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RESEARCH ARTICLE

Management of Multiple Sources of Risk in Livestock Production

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Abstract
Firm operators continually manage multiple sources of risk. In an application to cattle feedlot operations, our objective is to determine if producers view output price and animal health risks separately or jointly. We conduct a survey with a choice experiment placing operators in forward looking, decision-making scenarios, and capture information on past risk management approaches. Evidence regarding a relationship between animal health and output price risk mitigation is mixed and depends on the decision being made. Combined, these results provide new insight into how managers approach multiple risks when facing resource constraints.

Keywords: animal health; cattle; feedlot; price; management; risk

JEL Classifications: D22; D81; Q02; Q12; Q13

Firms must continually manage multiple sources of risk while operating with a resource constraint, whether that firm is a commercial fishing operation (Smith and Wilen, 2005), a space shuttle tile manufacturer (Pate-Cornell, 1996), or a livestock producer. Economists recognize potential correlations between multiple sources of risk and understand trade-offs exist between risk mitigation strategies (Smith and Wilen, 2005). For example, Du et al. (2015) investigated the relationship between crop producers' use of marketing contracts and crop insurance, two risk mitigation strategies. Furthermore, Smith and Wilen (2005) determined commercial fishermen's preferences for physical and financial risks are positively correlated. Similar to fishermen and crop producers, cattle feedlot operators face multiple sources of risk, which impact profitability.

Cattle feedlot operators buy feeder cattle (approximately 1 year of age, weighing between 600 and 1,000 pounds (lbs)), feed and care for them for about 6 months, and then sell fed (or live) cattle (finish weight between 1,200 and 1,400 lbs) to a beef processor.[1] Agricultural producers, including feedlot operations, face input and output price (marketing), production, human, legal, and financial risk (Crane et al., 2013). Past literature has often focused on price or yield risk in isolation. Few studies have sought to understand the relationship between multiple risks and no study has investigated how feedlot producers actually manage these multiple risks. Our analysis seeks to fill this gap.

Price risk is one of the largest risks faced by producers (Belasco et al., 2009; Goodwin and Schroeder, 1994). Furthermore, beef cattle producers rank cattle price variability as one of the

[1]For overview of the beef industry, see figure 1 pp 6 of U.S. Government Accountability Office (2018).

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top potential risk factors on their operation (Hall et al., 2003). Accordingly, research has largely focused on the role of futures and options markets to mitigate price risk from corn price increases (input), feeder cattle price increases (input), and live cattle price decreases (output) (Hart, Babcock, and Hayes, 2001; Mark, Schroeder, and Jones, 2000; Schroeder and Hayenga, 1988; Tonsor and Schroeder, 2011). Recognizing the price risk faced by livestock producers, the 2000 Agricultural Protection Act extended crop insurance to livestock. The U.S. Department of Agriculture (USDA) Risk Management Agency oversees two insurance programs to help livestock producers manage price risk, the Livestock Risk Protection (LRP) and Livestock Gross Margin (LGM) programs. In 2019, both LGM and LRP were enhanced to better suit needs of livestock producers including expanded coverage to all 50 states and increased subsidy rates (Feedstuffs, 2019).

In addition to price risk, feedlot operators face production risks that extend beyond feed conversion and average daily gain (ADG). Many factors in U.S. cattle marketing practices contribute to the potential disease risk and stress of incoming cattle including cattle commingled from different sources, traveling long distances, and abrupt changes in diet and feed intake (Step et al., 2008). Given that feedlots recognize the impact different calf management practices can have on feedlot performance and carcass quality, premiums exist for value-added programs which decrease disease and production risk such as source and age verification, preconditioning and weaning programs (Blank, Saitone, and Sexton, 2016; Zimmerman et al., 2012). Furthermore, animal disease events, like bovine spongiform encephalopathy in late 2003, may be rare, but are damaging, if not devastating, to operations that experience drastic reductions in output or spikes in production costs (Schroeder et al., 2015). For this analysis, we choose to focus on one potential health and disease risk mitigation strategy—procuring feeder cattle from a single known source.

