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Price pass-through in the U.S. beef industry: Implications of feedlot capacity utilization

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Abstract

Transmission of prices, profits, and more generally, economic well-being across vertically connected sectors of agriculture have a long history of interest—arguably of most current interest in meat and livestock markets. Disruptions in live animal harvesting, especially from COVID-19, have corresponded with substantial market adjustment and hence elevated interest in inner-industry relationships, including from policymakers. This paper's main contribution is assessing how price changes in the U.S. feedlot industry manifest in feeder cattle markets. We use Ricardian rent theory as a framework to quantify price transmission by testing how price fluctuations actually pass through the supply chain versus theoretical expectations. We posit that the capacity utilization of feedlots changes because of market shocks, impacting price relationships. In the empirical model, when feedlot capacity utilization rates are below the 65% critical point, we find that both fed to feeder cattle and corn to feeder cattle pass-through rates are higher than hypothesized. When feedlot capacity utilization rates are high (>65%), estimated pass-through rates are lower and not statistically different from Ricardian rent theory. Understanding how prices pass through in the beef industry can help inform policy discussions about beef market competitiveness and promote efficient resource allocation.

KEYWORDS

fed cattle, feeder cattle, price transmission

Résumé

La transmission des prix, des bénéfices et, plus généralement, du bien-être économique entre les secteurs agricoles verticalement connectés suscite un intérêt de longue date—possiblement l'intérêt le plus actuel pour les marchés de la viande et du bétail. Les perturbations dans la récolte d'animaux vivants, en particulier à cause de la COVID-19, ont correspondu à un ajustement substantiel du marché et ont donc suscité un intérêt accru pour les relations au sein de l'industrie, y compris de la part des décideurs politiques. La principale contribution de cet article consiste à évaluer comment les changements de prix dans l'industrie américaine des parcs d'engraissement se manifestent sur les marchés des bovins d'engraissement. Nous utilisons la théorie de la rente ricardienne comme cadre pour quantifier la transmission des prix en testant la manière dont les fluctuations de prix se transmettent réellement à travers la chaîne d'approvisionnement par rapport aux attentes théoriques. Nous postulons que l'utilisation de la capacité des parcs d'engraissement change en raison des chocs du marché, ce qui a un impact sur les relations de prix. Dans le modèle empirique, lorsque les taux d'utilisation de la capacité des parcs d'engraissement sont inférieurs au point critique de 65 %, nous constatons que les taux de transmission des aliments du bétail aux bovins d'engraissement et du maïs aux bovins d'engraissement sont plus élevés que prévu. Lorsque les taux d'utilisation de la capacité des parcs d'engraissement sont élevés (> 65 %), les taux de répercussion estimés sont plus faibles et ne diffèrent pas statistiquement de la théorie ricardienne de la rente. Comprendre comment les prix se répercutent dans l'industrie de la viande bovine peut contribuer à éclairer les discussions politiques sur la compétitivité du marché de la viande bovine et à promouvoir une allocation efficace des ressources.

1 | INTRODUCTION

Transmission of prices, profits, and more generally, economic well-being across vertically connected sectors of agriculture have a long history of interest (Brester & Marsh, 2001; Brester et al., 2004; Lusk & Tonsor, 2021; Marsh, 2003, 2007; McKendree et al., 2020; Zhao et al., 2011). Discussion of "farmer's share of the retail dollar" (Atwood et al., 2009) and other popular metrics align with broader interest in how profitability in one industry segment compares to that of another. One of several considerations in relative profitability assessments is the extent to which changes in market conditions in one industry segment subsequently arise given changes in another industry segment. While this applies broadly to many U.S. agricultural industries, arguably the topic is of most current interest in meat and livestock markets. Narrowly, disruptions in operations of live animal harvesting and processing facilities in recent years have corresponded with substantial market adjustment and hence elevated interest in inner-industry relationships. For instance, following elevated interest given COVID-19 pandemic events, Ramsey et al. (2021) found wholesale and retail meat markets were well-integrated with pandemic based shocks being transitory. Meanwhile, much of the U.S. policy interest in expanding physical processing capacity (Bina et al., 2022) is related to statements around resilience and goals regarding profitability of livestock producers. Recently, the February 2023 introduction of Senate bill S.228 (*Cattle Price Discovery and Transparency Act of 2023*) reflects ongoing interest and policy relevance of price transparency and profitability comparisons across segments within the beef industry. Due to concerns some hold around price transparency between beef packers and fed cattle producers, the proposed bill would require more oversight in beef industry pricing requiring minimum levels of fed cattle purchases through negotiated cash and negotiated grid pricing mechanisms. Additionally, it would require a public library for marketing contracts. Together, the proposed actions could notably alter the prevalence and nature of Alternative Marketing Arrangements. Although these policies are mainly focused on fed cattle prices for harvest-ready cattle, these downstream changes would also impact upstream feeder cattle producers. Given this backdrop of both historical relevance and particularly of elevated current interest, this paper's main contribution is assessing how price changes in the U.S. feedlot industry manifest in feeder cattle markets that supply the sector.

Understanding how price delivers information and allocates resources to different beef producer segments, and what factors affect this mechanism could be a key for the long-term prosperity of the beef industry. Ricardian rent theory (RRT) provides a powerful framework to quantify price transmission by testing how price fluctuations actually pass through the supply chain versus expectations. According to Ricardian rent theory, holders of the relatively scarcest resource can extract any surplus (Ricardo, 1821). In Ricardo's application to land, rent is paid because the supply of the land is relatively scarce in relation to its demand. When crop price increases, competitive farmers bid up land rental rates until zero economic profit is generated. Consequently, the benefits of crop price increases pass from the farmer to the landowner through the higher rental rates. Although RRT has predominately been applied to studies on land prices, the notion of Ricardian rent theory can be used to analyze the relationship between the prices of feeder cattle and fed cattle (Zhao et al., 2011). In the short run, feeder animals are in fixed supply and are the relatively scarcer resource (critical for the production of fed cattle). Competitive buyers at feeder cattle auctions are expected to bid feeder cattle prices up or down until a level of zero (or close to zero) economic profit for the feedlot. Furthermore, over a long-term period competitive feeder cattle sellers would not be willing to accept a price lower than their cost of production.[1] Thus, when the price of fed cattle increases or the price of corn decreases, sellers of feeder cattle should obtain the extra surplus (Zhao et al., 2011). However, since the supply of feeder cattle could expand or shrink in the long run—unlike land—the sellers of feeder cattle may not receive all the "Ricardo rents." Thus, testing if Ricardian rent theory holds and how the prices pass through in the beef industry can help inform policy discussions about beef market competitiveness and promote efficient resource allocation.

Zhao et al. (2011) first tested if Ricardian rent theory held in the U.S. beef industry using time-series data from January 1979 to April 2004. Zhao et al. (2011) found live cattle[2] futures price passes through 93% to feeder cattle futures price and corn price changes have a negative effect of 87% pass-through to feeder cattle futures price. Since 2004, the U.S. beef industry has experienced profound changes which could impact price transmissions, necessitating this updated analysis. While some expected changes like technical progress, globalization, and climate change affect the industry, some unexpected changes like the COVID-19 pandemic (Rude, 2020; Weersink et al., 2021) and Tyson Holcomb Fire (USDA AMS, 2020) also impact the industry and led to the aforementioned policy discussions. An intuitive question is then, while all these shocks influenced cattle prices, did they also impact the pass-through rates in the beef industry? As an alternative to an event study, we posit that the capacity utilization of feedlots changes because of such events, and thus will impact fed to feeder cattle and corn to feeder cattle price relationships. When feedlot capacity is high (limited room to place additional feeder cattle), feedlots will have decreased demand for feeder cattle, lowering pass-through rates. This question, not proposed or answered in previous literature, is the focus of this study.

Beyond the inclusion of feedlot capacity utilization, we improve pass-through estimations in three additional ways. First, we use weekly data from January 1999 to September 2023 as monthly data may not fully capture pass-through changes as well as weekly data. Second, we update production assumptions used to calculate hypothesized pass-through rates by updating expected pass-through rates monthly to reflect industry practices across time (Herrington & Tonsor, 2013) instead of assuming the same expected/hypothesized pass-through rate over time. Third, we incorporate basis into price expectations—Zhao et al. (2011) use futures prices for price expectations, assuming a zero expected basis. Kastens et al. (1998) found incorporating historical basis results in more accurate forecasts.

2 | CONCEPTUAL MODEL

Below we describe the structure of the U.S. beef industry, derive fed cattle and corn to feeder cattle pass-through rates hypothesized by the Ricardian rent theory, and then show how capacity utilization could impact pass-through rates.

2.1 | U.S. beef industry structure

The U.S. beef supply chain is complex, with multiple potential paths through the chain before harvest. However, we describe and model the most common path. Calves are born on cow-calf operations, where ranchers and farmers own herds of beef cows (mothers) that graze in pastures. The calves will remain with their mothers until weaning between 6 and 10 months of age (about 500 lbs.). There are over 31 million beef cows in the U.S. on 729,000 cow-calf operations (average herd size of 43 head) (USDA NASS, 2019). Next, the calf can remain on the farm after weaning until sold directly to a feedlot, or they can be sold to a backgrounding operation where they will be on pasture and introduced to feed. At this stage calves are considered "feeder cattle" and weigh between 600 and 800 lbs. At the feedlot, the animal is confined in a lot with a group of like cattle, and intensively fed a high-energy grain-based diet. There are over 13,000 feedlots in the U.S. (USDA NASS, 2019). Typically, a steer will remain in a feedlot around 6 months until they reach between 1300 and

[1] We say long-term because in the short-term cattle are not easily storable and sellers will proceed with a sale if that is better than their alternative options. There are cases in the short-term where sale prices do not lead revenue to exceed production costs, but we do not anticipate that to be the long-term case.

