aggressive to secure supplies and maintain volumes to capture economies of size.

But the actual price adjustment path depends on the individuals in the marketplace. The resulting price adjustment may in fact be higher or may be lower. The resulting price might be \$132 or might also be \$124. And these are not hard limits nor a known range. What happens depends on the actions in the marketplace, but price determination tools summarize likely moves based on historical relationships between prices and quantities as summarized by supply and demand concepts. The prices that are observed are those discovered by the individuals in the market. The observed market prices and the price adjustment path depends on the actual bid and ask – and the willingness to make a market in that process.

Current and future prices also are impacted by the price history. A strong or weak price improvement becomes an anchoring point and is used as information in future bids and asks. Once prices move higher, or lower, then subsequent prices tend to stay high or low – relative to other market barometers – unless the initial move is a clear over or under-reaction. Then the subsequent price moves will reveal softening or acceleration of the original moves. Other market barometers include information such as the nearby live cattle futures price, the boxed beef product prices and the summary of such information into the composite value, information of weekly fed cattle slaughter volumes and animal weights, and knowledge about the inventory of, marketings from, and placements into cattle on feed. Finally, but not exhaustively, information about the distribution of animal numbers across animal weights and the is referred to as “currentness” of market ready cattle on feed. Many pieces of information come into play in the bid and ask process between packers and cattle feeders.

The marketing of fed cattle into the fresh beef production system is a continuous process. There is a need for regular daily flows of animals to produce flows of meat and these flows are coordinated through roughly weekly transactions. There is a multitude of information which impacts perceptions about what market participants think is likely to happen next in the market. Because of this, and because finished animals are only modestly storable, discovered prices reflect current market conditions and anticipated market conditions over the next several weeks. Price discovery is thus a fluid process whereby market participants work to create the current price recognizing the current price will impact future prices and is impacted by past prices.

There is also a distribution of knowledge across market participants. Not all market participants know the same information and believe in the likelihood of certain outcomes. Of course, cattle sellers want higher prices and cattle buyers want lower prices, but both also understand, to varying degrees, “What is the market price?” On any given day then there are a variety of bids and asks. And in fed cattle markets, being weekly, there is some market participant or group of market participants in every USDA AMS reporting region that initiates the weekly trade by accepting a set of bids or a set of offers. The

initiation of this process depends on individual information, costs of waiting, and perceptions about better or worse opportunities and potential outcomes later.

The price determination tools summarize and synthesize based on an understanding of what has happened in the past and is in historical data. The prior example tools are informative, but it is people that discovery prices in markets. The price discovery process is fluid and complex. There is a substantial depth and distribution of information. There is also a multitude of risk and return tradeoffs made. One of the questions that price discovery does not answer nor help understand is: what is the depth of market participation needed for effective price discovery? Effective price discovery results in price reflecting underlying market conditions. Ineffective price discovery might result in prices being too high, too low, too variable, or not responsive enough to changes in market conditions. And all of these at different points in time. This is a difficult question. Does price reflect marginal conditions and how quickly? Prices are correct if they reflect marginal values and marginal costs. And if adjustments are made timely. But these “right price” questions are specifically answered with price determination tools. So, price discovery and price determination are related and integrated. But the purpose here is to examine price discovery and the relationship between objective measures of price discovery and negotiated cash volumes. The purpose is to contribute to the policy discussion and not answer the question of if the prices we observe correct.

The number buyer and sellers or the amount of trading refers to a thin market or to examples of monopoly or, in this case, monopsony. There is research on this topic that is largely conclusive and worth mentioning. There may be single buyers at some cattle feeding locations, but this is usually because of transportation costs and location advantages. Competition in this case involves potential as opposed to actual buyers. Thus, monopoly/monopsony questions are usually not the issue, but it is the exercise of oligopoly/oligopsony power. This is a technical issue and results that will not be delved into here. But it is often an issue with producers. However, the research results are conclusive. There is market power exercised on fed cattle markets, but the magnitude of the market power exercised is economically small and is always substantially less than the gains due to economies of size. From a cost/benefit perspective, the societal costs of large packers and a concentrated beef packing industry are not zero but are small compared to the societal gains due large gains in efficiency due to economies of size. These societal costs and benefits are not nebulous but actual for consumers and producers, especially producers.

Price discovery is a complicated concept and application. But it should not be combined with what is known about market power. The questions are related and often confused but should not be combined. The question remains, how deep or thin can a market be an effectively discovery a reasonable price? This is not a simple question with an easy answer. The next section discusses, in part, this issue and does so in the context of how fed cattle markets have thinned.

AMA Use and the Supply/Demand Balance

AMAs have historically been referred to as “captive supplies.” This was a label heading chosen in a USDA Grain Inspection Packers and Stockyards Administration report where this activity was first reported. Captive supplies are an inappropriate description in that the inventory of fed cattle are not captive nor under the control of the packer. The animals are committed to the packer in a formula relationship. Feedlots control the marketing of formula animals and this is because most formulas have a premium/discount structure for meat quality. Feedlots determine the week the animals will be

slaughtered, and the packer determines when during the week. There is additional communication in that packers are informed about the placement of animals in anticipation of being marketed on the formula and the performance of animals in the feeding process. There are formal or informal arrangements as to the total volume and variability in the timing of marketings. Feeding performance as related to weather in particular impacts this timing.

Further, the prices for both negotiated cash and formula are, quality adjusted, equivalent for all practical purposes. Both sides of formula arrangements do not negotiate the base price. Both sides want to trade fed cattle and communicate that the interest is in having that happen at the market price. This has been repeatedly communicated in interviews with cattle feeders and packing entities. The interest is in trading cattle, “at the market.” There are not separate markets for formula and cash cattle. The base price is similar if not equivalent. USDA AMS regional reported prices are commonly used for the region where the formula arrangement is in place. Commonly, the TX-OK-NM price, or the Kansas price, or the Nebraska price as reported for the prior week is used. This price is the base of many formulas. The grid premiums and discounts are negotiated but infrequently. The premiums and discounts may be determined by the product end market – USDA Quality Grade or Yield Grade premium or discount. The base price has changed over time. Early formula arrangements used a plant-average price. Packers were willing to trade cattle through a formula at the value at which the packer was securing all other fed cattle purchases for the plant to which the cattle were sold. Over time, formulas have transitioned to using the USDA AMS reported price and mainly for the region in which the cattle are fed.

Opponents of AMAs and some academics often use the following argument illustrating the negative impact that AMAs have on the negotiated cash market. Supplies of captive cattle allow the packer to not bid in the cash market and thereby reduce demand in the cash market and depress price in the cash market. This is the argument used with policy makers and in legal settings to mandate negotiated cash trade. It was one of the arguments in the *Picket v. Tyson Fresh Meats* from 2004. But it remains an incomplete argument as it ignores the supply side of the market. If the packer does not have to bid on the cattle, then it also is true and one-for-one that the cattle feeders do not have to offer the cattle for sale. AMAs do not change the market fundamentals – do not change the total supply nor total demand. AMAs only change the channel in which animals are marketed.

The markets for negotiated cash and formula animals are also not separate markets where packers can choose to buy more or less in the formula or cash market. Separating markets is a strategy for exercising market power. But formula cattle are not “captive.” The cattle feeding enterprise decides the week the cattle will be marketed, communicates that to the packer – and it is usually not a surprise as communication between the seller and buyer is ongoing – and the packer decides the day of the week cattle will be delivered. The marketing decision belongs to the cattle feeders. Packers cannot call the cattle and almost all formula cattle are grid marketed and thus received premiums and discounts. Marketing cattle early will result in lost pounds sold and potential discounts to the cattle owner.