When feedlot operators make placement decisions, they can procure the quantity of feeder cattle desired from a single seller or assemble feeder cattle from multiple sources. When placed in feedlots, feeder cattle must adapt to new environments, establish a social hierarchy, and adjust to a new diet (Rambo, 2014). Commingling feeder cattle from multiple sources into a single pen at the feedlot versus cattle being from a single source has been associated with higher morbidity rates due to increased stress and pathogen exposure, especially in studies of bovine respiratory disease (Edwards, 2010; O'Connor, Sorden, and Apley, 2005; Step et al., 2008). Furthermore, Step et al. (2008) found that calves from single source tended to have higher ADG than calves in commingled pens or calves purchased from auction markets. Health costs were also less for calves from a single source that were weaned for 45 days prior to transport than those shipped immediately after weaning or commingled from multiple sources. Abidoye and Lawrence (2006) found that single source cattle had superior carcass quality, health, and performance than backgrounded or commingled preconditioned cattle. Therefore, single source cattle have been shown to decrease animal health and production risks compared to cattle of unknown backgrounds or commingled cattle.

Belasco et al. (2009) developed an ex-ante model of price and yield risks associated with cattle feeding, determining that both of these risks have statistically significant impacts on the conditional mean and variability of profits. However, no study has investigated how feedlot producers actually manage multiple risk sources. Our objective is to determine if feedlot producers manage output price risk and animal health risk as two separate and independent risks or if they manage them jointly. To accomplish this, we surveyed feedlot operators about their historical use of risk management strategies and risk attitudes. We also included a choice experiment where respondents made decisions in situations intentionally designed to meet this project objective. For output (live cattle) price risk management, we focus on producers' use of futures hedging (buying/selling futures contracts or buying options contracts), forward contracts, other programs (e.g., LRP insurance, LGM insurance), or accepting cash (spot market) price at the time of sale. For animal health risk we focus on a producers' management of animal health within their operation, specifically feeder cattle procurement. Determining if and what kind of relationship exists between animal

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health and output price risk mitigation can inform the development of more complete risk mitigation strategies.

The main contribution of this research is determining whether cattle feedlot operators manage output price and animal health risk independently or jointly. Operations have a fixed budget. Therefore, feedlot operators could decide to implement increased animal health risk mitigation strategies instead of hedging using futures market contracts (substitute relationship). Conversely, animal health and output price risk mitigation strategies could be complements. For example, management practices could decrease uncertainty in production and therefore operators could better match their production to futures contracts, increasing futures contract usage. This could possibly help explain past "surprises" by analysts when producers have hedged price risk less than scholars "expected" (Goodwin and Schroeder, 1994; Moschini and Hennessy, 2001).

1. Conceptual Model

Producers face uncertain outcomes when utilizing risk management practices. They will choose to implement a practice if their expected utility of profits when using the practice exceeds their expected utility of profits without the practice. Following Moschini and Hennessy (2001), we assume feedlot operators make decisions on output price and animal health risk management by comparing the expected utility of profit from different scenarios. Assume feedlot operator i will make decisions to maximize their expected utility:

$$EU_i = E\left[U_i\left(w_{0,i} + \tilde{\pi}_i\right)\right] \tag{1}$$

where EU_i is the expected utility of feedlot operator i, $w_{0,i}$ is initial wealth, and $\tilde{\pi}_i$ is profit from the cattle feeding enterprise which is a random variable (i subscripts are hereafter omitted for convenience). Profit for the cattle feeding enterprise is the sum of profit per pen (b pens):

$$\tilde{\pi} = \sum_b \tilde{\pi}_b. \tag{2}$$

Profit per pen of cattle is a function of input and output prices and quantities. However, when feedlot operators place cattle there is uncertainty about prices and quantities—making profit a random variable. Following Moschini and Hennessy (2001), profit can be rewritten as:

$$\tilde{\pi} = PG(x;\ \tilde{e}) - rx - K \tag{3}$$

where P is output price, $G(x; \tilde{e})$ is a stochastic production function where realized output depends on the input vector x and a random variable $\tilde{e}$, r is a vector of input prices, and K is fixed costs. This framework can be adapted to feedlot operators' decision-making under price and animal health risk, holding all else equal. In online supplementary Appendix A, we consider two demonstrative scenarios, allowing one risk type to vary while holding the other fixed.

