Pass-through in the United States Beef Industry: An Update and Expansion

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Abstract

Understanding how signals for change are transmitted from primary consumer demand through the supply chain is key for long-term prosperity of the cattle industry. Zhao, Du, and Hennessy (2011) used Ricardian rent theory (RRT) to determine if complete pass-through occurs from fed cattle and corn prices to feeder cattle prices. Due to changes in the beef industry since 2004, this study updates and expands Zhao, Du, and Hennessy (2011). This article presents three analyses. First, an update using data from 2004 to 2016 is presented. Next, an analysis using futures market feeder and live cattle prices from 1994 to 2016 identifies four different regimes and tests RRT in each regime. Finally, Kansas cash feeder cattle and expected live cattle prices using historical basis are used to test RRT with two structural breaks. Evidence supporting RRT in cattle markets is mixed. The future direction of expansion for this study is discussed.

Keywords: cattle, futures prices, pass-through, Ricardian rent theory

JEL Classification: Q11, Q13

Introduction

Recently U.S. cattle markets have been characterized by extreme highs and lows. Record high prices throughout the beef industry were documented in 2014 to mid-2015 and then spiraled downward. This resulted in diverse profitability outcomes between cow-calf and feedlot operations in 2015. Some economists estimate losses to feedlots of around $500/head while cow-calf producers experienced historically high margins (Tonsor 2016). Beyond immediate profitability implications, understanding how signals for change from primary consumer demand are transmitted throughout the supply chain is key for longer-term prosperity of the industry (Marsh 2003).

Zhao, Du, and Hennessy (2011) used time-series data from January 1979 to April 2004 to determine if Ricardian rent theory (RRT) holds and complete pass-through occurs. According to RRT, rents will be bid up so the holder of the scarcest resource will extract the surplus (Ricardo 1821). In terms of the cattle industry, breeding stock and calves (young cattle) are fixed in supply in the short run. Thus, sellers of feeder animals (potentially cow-calf producers or backgrounders) could receive “Ricardian rents.”[1] Zhao, Du, and Hennessy (2011) found fed cattle futures prices have 93% of complete pass-through to feeder cattle futures prices and corn price increases have a negative effect around 87% of complete pass-through. This study, while important, needs to be updated and improved given the changing environment in the beef industry.

The objectives are to update and expand Zhao, Du, and Hennessy (2011) in the following ways:

[1] Potentially, Ricardian rents could be held by seed stock owners rather than cow-calf producers.

1. More recent data through 2016 will be used. Zhao, Du, and Hennessy (2011) found a structural break in the data in 2004 and thus did not use data past 2004. Therefore, an update with more recent data and reinvestigation into structural change is warranted. Given the record price changes recently, periods of herd expansion and contraction, etc., pass-through estimates in recent years could potentially be different.
2. Data from the *Focus on Feedlot* series, which surveys Kansas feedlots monthly, will be used to update production assumptions. Specifically, the fixed weights of feeder and finished cattle, death loss percent, annual discount rate, and bushels of corn needed for feed will be updated to reflect industry practices.
3. Zhao, Du, and Hennessy (2011) used live cattle and feeder cattle futures prices for price expectations. Solely using futures prices assumes zero expected basis. However, according to Kastens, Jones, and Schroeder (1998), forecasts incorporating historical basis are more accurate. We relax the zero basis assumption by testing RRT when using cash Kansas feeder cattle prices and expected live cattle prices calculated using deferred futures contract values, Kansas cash live cattle prices, and a four year historical average basis.

The following presents three analyses. First, updated pass-through calculations will be estimated using data from 2004 to 2016. Second, an analysis of 1994 to 2016 will be conducted while simultaneously testing for structural breaks. Third, an analysis from 1994 to 2016 using cash feeder cattle prices and expected live cattle prices based upon deferred future contract values and historical basis patterns will be presented while also testing for structural breaks.

Applying Ricardian Rent Theory to the Beef Industry

Consider the following profit per head for a finished steer sold from a representative feedlot where π_t is the net present value of expected profit per head in time t:

$$\pi_t = \frac{P_{t,T}^{Fed} W^{Fed}(1-D)}{1+r} - P_t^{Feeder} W^{Feeder} - P_t^{Corn} B^{Corn} - OC. \quad (1)$$

Subscript t is time of placement and T represents the expected finishing time. $P_{t,T}^{Fed}$ is the expectation at time t, of time T fed cattle price in dollars per hundredweight (cwt). P_t^{Feeder} is feeder cattle price at time t in dollars per cwt. W^{Feeder} and W^{Fed} are the steer's weight at placement and finishing in cwt, respectively. P_t^{Corn} is the corn price at time t in dollars per bushel (bu) and B^{Corn} is total corn bu fed. We are assuming all the corn fed is purchased at placement. D is death loss percent and r is the discount rate. OC represents other costs of feeding the steer, such as veterinary costs, marketing, transportation, etc. OC is assumed to be constant and small and thus ignored for the following analyses.

Assuming profit is equal to a fixed K, the following hypotheses can be derived to test if RRT holds in the beef industry, following Zhao, Du, and Hennessy (2011). If RRT holds, then feeder cattle prices will be bid up or down when economic changes occur in cattle finishing. The first testable hypothesis is:

H_0^{Fed}: a dollar increase in expected fed cattle price, $P_{t,T}^{Fed}$, affects the feeder cattle price, P_t^{Feeder} by:

$$\phi_1 = \frac{W^{Fed}(1-D)}{W^{Feeder}(1+r)}. \quad (2)$$

The second testable hypothesis is:

H_0^{Corn}: a dollar increase in corn price, P_t^{Corn}, affects the feeder cattle price, P_t^{Feeder} by:

$$\phi_2 = -\frac{B^{Corn}}{W^{Feeder}}. \quad (3)$$

To obtain 100% pass-through hypotheses values, multiple assumptions are made and plugged into equations (2) and (3). These assumptions will depend on the time period under investigation. Feeder cattle weight, fed cattle weight, death loss percent, and feed conversion ratio will be the averages over the corresponding time period from the *KSU Focus on Feedlot* spreadsheet (LMIC 2016a). Through the entire analysis 56 lb of corn per bu is assumed. The average annual interest rate for feeder livestock, non-real estate bank loans from the Kansas City Federal Reserve Bank, was used as a proxy for the discount rate (Federal Reserve Bank of Kansas City 2016). The effective semi-annual discount rate is calculated using $[(1 - annual\ rate)^{1/2} - 1]$.

Data and Methodology

Using feeder and live cattle futures prices (Analysis 1 and 2)

To complete the first two analyses, monthly data from November 1989 to May 2016 were collected from the Livestock Marketing Information Center (LMIC; LMIC 2016a). However, after considering all possible lags in the following models and availability of the data needed in the three analyses, data from February 1994 to May 2016 will be used. Following Zhao, Du, and Hennessy (2011), $P_{t,T}^{Fed}$ is the price of the appropriate deferred live cattle futures contract at time t and P_t^{Feeder} is the nearby feeder cattle futures contract price at time t.[2] The Chicago

[2] This assumes a zero basis for both feeder and fed cattle prices.