[2] Live cattle, fed cattle, and fat cattle are all terms used for cattle that are ready for harvest. The CME uses the term live cattle for the futures contact.

1500 lbs. at which point they are considered “fed cattle.” The animal is then sold to a beef packer where the animal will be processed into beef and beef byproducts that are distributed to retailers, restaurants, institutions, and export markets. For this analysis, we are focused on estimating the vertical price transmission between fed and feeder cattle price, as well as the price transmission between the two competing inputs at the feedlot level—corn and feeder cattle prices.

2.2 | Pass-through following Ricardian rent theory

Following Zhao et al. (2011), the model where the net present value of expected profit per head for a finished steer sold from a representative feedlot at time of placement (π_t) is:

$$\pi_t = \frac{E_t\left[P_T^{Fed}\right] W^{Fed}(1-D)}{1+r} - P_t^{Feeder} W^{Feeder} - P_t^{Corn} B^{Corn} - oc \tag{1}$$

Subscript t is time of placement and T represents the expected finishing time. The *Kansas State University Focus on Feedlots* series (LMIC, 2023) shows the average days on feed is about 156 days, thus a 22-week feeding horizon is assumed resulting in $T = t + 22$. P_t^{Feeder} is the feeder cattle price at time t in dollars per hundredweight (cwt). $E_t[P_T^{Fed}]$ is expectation at time t of time T fed cattle price 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.[3] All corn is assumed to be purchased at placement. D is death loss percentage and r is the discount rate. oc represents other costs such as veterinary costs, marketing, transportation, etc. and is assumed to be constant and relatively small.

Assuming profit is equal to a fixed K, the following hypotheses can be derived to test if Ricardian rent theory holds in the beef industry (Zhao et al., 2011). If Ricardian rent theory holds, then feeder cattle prices will be bid up or down when economic changes occur in cattle finishing. The first testable hypothesis, the 100% fed cattle to feeder cattle pass-through, is:

H_0^{Fed} : a dollar increase in expected fed cattle price, $E_t[P_T^{Fed}]$, affects the feeder cattle price, P_t^{Feeder} by:

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

The second testable hypothesis, the 100% corn to feeder cattle pass-through, is:

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

$$\phi_2 = -\frac{B^{Corn}}{W^{Feeder}} \tag{3}$$

Multiple assumptions are used to estimate the hypothesized Ricardian rent theory pass-throughs in Equations (2) and (3). Monthly data, from January 1999 to September 2023, of feeder cattle weight, fed cattle weight, death loss percentage, and feed conversion ratio are obtained from the *Kansas State University Focus on Feedlots* series (LMIC, 2023). Quarterly observations from Q1 1999 to Q3 2023 for average annual interest rate for feeder livestock, non-real estate bank loans from the Kansas City Federal Reserve Bank, were used as the discount rate (Federal Reserve Bank of Kansas City, 2022).[4] The effective semi-annual discount rate is calculated using $[(1 + annual\ rate)^{1/2} - 1]$.

The pass-through values hypothesized by Ricardian rent theory, ϕ_1 and ϕ_2, are calculated for each month and averaged for the whole period under investigation. The hypothesized ϕ_1 and ϕ_2 from Ricardian rent theory (henceforth called RRT ϕ_1 and RRT ϕ_2) are tested against the pass-through estimates from the regression analyses. See Table 1 for the average values of assumptions and RRT ϕ_1 and ϕ_2 values. The estimated RRT ϕ_1 of 1.64 can be interpreted as, if the fed cattle price increases by \$1 per cwt, we expect the feeder cattle price to increase by \$1.64 per cwt. The estimated RRT ϕ_2 of −7.66 can be interpreted as, if the corn price increases by \$1 per bu., we expect the feeder cattle price to decreased by \$7.66 per cwt. See Appendix Table A.1, Figure A.1, Figure A.2, Figure A.3, and Figure A.4 for RRT ϕ_1 and ϕ_2 descriptive statistics, plots over time, and histograms.

[3] $B^{Corn} = \frac{(W^{Fed} - W^{Feeder}) * (Feed\ conversion\ ratio)}{56\ lbs\ of\ corn\ per\ bushel}$.

[4] To get monthly observations, quarterly values were assumed for each month in the quarter. For example, quarter 1 values were used for January, February, and March.

TABLE 1 Hypothesized 100% pass-through assumptions and estimates from *Focus on Feedlots* data from January 1999 to September 2023.

Assumption	Mean value
Feeder weight (lbs.)	790.36
Finish weight (lbs.)	1347.69
Pounds of gain	557.34
Feed conversion ratio	6.07
Total lbs. of corn needed	3381.47
Pounds of corn per bu	56.00
Corn needed (bu)	60.42
Death loss (%)	1.43%
Discount rate	2.82%
Hypothesized Ricardian rent theory pass-through values	
RRT ϕ_1	1.64
RRT ϕ_2	−7.66

2.3 | Incorporating feedlot capacity utilization into pass-through rates

Previous studies of Ricardian rent theory in beef cattle markets have assumed that feeder cattle are the only scarce resource, and thus feeder cattle suppliers would collect economic rents. However, this assumption may fail under some circumstance. Potentially, the actual facility where cattle are raised, the feedlot, could be another scare resource in the supply chain; in the short run feedlot capacities are fixed.

When considering feedlot capacity as a scare resource, there are two potential situations. In the first, when feedlot capacity utilization rate is low, the feedlot owner has strong motivation to buy more feeder cattle given that the feedlot capacity is a fixed cost, but the number of feeder cattle is limited in the short run (scarce resource). Therefore, in situation 1, the feeder cattle seller can obtain the full Ricardian rent. In the second situation, feedlots reach a high capacity utilization rate. We saw explicit examples of this during COVID-19, due to backups at beef slaughter and processing establishments. In these situations, the feedlot capacities will also be scarce resource, which makes pass-through rates change, as the feedlots will decrease demand for feeder cattle due to space restrictions. Under this circumstance, feedlots will not pass back as much of the price changes in fed cattle prices. Now assume a feeder cattle profit function that is dependent on feeder cattle quantity, Q:

$$\Pi = PQ' - C(Q) \tag{4}$$

where Q is the quantity of feeder cattle input, and $Q' = (1-D)Q$ is the fed cattle output, and D is death loss percentage. More specifically,

$$\Pi_t = P_T^{Fed} Q_T' - C(Q_t) = \frac{E_t\left[P_T^{Fed}\right] W^{Fed}(1-D)}{1+r} Q_t - P_t^{Feeder} W^{Feeder} Q_t - P_t^{Corn} B^{Corn} Q_t - OC \tag{5}$$

where Q_t is the steer input in a feeding period. Then, let the capacity utilization rate of the feedlot be $u_t = \frac{Q_t}{N}$, $u \in [0,1]$, where N is the full capacity of a feedlot. Since a feedlot cannot change its maximum capacity in short run, N is exogenous. We assume there is a critical point u^* (could be a management objective or based on feedlots owners' experience), where if $u < u^*$, feedlots owners have strong motivation to buy more feeder cattle, but if $u > u^*$, the feedlots owners will be less eager to buy more feeder cattle. Then feedlot owners maximize their profit by choosing u:

$$\max_{u_t} \Pi_t = P_T^{Fed} Q_T' - C(Q_t) = \frac{E\left[P_T^{Fed}\right] W^{Fed}(1-D)}{1+r} u_t N - P_t^{Feeder}(u_t N) W^{Feeder} u_t N - P_t^{Corn} B^{Corn} u_t N - OC \tag{6}$$

where $P_t^{Feeder}(Q_t) = P_t^{Feeder}(u_t N)$ is the inverse demand curve in the feeder cattle market and $P_t^{Feeder'} = \frac{\partial P_t^{Feeder}(Q_t)}{\partial Q_t} = \frac{\partial P_t^{Feeder\prime}(u_t N)}{\partial (u_t N)} > 0$.

The first order conditions give us:

$$\frac{\partial \Pi_t}{\partial u_t} = \frac{E\left[P_T^{Fed}\right] W^{Fed}}{1+r}(1-D)N - P_t^{Feeder\prime}(u_t N) W^{Feeder} N u_t N - P_t^{Feeder}(uN) W^{Feeder} N - P_t^{Corn} B^{Corn} N = 0 \quad (7)$$

Then, let $\frac{\partial \Pi_t}{\partial u_t} = \varphi$, by implicit function theorem (IFT), we have pass-through rates:

$$\frac{\partial P_t^{Feeder}}{\partial P_T^{Fed}} = -\frac{\frac{\partial \varphi}{\partial P_T^{Fed}}}{\frac{\partial \varphi}{\partial P_t^{Feeder}}} = \frac{\frac{W^{Fed}}{1+r}(1-D)}{\frac{\partial P_t^{Feeder\prime}}{\partial P_t^{Feeder}} W^{Feeder} uN + W^{Feeder}} = \phi_1{}' \quad (8)$$

$$\frac{\partial P_t^{Feeder}}{\partial P_t^{Corn}} = -\frac{\frac{\partial \varphi}{\partial P_t^{Corn}}}{\frac{\partial \varphi}{\partial P_t^{Feeder}}} = \frac{-B^{Corn}}{\frac{\partial P_t^{Feeder\prime}}{\partial P_t^{Feeder}} W^{Feeder} uN + W^{Feeder}} = \phi_2{}' \quad (9)$$

Although we cannot determine a numerical hypothesized value for $\phi_1{}'$ and $\phi_2{}'$, we expect:

$$\phi_1{}' < \phi_1 \quad (10)$$

$$\phi_2{}' > \phi_2 \quad (11)$$

Therefore, when capacity utilization is high, feedlots will not pass-through as much of the price changes to feeder cattle producers, so the pass-through rate should be smaller than the hypothesized pass-through rate under Ricardian rent theory.