One link between mitigating output price risk and utilizing animal health production practices could be the expectation of total pounds of finished cattle versus the actual pounds produced. Expected and actual pounds produced can vary from weather, animal disease, and management, among other factors. These production risks can result in reductions in ADG per animal or death loss. A large variance in pounds produced per pen could alter producers' risk mitigation strategies. For example, feedlot operators may be less likely to establish an expected selling price because they cannot properly assess the number of futures contracts needed or specifications they should agree to in a forward contract. However, if animal health production practices decrease finishing weight variability and death loss, then operators may make more informed output price risk management decisions.

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Substitute, complementary, or no relationship could exist between output price risk and animal health risk mitigation strategies. Risk mitigation strategies are not free and feedlot operations have a limited budget. A feedlot operator could decide the feedlot should only invest in animal health mitigation strategies instead of also managing output price risk—an example of substitution. Alternatively, operators could view output price and animal health risk mitigation strategies as complements. Instead there could be no relationship between feedlot operators' decisions regarding price risk and animal health risk mitigation strategies. Determining this relationship is a core component of our analysis. We hypothesize there is some relationship between output price risk and animal health risk mitigation strategies. However, to investigate this hypothesis, we need to analyze individual feedlot operators' decision-making.

2. Data Collection

Primary data were collected from feedlot operators, see online supplementary Appendix B for the survey instrument. The survey was programmed for Web application using Qualtrics software (Qualtrics Provo, UT, USA). Feedlots in Colorado, Iowa, Kansas, Nebraska, and Texas were surveyed. These states comprise five of the eight states in the widely cited, "5-market" average price reported by the USDA. Furthermore, these states house nearly 31% of U.S. feedlots with sales for slaughter and 76% of feedlot sales according to the 2017 Census of Agriculture (USDA-NASS, 2019a). The Colorado Livestock Association, Iowa Cattlemen's Association, Kansas Livestock Association, Nebraska Cattleman, and Texas Cattle Feeders Association distributed a uniform resource locator through an email list of members. To increase survey response and expand distribution, Feedlot Magazine also distributed the survey web address to its subscribers.[2]

After answering several introductory questions on the survey, respondents were asked to participate in a choice experiment. The respondent's past use of risk management and attitudes concerning risk were also obtained in the survey.

The survey was live from January 19, 2017 to February 14, 2017.[3] There were 588 responses.[4] However, 232 participants who did not have a feedlot enterprise and/or did not make price or animal health risk management decisions were dismissed from the survey after the qualification questions. Additionally, 75 participants who qualified to continue but did not answer the choice experiment questions were excluded—reducing the useable sample to 281.

Table 1 reports selected survey respondent characteristics. The sample is representative of U.S. feedlot producers. Feedlot operators from Iowa comprise 50% of the sample, Nebraska 19%, Texas 10%, Kansas 6%, and Colorado 5%. According to the 2017 Census of Agriculture, there were 9,309 feedlot operations with sales for slaughter in these five states: 4% from Colorado, 59% from Iowa, 11% from Kansas, 22% from Nebraska, and 4% from Texas (USDA-NASS, 2019a). Fifty-eight percent of respondents are from operations with capacity over 1,000 head. With respect to December 1, 2017, the Census of Agriculture reports operations with 1,000 or more head of cattle on feed comprised 12% of feedlots from these five states but 86% of the cattle on feed inventory (USDA-NASS, 2019a). Thus, the operations within our sample are larger than the census average

[2]An operation could have received an invitation from multiple sources (i.e., their state cattlemen's association and Feedlot Magazine). However, the "prevent ballot box stuffing" option was used in Qualtrics to prevent participants from taking the survey more than once.