Mercantile Exchange (CME) fed cattle and feeder cattle futures prices, and cash corn prices were obtained from the LMIC database (LMIC 2016a).

The expected fed cattle price, $P_{t,T}^{Fed}$, was calculated using the nearby live cattle contract price for the contract corresponding to five months in the future. For example, if the steer is placed in January, it will finish feeding in June, so the June futures price in January is used. However, if the steer is placed in February, it will finish feeding in July. There is no July futures contract and therefore the August futures contract price in February will be used.[3] Figures 1 to 3 detail the nearby feeder cattle futures, deferred live cattle futures, and cash corn price series from February 1994 to May 2016.

Augmented Dickey Fuller (ADF) tests were conducted to test for nonstationary and unit root (Dickey and Fuller 1979). The unit root test results are displayed in Table 1. The ADF tests allow for a constant drift term and one lag of the variable. All three price series used in analysis 1 and 2 display unit root. Thus, the following analyses are conducted using differenced data to avoid spurious results.

Similar to Zhao, Du, and Hennessy (2011), the static empirical model in differences can be written as:

$$\Delta P_t^{Feeder} = \alpha_0 + \beta_0 \Delta P_{t,T}^{Fed} + \gamma_0 \Delta P_t^{Corn} + \sum_{k=1}^{11} d_k m_k + \varepsilon_t \quad (4)$$

where m_k are monthly placement dummies for January to November with $k \in \{1,2,\ldots 11\}$ representing the 11 months. α_0, β_0, γ_0 and d_k are parameters. We will compare the values of β_0

[3] Live cattle contracts are only traded for February, April, May, June, August, September, October, and December. We are also assuming that the basis in July and August is the same ($0) when in reality it might be different.

and γ_0 to the hypothesized values in equations (2) and (3) to test for 100% pass-through. ε_t is the error term.

Data are monthly averages and prices are discovered in the market with noise, thus a model specification allowing for possible dynamic effects is considered. Accordingly, equation (4) can be extended dynamically as follows:

$$\Delta P_t^{Feeder} = \alpha_0 + \sum_{i=0}^{p} \beta_i \Delta P_{t-i,T-i}^{Fed} + \sum_{j=1}^{q} \gamma_j \Delta P_{t-j}^{Corn} + \sum_{k=1}^{11} d_k m_k + \varepsilon_t \quad (5)$$

where β_i and γ_j are the pass-through rate from a change in live cattle and corn prices i or j periods earlier. Following Campa and Goldberg (2006) and Zhao, Du, and Hennessy (2011), the instantaneous effect is given by the coefficient in the same period and the total effect of fed cattle and corn is the sum of the respective coefficients. These values will be tested against hypothesized pass-through threshold values to see if RRT holds in the cattle industry; therefore, ϕ_1 is $\sum_{i=0}^{p} \beta_i$ and ϕ_2 is $\sum_{j=0}^{q} \gamma_j$. Lag lengths (p and q) are selected by choosing the model with the lowest Akaike Information Criterion (AIC) value with consecutive lags and all monthly dummy variables. For the dynamic models up to five lags of live cattle and corn prices were considered.

Incorporating basis into expected live cattle price (Analysis 3)

Using feeder and live cattle futures prices for price expectations assumes a zero basis expectation. This can be seen using the well-known formulas,

$$basis = cash - futures \quad (6)$$

and

$$expected\ price = current\ futures + expected\ basis. \quad (7)$$

However, assuming zero basis when forecasting is usually not accurate (Kastens, Jones, and Schroeder 1998). To relax this assumption, Kansas feeder steer cash prices by weight and live cattle prices were obtained from LMIC (2016a). Kansas cash feeder steer prices were available beginning January 1992 for 500 to 599 lb, 600 to 699 lb, 700 to 799 lb, and 800 to 899 lb animals. From 1995 to 2016, of the feeder cattle placed on feed 24% were less than 600 lb, 22% were 600 to 699 lb, 27% were 700 to 799 lb, and 27% were 800 lb plus animals, on average. Using the four steer prices by weight and the average number placed by weight, a weighted feeder cattle cash price was constructed for P_t^{Feeder} (Figure 1).

Additionally, an expected live cattle price, $P_{t,T}^{Fed}$, can alternatively be calculated using historical Kansas live cattle basis and live cattle futures prices following equation (7). Kansas live cattle cash prices were available beginning January 1990. According to Kastens, Jones, and Schroeder (1998) the most accurate method to use for price forecasting is deferred futures plus historical basis. A four year historical average basis for live cattle was used for expected basis (Tonsor, Dhuyvetter, and Mintert 2004). Figure 2 shows the expected live cattle price series. Evidence of unit root was also found in both cash feeder cattle and expected live cattle price series (Table 1). Using the differenced weighted cash feeder cattle price for ΔP_t^{Feeder} and expected live cattle price for $\Delta P_{t,T}^{Fed}$, equations (4) and (5) can be estimated again and used to test RRT.

Results

Analysis 1: Update of Zhao, Du, and Hennessy (2011) for January 2004 to May 2016

The regression results of the static and dynamic models in differences for 2004 to 2016 are shown in Table 2. The model with three live cattle futures price lags and two corn price lags was selected based on lowest AIC value. Neither the static nor dynamic model exhibits first order autocorrelation as indicated by the Durbin Watson statistic. The dynamic model is preferred to the static model due to the lower AIC value and significant lags. Thus the dynamic model will be used to test for RRT. Of the live cattle futures variables, the contemporaneous live cattle price has the largest effect on feeder cattle price followed by the third lag. Furthermore, the contemporaneous corn price has the largest effect on feeder cattle price of the corn variables, followed by the second lagged corn price. Seasonality is important as indicated by the significant monthly placement dummies. January to November nearby feeder cattle futures are discounted relative to December nearby feeder cattle futures prices.

Next, the regression results are used to test for RRT. First, the 100% pass-through hypothesized values need to be calculated. The average values used for assumptions from January 2004 to May 2016 are shown in Table 3. Plugging these assumptions into equations (2) and (3) the hypotheses can be written as:

$$H_0^{Fed}: \phi_1 = \frac{W^{Fed}(1-D)}{W^{Feeder}(1+r)} = \frac{1.343(1-0.0136)}{7.98(1+0.0272)} = 1.62; \quad H_a^{Feeder}: \phi_1 \neq 1.62 \tag{8}$$

$$H_0^{Corn}: \phi_2 = -\frac{58.69}{7.98} = -7.35; \quad H_a^{Corn}: \phi_1 \neq -7.35 \tag{9}$$

Therefore, 115% pass-through for live cattle futures price [(1.48 + 0.13 -0.001 + 0.25) /1.62] and 139% pass-through for corn [(-6.24 -1.52 -2.46)/-7.35] to feeder cattle futures price were found. F-tests were completed to test the hypotheses in equations (8) and (9) against the calculated 100% pass-through values. At the five percent level, we reject the null hypothesis of 100% live cattle futures pass-through to feeder cattle futures price (F=4.23, p- value =0.04) and the null hypothesis of 100% pass-through of corn price to feeder cattle futures price (F=4.34, p-value=0.04). Therefore, more than 100% pass-through of live cattle futures and cash corn price to the futures feeder cattle price occurs. These pass-through calculations contrast those of Zhao, Du, and Hennessy (2011) from 1979 to 2004 which failed to reject 100% pass-through of both live cattle futures and corn prices to feeder cattle futures prices. The pass-through point estimates for 2004 to 2016 are larger than those of Zhao, Du, and Hennessy (2011) from 1979 to 2004.[4] This suggests that more revenue from live cattle futures price increases and costs from corn price increases are passed from the feedlot operations to the cow-calf operations in 2004 to 2016 than in earlier periods.