Table 1 attempts to illustrate how to think about AMA cattle in a manner accounting for both demand and supply impacts on the market. The top three rows, after the row headings, are the feedlot availability of animals from an illustrative region. Round numbers are used for simplicity. In the first column, the cattle feeding sector in this region has 100,000 head of fed cattle available in a given week. Cattle feeders will market 40,000 head through formulas and 60,000 head through negotiated cash trade. The last three rows are the packing sector’s needs for a given week in this example region. Also,

in the first column, the packers need 100,000 head and by definition will procure 40,000 head through formula and 60,000 head through cash. It is by definition because the methods are agreed upon and used by both the cattle feeding businesses and packing businesses. Whatever the packers' formula purchases are, they must match the formula marketings from feedlots. Formulas cannot be used to depress demand as formula cattle are removed from feedlot availability.

The first column illustrates a low-AMA scenario, and the second column illustrates a high-AMA scenario. The total availability is the same – 100,000 head. Packers procure 80,000 head per week through formula and the cattle feeders will market exactly that amount through formula. The remaining purchases are 20,000 head through cash trade. In these two scenarios, the market is in balance as the availability of cattle from feedlots is the same as the packer needs. This illustrates that AMA use does not change market fundamentals. High versus low AMA use does not create a disadvantage or advantage for either buyers or sellers.

The issue emerges when supply and demand are out of balance. This is when cattle availability is low relative to packer demand or when cattle availability is high relative to packer demand. These two examples are illustrated in the third and fourth columns. In the third column, the packer has incentives to purchase 100,000 head that week but there are only 90,000 head available. Competitive pressure across packing firms would likely cause one or more of them to bid aggressively to secure a larger portion of 10,000 head that is available to satisfy a demand for 20,000 head. This is similar to the actual fed cattle and beef market scenarios in many years prior to 2016. Formula use was high and the demand for the remaining cash cattle was aggressive. This period was characterized by excess capacity in the packing industry along with increasing returns to size. Packers bid aggressively for cash fed cattle and this impact spilled over into the valuation of formula cattle. High or low use of AMAs does not create this market scenario. And there is essentially one price across both formula and cash cattle.

The same argument holds for the excess supply scenario but who benefits is reversed. This is the fourth column of Table 1, and it is a reasonable facsimile of the fed cattle and beef market since late 2016 and early 2017. The packer has incentives to purchase 100,000 head that week but there are 110,000 head available. There is little competitive pressure across packing firms and cattle can be secured with relative ease. Further, it is likely there would be additional formula cattle, for example, 90,000 head per week. Formula cattle are valued no different than cash. In the end, more cattle are available than are needed and the cause of the issue is this supply/ demand imbalance and not the use of formulas. In this market environment, there are more animals available than needed. Cattle prices have to be lowered and packer margins increased so as to encourage the processing of the excess supplies. Again, negotiated cash trade feedlots may go weeks without a bid in this environment. But the problem is not how the available supply is split across marketing methods.

This discussion, in part, helps address the question of AMA use and market power. It, in part, reveals why the impact of AMA use on fed cattle prices are found to be small in the research literature. AMAs do impart a cost on fed cattle markets, but it is not power related. The cost is related to the provision information. The marketing of fed cattle through AMAs makes use of the price information discovered by those that negotiate in the cash market. Formulas are almost always based on a USDA AMS price reported in one or more of the five major regional markets. Likewise, forward contracts make use of basis information – basis of cash relative to futures prices – where the underlying cash price is a USDA reported price. Finally, almost all cattle feeding operations benchmark transactions against some

reported USDA AMS reported price. Price discovery and the information provided through that process is a public good. The many marketing methods that do not use the cash market make use of information provided by that process. Price discovery is work. And users of AMAs avoid that work. Users of AMAs make use of cash price information, save the cost of negotiating and the cost associated with the risk of the negotiation failing, and contribute little. This is the tragedy of the commons and is a market failure. However, market failures in the provision of information are common and certainly not at all unique to fed cattle markets.

Public goods are underprovided in a market economy – this is the case with negotiated fed cattle cash price information – and it is made worse by AMAs. But the issue is not that the market failure exists. Under provision of public goods more or less a tautology. The examples of portions of our economy and society that benefit from the benevolence of others – without payment – are substantial and numerous. The issue is: are the remaining and resulting cash market transactions not accurate? Are the transactions that take place in the resulting thinned cash market biased or inefficient? Are the resulting transactions systematically incorrect? There is no research evidence of this. This is a result that cannot be found in the scientific literature. There are changes to marketing institutions that can improve market function – and limit market power – but are more sophisticated than volume mandates.

The end conclusion from this section is that AMAs do not create power by definition as AMA use does not change the supply and demand fundamentals nor do AMAs change control of the transaction process. AMAs do impact the provision of information but there is no evidence that the resulting prices are somehow wrong. Market participants need to work to improve market function but there remains balance between innovation, knowledge, and mandates. Changing one thing will not improve market prices for cattle producers, nor change the supply and demand picture, but has the potential to disrupt efficient operations and make market outcomes worse for producers.

While it should be clear that AMA use does not impact the fundamental supply and demand conditions, it should also be clear that valuing a weeks' worth of fed cattle transaction based on a very small number of animals upon which price is actually negotiated is not without problems. The market power question and potential problem is not the same as the question or problem of how thin is too thin. The next two sections move into exploring how thin is too thin? Next, objective measures of price discovery are illustrated and discussed. And the section following the next section will examine relationships between these objective measures and the volume of cash trade.

Objective Measures of Price Discovery

Price discovery is potentially a complicated issue but can and must be measured objectively. Objective measurement is required for scientifically sound conclusions and discussion of implications. Objective measurements also require a tradeoff between what is measured and interpretation. Therefore, there is a tendency to use more than one measure and in fact it is important to recognize that there is not a single perfect measure of price discovery.

Price discovery is measured within a single unified statistical approach but through using three different measures produced within that approach. The unified approach is that of time series econometric modeling (see Johansen; Gonzalo and Granger; Myers et al.). A variety of cattle and beef prices are explained by their own past and by the past movements of other prices within the system of prices being considered. These time series models can be used to predict future price movements and can be

assessed in detail to understand how changes in price for an individual market then impacts subsequent changes in prices in other markets.

This model is not a price determination model – it does not communicate what is the correct price – or measure the impact of market fundamentals on price. It does communicate how prices dynamically interact through time. Which prices move first, and which follow? How strong are the relationships? And how does the system stay together in the long run?

Figure 1 presents the weekly negotiated cash prices for fed cattle in the five USDA AMS reported regions: TX-OK-NM, KS, CO, NE, and IA-MN. Also included in the figure are the rolling nearby weekly average live cattle futures contract price and a weekly downstream beef value. The fed cattle market is a weekly market – bid and ask occurs through the week and there is significant trade approximately once per week. Thus, weekly prices are used to understand price discovery. A weighted average fed cattle price is used for each region. Steers and heifers are combined as are all USDA Quality Grades. Further, carcass prices for animals are converted to live prices and included in the weighted average by making use of the USDA reported weekly dressing percentage. A 20-business-day window is used to transition the futures price from the nearby contract to the next-to nearby contract. The delivery month is avoided. A weighted average boxed beef composite value is constructed from different USDA Quality Grades. The downstream beef value also includes the weekly aggregate by-product value and is also converted to a live animal price using USDA reported dressing percentage. The downstream beef value is communicated in live animal units. The seven-price series are used in an econometric time series model. This model is the tool underlying from which price discovery measures are produced.

The first measure of price discovery measured by the model are the strength of information flows between the different prices. The modeling method reveals how changes in one region's price leads to changes in prices in other regions. This can be thought of as information being discovered in one region, being incorporated into price, and then impacting price discovery in other regions. These measures are termed "information flows" and have been used by the agricultural economics profession to study price discovery since the late-1970s. Price discovery in a large variety of commodity markets, including futures markets, have been researched. The financial economics profession has also used these measures and has more recently transitioned into two alternative measures. (See Garbade and Silber, Goodwin and Schroeder, Koontz, Hudson, and Garcia, and Geweke.)