3 | EMPIRICAL METHODOLOGY AND DATA

Building upon the empirical model of Zhao et al. (2011), we introduce a binary variable that indicates whether the average feedlot utilization rate is greater than the critical capacity rate. The static model is:

$$P_t^{Feeder} = \alpha_0 + \psi_0 \times 1(u_t > u^*) + \beta_0 E\left[P_T^{Fed}\right] + \zeta_0 E\left[P_T^{Fed}\right] \times 1(u_t > u^*) + \gamma_0 P_t^{Corn} + \kappa_0 P_t^{Corn} \times 1(u_t > u^*)$$
$$+ \sum_{k=1}^{11} d_k m_k + \sum_{k=1}^{11} \chi_k m_k \times 1(u_t > u^*) + \tau_0 time_t + \rho_0 time_t \times 1(u_t > u^*) + \varepsilon_t \quad (12)$$

P_t^{Feeder}, $E_t[P_T^{Fed}]$, P_t^{Corn}, u_t, and u^* are as previously defined. m_k are monthly placement dummies for January to November with $k \in \{1, 2, \ldots 11\}$. $time_t$ is a time trend to capture other unobservable factors. ε_t is the estimated error term. α_0, ψ_0, β_0, ζ_0, γ_0, κ_0, d_k, and τ_w are parameters to be estimated. The values of β_0 and γ_0 are compared to the hypothesized RRT ϕ_1 and ϕ_2 to test for 100% pass-through. Both the Wald test and complete combinational test (Poe et al., 2005) are used to test if the estimated pass-through values from the regression are different from the RRT pass-through hypotheses. Two one-sided complete combinational tests (Poe et al., 2005) utilize the mean and standard deviation of the monthly ϕ calculations, relaxing the assumption of the hypothesized pass-through being fixed from previous studies.[5]

[5] 1,000 Krinsky-Robb bootstrapped estimates of each of the hypothesized ϕ and estimated pass-through values from the regression were completed. H_0 : $regression\ pass-through > RRT\ \phi$

TABLE 2 Descriptive statistics from January 3, 1999 to September 24, 2023.

Variable	Mean	St Dev	Min	Max
Real corn price ($/bu)	1.74	0.64	0.92	3.76
Real feeder cattle futures price ($/cwt)	56.97	11.41	40.93	101.35
Real KS cash weighted feeder price ($/cwt)	58.64	12.11	41.40	108.71
Real live (fed) cattle futures price ($/cwt)	47.07	6.98	33.97	72.03
Real KS 4-year historical average basis ($/cwt)	0.15	1.07	−1.91	5.91
Real KS expected fed cattle price ($/cwt)	47.23	7.15	34.81	73.02

Data are weekly averages and prices are discovered and reported in the market with noise, thus a model specification allowing for possible dynamic effects is estimated. Equation (12) is extended dynamically as:

$$P_t^{Feeder} = \alpha_0 + \psi_0 \times 1(u_t > u^*) + \sum_{i=0}^{p} \beta_i E_{t-i}\left[P_{T-i}^{Fed}\right] + \sum_{i=0}^{p} \zeta_i E_{t-i}\left[P_{T-i}^{Fed}\right] \times 1(u_t > u^*) + \sum_{j=0}^{q} \gamma_j P_{t-j}^{Corn}$$
$$+ \sum_{j=0}^{q} \kappa_j P_{t-j}^{Corn} \times 1(u_t > u^*) + \sum_{k=1}^{11} d_k m_k + \sum_{k=1}^{11} \chi_k m_k \times 1(u_t > u^*) + \sum_{w=0}^{W} \tau_w time_t^w$$
$$+ \sum_{w=0}^{W} \rho_w time_t^w \times 1(u_t > u^*) + \varepsilon_t \tag{13}$$

where β_i and γ_j are the pass-through rate from a change in fed cattle and corn prices i or j periods earlier (Zhao et al., 2011). $time_t$ is a time trend allowing up to $time_t^w$, where $w \in \{1,\ 2\}$, to be included in the model to capture other unobservable factors. Following Campa & Goldberg (2006) and Zhao et al. (2011), the instantaneous effect is given by the coefficient in the same period and the total effect of fed cattle and corn changes are the sum of the respective coefficients. These values are tested against hypothesized pass-through threshold values to see if Ricardian rent theory holds in the cattle industry using the Wald and complete combinational tests (Poe et al., 2005). Therefore, RRT ϕ_1 is compared to $\sum_{i=0}^{p} \beta_i$ and RRT ϕ_2 is compared to $\sum_{j=0}^{q} \gamma_j$. Lag lengths (p and q) and trends included are determined by minimizing the Schwarz Bayesian Criteria (SBC) value in models that included consecutive lags and all monthly dummy variables. For the dynamic model, up to 52 lags of fed cattle and corn prices were considered.

3.1 | Data

Weekly data from January 3, 1999 to September 24, 2023 were collected from the Livestock Marketing Information Center (LMIC, 2023). LMIC complies and cleans time series data from multiple source such as the USDA Agricultural Marketing Service. A complete listing of data spreadsheets from LMIC used can be found in Appendix Table A.4. All prices are deflated by the Consumer Price Index (CPI; 1982–1984 = 100; U.S. Bureau of Labor Statistics, 2022). Summary statistics of price series are reported in Table 2.

Using feeder and live cattle futures prices for price expectations assumes an expected basis of zero. Assuming a zero basis, as in Zhao et al. (2011), for forecasting is usually not accurate (Kastens et al., 1998). This assumption is relaxed in two ways, using a weighted cash price for feeder steers and an expected fed cattle price. Kansas cash feeder steer prices are available beginning January 1992 for 500–599 lb, 600–699 lb, 700–799 lb, and 800–899 lb animals. Feedlot placements by weight class (less than 600 lb, 600–699 lb, 700–799 lb, 800 lb plus) for Kansas. Using the four steer prices and the percentage of cattle placed by weight in that month, a real weighted feeder cattle cash price is constructed for $E_t[P_t^{Feeder}]$. See Figure 1.

Moreover, $E_t[P_T^{Fed}]$ can be calculated using historical Kansas fed cattle basis and live cattle futures price following:

$$basis = cash\ price - futures\ price \tag{14}$$

FIGURE 1 Weekly real Kansas weighted feeder cattle price ($/cwt) from January 03, 1999 to September 24, 2023.

FIGURE 2 Weekly real expected Kansas fed cattle price ($/cwt) from January 03, 1999 to September 24, 2023.

and

$$expected\ price = current\ deferred\ futures\ price + expected\ basis \tag{15}$$

A 22-week feeding period is assumed throughout. Accordingly, the current deferred futures price is the nearby live cattle contract price for the contract corresponding to 22 weeks in the future. For example, if a steer is placed on May 11th, it is assumed to finish feeding on Oct. 12th, so the October live cattle futures price in May is used. However, if a steer is placed in February, it will finish feeding in July. There is no July live cattle futures contract and hence the August live cattle futures contract price in February is used.[6]

Kansas fed cattle cash prices are used to calculate expected basis. Kastens et al. (1998) found that the most accurate method to use for price forecasting is deferred futures plus historical basis. A 4-year historical average basis for fed cattle is used for expected basis as suggested by Tonsor et al. (2004). The average real expected basis is −\$0.15/cwt (t-test against $0 = 5.16$, p-value < 0.001) with a minimum and maximum of −\$1.91/cwt and \$5.91/cwt, respectively. Expected basis is seasonal with the highest basis usually occurring in December. Figure 2 shows the real expected fed cattle price series.

[6] Live cattle future contracts are traded for February, April, May, June, August, September, October, and December.

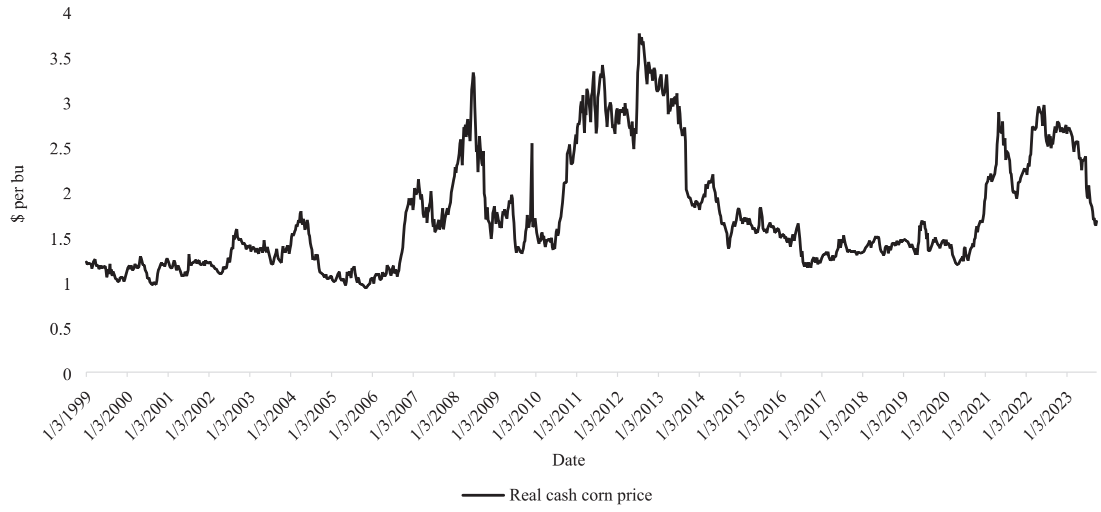

FIGURE 3 Weekly real cash corn price ($/bu) from January 03, 1999 to September 24, 2023.