Analysis 2: Results using feeder and live cattle futures prices while simultaneously testing for structural breaks (February 1994 to May 2016)

Over the past few decades, the cattle and agriculture industries have changed in many ways. Therefore, investigating pass-through for the updated period of 2004 to 2016 in aggregate may be insufficient. For example, finishing weights of fed steers have increased from approximately 1,225 lb in the 1990s to 1,375 lb since 2010 (LMIC 2016a). This increased finishing weight means more pounds are added per animal which translates to increased corn needed per head. At the same time, the Energy Policy Act of 2005 and the Energy Independence and Security Act of 2007 increased ethanol demand and hence corn demand (McPhail 2001). This increased corn demand, subsequently increased feed prices. Fed cattle prices are also increasingly exposed to trade relations. For example, the bovine spongiform encephalopathy (BSE) case in 2004 reduced U.S. beef trade to near zero. However, since the threat of BSE has declined, approximately 10%

[4] However, it should be noted that the lag structure differs between this analysis and Zhao, Du, and Hennessy (2011).

of beef is now being exported (USDA 2016). Additionally, from 2004 to 2007 the cattle cycle was in an expansion phase, but from 2008 to 2013 it was in a contraction phase (LMIC 2016a). Recently, a new cattle cycle began in 2014 and the herd is expanding. Given the changes in the cattle market it is necessary to test for structural breaks in the relationships between fed cattle and corn prices and feeder cattle prices.

Two traditional methods are used to test for structural change. The Chow test is used if break dates are known (Chow 1960). However, if breaks dates are not known and multiple break dates are possible the Bai Perron (BP) test is used to simultaneously determine the number and timing of structural breaks (Bai and Perron 2003; Twine, Rude, and Unterschultz 2015). A 15% trimming factor with a maximum of five structural breaks possible was used in the BP tests (Bai and Perron 2003; Twine, Rude, and Unterschultz 2015). The supF, UDmaxF and WDmaxF tests indicate at least one structural break at the <0.0001 level.[5] The BP test results are shown in Table 4. Based on the SupF(l+1|l) test, we fail to reject three structural breaks in favor of four structural breaks. Therefore, we have three structural breaks and four resulting regimes. The four regimes are February 1994 to May 2004 (R1), June 2004 to July 2008 (R2), August 2008 to January 2012 (R3), and February 2012 to May 2016 (R4). Structural break 1 in May 2004 aligns with the breaks identified in Zhao, Du, and Hennessy (2011). Additionally, break 1 occurs around the time of the BSE cases in Canada (May 2003) and the U.S. (December 2003). The BSE cases closed down trading borders and thus likely impacted the fed and feeder cattle price relationship. The next structural break in July 2008 corresponds with changes in the corn market due to ethanol demand. This likely impacted the relationship between corn and feeder cattle

[5] The results from the model with three live cattle lags and two corn lags are shown because this model had the lowest AIC. However, the break dates found are robust across various model specifications.

prices. Potentially, the third break in January 2012 corresponds with the drought conditions experienced throughout portions of the U.S. from 2010 to 2012. Droughts result in lower corn yields and pasture conditions, thus potentially impacting corn and fed cattle prices relationships with feeder cattle prices.

The empirical results for the full period static, full period dynamic, and R1 to R4 are shown in Table 5. Based on the lower AIC value, the dynamic model is preferred to the static model. Additionally, the four separate regime models are preferred to the full period dynamic model. The parameters vary substantially between each regime. The live cattle contemporaneous effect is largest in R2 and smallest in R3. The second lag of the live cattle futures price in R1, R2 and R4, and the fifth lag of live cattle futures price in R3 have counterintuitive signs. However, the total live cattle futures price effect is positive in all four regimes, as expected. The contemporaneous corn effect is largest in R4. The first and third corn lags in R4 have counterintuitive signs. However, the total corn effect is negative as expected.

For each model, 100% pass-through hypothesized values were calculated based on assumptions detailed in Table 6. The 100% pass-through estimates hypothesized using RRT are different for each period. The changes in 100% pass-through critical values are attributed to increased finished weight and subsequent need for more corn to feed to these heavier weights. Based on the empirical models, the pass-through point estimates for fed cattle futures to feeder cattle futures for R1 to R4 are 104%, 143%, 80%, and 132% of the hypothesized values (Table 7). The pass-through point estimates for cash corn to nearby feeder futures for R1 to R4 are 54%, 198%, 74%, and 117% of the hypothesized values. F-tests were conducted to determine if the calculated pass-through is statistically different than the 100% pass-through value hypothesized by RRT. When using a five percent critical level, 100% pass-through is rejected in some cases but holds in others. RRT between fed cattle and feeder cattle futures holds in R1 and R3. However, in R2 and R4 pass-through is statistically greater than 100%. During these times, live cattle futures prices were generally increasing. Thus, a larger than expected share of live cattle price increases were being passed on to cow-calf operators through higher feeder cattle prices. This means that a smaller percentage of these price increases were staying at the feedlot level.

Corn price pass-through to feeder cattle futures is statistically different than hypothesized by RRT in R1 and R2. In R1, pass-through was only 54% of that hypothesized by RRT. During this time corn prices varied, but generally declined. Thus, a smaller percentage of cost savings were being passed on to cow-calf producers through higher feeder cattle prices. When input prices are generally falling and pass-through is less than hypothesized by RRT this is negative for cow-calf operations, but positive for feedlot operations. In R2, corn prices were increasing and pass-through was statistically greater than 100%. Therefore, higher corn input costs were being passed-through to cow-calf producers through lower feeder cattle prices in proportions larger than the corn price increase. This would hurt cow-calf operations through lower than expected feeder prices, but would be positive for feedlot operations which are able to maintain those cost savings. In R3 and R4, the calculated pass-through estimates were not statistically different than 100% pass-through estimates hypothesized in RRT.

Pass-through calculations may detail signals of expansion or contraction to cow-calf producers, but it is not the only factor to consider in these decisions. Even if higher fed cattle prices are being passed through to cow-calf producers through higher feeder cattle prices, this does not guarantee that cow-calf producers will expand their herds. Other factors such as drought, replacement costs, and operating costs are considered by cow-calf producers in expansion or contraction decisions. However, in R4, live cattle prices were increasing, live cattle pass-through was greater than 100%, corn prices were decreasing and corn pass-through was greater than 100%. These are all signals from the feedlot level to the cow-calf level to expand the herd. Given biological lags, this is consistent with the cattle cycle and increase in cattle inventory beginning in 2014 (LMIC 2016a).