The first alternative financial economics measure, and second measure in this report, is termed "component shares." There are seven price series in Figure 1, but all the series move in very close tandem. Thus, there is in essence one underlying cattle-beef price. The financial economics research literature refers to this as the equilibrium price of the asset in question. This equilibrium value is unobserved but can be constructed through statistical methods. This underlying price is an implied price from the seven prices that are observed. This idea is statistically testable, and the test confirms a single underlying cattle-beef equilibrium value. Further, the seven observed prices are combined with different weights to construct the implied cattle-beef value. This value is reported in Figure 1 and labeled "Common Trend." The weights are the component shares and communicate the contribution of each observed price to the equilibrium price. The weights communicate contribution of each individual price to the equilibrium price and is thus a measure of price discovery. (See Harris, McInish, and Wood, and Baillie et al.)

The second alternative financial economics measure, and third measure in this report, is termed “information shares” and is a roughly a combination of agricultural economics information flow measure and the financial economics component share measure. Using the results from the time series model, each price can be one-at-a-time changed a uniform amount to reveal the impact on all of the other prices. The component shares measure comes into play and the information flows measures also comes into play in this exercise. Thus, we can, for example, examine the impact that, for example, a \$1/cwt change in the TX-OK-NM price has on all the other four regions. The method is also careful to recognize and attempt to disentangle potential correlations within the price series. This is a substantial advantage of the component share approach – a limitation is that the method requires recognizing a number of alternative correlation structures and averaging across findings. (See Hasbrouck, and Yan and Zivot.)

Each of the three objective measures of price discovery have their strengths and are not without weaknesses. The information flows measure the movement of information through prices and are not shares – percentages between zero and one hundred – and therefore are the potential to be most useful but do not account for the potential correlations in prices nor the contribution to the underlying equilibrium price. Component shares measure the contribution to the equilibrium price but none of the dynamics of price discovery. Information shares have the weakness of being shares as opposed to overall measure and have the strength of combining information flows and component shares. Further, the averaging across potential correlations further smooths the result. All measures have merit and are informative but there is no single best measure of price discovery. However, the “information shares” measure has good strengths, the fewest weaknesses, and are the most acceptable within the financial economic research profession and are emerging as preferred within the agricultural economics research profession (Putniņš; Adämmer and Bohl).

The final communication step in the overall study is to inform that the analysis was done using of two-year rolling window samples. The USDA AMS price data from 2002 through 2019 are used and are sliced up into multiple two-year windows. Price discovery measures are estimated for each window. And then the relationship between price discovery measures and regional market volumes in those windows is examined. Price discovery results from each window are linked to the volume of cash trade in that window for each regional market. This analysis examines the relationship between price discovery and volume. And allows the conclusion associated with the question: is price discovery related to the volume of negotiated cash trade?

Before discussing the results, let’s address some additional data questions. Alternative rolling window sizes were examined. Shorter windows gave more variable results and are not recommended. Longer windows gave results that were less informative – there is less variation and less explanatory power. Windows of one, three, and four years were examined. Two years was settled upon as most informative. The sample was concluded with 2019 for two reasons. First, the Colorado regional fed cattle price is less and less available over time. Colorado routinely has two packers making purchases and therefore does not meet confidentiality requirements. The overall modeling framework requires complete data – all seven-price series – and losing the Colorado price series limits use at later dates. Second, while price discovery into the COVID period is relevant, interesting, and informative, it is also reasonable to suggest that policy should not be considered based on COVID impact findings. Thus, the sample period is since the beginning of Livestock Mandatory Price Reporting – 2002 – and prior to COVID market disruptions and limited data from all the five USDA AMS reporting regions – 2019.

The Relationship Between Price Discovery and Volume of Cash Trade

So, what is found in the relationship between objective measures of price discovery and the volume of negotiated cash trade? In short, there is no clear and definitive relationship. Substantial price discovery occurs in all regional USDA AMS markets when there is substantial cash trade and when there is little cash trade. Price discovery is more complicated, and more fluid than simply determined by the volume of trade in the cash market. Price discovery is a human activity and is not simply determined by the volume transacted. There are times where substantial volumes are needed and there are times where little volume is needed. Cash trade minimum mandates will not improve price discovery and are not needed to protect price discovery. The remainder of this section provides more depth and detail supporting this assessment.

The three objective measures of price discovery were produced, are discussed in turn, and results compared to the changes in volume of negotiated cash market transactions in each USDA AMS reporting region. Figure 2 presents the regional negotiated cash trade volumes. The trend is to lower negotiated cash market volumes. The negotiated cash trade volumes decline in all regions. The declines stop in 2015 and then negotiated cash trade volumes modestly increase. The trends towards smaller cash trade have slowed with expanding fed cattle numbers since the low mark in 2014. These negotiated cash volumes are different than total fed cattle volumes marketed and slaughtered. But move in similar fashion and trend smaller. Supplies shrink across the entire first two-thirds of the sample considered. The cattle cycle lows in terms of animal numbers were in 2014. And animal numbers have increased since. Thus, post-2014 in Figure 2 are increasing cash volumes in the context of greater cattle numbers. Prior to 2014, the negotiated cash trade is smaller as are total animal numbers.

The objective price discovery measures will be compared to the volume of cash trade and similarly the percent of cash trade within the overall animal volume. These relationships can be just discussed and do not need more formal statistical summary. The volume movement is clear. The negotiated cash volume shrinks from 2002 until 2014 and then from 2014 to 2019 it expands modestly and oscillates somewhat. The exception is IA-MN as the cash volumes are relatively constant in that regional market. Price discovery measures will be compared to these changes in volumes.

Strength of information flows are presented in Figure 3. There are flows for each USDA AMS regional market, the nearby live cattle futures series, and the boxed beef downstream values series to all other series. These information flows are summaries – from the specific market to all other markets. A formal analysis was conducted on information flows from each market to each other market but is not included here for simplicity. The results are not different for the individual markets and the summary. From 2002 until 2014-15 the information flows decline. This indicates that less price discovery is occurring. Each market has a smaller and smaller impact on price changes in other markets. This is occurring when the volume of negotiated cash trade is also shrinking. It is easy and reasonable to assume a causal relationship. However, there are substantial increases to the information flows in 2015-16 and 2016-17. There are modest increases in cash trade in this period, but the amount of price discovery is as great as in the 2006 to 2012 time period. Large amounts of price discovery are occurring with very modest increases in negotiated cash trade.

What is measured in Figure 3? What are these strength of information flow measures? These are essentially contributions to the time series model R-squared. The vertical axis is the portion of total explanatory power of the model that is measured by the price dynamics. For example, if TX-OK-NM is

0.45 then this implies that 45% of the how much the other prices – KS, CO, NE, and IA-MN – can be explained is due to TX-OK-NM. This measure is not total explanatory power but the portion of the explanatory within how much the model explains. It is observed in Figure 3 that TX-OK-NM begins at 30% 2002-03, increases to 45% in 2004-05, declines to 5% by 2012-13, and then improves to about 25% in 2015-16 and 2016-17. All regional markets contribution to price discovery decline over the rolling windows to lows through 2011-12 to 2013-14. Contributions improve in 2015-16 and 2016-17. The only market price where the contribution is relatively steady is the downstream boxed beef value.

Figure 4 illustrates the relationship in TX-OK-NM specifically. There are strong declines in both price discovery and cash volume early in the sample period. And then there are strong improvements in price discovery, as objectively measured, that are far in excess of the commensurate increases in negotiated cash trade. Thus, the relationship observed in the 2002 through 2015 period does not occur in the later sample. The early relationship does not generalize to a broader understanding of price discovery. Something else is the causal impact rather than the volume of negotiated cash trade.

This is what is seen in one objective measure of price discovery. What about the remaining two? The other two measures suggest no relationship between volume and price discovery and a changing nature of price discovery over time.