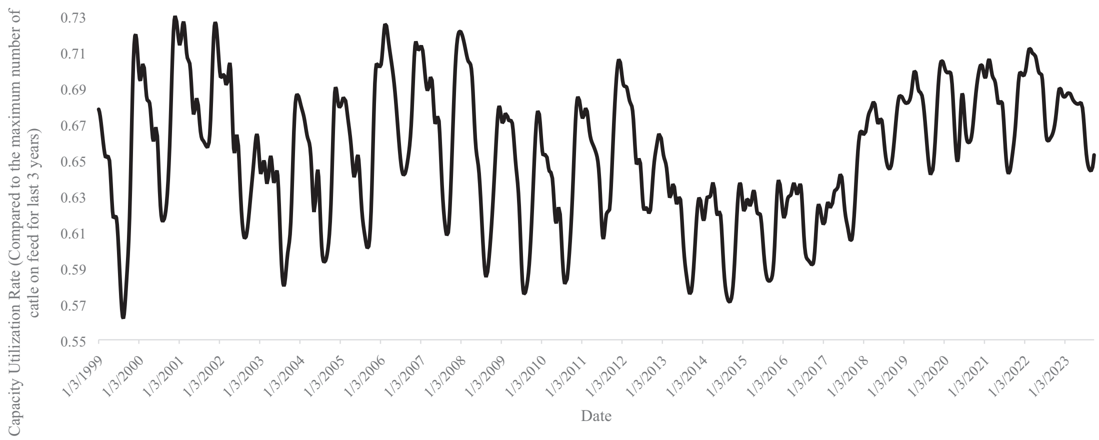

FIGURE 4 Feedlot capacity utilization rate from January 03, 1999 to September 24, 2023.

The real cash corn price is used for P_t^{Corn} (Figure 3). The largest run up in the real corn price, from $1.35/bu to $3.71/bu, occurred between June 2010 and August 2012. Descriptive statistics of the corn and cattle price series are found in Table 2.

We created the weekly *feedlot capacity utilization rate (u)* as:

$$u = \frac{cattle\ on\ feed}{feedlot\ capacity} \tag{14}$$

Cattle on feed data are compiled by LMIC (2023) from the USDA Cattle on Feed Report. It provides monthly total number of cattle on feed on feedlots with capacity 1000+ cattle capacity. Feedlot capacity is an annual feedlot capacity estimate for feedlots with 1000+ capacity from the USDA National Agricultural Statistics Service that is reported in the February Cattle on Feed report. Feedlot capacity utilization is plotted in Figure 4.[7] When identifying the critical point of capacity utilization rate (u^*), we tested 62%, 65%, and 68% capacity utilization rates. We choose these three potential critical points according to the distribution of the utilization rates. Based on SBC and the results of regressions, 65% capacity is considered the critical switching point (u^*) for capacity utilization (Figure 5).

[7] Due to differences in data aggregation, smoothing was required (proc expand in SAS). The feedlot capacity data are annual, so we smoothed these values to monthly first, to match the cattle on feed data. Next, we calculated u monthly and then smoothed u to weekly.

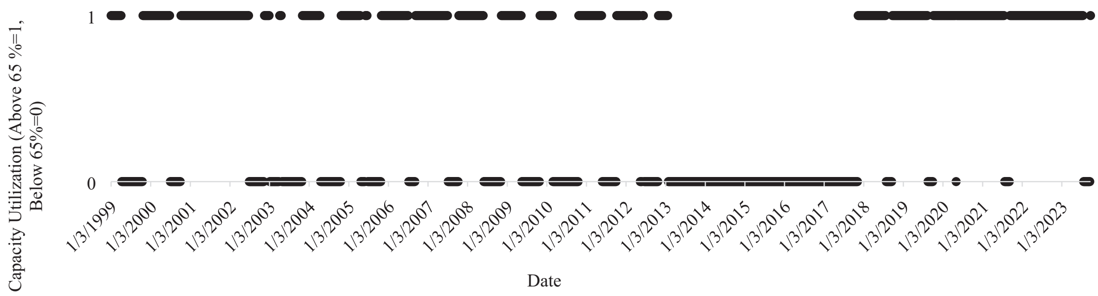

FIGURE 5 Feedlot capacity utilization rate binary variable where above 65% = 1 and below 65% = 0 from January 03, 1999 to September 24, 2023.

3.2 | Augmented Dickey Fuller and misspecification tests

Augmented Dickey Fuller (ADF) tests with and without accounting for seasonality were conducted to test for nonstationary and unit roots (Dickey & Fuller, 1979). The seasonal ADF tests reject unit root in the corn, feeder cattle, and fed cattle price series. See Appendix Table A.2.

Details of misspecification tests conducted are in Appendix Table A.3. In all models, homoscedasticity and/or independence are rejected. Thus, generalized method of moments with the Newey–West correction on the errors terms is completed (Greene, 2003).

4 | RESULTS

We present two analyses. The first analysis is a replication of the methods used by Zhao et al. (2011), using futures prices with more recent weekly data. The second analysis, including updated expected prices and feedlot capacity utilization, is the main focus of the analysis.

4.1 | Replication of Zhao et al. (2011)

Further details and result tables from this analysis are presented in Appendix B. In the dynamic model, we find the live cattle futures to feeder cattle futures price transmission is 1.84. This means that if the real live cattle futures price increases by $1.00/cwt then the feeder cattle futures price increases by $1.84/cwt. This is statistically significantly larger than the hypothesized RRT ϕ_1 of 1.64 (114%). The estimated cash corn to feeder cattle futures price transmissions of −7.53 is consistent with (not statistically different than) the RRT ϕ_2 of −7.66 (98%).

These results contrast Zhao et al. (2011) who found incomplete pass-through rates, indicating that pass-through rates have changed since their analysis. At first the fed to feeder cattle pass-through rate greater than 100% may seem counterintuitive—this indicates feedlots were passing more of the price increases onto feeder cattle producers than hypothesized. However, recall that profit-maximizing firms will operate as long as they are covering variable costs as hence they are better off than not operating (i.e., income over variable costs is positive). This is key for feedlots who have relatively high fixed costs and asset specificity. Pragmatically this indicates there can be periods when a feedlot operation is placing cattle when they expect to lose money yet the amount they lose is less than fixed costs per head (i.e., they are covering variable but not total costs). Moreover, there are cases where feedlot sellers receive, or expect to receive, beef-quality based price premiums that may alter expectations at time of feedlot placement which helps "justify" the placement decision. An additional explanation is that feedlot producers often cannot lock in a profit at placement (with hedging or forward contacts) but are "betting on the come" at placement—hoping for higher fed cattle prices by the end of the feeding period or cheaper feed costs.[8] Academic estimates of feedlot returns (when not accounting for extra revenue via grid premiums, hedging gains, etc.) for typical feedlot operations can be slightly negative (Herrington & Tonsor, 2013; Tonsor,

[8] The authors would like to thank the anonymous reviewer for this suggestion. "Betting on the come" is a gambling term meaning you may not have what you want now, but you are hoping/betting you will when the time comes.

TABLE 3 Coefficient estimates using weighted Kansas cash feeder and expected fed cattle prices, and 65% capacity utilization critical point.

Variable	1 Static	2 Dynamic
Expected fed price	2.10***	1.35***
	(0.04)	(0.11)
Expected fed price lag effects	–	0.77***
	–	(0.12)
Cash corn price	−8.78***	−3.86***
	(0.43)	(1.15)
Cash corn price lag effects	–	−5.53***
	–	(1.25)
Capacity ($1(u_t > 65\%)$)	17.74***	15.24***
	(3.58)	(3.45)
Expected fed price × $1(u_t > 65\%)$	−0.51***	−0.57***
	(0.09)	(0.15)
Expected fed price lag effect × $1(u_t > 65\%)$	–	0.14
	–	(0.15)
Cash corn price × $1(u_t > 65\%)$	3.05***	1.99
	(0.64)	(1.64)
Cash corn price lag effect × $1(u_t > 65\%)$	–	1.15
	–	(1.70)
Trend	−0.002**	0.004
	(0.001)	(0.004)
Trend × $1(u_t > 65\%)$	0.001	−0.0008
	(0.001)	(0.004)
Trend^2	–	-5.32×10^{-6}*
	–	(3.08×10^{-6})
Trend^2 × $1(u_t > 65\%)$	–	2.04×10^{-6}
	–	(3.52×10^{-6})
Intercept	−26.25***	−29.18***
	(1.81)	(1.61)
SBC	2661.41	2474.10
Monthly dummies	Yes	Yes
Monthly dummies × $1(u_t > 65\%)$	Yes	Yes

Note: *$p < 0.10$, **$p < 0.05$, ***$p < 0.01$. Newey–West adjusted standard errors are shown in (). The estimators of "Expected fed price lag effects", "Cash corn price lag effects", "Expected fed price lag effect × $1(u_t > 65\%)$" and "Cash corn price lag effect × $1(u_t > 65\%)$" reported in column 2 are the summation of a series of dynamic variables.