[3]Feedlot Magazine sent the survey invitation on January 19 and 26, Iowa Cattlemen's Association on January 19 and 26, Kansas Livestock Association on January 19 and 30, Nebraska Cattleman on January 23 and 30, Texas Cattle Feeders Association on January 24 and 30, and Colorado Livestock Association on February 8.

[4]The authors did not have access to the email lists of possible participants as the partner organizations sent the invitations to participants. Therefore, we do not know the total number of operations who received an invitation to complete the survey. As such, no response rate could be calculated because there was no defined sample.

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Table 1. Summary statistics

	Full sample	Treatment 1	2	3	4	5	6	7
Number of observations	281	40	41	42	36	42	41	38
CO	5.34%	5.00%	7.32%	4.76%	5.56%	2.38%	4.88%	7.89%
IA	49.47%	47.50%	51.22%	40.48%	44.44%	61.90%	46.34%	55.26%
KS	6.41%	2.50%	4.88%	11.90%	11.11%	0.00%	9.76%	5.26%
NE	18.86%	22.50%	17.07%	19.05%	22.22%	14.29%	21.95%	15.79%
TX	10.32%	12.50%	14.63%	7.14%	8.33%	11.90%	12.20%	5.26%
Age (years)	49.16	51.60	49.17	46.31	49.58	49.59	50.83	46.75
Bachelor's degree	49.47%	40.00%	60.98%	45.24%	44.44%	42.86%	56.10%	57.89%
Risk averse	56.58%	52.50%	56.10%	57.14%	61.11%	69.05%	51.22%	50.00%
Capacity 1,000+	58.36%	50.00%	63.41%	69.05%	58.33%	54.76%	53.66%	60.53%
Custom feeders	21.35%	12.50%	19.51%	26.19%	22.22%	23.81%	17.07%	26.32%
Purchased single source before	64.77%	70.00%	63.41%	66.67%	63.89%	66.67%	63.41%	60.53%
Past futures hedge percent	18.50%	19.00%	20.98%	17.41%	15.83%	17.62%	20.20%	18.68%
Past forward contract percent	17.78%	14.23%	21.76%	24.86%	17.50%	14.88%	14.08%	15.92%

but do represent the majority of feedlot inventories.[5] Just over 20% of survey participants are considered custom feeders owning less than 40% of cattle in their feedlot.[6] According to the 2017 Census of Agriculture, in these five states 7% of farms custom fed cattle shipped directly for slaughter, accounting for 42% of the sales for slaughter (USDA-NASS, 2019a).

The average respondent age is 49 years old, with a minimum and maximum age of 23 and 85 years. In the 2017 Census of Agriculture, the simple average age of cattle feedlot producers was 55 for the five surveyed states (USDA-NASS, 2019b).[7] Given that our survey was administered online, the younger average age is expected. Nearly half of the participants have at least a Bachelor's degree. This educational attainment is similar to other studies of beef producers. In McKendree, Tonsor and Wolf (2018), 51% of cow–calf producers surveyed had earned at least a Bachelor's degree.

Participants were asked questions to gauge their risk aversion following the Global Risk-Attitude Construct (GRAC) defined in Pennings and Garcia (2001). It was determined that factor variables were not needed as only one GRAC question captures risk attitudes. Therefore, participants are considered risk averse (nearly 57%) if they somewhat agree, agree, or strongly agree with the statement, "I usually like 'playing it safe' (for instance, 'locking in a price') instead of taking risks for market prices for fed cattle."

Since animal health and price risk management are of key interest, participants were asked about their past price determination methods and past feeder cattle sourcing. Participants were

[5]The census definition of a farm is any place that produced and sold, or normally would have sold, $1,000 or more of agricultural products during the census year (USDA-NASS, 2019a).

[6]The custom feeder determination was made by the researchers such that the majority of animals fed were not owned by the feedlot.