Component shares are communicated in Figure 5 across the sample periods examined. These measures are relative weights across markets. It is seen that the markets in the upper Midwest are important in early time periods and the markets in the southern plains were most important during the time periods of tightest fed animal supplies. Recently, the situation has transitioned back to markets in the upper Midwest being important. The relative aspect of the weights is important to remember. This objective measure only provides a relative weighting and not a weight specific to each market. The group is assessed relative to a total of one or 100%. And this is a nature interpretation in that it is a percentage or a share. A second interesting feature of this measurement subsets of markets can be assessed. For example, the boxed beef downstream value can be ignored as can the nearby live cattle futures series. This focuses the relative weights only on the USDA AMS reporting regions. Figure 6 presents the relative weights for only the cash fed cattle markets. Live cattle futures and boxed beef values are important determinants of price discovery prior to 2008-09 but much less so from 2009-10 until 2016-17 and we can remove those influences to just examine the importance of various cash markets. If price discovery was impacted mainly by the negotiated cash trade in a regional market, or changes in the volume of cash trade in those markets, or changes in the percentage of cash trade in those markets then it would be that the upper Midwestern markets would be first less important and then later more important. This is the opposite as to what is observed.

Detailing information in Figures 5 and 6 is useful. It is observed that live cattle futures are important for price discovery over long periods of time. Downstream boxed beef values have minor importance but periodically are significant. In the seven-market mix, there is no dominant regional market. The contribution of the different regional markets varies through the sample. Markets in the upper Midwest are most important when live cattle futures are also important. The markets in the southern plains and in Colorado are most important when fed cattle supplies are the tightest and when live cattle futures contribute relatively little. Again, the results of the component shares are rather opposite from the information flows measures.

Notice that the component shares are relative weights that cannot convey information that absolute weights associated with the information flows that those measures can convey. The relative weights transition between markets and the absolute weights shows all markets declining and then increasing. The second measure cannot do this – it cannot provide an absolute measure. In this context the information flows are unique and revealing. The third objective measure is also a relative measure.

Figure 7 communicates the information share averages for the various markets and across the sample periods. While this information, the averages, are percentage and relative measures, the underlying information can be delved into to be more informative. The relative weights associated with information shares, which are average of percentages, are discussed first. The information share measures communicate how movements in one market price are precipitated through the various markets to impact those other prices. To understand the resulting market path then the correlations in the underlying market prices needs to be removed. The tools to remove the correlations across the seven market also do not produce unique results. It depends on the assumed market correlation path. Therefore, the approach to examine all possible paths and take the average of the results across all permutations of the markets. Because the boxed beef valuation is least correlated with the other markets and because nearby live cattle futures are a national and forward-looking market then these two markets are assumed last and first in the path, and then all permutations of the cash markets are used in between those two – live cattle futures first and downstream boxed beef value last.

The most notable feature in Figure 7 is the stability of the contribution by the five fed cattle markets to the price discovery process. The nearby live cattle futures, Texas-Oklahoma-New Mexico, Kansas, Nebraska, and Iowa-Minnesota cash prices each contribute slightly less than 20% each to the market adjustment to new information. The Colorado regional market and the boxed beef downstream valuation each contribute the remainder which are each less than 5%. Figure 8 presents the same information as in Figure 7 but in a manner such as Figures 5 and 6. The percentages sum to one and are presented as a contribution to 100%. The stability of the information share measure over time is clear. With this measure of price discovery there is little variation across the two-year rolling samples and there is no relationship between the amount of price discovery done in each market and the change in the volume of cash trade. The stability of the relationship was only disturbed by the market adjustments following the BSE event and the reestablishment of international beef trade.

Figure 9 delves into the information share measures in more detail. Presented here are not the averages of the information shares but the 75th quantile. Across the different permutations of correlations there are different information shares produced. This figure shows that when the information share is large then how large is it? There is more variation in this information share but there is also not a relationship between contribution to price discovery and volume. Price information from Colorado and the downstream boxed beef value again contribute the least. The contribution of Iowa-Minnesota is the lowest while Kansas, Nebraska, and TX-OK-NM are periodically the highest. Live cattle futures often contribute to price discovery similar to that of the most important regional cash markets, but there are periods where its contribution is similar to IA-MN.

There are three measures of price discovery that are examined and none display a clear, or even a modest, relationship with the volume of cash trade. There is no evidence that mandating a volume of cash trade will guarantee a level of performance of price discovery in USDA AMS regional fed cattle markets as can be measured objectively. So, is there a best measure of price discovery or is there a

portion of the results where our interest and interpretation should be concentrated? The answer is yes and no. The third measure of price discovery is likely the most settled upon in the finance literature. This third measure is similar to the second and more carefully separates the relationships between individual prices. The second measure is the second most settled upon measure in the finance literature. But most of the finance literature uses this tool with a small number of prices. The measure tends to be sensitive. The first measure is used commonly in the agricultural economics literature and has been used historically in the finance literature. The first measure examines the dynamic adjustments in price. Whereas the second two measures track how the examined prices follows the underlying unobserved equilibrium price for the base asset. The finance literature considers the subsequent dynamic adjustments – the first measure – as imperfections in the market. None of the interpretations are clearly challengeable as incorrect. And both – the first measure and the combined second and third – the agricultural economics literature and the finance literature approaches – are all useful and informative.

And none are significantly related to the volume of cash trade in the underlying fed cattle market. The first measure appeared to be related to volume in work conducted prior to 2015. But the relationships have changed in the subsequent time period. And the relationship between price discovery and volume is clearly not present in other objective measures of price discovery – the second and third measures used in the financial market literature.

Conclusions

Price discovery is an important issue. And to reveal a fed cattle price then fed cattle must be traded. But there is not clear relationship between the volume of trade in the negotiated cash market and the amount of price discovery as objectively measured. Further, there is no relationship between objective measures of price discovery and the volume of negotiated cash trade in different regional markets.

Thinning markets, and in particular livestock markets, have been a long-time research topic (see e.g., Tomek; Franken and Parcell; Mathews et al.). There is no research that identifies specifically how thin is too thin. The economic incentives to not use the cash market are strong and well documented in the USDA-RTI Livestock and Meat Marketing Study. Further, the underlying economics has not changed since that study but the costs to using cash markets and benefits to not using cash markets have likely increased. There is not a simple first-choice solution. Effective price discovery remains a concern but this study clearly finds that, while one measure declined for the period 2002-2012, that same measure increased substantially from 2014-2016. The increase in question is far in excess of increases in cash trade during that period. Further, other measures show no relationship between price discovery and the volume of negotiated cash trade.

While price discovery is identified as the issue, there also appears to be an interest in a policy solution to due to what we have observed as market outcomes. That may be the true issue at hand. This is price determination and not price discovery. Further, it is presented here that mandating cash trade will not change the underlying fundamentals in the marketplace. Changing where and how cattle are sold does not change the number of cattle. It does change the transactions costs, risk aspects, and potentially animal and meat quality. And the changes increase costs and risks while impeding quality. But these topics are addressed elsewhere.

Price discovery is a human activity. It is work. It is bid and ask. It is the revealing of underlying supply and demand conditions in price. And not only current supply and demand conditions but those in the future – the current market and decisions today impact the future. Increasing the volume of cash trade likely increases the depth of price discovery. But that is not revealed in the data. The data reveal that price discovery ebbs and flows. Different regions do the work in different time periods. Live cattle futures are important to price discovery. Downstream beef values are not unimportant. The data reveal that less price discovery can occur with less negotiated cash trade and the data reveal that substantial price discovery can occur with little cash trade. Price discovery is a more subtle thing. It is impacted much by information and market institutions. Policy should emphasize provision of information and facilitation of institutions that do more price discovery work without disrupting market coordination and increasing the cost of doing business.

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Table 1: An Illustration of How Variation in AMA Volumes Do Not Impact Cattle Market Fundamentals.

	Low AMA Volume	High AMA Volume	Excess Fed Cattle Demand	Excess Fed Cattle Supply
Feedlot Availability:	100,000	100,000	90,000	<i>110,000</i>
Formula	40,000	80,000	80,000	90,000
Cash	60,000	20,000	10,000	20,000
Packer Needs:	100,000	100,000	<i>100,000</i>	100,000
Formula	40,000	80,000	80,000	90,000
Cash	60,000	20,000	20,000	10,000

Figure 1: The 5 USDA Regional Fed Cattle Prices, Nearby Live Cattle Futures Prices, a Downstream Box Value, and the Underlying Common Trend.