Analysis 3: Results using cash feeder cattle and expected live cattle price while simultaneously testing for structural breaks (February 1994 to May 2016)

The third analysis relaxes the zero basis assumptions in both feeder cattle and live cattle prices. In analysis 3, Kansas cash feeder cattle and expected live cattle prices are used instead of futures prices.[6] Following the same procedure as in analysis 2, one structural break was identified in May 2012 (Table 8). The two regimes for analysis 3 are February 1994 to May 2012 (RA), and June 2012 to May 2016 (RB). The breaks identified differ from analysis 2. Potentially, feeder cattle and live cattle basis shifts over time are causing the increased number of structural breaks in analysis 2 versus analysis 3. However, R4 in analysis 2 and RB in analysis 3 are similar time periods.

The estimation results of the full period static and dynamic model as well as the two regime models are shown in Table 9. The coefficients differ across RA and RB. Of the expected live cattle effects, the contemporaneous expected live cattle price is the largest in both regimes. However, the contemporaneous effect is larger in RB. In both regimes the expected live cattle lag two has an unexpected sign, however, the overall expected live cattle price is positive as expected. The corn coefficients vary substantially more than the expected live cattle

[6] Four year historical basis was used as expected basis.

coefficients. The contemporaneous corn effect is largest in both regimes, but is five times larger in RB than RA. Corn lags one, three and five in RB have large coefficients with unexpected signs. Overall, in both models, the total effect of corn is negative as expected.

These models were then used to test the 100% pass-through values hypothesized by RRT. Hypothesized RRT values were constructed using averages over the regime dates and for the full period. The assumptions and hypothesized values are shown in Table 10. The differences in ϕ_1 and ϕ_2 across regimes can be attributed to the increased pounds added to the steers and corn required to add these extra pounds.

The estimated pass-through for all models in analysis 3 and comparison to their hypothesized values are shown in Table 11. The expected live cattle pass-through to cash feeder cattle is smaller than that hypothesized in RA (94%), but larger than hypothesized in RB (143%). Using the F-test and five percent critical value, 100% pass-through is not rejected in RA, but is rejected in RB. Thus, there is evidence (depending on critical level used) that more than 100% pass-through occurred from expected live cattle price to cash feeder cattle price from June 2012 to May 2016. During this time, expected live cattle prices were generally increasing. Thus, more than 100% of this expected price increase was passed along to cow-calf producers. This generally could be seen as a signal for expansion. However, as mentioned in analysis 2, this signal for expansion from the feedlot sector does not guarantee herd expansion at the cow-calf level. Many other factors play into the expansion decision. Again, this timing is consistent with the cattle cycle's expansion phase beginning in 2014 (LMIC 2016a).

The corn to cash feeder cattle pass-through varies substantially between RA (84%) and RB (131%), but neither are statistically different than the hypothesized pass-through value. Thus RRT holds from corn to cash feeder cattle price in both RA and RB.

Regime 4 in analysis 2 and RB in analysis 3 are similar time periods. Although the basis assumptions differ across the two analyses for the last regime, the conclusions regarding 100% pass-through and RRT are similar. In both R4 and RB, more than 100% pass-through was found for live cattle to feeder cattle price. However, RRT held for corn to feeder cattle price. Since 2012, the increased live cattle or expected live cattle prices are being passed along to cow-calf producers at higher than hypothesized rates.

Sensitivity analysis

The 100% pass-through and RRT results can be subject to assumptions. In order to conduct a sensitivity analysis, we determine the value at which the F-statistic changes from significant to insignificant or from insignificant to significant, therefore changing the reject or fail to reject conclusions about 100% pass-through. Next, we determine the change in assumptions needed to reach that critical value. We will use RA and RB in analysis 3 for the sensitivity analysis.

First, examine the expected live cattle pass-through values. The estimated value was 1.48 in RA, which was not statistically different from the hypothesized 1.57. The hypothesized value would have to be 1.72 to be statistically different than the estimated value (1.48) and RRT not hold. In order for this to occur, changing only one assumption at a time, either (1) W^{Fed} would be 1399 lb, a nine percent increase, or (2) W^{Feeder} would be 710 lb, an eight percent decrease. Death loss (D) and discount rate (r) cannot decrease enough to change the hypothesized value to 1.72. Second, for the RB conclusion for expected live cattle to feeder cattle price pass-through to change, the hypothesized value would need to increase from 1.64 to 1.735 (a six percent change). For this to happen, one of the following assumptions would need to change: (1) W^{Fed} increases six percent to 1478 lb, or (2) W^{Feeder} decreases five percent to 778 lb. Again, D and r

cannot decrease enough alone for the hypothesized value to reach 1.735. For comparison, the average live cattle weight of Kansas slaughter steers from LMIC (2016a) was 1265 lb for RA and 1364 lb for RB. Thus, these numbers are well within the range needed for the pass-through RRT conclusions to remain the same. In summary, our conclusions about expected live cattle to cash feeder price pass-through are not sensitive to defendable assumptions used for ϕ_1.

Next, the sensitivity of corn pass-through (ϕ_2) was investigated. In both RA and RB, 100% pass-through and thus RRT was not rejected. F-statistics which would cause 100% pass-through to be rejected were identified. In RA, the estimated value was less than the hypothesized value. In order for RRT to be rejected, the F-statistic would need to increase by 15% to -8.135. For this to occur, W^{feeder} would need to decrease by six percent to 732.70 lb, increasing B^{corn} by eight percent to 59.6 bu. In RB, the estimated pass-through, -9.79, was larger than the hypothesized pass-through, -7.49. In order to reject 100% pass-through, the hypothesized value would need to be -0.39. This large change needed is likely attributed to the large standard errors on the corn lags in the model. This is very unlikely as W^{Feeder} would need to increase to 1352.3 lb, implying B^{Corn} is only 4.73 bu. Thus, our RRT conclusions for the corn to feeder cattle price pass-through are robust to our assumptions used in ϕ_2.

Conclusion

This analysis presents an update and expansion of Zhao, Du, and Hennessy’s (2011) application of Ricardian rent theory (RRT) to cattle markets. Based on RRT, surplus rents should pass through the market to the holder of the scarcest resource. In the cattle markets, feeder calves are the scarcest, widely traded resource and thus gains and losses at the feedlot level should be passed through to feeder cattle prices following RRT. Using monthly futures market feeder and live cattle prices, results were presented for 2004 to 2016 and for the four regimes identified using structural break tests for 1994 to 2016. Additionally, a third analysis presented results for the two regimes identified using structural break tests for 1994 to 2016 with cash feeder and expected live cattle prices.

One-hundred percent pass-through between live cattle and corn with feeder cattle prices held in some cases, but not in others. However, overall there seems to be efficient information exchange between the feedlot sector and the cow-calf sector. When live cattle or corn prices change, these changes are fully, and in several instances more than fully, passed to cow-calf producers through the feeder cattle price. This occurred with both price increases and decreases, whether good or bad for cow-calf producers. These larger than expected pass-through estimates are consistent with the divergent profitability outcomes between cow-calf operations and feeding operations recently. Both cow-calf producers and cattle feeders experienced historically high returns in 2014. However, in 2015 and 2016 average net returns for finished steers ranged from -$100 to -$500 per head (Tonsor 2016). At the same time, cow-calf returns were around $300 per cow (LMIC 2016b).