[7]The cattle feedlots (North American Industry Classification System [NAICS] 112112) industry was used and comprises establishments primarily engaged in feeding cattle for fattening (OMB, 2017).

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Table 2. Participants' response to "Compared to calves sourced from auctions with unknown backgrounds, how do you believe calves from a single source ranch perform (i.e. average daily gain, feed conversion, morbidity) in the feedlot?"

	Number reporting	Percent reporting
Much worse	1	0%
Somewhat worse	5	2%
About the same	34	12%
Somewhat better	145	52%
Much better	95	34%
Total	280	100%

considered to actively manage animal health risk if they purchased feeder cattle from a single source. Nearly 65% of participants have purchased single source calves before. This finding is consistent with NAHMS beef feedlot 2011 study which found that 56.4% of feedlots had purchased feeder cattle through direct sales. However, direct sales accounted for less than 30% of feeder cattle purchased (USDA-APHIS-VS-NAHMS, 2013). Participants were also asked how they believed calves from a single source perform compared to calves sourced with unknown backgrounds (Table 2). Over 85% of producers stated single source calves performed somewhat or much better than calves from unknown backgrounds.[8]

There was variability in futures hedging and forward contracting behavior, with the percentage use of each ranging from 0 to 100% (Table 3). On average, participants hedged 19% of finished cattle using futures contracts and 18% utilized forward contracts (Tables 1 and 3). Spot cash market was the most frequently used with over 50% of producers selling at least 50% of their cattle this way. LRP insurance and LGM insurance were rarely used.

3. Research Methodology: Past Behavior

The survey contained two questions regarding past risk management behavior which serves as the first test of whether a relationship exists between price and animal health risk management. The first question was designed to identify feeder cattle sources. Respondents were asked to allocate the percentage (summing to 100%) for each source including traditional auction; satellite/video auction; purchased direct from seller (ranch); home raised from own cow-herd; custom

[8]A reviewer aptly pointed out single source feeder calves, originating from a single ranch of origin, may not be the only source of calves that are considered less risky from an animal health standpoint. First, stocker producers could decrease animal health risk by commingling cattle and then selling them as large lots either through a traditional auction, satellite/video auction, or some other method to feedlot operators. Second, producers exist who market feeder cattle after commingling them from multiple sources who have a reputation for putting together low risk cattle from a health standpoint. We agree, however, this does not necessarily diminish the importance of single source calves to producers. To examine how these two factors may impact how feedlot producers perceive the value of single source calves, we estimated two cross tabulations from the survey data used for this analysis. Specifically, (1) "Compared to calves sourced from auctions with unknown backgrounds, how do you believe calves from a single source ranch perform (i.e. average daily gain, feed conversion, morbidity) in the feedlot?" and "What is the average placement weight of calves your feeding operation places in March?" and (2) "Compared to calves sourced from auctions with unknown backgrounds, how do you believe calves from a single source ranch perform (i.e. average daily gain, feed conversion, morbidity) in the feedlot?" and "How important is seller reputation for the feeder cattle you buy?" Using Persons χ^2, we find no statistical differences in either cross-tabulation. Thus, there is additional evidence of the value single known source feeder cattle to feedlot buyers. See online supplementary appendix D for cross-tabulations and explanations.

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Table 3. Participants' response to "In the past 12 months, what percentage of the following pricing methods did your operation use for marketing finished cattle (should sum to 100%)"

	Spot cash market		Forward contract or marketing agreement		Futures hedge	
	#	%	#	%	#	%
0%	45	16%	176	63%	165	59%
1–25%	53	19%	37	13%	42	15%
26–50%	39	14%	24	9%	40	14%
51–75%	27	10%	13	5%	17	6%
76–100%	114	41%	29	10%	16	6%
Total	278	100%	279	100%	280	100%