2023). In this environment, a feedlot may still be better off paying "more than a break-even implied price" for incoming feeder cattle (as long as doing so covers variable costs). In this assessment this corresponds with a clear implication that we may derive pass through rates exceeding 100%. Indeed, McKendree et al. (2020) found a fed cattle to feeder cattle transmission elasticity greater than one. To further explore what could be driving fed cattle to feeder cattle pass-through rates greater than 100%, we update expected prices to include basis and also include feedlot capacity utilization.

4.2 | Using weighted Kansas cash feeder and expected fed cattle prices, and capacity utilization

In this analysis, the expected feeder cattle price, $E_t[P_t^{Feeder}]$, is a weighted Kansas feeder cattle cash price at time t, $E_t[P_T^{Fed}]$ is the appropriate deferred CME live cattle futures contract price minus the Kansas fed cattle basis at time t, and $E_t[P_t^{Corn}]$

TABLE 4 Testing ϕ_1 (fed cattle price) pass-through.

Estimate	RRT pass-through	Regression pass-through	Percent pass-through	RRT ϕ_1 Wald tests $H_0: \phi_{1,Reg} = \phi_{1,RRT}$ *p*-value	Conclusion
Dynamic	1.64	2.12	129%	<0.0001	Regression pass-through different than RRT pass-through
Dynamic ($u_t > 65\%$)	1.64	1.69	103%	0.5448	No significant difference

Estimate	RRT pass-through	Regression pass-through	Percent pass-through	Complete combinational tests $\phi_{1,Reg} < \phi_{1,RRT}$ p-value	$\phi_{1,Reg} > \phi_{1,RRT}$ *p*-value	Conclusion
Dynamic	1.64	2.12	129%	0	1	Regression pass-through larger than RRT pass-through
Dynamic ($u_t > 65\%$)	1.64	1.69	103%	0.3454	0.6546	No significant difference

TABLE 5 Testing ϕ_2 (corn price) pass-through.

Estimate	RRT pass-through	Regression pass-through	Percent pass-through	Wald tests $H_0: \phi_{2,Reg} = \phi_{2,RRT}$ *p*-value	Conclusion
Dynamic	−7.66	−9.39	123%	<0.0001	Regression pass-through different than RRT pass-through
Dynamic ($u_t > 65\%$)	−7.66	−6.25	82%	0.0036	Regression pass-through different than RRT pass-through

Estimate	RRT pass-through	Regression pass-through	Percent pass-through	Complete combinational tests $\phi_{2,Reg} < \phi_{2,RRT}$ *p*-value	$\phi_{2,Reg} > \phi_{2,RRT}$ *p*-value	Conclusion
Dynamic	−7.66	−9.39	123%	0.9748	0.0252	Regression pass-through smaller than RRT pass-through
Dynamic ($u_t > 65\%$)	−7.66	−6.25	82%	0.1101	0.8899	No significant difference

is the cash corn price. In Table 3, model 1 is the static specification, where there are no lags on fed price or corn price, and model 2 is an abbreviated version of the dynamic model that includes five lags for the expected fed cattle price and three lags for corn price. Given the lower SBC value, the dynamic model is preferred to the static model. A table of full coefficient estimates is available in Appendix C Table C.1.

First, consider the situation when the capacity utilization rate is below u^* (65%). The contemporaneous fed cattle pass-through is 1.35, and the lagged pass-through over the next 5 weeks is 0.77, for a total fed cattle to feeder cattle pass-through of \$2.12/cwt (Table 3). The total corn to feeder cattle pass-through is \$−9.39/cwt with the lagged pass-through (−5.53) being larger than the contemporaneous pass-through (−3.86).

Next, consider the impacts of capacity utilization rate above u^* (65%). The critical capacity utilization binary variable is statistically significant and positive, meaning that feeder cattle prices are higher when feedlot capacity utilization rate is above the critical point. Note, this is not a price transmission, just an intercept shifter meaning that generally prices are higher during these periods. The interaction of capacity utilization and the contemporaneous expected fed cattle pass-through is \$−0.57 indicating that pass-through rates are lower when capacity utilization rate is above the critical point, consistent with our conceptual model. The total fed to feeder cattle pass-through is \$1.69/cwt (1.35+0.77−0.57+0.14) when capacity utilization rate is over 65%. When capacity utilization rate is over 65% corn pass-through is -\$6.25/cwt (−3.86−5.53 + 1.99 + 1.15). Furthermore, although the contemporaneous and lagged interactions between corn price and capacity utilization are not individually significant, they are jointly significant (t-stat = 5.00, *p*-value < 0.001). The trend coefficient and capacity utilization interaction are small and statistically insignificant. The feeder cattle price displays seasonality and these seasonal patterns are also impacted by capacity utilization rate (see Appendix Table C.1 for full seasonality coefficients).

Next, how do the estimated price transmissions compare to those hypothesized by Ricardian rent theory? The total fed cattle estimated pass-throughs are compared to the RRT ϕ_1 (\$1.64/cwt) using both Wald and complete combinatorial tests in Table 4. For the dynamic model, the estimated pass-through is statistically significantly greater (129%) than the hypothesized RRT pass-through when capacity utilization rate is lower than 65%. This suggests that feeder cattle prices increase more than hypothesized by RRT when fed cattle prices increase. However, the estimated pass-through, 1.69 (103%), when capacity utilization rate is over 65% is not statistically significant different than RRT ϕ_1. Potentially, this could be indicative of situation described in the previous subsection where feedlots are willing to pay more than break-even for the feeder cattle, potentially able to pay all variable costs and contribute to fixed costs, but not cover total costs. However, when feedlot capacity utilization rates are above the critical point, price transmissions are more consistent with expected rates from RRT.

The corn pass-through estimates are compared to the RRT ϕ_2 (−7.66) in Table 5. A similar story emerges, where the corn to feeder cattle pass-through is smaller (larger in absolute terms) than RRT pass-through when the feedlot capacity utilization rate is below the critical point, and not statistically different when the feedlot capacity utilization rate is over 65% (based on complete combinatorial test). These findings are consistent with our conceptual model.

5 | CONCLUSIONS AND IMPLICATIONS

This article contributes to the literature on the transmission of prices across vertically connected sectors of agriculture, with a specific focus on how price changes in the U.S. feedlot industry manifest in feeder cattle markets that supply the sector. We use Ricardian rent theory (RRT) to determine expected pass-through rates for both fed to feeder cattle, and corn to feeder cattle price transmissions. Based on RRT, surplus rents should pass through the market to the holder of the scarcest resource. Previous studies on RRT in cattle markets have assumed that feeder calves are the scarcest (in that they are required for fed cattle production), widely traded resource and thus gains and losses at the feedlot should be passed through to feeder cattle prices. However, we develop a conceptual model and empirically test for pass-through rates when feedlot capacity is also a scarce resource. Here we use feedlot capacity utilization greater than 65% as a proxy for high feedlot capacity utilization. In addition to the inclusion of feedlot capacity utilization rate, we improve on the methodology used in previous studies in three ways: by using weekly data, updating production assumptions used to determine the hypothesized RRT pass-through values, and incorporating basis into price expectations.

In the empirical model, when feedlot capacity utilization rates are below the critical point (65%), we find that both fed to feeder cattle and corn to feeder cattle pass-through rates are higher (in absolute terms for corn) than hypothesized by RRT. When capacity utilization rates are high, over the 65% critical point, estimated pass-through rates are lower (in absolute terms for corn) and not statistically different than Ricardian rent theory. This unique finding is potentially driven by the high fixed costs in the cattle feeding sector, and high asset fixity. Therefore, feedlots could be passing back more of the price increases than anticipated to feeder cattle producers to cover variable costs, even if they are not fully covering total costs.

Cow-calf, stocker, and background producers should consider the potential implications of greater than 100% pass-through from fed cattle and corn prices. In vertical markets, anything that increases retail beef demand will subsequently increase fed cattle price. These benefits will be more than proportionally passed to producers operating before the feedlot stage of production. Considering the horizontal corn and feeder cattle markets, the large corn pass-through, could indicate a higher degree of input substitutability between corn and feeder cattle. Potentially, if corn price increases and these higher feed costs result in adversely lower feeder cattle prices, cow-calf producers could consider delaying sale or even retaining ownership of the steer through slaughter. Generally, cow-calf producers cannot react as quickly to shocks. Therefore, cow-calf producers should not only follow current events and changes at the retail beef demand level but also the horizontal feed markets to understand the potential ramifications on feeder cattle prices, and ultimately revenue, they receive. Finally, the results of this study can help inform policy ongoing discussions about beef market competitiveness and promote efficient resource allocation. Namely, this study indicates market conditions such as feedlot capacity utilization directly impact expected relationships between prices in two vertically connected markets. Similar assessment on the role of packing capacity on price relationships has been discussed in the literature and in several recent policy debates. While we hope our research helps guide an improved discussion, indeed ongoing research is encouraged.