Additionally, it is well documented that the feedlot industry has excess capacity (Allen 2014). Our results are generally consistent with expectations of an industry with excess capacity that wants to incentivize more throughput and is operating consistent with RRT. Thus, feedlot operators could potentially be incentivizing cow-calf producers to increase the calf inventory through higher feeder cattle prices, whether the result of increased live cattle prices or decreased feeding costs.

Moving forward, other sectors of the beef complex can be included if data is available. Also, the assumption of symmetric price transmission can be investigated. Potentially, the pass-through rate to feeder cattle prices when fed cattle or corn prices rise is different than the pass-through rate when fed cattle or corn prices fall. Another extension would be to examine states besides Kansas to see if conclusions hold across states.

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Table 1. Augmented Dickey Fuller (ADF) tests

	Feeder Cattle Futures	Live Cattle Futures	Cash Corn	Cash Feeder Cattle	Expected Live Cattle
ADF Test Statistic	-1.24	-1.02	-1.71	-1.19	-1.18
5% Tau Critical Value	-2.87	-2.87	-2.87	-2.87	-2.87
P-value	0.66	0.75	0.42	0.68	0.69
Conclusion	Fail to reject unit root	Fail to reject unit root	Fail to reject unit root	Fail to reject unit root	Fail to reject unit root

Note: ADF tests allow for constant drift term and one lag

Table 2. Estimation results for January 2004 to May 2016 (Analysis 1)

Variable	Static Model	Dynamic Model
Live cattle price	1.50***	1.48***
	(0.08)	(0.08)
Live cattle price lag 1		0.13*
		(0.08)
Live cattle price lag 2		-0.001
		(0.08)
Live cattle price lag 3		0.25***
		(0.08)
Corn price	-7.13***	-6.24***
	(1.02)	(1.01)
Corn price lag 1		-1.52
		(1.04)
Corn price lag 2		-2.46**
		(1.01)
January	-5.83***	-4.69***
	(1.25)	(1.30)
February	-6.40***	-5.83***
	(1.22)	(1.29)
March	-4.11***	-1.96
	(1.25)	(1.27)
April	-7.62***	-7.18***
	(1.32)	(1.27)
May	-4.38***	-4.49***
	(1.28)	(1.20)
June	-5.34***	-4.86***
	(1.34)	(1.29)
July	-6.61***	-7.32***
	(1.30)	(1.27)
August	-7.09***	-7.07***
	(1.29)	(1.23)
September	-7.77***	-8.20***
	(1.30)	(1.24)
October	-8.02***	-8.28***
	(1.29)	(1.24)
November	-8.10***	-8.66***
	(1.25)	(1.20)
Intercept	5.96***	5.62***
	(0.94)	(0.90)
Durbin-Watson test statistic	2.21	2.38
AIC	749.54	741.63

Table 3. Assumptions for 2004 to 2016 used to calculate 100% pass-through estimates (Analysis 1)

Assumption	**2004-2016**
Feeder weight (lbs.)	798.41
Finish weight (lbs.)	1343.87
Pounds of gain	545.46
Feed conversion ratio	6.03
Total lbs of corn needed	3286.70
Pounds of corn per bu	56.00
Corn needed (bu.)	58.69
Deathloss (%)	1.36%
Discount rate	2.72%
ϕ_1	1.62
ϕ_2	-7.35

Table 4. Bai Perron test results for feeder and live cattle futures prices (Analysis 2)

l	**SupF(l+1|l) statistic**	**P-value**	**Break point observation**	**Regimes identified**
0	74.12	<.0001	124	R1: February 1994 to May 2004
1	68.18	0.0002	174	R2: June 2004 to July 2008
2	88.12	<.0001	216	R3: August 2008 to January 2012
3	33.68	0.7731		R4: February 2012 to May 2016

Note: Statistics from model with 3 live cattle and 2 corn lags (lowest AIC). Structural break dates are robust across different model specifications.

Table 5. Estimation results using feeder and live cattle futures (February 1994 to May 2016) (Analysis 2)

Variable	Full Period-Static 02/94 to 05/16	Full Period-Dynamic 02/94 to 05/16	R1 02/94 to 05/04	R2 06/04 to 07/08	R3 08/08 to 02/12	R4 02/12 to 05/16
Live cattle futures price	1.47***	1.44***	1.16***	1.85***	0.89***	1.52***
	(0.06)	(0.06)	(0.08)	(0.16)	(0.14)	(0.14)
Live cattle futures price lag 1		0.20***	0.60***	0.32**	0.05	0.37**
		(0.06)	(0.08)	(0.14)	(0.13)	(0.15)
Live cattle futures price lag 2		-0.03	-0.12	-0.41***	0.18	-0.09
		(0.06)	(0.08)	(0.15)	(0.13)	(0.14)
Live cattle futures price lag 3		0.19***		0.55***	0.14	0.19
		(0.06)		(0.15)	(0.13)	(0.15)
Live cattle futures price lag 4					0.15	0.20
					(0.14)	(0.14)
Live cattle futures price lag 5					-0.09	
					(0.13)	
Cash corn price	-6.25***	-5.54***	-3.72***	-2.56	-4.07***	-10.29***
	(0.75)	(0.76)	(0.89)	(2.08)	(1.35)	(2.09)
Cash corn price lag 1		-0.89		-7.09***	-1.27	3.70
		(0.80)		(2.14)	(1.36)	(2.44)
Cash corn price lag 2		-1.73**		-4.86**		-7.06**
		(0.76)		(2.29)		(2.58)
Cash corn price lag 3						4.85**
						(2.21)
January	-5.85***	-4.69***	-2.56***	-4.95***	-0.81	-3.49
	(0.79)	(0.85)	(0.77)	(1.54)	(1.71)	(2.92)
February	-6.07***	-5.85***	-5.50***	-4.79***	-2.87	-10.43***
	(0.76)	(0.83)	(0.74)	(1.35)	(1.70)	(2.98)
March	-4.45***	-2.95***	-3.20***	0.38	-2.87	-3.17
	(0.78)	(0.79)	(0.64)	(1.53)	(1.70)	(2.70)
April	-7.56***	-7.16***	-5.58***	-8.30***	-2.16	-9.32***
	(0.83)	(0.82)	(0.74)	(1.58)	(1.95)	(2.87)
May	-4.59***	-4.44***	-4.02***	-5.22***	-4.44**	-6.96**
	(0.78)	(0.76)	(0.67)	(1.51)	(1.74)	(2.62)
June	-5.06***	-4.48***	-2.78***	-5.11***	-4.66**	-6.49**
	(0.83)	(0.80)	(0.71)	(1.58)	(1.76)	(2.96)
July	-6.02***	-6.42***	-4.40***	-5.22***	-1.63	-13.14***
	(0.82)	(0.81)	(0.71)	(1.57)	(1.86)	(2.83)
August	-6.71***	-6.56***	-5.01***	-8.50***	-6.66***	-10.67***
	(0.81)	(0.78)	(0.70)	(1.67)	(1.61)	(2.57)
September	-6.43***	-6.63***	-4.14***	-8.69***	-5.77***	-11.90***
	(0.80)	(0.78)	(0.66)	(1.58)	(1.60)	(2.94)
October	-7.50***	-7.42***	-4.99***	-6.38***	-8.16***	-11.83***
	(0.82)	(0.79)	(0.73)	(1.42)	(1.52)	(3.15)
November	-6.97***	-7.26***	-4.85***	-9.99***	-2.41	-14.73***
	(0.79)	(0.76)	(0.69)	(1.43)	(1.47)	(2.59)
Intercept	5.63***	5.30***	3.98***	5.27***	4.04***	8.28***
	(0.59)	(0.58)	(0.53)	(1.11)	(1.06)	(2.220)
Durbin-Watson test statistic	2.19	2.26	2.08	2.39	2.26	2.08
AIC	1251.53	1228.65	432.73	208.77	184.78	274.06