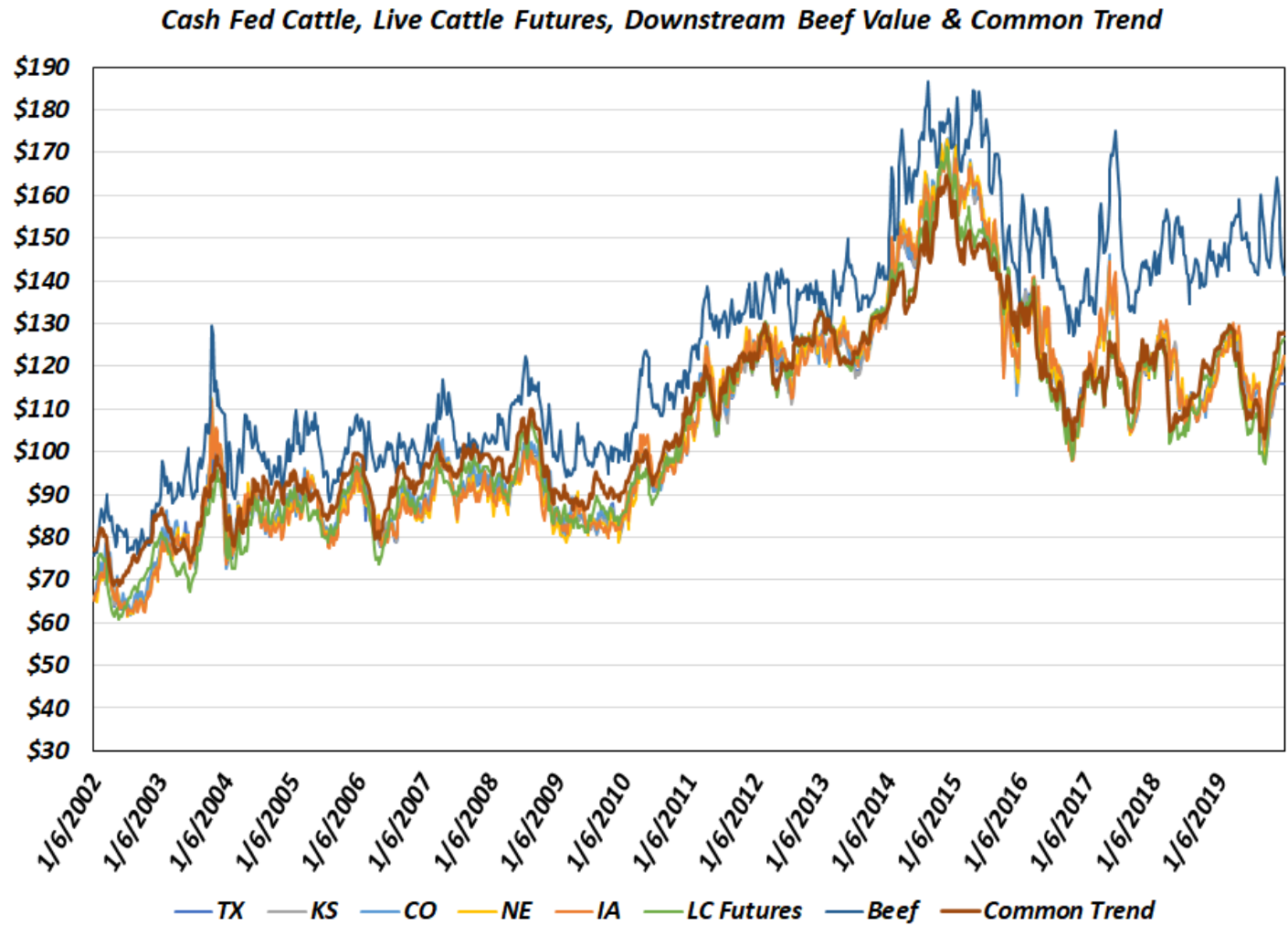


Figure 2: USDA AMS Average Weekly Negotiated Cash Volumes and the National Weekly Negotiated Cash Market Volume for the Two-Year Rolling Window Samples.

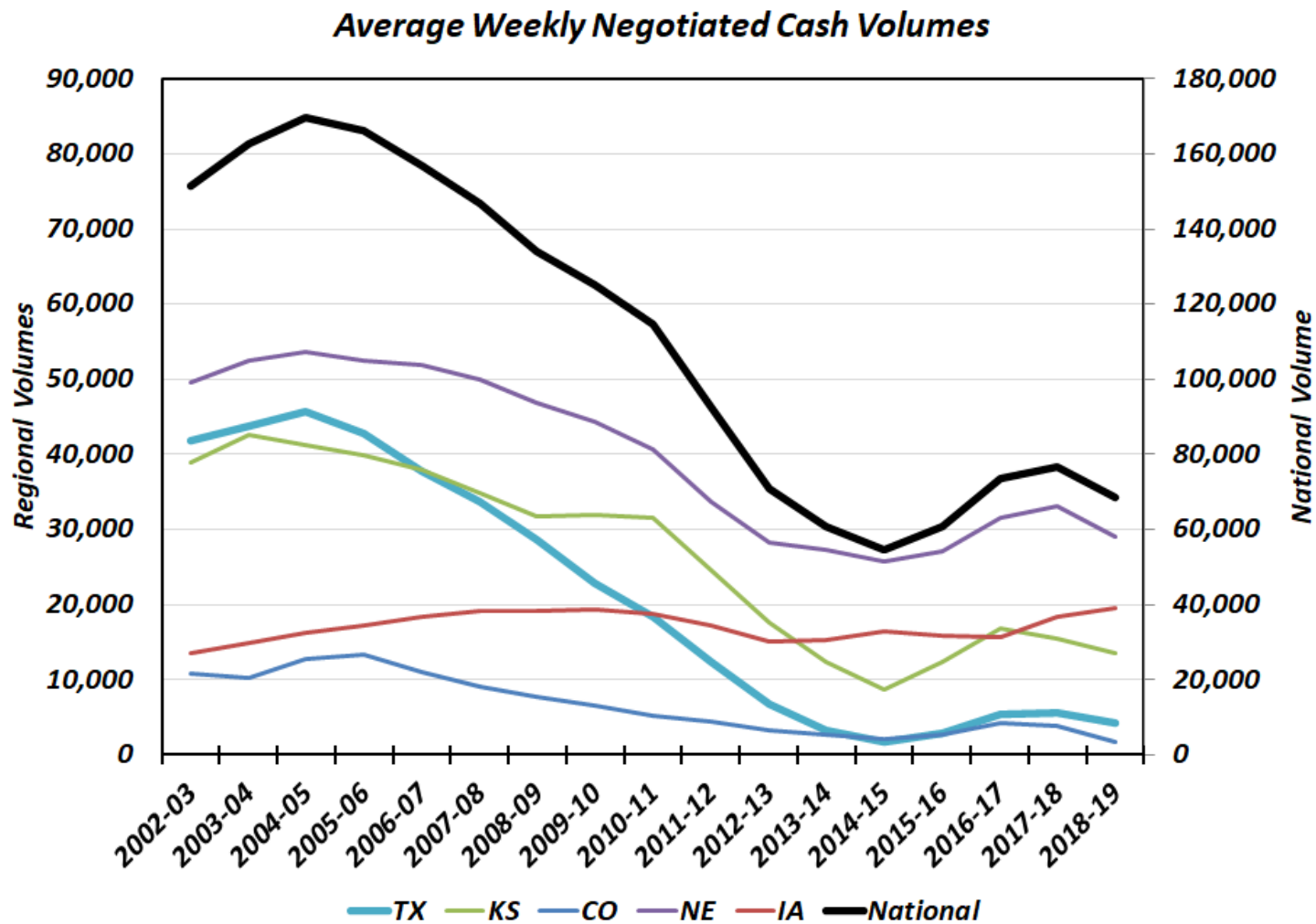


Figure 3: Information flows from the given market to all other markets.