	Options hedge		Livestock Risk Protection (LRP) insurance		Livestock Gross Margin (LGM) insurance		Other	
	#	%	#	%	#	%	#	%
0%	224	80%	278	99%	281	100%	276	98%
1–25%	26	9%	2	1%	0	0%	0	0%
26–50%	22	8%	1	0%	0	0%	1	0%
51–75%	5	2%	0	0%	0	0%	0	0%
76–100%	4	1%	0	0%	0	0%	4	1%
Total	281	100%	281	100%	281	100%	281	100%

fed, so I did not buy or own animals; and other. We choose to look at participants' use of purchasing direct from seller (ranch) as the health risk mitigation strategy of interest. Participants were considered to mitigate animal health risk if they purchased feeder cattle directly from the seller (ranch). The second question was designed to identify pricing methods for marketing finished cattle. Respondents were asked to allocate the percentage (summing to 100%) for each method including spot cash market; forward contract or marketing agreement; futures hedge; options hedge; LRP insurance; LGM insurance; and other. Cattle marketed using the spot price only were considered to not be mitigating price risk.

Tobit models were utilized to estimate the relationship between past behavior of purchasing feeder animals direct from seller and output price risk management. The two latent variables of interest (indicated with a * subscript), the percent of feeder cattle purchased direct from seller ($directseller_i^*$), and the percent of finished cattle marketed on the spot cash market ($spot_i^*$) were modeled as:

$$directseller_i^* = \delta_1 spot_i + X'_{direct,i}\boldsymbol{\beta}_{direct} + \varepsilon_{direct,i} \tag{4}$$

$$spot_i^* = \delta_2 directseller_i + X'_{spot,i}\boldsymbol{\beta}_{spot} + \varepsilon_{spot,i} \tag{5}$$

where the relationships between the latent variables and the observed variables are

$$directseller_i = \begin{cases} directseller_i^* & if\ 0 \leq directseller_i^* \leq 100 \\ 0 & if\ directseller_i^* < 0 \\ 100 & if\ directseller_i^* > 100 \end{cases} \tag{6}$$

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$$spot_i = \begin{cases} spot_i^* & if\ 0 \le spot_i^* \le 100 \\ 0 & if\ spot_i^* < 0 \\ 100 & if\ spot_i^* > 100. \end{cases} \tag{7}$$

In equations (4) and (5), δ_1 and δ_2 are the coefficients of interest. $\boldsymbol{X}'_{S,i}$ (where $S = direct,\ spot$) is a vector of explanatory variables for each individual i and an intercept, $\boldsymbol{\beta}_S$ are coefficient estimate vectors, and $\varepsilon_{S,i} \sim N(0, \sigma_S^2)$. Equations (4) and (5) are estimated with maximum likelihood. Models were estimated using the cmp command in Stata (Roodman, 2011).

4. Results and Discussion: Past Behavior

Average marginal effects (AME) for historical single source feeder cattle purchases are shown in Table 4. Model A is the base model, including an intercept and past percent of finished animals priced only on the spot market. Model B includes three additional binary explanatory variables: 1,000+ head capacity equals 1 if the feedlot's capacity is greater than or equal to 1,000 head, 0 otherwise; risk aversion equals 1 if participants somewhat agree, agree, or strongly agree with the statement, "I usually like 'playing it safe' (for instance, 'locking in a price') instead of taking risks for market prices for fed cattle.", 0 otherwise; and custom feeder equals 1 if the operation owned less than 40% of the calves placed on feed in the last 12 months, 0 otherwise.

The historical spot marketing AMEs are statistically significant and similar in models A and B (Table 4). Based on model B, when the historical percentage of finished cattle priced on the spot market increases by 1%, the historical percentage of feeder cattle purchased direct from seller decreases by 0.09%. Thus, those who purchase single source feeder animals were also more likely to use output price risk management as opposed to pricing fed cattle on the spot cash market. Additionally, in model B, operations with 1,000+ head capacity historically purchased approximately 7% more of their feeder animals directly from sellers than smaller operations.