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REFERENCES

Bina, J. D., Tonsor, G. T., Schulz, L. L., & Hahn, W. F. (2022). Regional and plant-size impacts of COVID-19 on beef processing. *Food Policy*, *108*, 102247. https://doi.org/10.1016/j.foodpol.2022.102247

Brester, G. W., & Marsh, J. M. (2001). The effects of US meat packing and livestock production technologies on marketing margins and prices. *Journal of Agricultural and Resource Economics*, *26*, 445–462. 10.22004/ag.econ.31052

Brester, G. W., Marsh, J. M., & Atwood, J. A. (2004). Distributional impacts of country-of-origin labeling in the US meat industry. *Journal of Agricultural and Resource Economics*, *29*, 206–227. 10.22004/ag.econ.31109

Brester, G. W., Marsh, J. M., & Atwood, J. A. (2009). Evaluating the Farmer's-share-of-the-retail-dollar Statistic. *Journal of Agricultural and Resource Economics*, *34*, 213–236. 10.22004/ag.econ.54543

Dickey, D. A., & Fuller, W. A. (1979). Distribution of the estimators for autoregressive time series with a unit root. *Journal of the American Statistical Association*, *74*(366a), 427–431. https://doi.org/10.1080/01621459.1979.10482531

Federal Reserve Bank of Kansas City. (2023). *Ag Finance updates*. Federal Reserve Bank of Kansas City. Retrieved July 2023, from https://www.kansascityfed.org/agriculture/agfinance-updates/

Goldberg, L. S., & Campa, J. M. (2006). Distribution margins, imported inputs, and the sensitivity of the CPI to exchange rates. *Review of Economics and Statistics*, *92*(2), 392–407. https://doi.org/10.2307/27867544

Herrington, M. A., & Tonsor, G. T. (2013). Econometric estimations of performance improvements in Kansas feedlot cattle. *The Professional Animal Scientist*, *29*(4), 435–442. 10.15232/S1080-7446(15)30257-6

Kastens, T. L., Jones, R., & Schroeder, T. C. (1998). Futures-based price forecasts for agricultural producers and businesses. *Journal of Agricultural and Resource Economics*, *23*, 294–307. 10.22004/ag.econ.31187

Livestock Marketing Information Center. (2023). Livestock Marketing Information Center Spreadsheets. Retrieved November 2023 http://www.lmic.info/members/spreadsheets

Lusk, J. L., & Tonsor, G. T. (2021). Supply and demand indices and their welfare implications. *Q Open*, *1*(1). https://doi.org/10.1093/qopen/qoaa008

Marsh, J. M. (2007). Cross-sector relationships between the corn feed grains and livestock and poultry economies. *Journal of Agricultural and Resource Economics*, *32*(1), 93–114. 10.22004/ag.econ.8595

McKendree, M. G., Tonsor, G. T., Schroeder, T. C., & Hendricks, N. P. (2020). Impacts of retail and export demand on United States cattle producers. *American Journal of Agricultural Economics*, *102*(3), 866–883. https://doi.org/10.1093/ajae/aaz034

Poe, G. L., Giraud, K. L., & Loomis, J. B. (2005). Computational methods for measuring the difference of empirical distributions. *American Journal of Agricultural Economics*, *87*(2), 353–365. https://doi.org/10.1111/j.1467-8276.2005.00727.x

Ramsey, A. F., Goodwin, B. K., Hahn, W. F., & Holt, M. T. (2021). Impacts of COVID-19 and price transmission in US meat markets. *Agricultural Economics*, *52*(3), 441–458. https://doi.org/10.1111/agec.12628

Ricardo, D. (1821). *On the principles of political economy*. J. Murray. https://doi.org/10.1017/CBO9781107589421

Rude, J. (2020). COVID-19 and the Canadian cattle/beef sector: Some preliminary analysis. *Canadian Journal of Agricultural Economics/Revue Canadienne d'agroeconomie*, *68*(2), 207–213. https://doi.org/10.1111/cjag.12228

Tonsor, G. (2023). *Historical and projected Kansas feedlot net returns*. Kansas State University Department of Agricultural Economics Extension Publication. (Accessed March, 2023) Available online at https://www.agmanager.info/livestock-meat/cattle-finishing-historical-and-projected-returns/cattle-feeding-returns-february-4

Tonsor, G. T., Dhuyvetter, K. C., & Mintert, J. R. (2004). Improving cattle basis forecasting. *Journal of Agricultural and Resource Economics*, *29*(2), 228–241. 10.22004/ag.econ.31115

U.S. Bureau of Labor Statistics. (n.d.). *CPI Home*. U.S. Bureau of Labor Statistics. Retrieved July 2022, from https://www.bls.gov/cpi/

United States Department of Agriculture Agricultural Marketing Service. (2020). *Boxed Beef & Fed Cattle Price Spread Investigation Report*. United States Department of Agriculture, Agricultural Marketing Service. https://www.ams.usda.gov/sites/default/files/media/CattleandBeefPriceMarginReport.pdf

United States Department of Agriculture, National Agricultural Statistics Service. (n.d.). USDA—National Agricultural Statistics Service—2017 Census of Agriculture—Volume 1, Chapter 1: U.S. National Level Data. Retrieved March 2023, from https://www.nass.usda.gov/Publications/AgCensus/2017/Full_Report/Volume_1,_Chapter_1_US/

Weersink, A., von Massow, M., Bannon, N., Ifft, J., Maples, J., McEwan, K., McKendree, M. G. S., Nicholson, C., Novakovic, A., Rangarajan, A., Richards, T., Rickard, B., Rude, J., Schipanski, M., Schnitkey, G., Schulz, L., Schuurman, D., Schwartzkopf-Genswein, K., Stephenson, M., … Wood, K. (2021). COVID-19 and the agri-food system in the United States and Canada. *Agricultural Systems*, *188*, 103039. https://doi.org/10.1016/j.agsy.2020.103039

Zhao, H., Du, X., & Hennessy, D. A. (2011). Pass-through in United States beef cattle prices: A test of Ricardian rent theory. *Empirical Economics*, *40*, 497–508. https://doi.org/10.1007/s00181-010-0339-x

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APPENDIX A
ϕ_1 and ϕ_2 descriptive statistics and plots

TABLE A.1 Ricardian rent theory ϕ_1 and ϕ_2 descriptive statistics for January 1999 to September 2023.

	RRT ϕ_1	RRT ϕ_2
Mean	1.64	−7.66
Median	1.63	−7.50
Standard deviation	0.08	0.95
Kurtosis	0.002	0.20
Skewness	0.41	−0.66
Range	0.40	4.81
Minimum	1.47	−10.39
Maximum	1.87	−5.58
Count	297	297

UNIT ROOT TESTING

The null hypothesis of the ADF test is the data display one unit root. The minimum Tau value or F value were used to select the appropriate lag length in all ADF tests. ADF tests with seasonality include 11 monthly dummy variables. PROC ARIMA procedure in SAS with ADF = 30 and DLAG = 12 were specified for the ADF tests with seasonality.

Misspecification tests results

Models are initially estimated using ordinary least squares and then misspecification tests are conducted to check for normality, homoscedasticity, and independence following McGuirk, Driscoll and Alwang (1993). The D'Agostino third sample moment tests, the Anscombe and Glynn fourth sample moment test, and D'Agostino-Pearson K^2 omnibus tests are used to test for normality (Anscombe & Glynn, 1983; D'Agostino, Belanger, & D'Agostino, 1990). Static and dynamic homoscedasticity are examined using a RESET2 test and autoregressive conditional heteroscedasticity (ARCH) test, respectively. Independence is checked using the following auxiliary regression:

$$\hat{\varepsilon}_t = \beta_0' \boldsymbol{X}_t + \Lambda' \widehat{\varepsilon_{t-1}} + \upsilon_t \tag{A.1}$$

where $\boldsymbol{X}_t$ is a $k \times 1$ vector of independent variables, ε_t is the residual from the original model and υ_t is the estimated residuals from the auxiliary regression (McGuirk, Driscoll, & Alwang, 1993). If Λ is significant then independence is rejected. If homoscedasticity and/or independence are rejected, then generalized method of moments with the Newey-West correction on the errors terms is completed (Greene, 2003).[9].

[9] See http://support.sas.com/kb/40/098.html. The Newey-West standard error correction in SAS can be completed using proc model specifying GMM and kernel = (Bartlett, L+1, 0) in the fit statement. L is the maximum lag length determined by the researcher. We use L = 9 because if $L + 1 > N^{\frac{1}{3}} \approx 11$ may generate inaccurate standard error.

TABLE A.2 Augmented Dickey Fuller tests.

Augmented Dickey–Fuller unit root tests

	Zero mean			Single mean			Trend			
Variables	**Optimal lags**	**Tau**	**Pr < Tau**	**Optimal lags**	**F**	**Pr > F**	**Optimal lags**	**F**	**Pr > F**	**Conclusion**
Real corn price	15	−0.77	0.3830	18	3.57	0.1549	18	3.85	0.4010	Fail to reject unit root
Expected fed cattle price	9	0.30	0.7730	11	3.66	0.1315	11	5.31	0.1058	Fail to reject unit root
Weighted feeder price	12	0.16	0.7330	12	3.07	0.2816	12	3.77	0.4178	Fail to reject unit root

Seasonal augmented Dickey–Fuller unit root tests

	Zero mean			Single mean			
Variables	**Optimal lags**	**Tau**	**Pr < Tau**	**Optimal lags**	**Tau**	**Pr < Tau**	**Conclusion**
Real corn price	1	−11.93	<0.0001	0	−8.38	<0.0001	Reject unit root
Expected fed cattle price	1	−5.67	<0.0001	0	−8.29	<0.0001	Reject unit root
Weighted feeder price	1	−6.77	<.0001	0	−6.95	<0.0001	Reject unit root

TABLE A.3 Misspecification tests results for models with basis and feedlot capacity utilization.