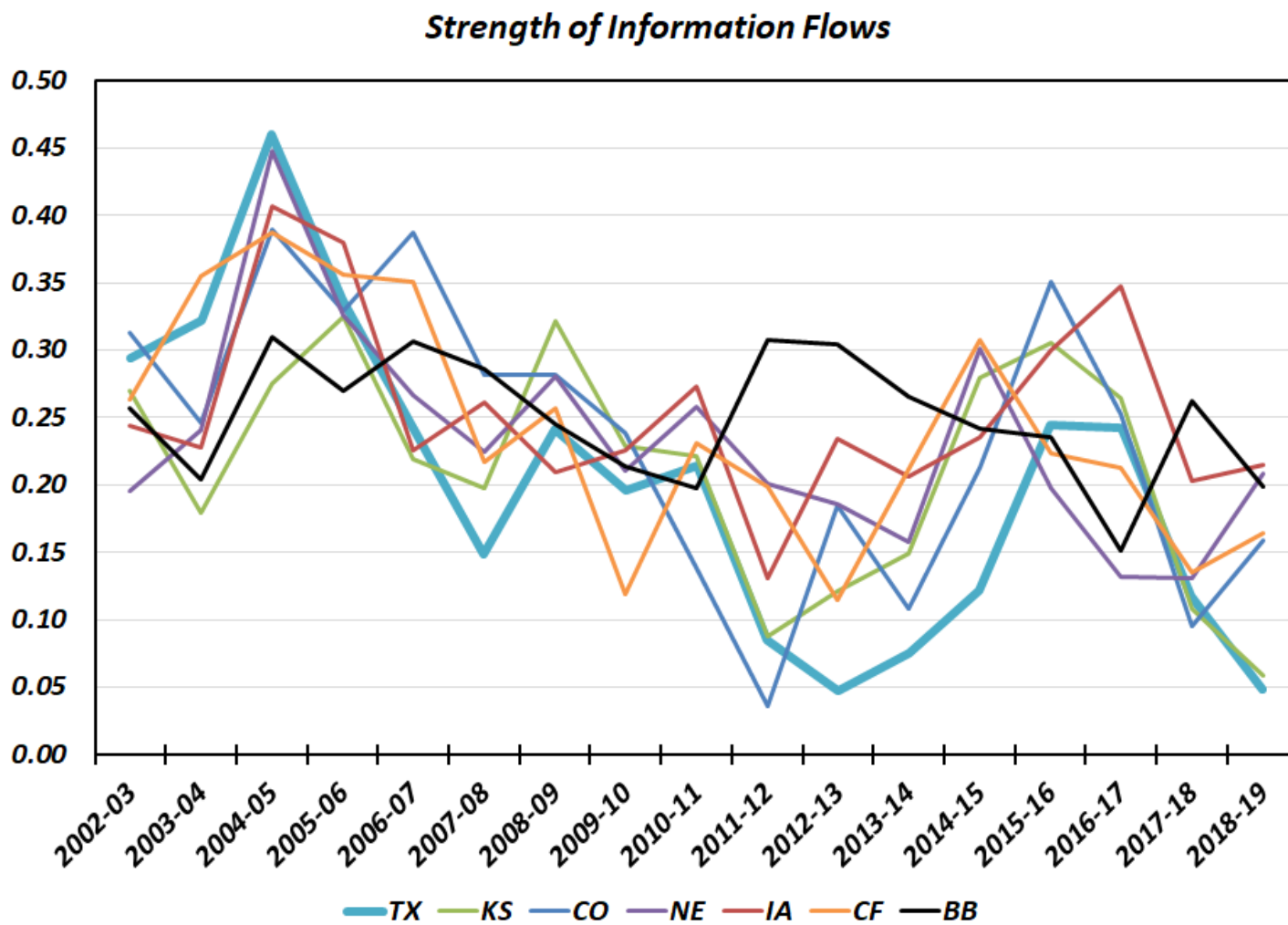


Figure 4: Strength of Information Flows from TX-OK-NM to all other USDA AMS Reported Markets and Cash Market Volume for TX-OK-NM.

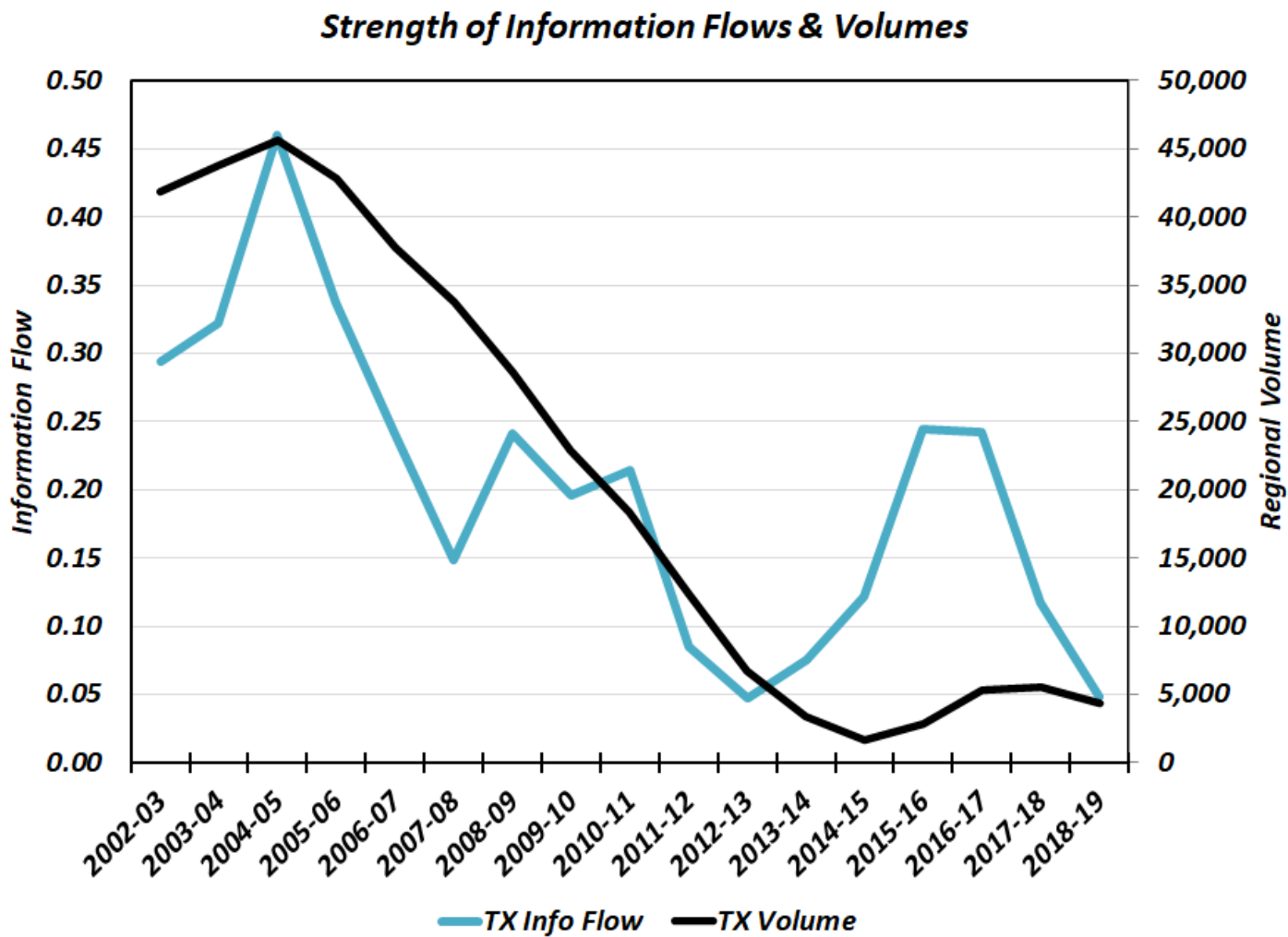


Figure 5: Component Shares Associated with Each USDA Regional Market, the Live Cattle Futures Market, and Down Stream Beef Values and By Rolling Window Sample Period.