Table 6. Assumptions used to calculate 100% pass-through estimates using feeder and live cattle futures prices (Analysis 2)

Assumption	**Full Time Period 02/94 to 05/16**	**R1 02/92 to 05/04**	**R2 06/04 to 07/08**	**R3 08/08 to 01/12**	**R4 02/12 to 05/16**
Feeder weight (lbs.)	783.87	764.87	777.61	803.92	818.97
Finish weight (lbs.)	1301.32	1248.20	1303.86	1343.45	1391.54
Pounds of gain	517.46	483.33	526.25	539.53	572.57
Feed conversion ratio	6.08	6.14	6.05	6.01	6.01
Total lbs of corn needed	3145.50	2967.52	3184.64	3243.24	3443.34
Pounds of corn per bu	56.00	56.00	56.00	56.00	56.00
Corn needed (bu.)	56.17	52.99	56.87	57.91	61.49
Deathloss (%)	1.24%	1.12%	1.33%	1.24%	1.43%
Discount rate	2.1%	4.1%	3.6%	2.5%	2.1%
ϕ_1	1.62	1.55	1.60	1.61	1.64
ϕ_2	-7.17	-6.93	-7.31	-7.20	-7.51

Table 7. Calculated pass-through estimates and RRT tests for models using feeder and live cattle futures prices (Analysis 2)

	Hypothesized pass-through	Calculated pass-through	Percent pass-through	F-value	p-value	Conclusion
Live cattle futures						
Full Static (02/94 to 05/16)	1.62	1.47	91%	6.34	0.01	Reject 100% PT
Full Dynamic (02/94 to 05/16)	1.62	1.80	111%	3.92	0.05	Reject 100% PT (marginally)
R1 (02/94 to 05/04)	1.57	1.64	104%	0.36	0.55	Fail to reject 100% PT
R2 (06/04 to 07/08)	1.62	2.32	143%	7.55	0.01	Reject 100% PT
R3 (08/08 to 02/12)	1.63	1.31	80%	2.04	0.17	Fail to reject 100% PT
R4 (02/12 to 05/16)	1.66	2.19	132%	6.22	0.02	Reject 100% PT
Cash corn						
Full Static (02/94 to 05/16)	-7.17	-6.25	87%	1.48	0.22	Fail to reject 100% PT
Full Dynamic (02/94 to 05/16)	-7.17	-8.17	114%	0.99	0.32	Fail to reject 100% PT
R1 (02/94 to 05/04)	-6.93	-3.72	54%	13.11	0.0004	Reject 100% PT
R2 (06/04 to 07/08)	-7.31	-14.51	198%	8.88	0.01	Reject 100% PT
R3 (08/08 to 02/12)	-7.20	-5.34	74%	1.04	0.32	Fail to reject 100% PT
R4 (02/12 to 05/16)	-7.51	-8.80	117%	0.22	0.65	Fail to reject 100% PT

Table 8. Bia Perron test results for cash feeder and expected live cattle price (Analysis 3)

l	SupF(l+1|l) statistic	P-value	Break point observation	Regimes identified
0	75.27	<.0001	220	RA: February 1994 to May 2012
1	43.28	0.14		RB: June 2012 to May 2016

Note: Statistics from model with 3 live cattle and 2 corn lags (lowest AIC). Structural break dates are robust across different model specifications.

Table 9. Estimation results for models using cash feeder cattle and expected live cattle prices (Analysis 3)

Variable	Full Period-Static 02/94 to 05/16	Full Period-Dynamic 02/94 to 05/16	RA 02/94 to 05/12	RB 06/12 to 05/16
Expected live cattle price	1.45***	1.40***	1.06***	1.95***
	(0.07)	(0.07)	(0.08)	(0.21)
Expected live cattle price lag 1		0.31***	0.42***	0.17
		(0.07)	(0.08)	(0.21)
Expected live cattle price lag 2		-0.1	-0.14*	-0.33
		(0.08)	(0.08)	(0.23)
Expected live cattle price lag 3		0.24***	0.14*	0.75***
		(0.07)	(0.08)	(0.21)
Expected live cattle price lag 4				-0.20
				(0.17)
Cash corn price	-6.86***	-6.34***	-3.33***	-15.22***
	(0.92)	(0.94)	(0.93)	(2.97)
Cash corn price lag 1		-0.42	-2.59***	6.76*
		(0.98)	(0.93)	(3.73)
Cash corn price lag 2		-1.16		-4.77
		(0.97)		(4.01)
Cash corn price lag 3		-0.45		6.44
		(0.97)		(3.89)
Cash corn price lag 4		0.22		-6.49*
		(0.96)		(3.78)
Cash corn price lag 5		-1.21		3.49
		(0.93)		(3.19)
January	0.35	0.72	0.510	-1.24
	(0.90)	(0.91)	(0.80)	(3.54)
February	0.94	1.38	0.93	1.80
	(0.89)	(0.93)	(0.80)	(4.09)
March	-1.52*	-0.22	0.09	-3.83
	(0.91)	(0.96)	(0.80)	(4.69)
April	-3.92***	-3.28***	-2.59***	-7.43*
	(0.93)	(0.97)	(0.83)	(4.15)
May	-3.25***	-2.69***	-2.75***	-2.26
	(0.92)	(0.92)	(0.79)	(3.44)
June	-5.19***	-4.71***	-3.71***	-12.14***
	(0.97)	(0.94)	(0.82)	(3.82)
July	-1.97**	-2.76***	-1.94**	-5.89
	(0.93)	(0.93)	(0.82)	(3.54)
August	-4.16***	-3.81***	-3.68***	-6.77**
	(0.94)	(0.91)	(0.80)	(3.15)
September	-4.36***	-4.91***	-3.86***	-14.98***
	(0.93)	(0.93)	(0.81)	(3.84)
October	-7.17***	-6.76***	-5.76***	-11.02**
	(0.97)	(0.94)	(0.82)	(4.31)
November	-3.84***	-4.55***	-3.87***	-6.83*
	(0.92)	(0.91)	(0.81)	(3.44)
Intercept	2.90***	2.64***	2.33***	5.72*
	(0.66)	(0.66)	(0.57)	(2.82)
Durbin-Watson test statistic	2.16	2.13	1.99	2.10
AIC	1361.52	1339.9	1001.65	277.94

Table 10. Assumptions used to calculate 100% pass-through estimates for models using cash feeder and expected live cattle prices (Analysis 3)