Misspecification test *p*-values	Static 01/03/1999 to 09/24/2023	Dynamic 01/03/1999 to 09/24/2023
Normality:		
Skewness	0.21	0.13
Kurtosis	0.26	0.47
Omnibus	0.24	0.24
Homoscedasticity:		
Static	<0.01	0.06
Dynamic	<0.01	<0.01
Independence:	<0.01	<0.01

TABLE A.4 Data from the livestock marketing information center and other sources.

Data	Spreadsheet name on LMIC	Data file name on LMIC or other websites	Smallest time level	Source
CPI	CPI	Monthly, Quarterly, & Annual Consumer Price Index	Monthly (smoothed to weekly)	Livestock Marketing Information Center (LMIC), CPI.xlsx, sheet monthly, column All Items, Base Period 1982-1984 = 100, updated 10/12/23
Corn price	Grainpr	Weekly Cash Grain Prices	weekly	LMIC, Grainpr.xls, sheet corn, column Dodge City, updated 11/03/23
Feeder cattle futures price	feederfutures	Daily and Weekly Feeder Futures Prices	Daily (without weekends; used weekly average)	LMIC, feederfutures.xls, sheet C, column nearby, updated 11/06/23
Kansas cash feeder price	AuctionsWestern	Dodge City, KS Feeder Cattle & Cull Cow Prices—Weekly and Monthly	weekly	LMIC, AuctionsWesternKS.xls, sheet A4, column 500-550, 550-600, 600-650, 650-700, 700-750, 750-800, 800-850, 850-900, updated on 11/01/23
Fed cattle futures price	fatfutures	Daily and Weekly Fed Futures Prices	Daily (used weekly average)	LMIC, fatfutures.xls, sheet C, column FEB APR JUN AUG OCT DEC Nearby, updated 11/06/23
Kansas direct slaughter cattle number and price	Mo182KansasFats	Monthly Weighted Average: Kansas	Monthly (smoothed to weekly)	LMIC, Mo182KansasFats.xls, sheet LV STEER, column Total all grades headcount, updated 11/08/23
Cattle on Feed Placements by Weight Group	COFWT	Monthly Cattle on Feed Placements by Weight Group	Monthly	LMIC, COFWTS.xls, sheet LV STEERS, column Total all grades, updated 10/20/23
Cattle on Feed	Cf100	Monthly Cattle on Feed (1,000 plus capacity)	Monthly	LMIC, Cf1000.xls, sheet B, column cattle on feed us total, updated 10/20/23
Feedlot capacity	–	CATTLE, ON FEED—CAPACITY, MEASURED IN HEAD	Annually (smoothed to monthly)	USDA National Ag Statistics Service, CATTLE, ON FEED—CAPACITY, MEASURED IN HEAD, updated in 2023
The average annual interest rate for feeder livestock, non-real estate bank loans	–	Q323_National_Survey_of_Terms_of_Lending_Historical_Data	Quarterly	Federal Reserve Bank of Kansas City, Q323_National_Survey_of_Terms_of_Lending_Historical_Data, sheet Data, column 050B, updated in 2023 Q3
Feed conversion ratio; Death loss percentage; Input feeder cattle average weight; Output fed cattle average weight	KSUFeedlot	Monthly Kansas feedlot data	Monthly	LMIC, KSUFeedlot.xls, sheet B, Multiple columns, updated 11/01/23

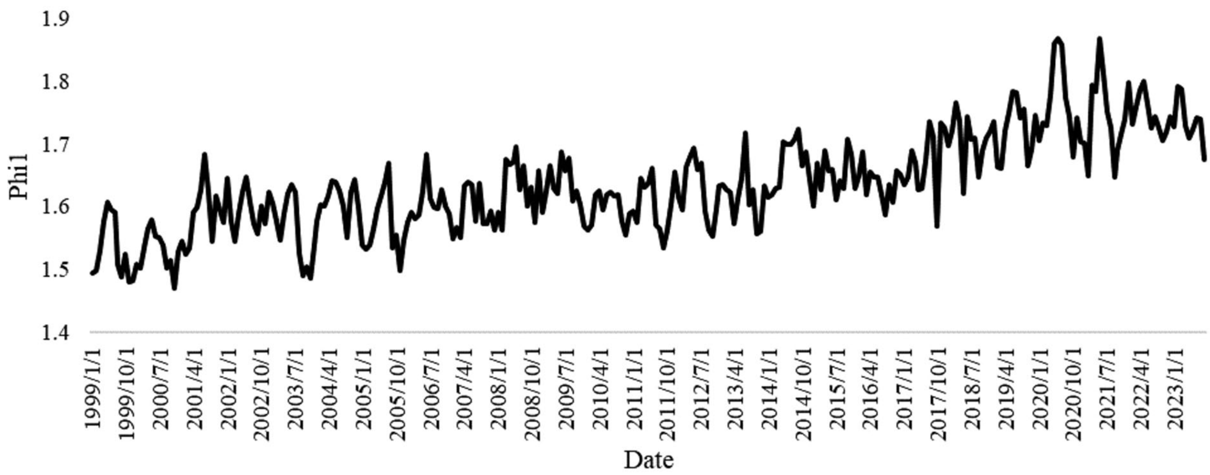

FIGURE A.1 Monthly ϕ_1 hypothesized by Ricardian rent theory using data from *Focus on Feedlots* from January 1999 to September 2023.

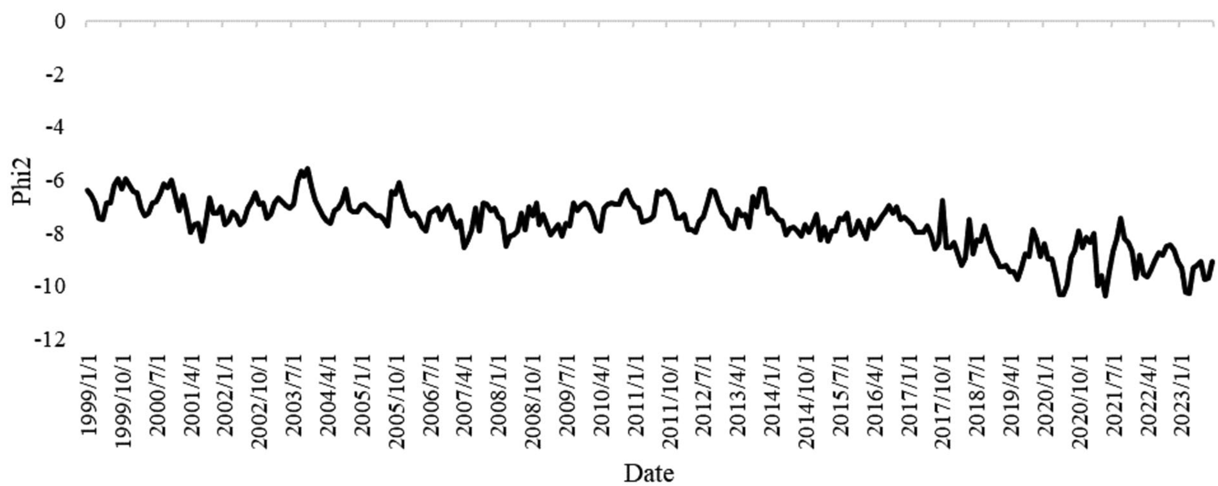

FIGURE A.2 Monthly ϕ_2 hypothesized by Ricardian rent theory using data from Focus on Feedlots from January 1999 to September 2023.

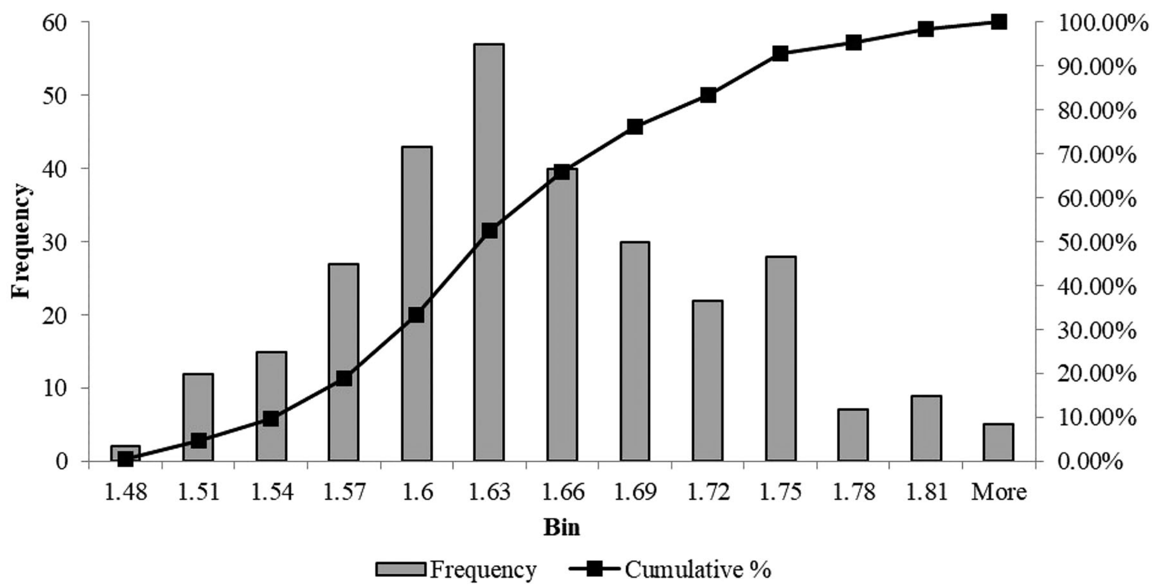

FIGURE A.3 ϕ_1 histogram.