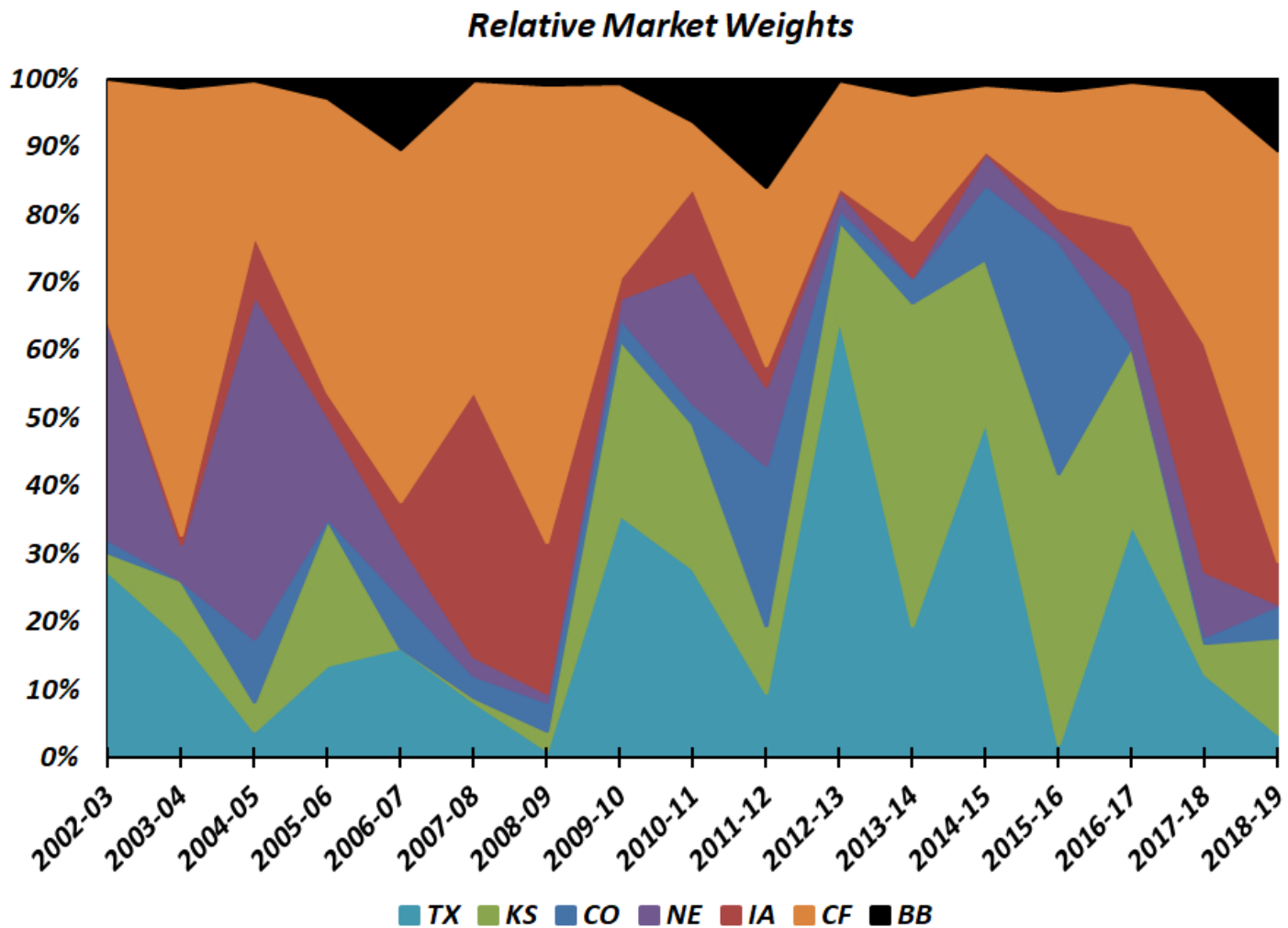


Figure 6: Component Shares Associated with Only the USDA Regional Markets and By Rolling Window Sample Period.

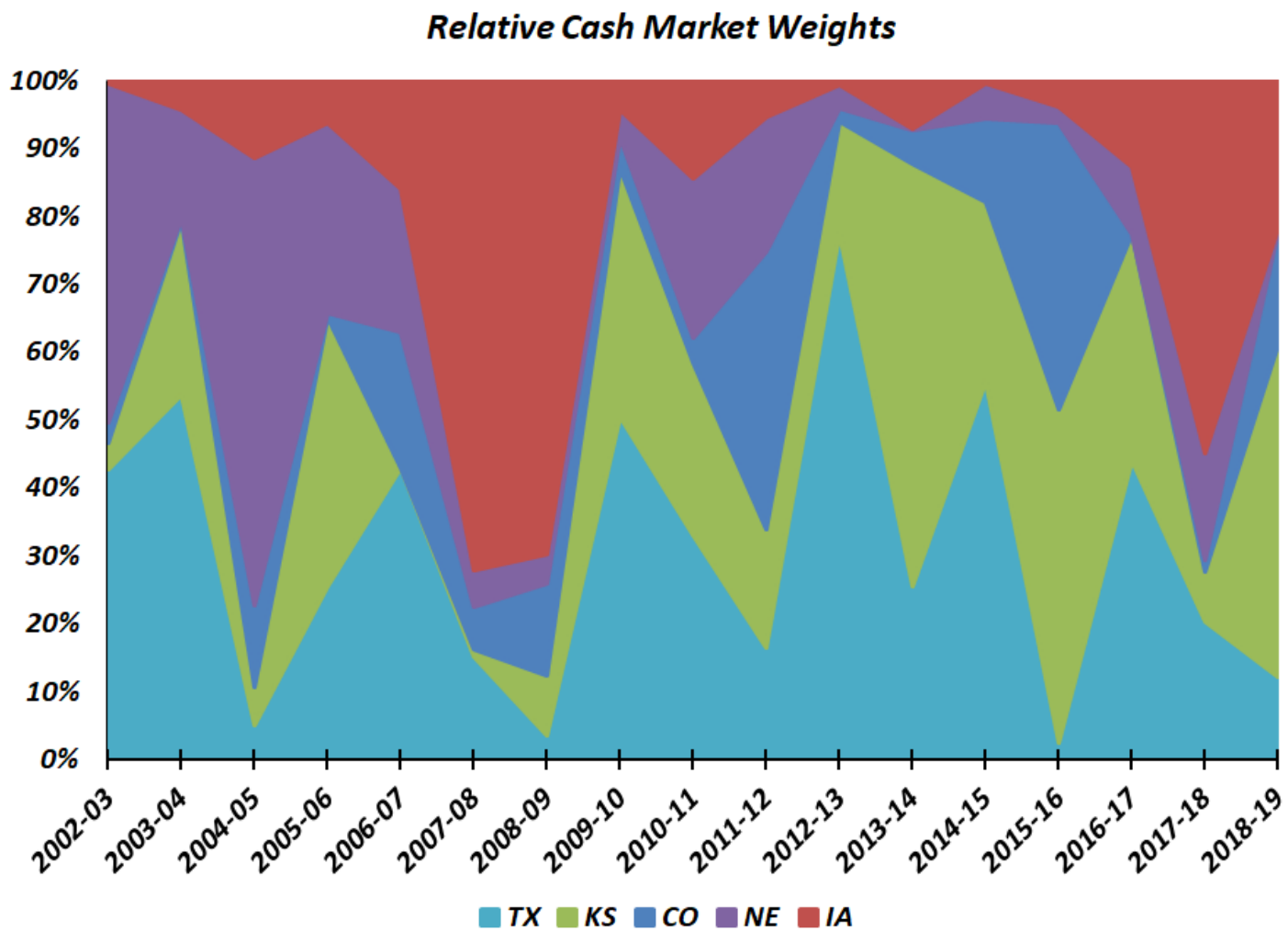


Figure 7: Averages of Information Shares Associated with Each USDA Regional Market, the Live Cattle Futures Market, and Down Stream Beef Values and By Rolling Window Sample Period.