Assumption	**Full Time Period 02/94 to 05/16**	**RA 02/94 to 05/12**	**RB 06/12 to 05/16**
Feeder weight (lbs.)	783.87	775.36	822.84
Finish weight (lbs.)	1301.32	1280.60	1396.33
Pounds of gain	517.46	505.23	573.50
Feed conversion ratio	6.08	6.09	6.02
Total lbs of corn needed	3145.50	3077.97	3450.77
Pounds of corn per bu	56.00	56.00	56.00
Corn needed (bu.)	56.17	54.96	61.62
Deathloss (%)	1.24%	1.20%	1.40%
Discount rate	2.7%	3.6%	2.1%
ϕ_1	1.62	1.57	1.64
ϕ_2	-7.17	-7.09	-7.49

Table 11. Calculated pass-through estimates and RRT tests for models using cash feeder and expected live cattle prices (Analysis 3)

	Hypothesized pass-through	Calculated pass-through	Percent pass-through	F-value	p-value	Conclusion
Expected live cattle						
Full Static (02/94 to 05/16)	1.62	1.45	90%	5.75	0.02	Reject 100% PT
Full Dynamic (02/94 to 05/16)	1.62	1.86	115%	4.63	0.03	Reject 100% PT
RA (02/94 to 05/12)	1.57	1.48	94%	0.57	0.45	Fail to reject 100% PT
RB (06/12 to 05/16)	1.64	2.35	143%	5.67	0.03	Reject 100% PT
Cash corn						
Full Static (02/94 to 05/16)	-7.17	-5.42	76%	0.11	0.74	Fail to reject 100% PT
Full Dynamic (02/94 to 05/16)	-7.17	-9.36	131%	1.93	0.17	Fail to reject 100% PT
RA (02/94 to 05/12)	-7.09	-5.92	84%	1.08	0.30	Fail to reject 100% PT
RB (06/12 to 05/16)	-7.49	-9.79	131%	0.25	0.62	Fail to reject 100% PT

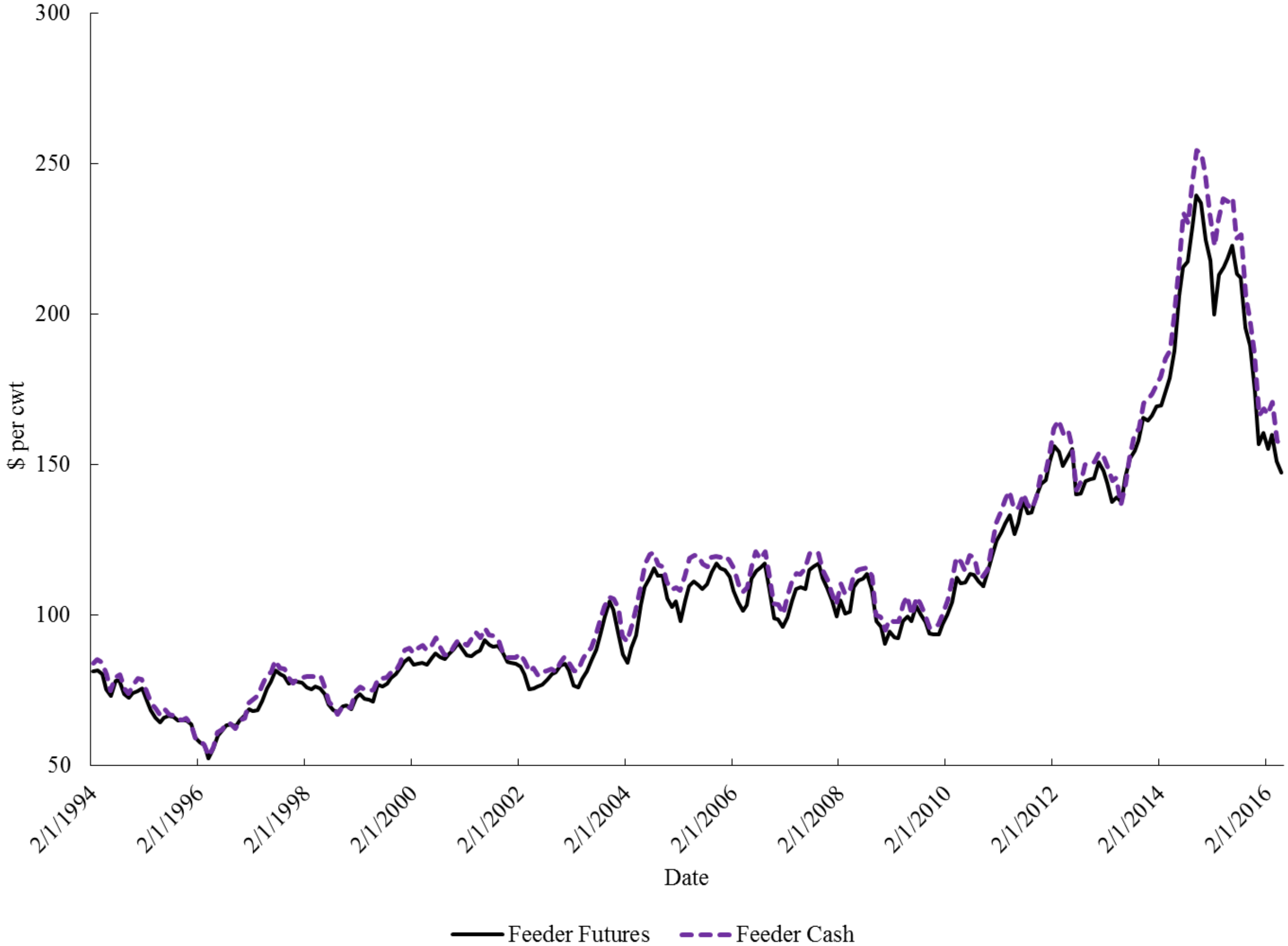

Figure 1. Monthly average feeder cattle nearby futures and weighted cash feeder cattle prices from February 1994 to May 2016