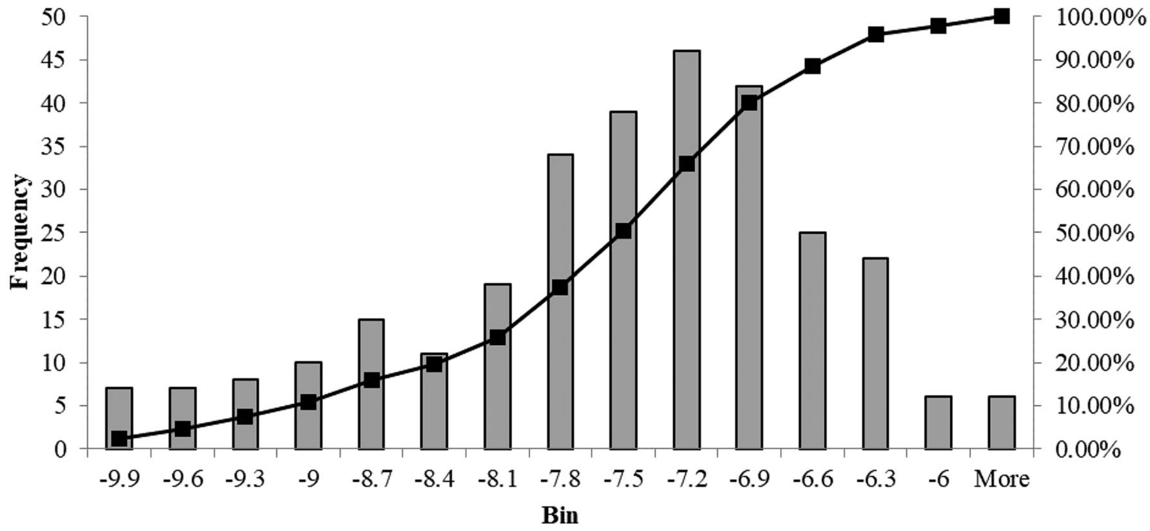

FIGURE A.4 ϕ_2 histogram.

APPENDIX B

USING METHODS OF ZHAO, DU, AND HENNESSY (2011)

Data

Following Zhao, Du, and Hennessy (2011), $E_t[P_t^{Feeder}]$ is the nearby Chicago Mercantile Exchange (CME) feeder cattle futures contract price at time t, $E_t[P_T^{Fed}]$ is the appropriate deferred CME live cattle futures contract price at time t, and $E_t[P_t^{Corn}]$ is the cash corn price.[10]

Results

The detailed results of static model and dynamic model are shown in Table B.1. Estimated fed cattle and corn pass-through from the static model are \$1.84/cwt and -\$7.31/cwt.

The optimal dynamic model based on minimizing the SBC value, includes seven fed cattle lags, three corn lag and a time trend. From the results of dynamic model, we can see that estimated fed cattle and corn pass-through are \$1.87/cwt and −\$7.43/cwt.

In Table B.2, we compare the hypothesized RRT pass-through and estimated pass-through from the regression. The regression pass-through of fed cattle futures price is statistically significantly larger than RRT pass-through. For the pass-through of corn price, we observe that the estimated pass-through is not significantly difference with RRT pass-through.

[10] This assumes a zero basis for both feeder and live cattle prices.

TABLE B.1 Regression results for replication of Zhao, Du and Hennessey with futures prices.

Variable	1 Full Period Static 01/03/1999 to 09/24/2023	2 Full Period Dynamic 01/03/1999 to 09/24/2023
Live futures price	1.84***	1.26***
	(0.03)	(0.08)
Live futures price lag effects	–	0.61***
	–	(0.08)
Cash corn price	−7.43***	−2.71***
	(0.28)	(0.67)
Cash corn price lag effects	–	−4.83***
	–	(0.71)
Trend	0.002***	0.002***
	(0.0004)	(0.0004)
Intercept	−17.73***	−19.57***
	(1.17)	(1.04)
SBC	1854.16	1685.51
Monthly dummies	Yes	Yes
Monthly dummies × $1(u_t > 65\%)$	Yes	Yes

Note: *$p < 0.10$, **$p < 0.05$, ***$p < 0.01$. Newey–West adjusted standard errors are shown in ( ). The estimators of “Fed futures price lag effects” and “Cash corn price lag effects” reported in column 2 are the summation of a series of dynamic variables. Specifically, seven lags for live cattle futures price and three lags for cash corn price are used.

TABLE B.2 ϕ_1 (fed cattle price) and ϕ_2 (corn price) pass-through tests for the replication of Zhao, Du, and Hennessey (2011) for the dynamic model only.

				RRT ϕ_i Wald tests	
Variable	RRT pass-through	Regression pass-through	Percent pass-through	$H_0 : \phi_{i,Re} = \phi_{i,RRT}$	Conclusion
ϕ_1	1.64	1.87	114%	<0.0001	Regression pass-through larger than RRT pass-through
ϕ_2	−7.66	−7.53	98%	0.6329	No significant difference

APPENDIX C
DETAILED REGRESSION RESULTS FOR DYNAMIC MODEL

TABLE C.1 Detailed regression results for the dynamic model.

Variable	1 Estimate	2 Approx Std Err	3 t Value	4 Pr > |t|
Intercept	−29.1805	1.6107	−18.12	<.0001
Fed futures price_Lag0	1.353308	0.1116	12.13	<.0001
Expected fed price_Lag1	0.245974	0.1221	2.02	0.0441
Expected fed price_Lag2	0.076997	0.1021	0.75	0.4509
Expected fed price_Lag3	0.12407	0.0904	1.37	0.1703
Expected fed price_Lag4	0.180801	0.1203	1.5	0.1331
Expected fed price_Lag5	0.140029	0.1279	1.09	0.274
Expected fed price_Lag0 × $1(u_t > 65\%)$	−0.57013	0.1497	−3.81	0.0001
Expected fed price_Lag1 × $1(u_t > 65\%)$	0.051453	0.1426	0.36	0.7184
Expected fed price_Lag2 × $1(u_t > 65\%)$	0.112984	0.1268	0.89	0.3729
Expected fed price_Lag3 × $1(u_t > 65\%)$	−0.03825	0.1087	−0.35	0.725
Expected fed price_Lag4 × $1(u_t > 65\%)$	−0.19542	0.1406	−1.39	0.1649
Expected fed price_Lag5 × $1(u_t > 65\%)$	0.20548	0.1614	1.27	0.2033
Cash corn price_Lag0	−3.86049	1.1464	−3.37	0.0008
Cash corn price_Lag1	−2.01538	1.1741	−1.72	0.0863
Cash corn price_Lag2	1.617049	0.9833	1.64	0.1003
Cash corn price_Lag3	−5.13361	1.0905	−4.71	<.0001
Capacity ($1(u_t > 65\%)$)	15.24029	3.4519	4.41	<.0001
Cash corn price _Lag0 × $1(u_t > 65\%)$	1.99189	1.6441	1.21	0.2259
Cash corn price _Lag1 × $1(u_t > 65\%)$	−0.46633	1.4743	−0.32	0.7518
Cash corn price _Lag2 × $1(u_t > 65\%)$	−2.50319	1.3695	−1.83	0.0678
Cash corn price _Lag3 × $1(u_t > 65\%)$	4.116677	1.497	2.75	0.006
Jan	3.831903	0.7625	5.03	<.0001
Feb	6.105524	1	6.11	<.0001
Mar	6.498027	1.1586	5.61	<.0001
Apr	4.97404	1.1656	4.27	<.0001
May	5.503917	1.0256	5.37	<.0001
Jun	5.359224	0.9913	5.41	<.0001
Jul	5.350189	0.948	5.64	<.0001
Aug	4.247974	0.9467	4.49	<.0001
Sep	3.499785	0.9761	3.59	0.0003
Oct	0.949624	0.9342	1.02	0.3096
Nov	−1.13378	0.8258	−1.37	0.17
Jan × $1(u_t > 65\%)$	−1.92783	0.9011	−2.14	0.0326
Feb × $1(u_t > 65\%)$	−2.33498	1.1605	−2.01	0.0444
Mar × $1(u_t > 65\%)$	−2.00425	1.3808	−1.45	0.1469
Apr × $1(u_t > 65\%)$	−0.08485	1.3972	−0.06	0.9516
May × $1(u_t > 65\%)$	−1.08744	1.3307	−0.82	0.414

(Continues)

TABLE C.1 (Continued)

Variable	1 Estimate	2 Approx Std Err	3 t Value	4 Pr > |t|
Jun × $1(u_t > 65\%)$	0.367342	1.3732	0.27	0.7891
Jul × $1(u_t > 65\%)$	0.205077	1.3465	0.15	0.879
Aug × $1(u_t > 65\%)$	−0.41657	1.3287	−0.31	0.7539
Sep × $1(u_t > 65\%)$	0.124283	1.1766	0.11	0.9159
Oct × $1(u_t > 65\%)$	−0.46534	1.1069	−0.42	0.6743
Nov × $1(u_t > 65\%)$	0.758346	0.9177	0.83	0.4087
Trend	0.004111	0.00367	1.12	0.2623
Trend^2	-5.32×10^{-6}	3.08×10^{-6}	−1.72	0.0848
Trend × $1(u_t > 65\%)$	−0.00082	0.00437	−0.19	0.8511
Trend^2 × $1(u_t > 65\%)$	2.04×10^{-6}	$3.52E\times10^{-6}$	0.58	0.5634