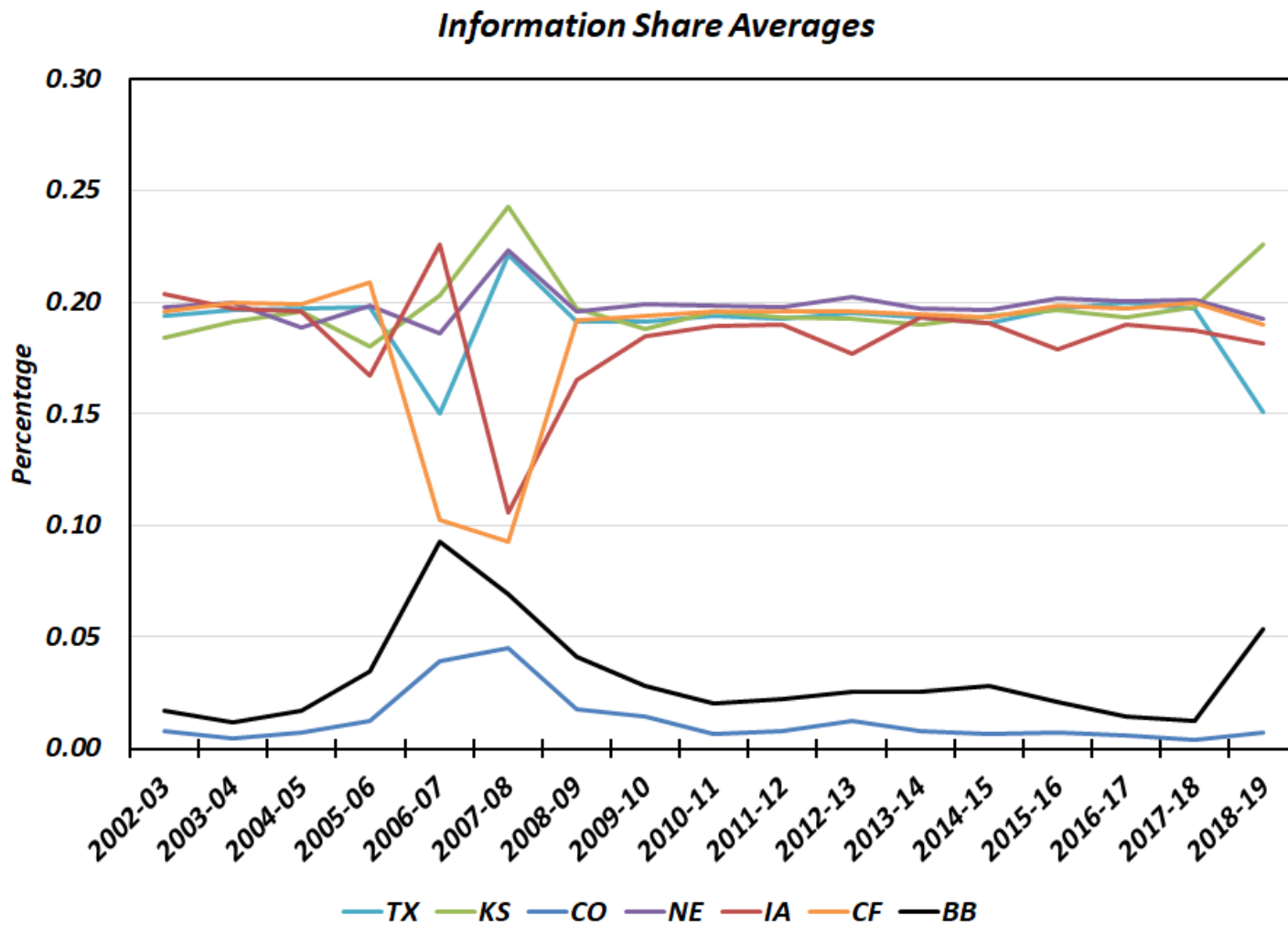


Figure 8: Information Shares Associated with Each USDA Regional Market, the Live Cattle Futures Market, and Down Stream Beef Values and By Rolling Window Sample Period Expressed as Relative Weights.

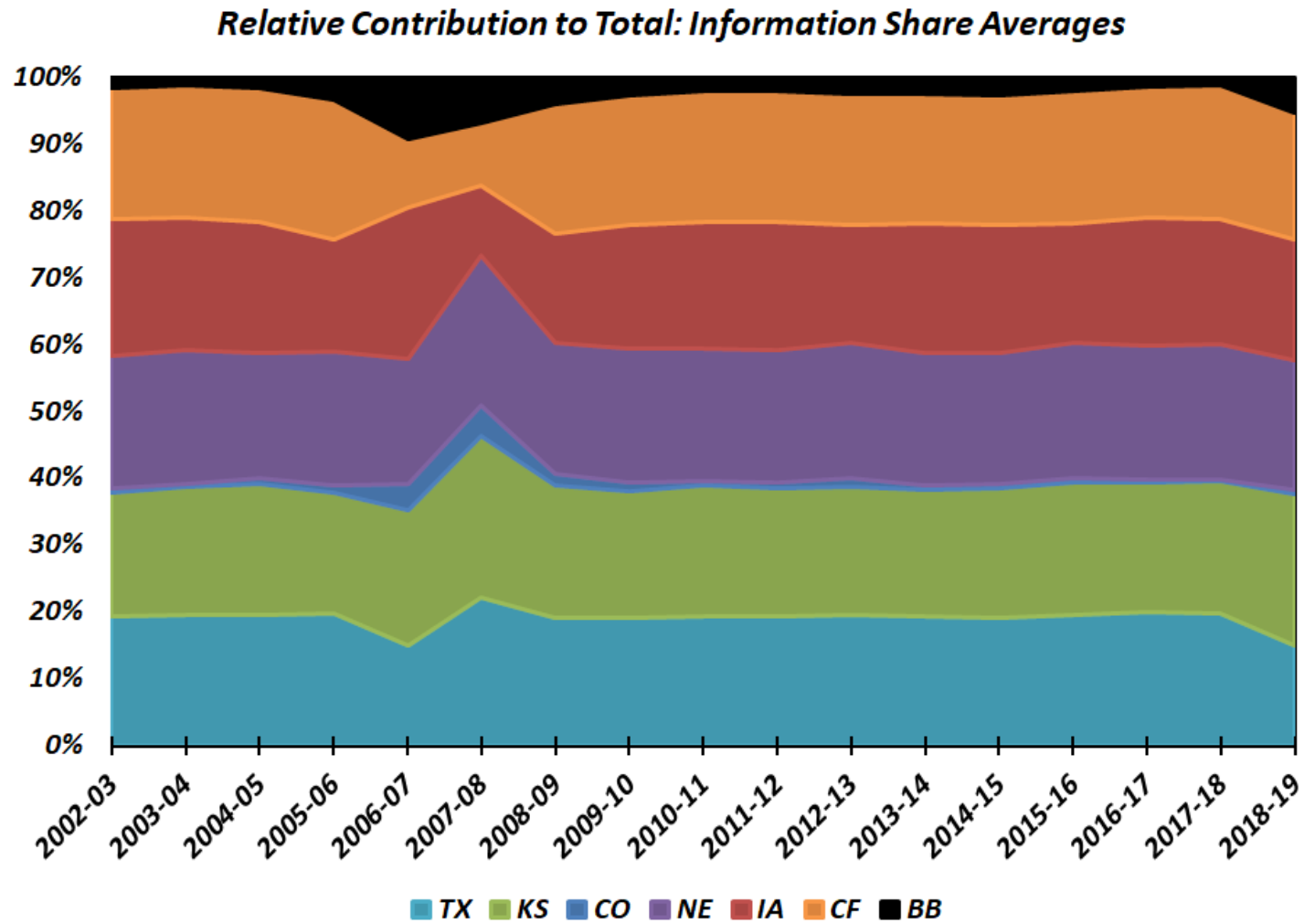


Figure 9: Information Shares Associated with Each USDA Regional Market, the Live Cattle Futures Market, and Down Stream Beef Values and By Rolling Window Sample Period. Information Shares When the Shares are Large Across Permutations.