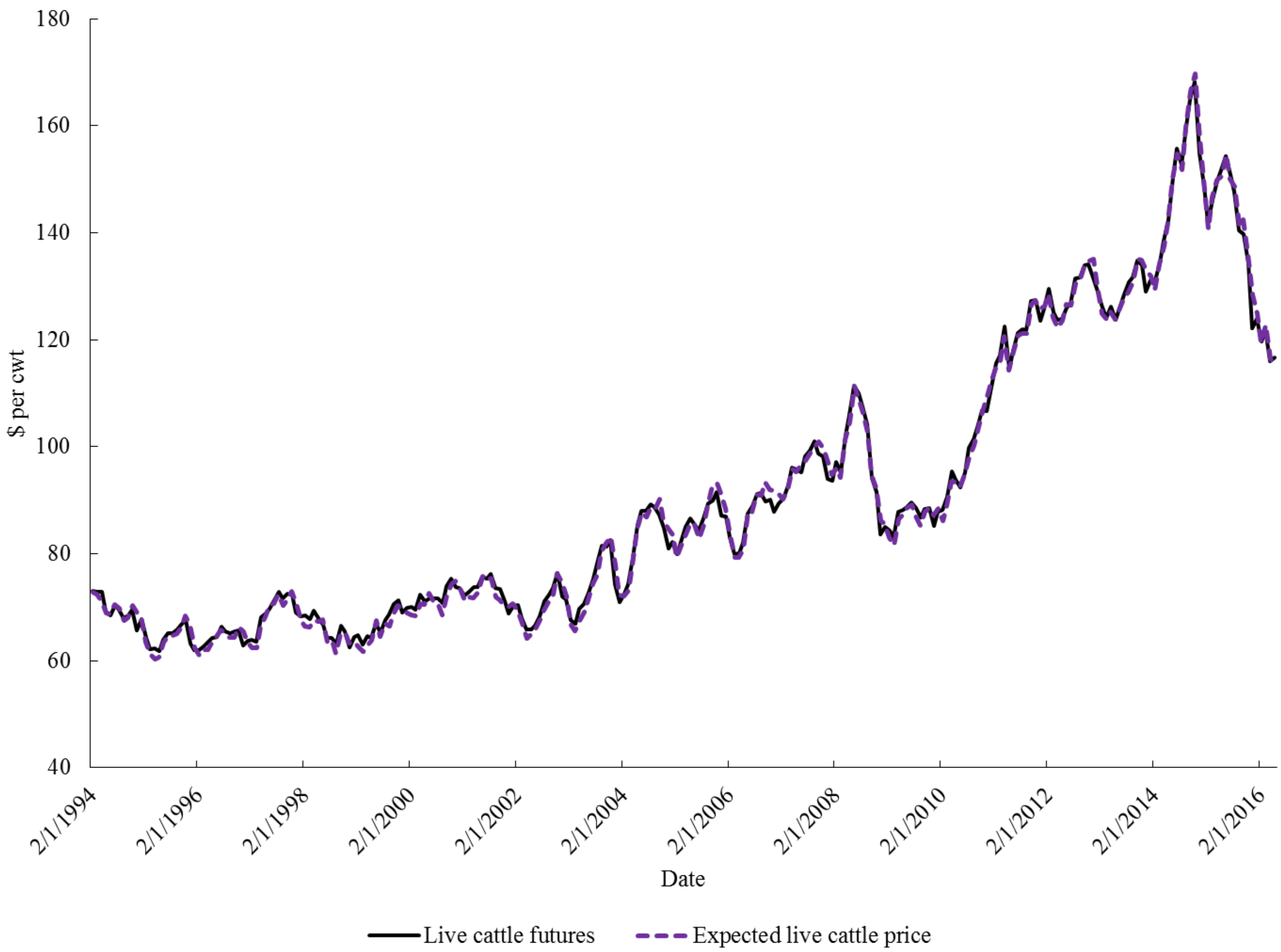

Figure 2. Monthly average live cattle futures and expected live cattle prices from February 1994 to May 2016

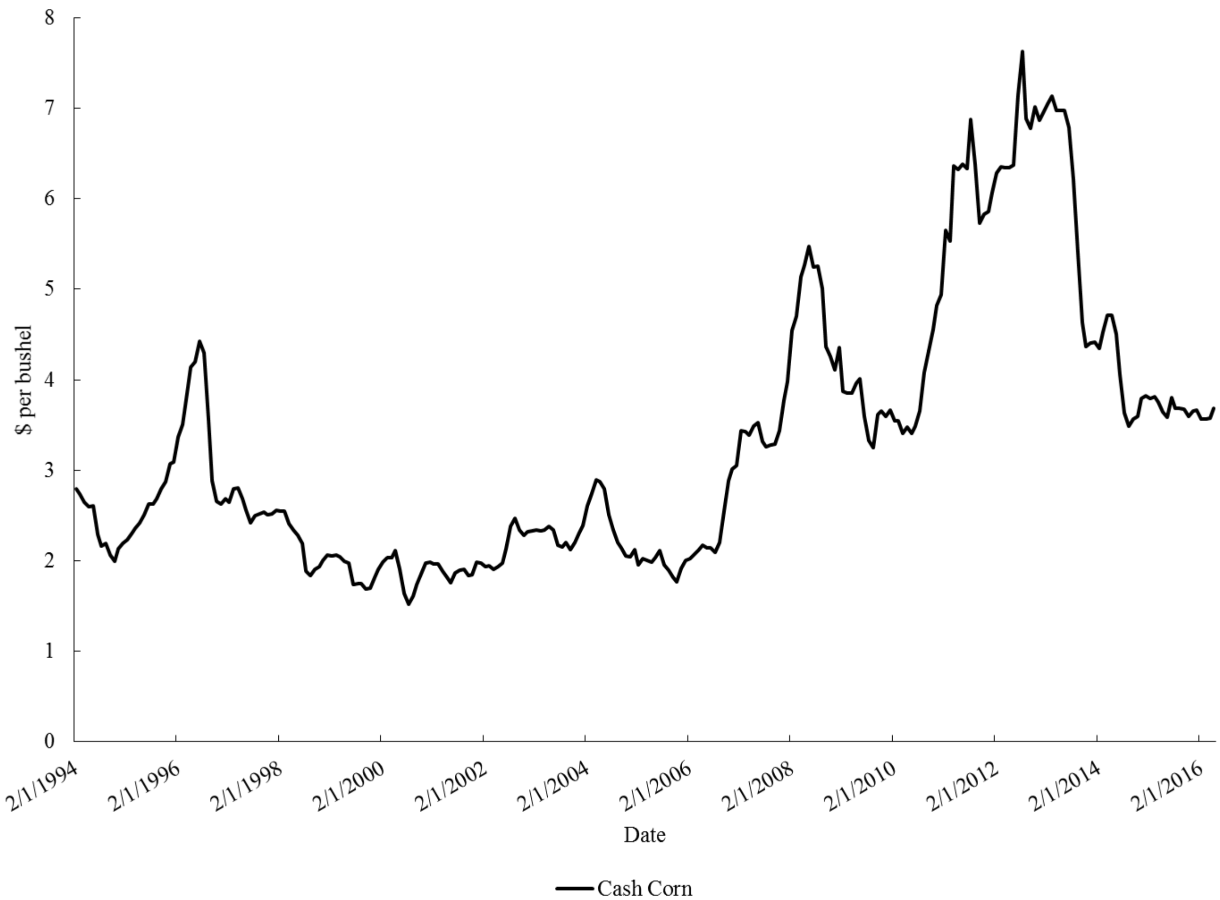

Figure 3. Corn monthly average price from February 1994 to May 2016

Appendix A.

Table A1. Data sources

Data	Source
KSU Focus on Feedlot	LMIC spreadsheet: KSUFeedlot
Discount rate	KC Fed spreadsheet: historicaldata.xls, tab afdr_a5, column Feeder livestock
CME live cattle futures price	LMIC spreadsheet: fatfutures.xlsx, tab C
CME feeder cattle futures price	LMIC spreadsheet: feederfutures.xlsx, tab C
Corn cash price	LMIC spreadsheet: feedpr.xlsx, tab C, corn column
Kansas feeder cash price	LMIC spreadsheet: AuctionsWesternKS.xls
Kansas live cattle price and weight	LMIC spreadsheet: Mo182KansasFat.xls