A relationship is also present between historical percentage of feeder cattle purchased direct from sellers and output price risk in models C and D (Table 5). Model C seeks to explain the historical percent of cattle priced on the spot market only (no price risk mitigation), controlling for an intercept, and the historical percent of feeder cattle purchased direct from seller. Model D includes additional explanatory variables for capacity, risk aversion, and custom feeders. Based on model D, a 1% increase in the historical percentage of feeder animals purchased direct from seller decreases head priced on the spot market by 0.18% (implying an increase in cattle marketed with some risk management technique). This is similar to the relationship found in models A and B, however, larger in magnitude. Additionally, larger operations and risk averse producers priced about 13% and 22% less of their finished animals on the spot market, respectively. Thus, larger feedlots and risk averse operators are more likely to use price risk mitigation strategies.

These regressions of past behavior suggest a relationship exists between animal health (purchasing feeder animals directly from sellers) and output price (spot market only versus establishing a selling price) risk mitigation strategies. Overall, there is a negative relationship between historical single source feeder animal purchases and solely pricing in the spot (cash) market. Conversely, a positive relationship exists between historical single source procurement and using an output price risk mitigation strategy (not solely using the spot market for price determination). The relationship between animal health and price risk mitigation is worth further investigating and the decision under consideration (feeder cattle procurement or output price hedging) is important when documenting the relationship.

These regressions do not control for other factors that might be considered in a producer's risk mitigation decision. For example, source premium, basis, Chicago Mercantile Exchange (CME) price, and the type of output price risk management strategy were not considered. Accordingly, we leverage the ability of choice experiments to better understand a feedlot operator's decision-making regarding risk management and to control for other information that impacts a producer's

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Table 4. Historical direct from seller average marginal effects (N = 278)

	Model A	Model B
Spot marketing percent	−0.10***	−0.09**
	(0.04)	(0.04)
Capacity 1,000+		7.06**
		(2.94)
Risk averse		−2.65
		(2.81)
Custom feeder		−3.88
		(3.38)

Notes: Robust standard errors are in parenthesis. * $P < 0.10$, ** $P < 0.05$, *** $P < 0.01$.

Table 5. Historical spot marketing of finished cattle average marginal effects (N = 278)

	Model C	Model D
Direct seller percent	−0.21**	−0.18**
	(0.09)	(0.08)
Capacity 1,000+		−13.19***
		(3.69)
Risk averse		−21.77***
		(3.35)
Custom feeder		2.58
		(4.94)

Notes: Robust standard errors are in parenthesis. * $P < 0.10$, ** $P < 0.05$, *** $P < 0.01$.

decision. Past studies of cattle producers that utilized surveys, including choice experiments, were successful in finding results consistent with market observations (Tonsor, 2018; Schumacher, Schroeder, and Tonsor, 2012; Schulz and Tonsor, 2010).

5. Research Methodology: Choice Experiment

Each respondent completed a choice experiment, designed to not be overly complex, which resembled a realistic turn of cattle in a feedlot and decisions regarding either feeder cattle procurement or live cattle marketing. To assess individual feedlot operators' decision-making process, operators were placed in a realistic decision-making mindset where they were making decisions and forming expectations around events that will happen in the future. They were asked to make decisions as if it were February 15, 2017 for feeder animals being placed in March 2017 with an expected August 2017 closeout.

A seven-treatment design (Table 6) was utilized to test if a relationship exists between animal health and output price risk management. Comparing results across scenarios isolates differences of central interest, similar to Tonsor, Schroeder, and Lusk (2013). The animal health, feeder cattle procurement practice of interest was known single source feeder steers versus feeder steers of unknown background. The live cattle output price risk management strategies were futures hedge, forward contract, other, or none (accept cash price at the time of sale). An additional difference across designs is how the expected futures basis was presented. The futures hedge basis was

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Table 6. Split-sample design

	1		2		3		4	5	6	7
	Placement, animal-health risk oriented						Output price risk oriented			
Treatment	Question A	Question B	Question A	Question B	Question A	Question B				
Single source premium shown?	Yes	Yes	Yes	Yes	Yes	Yes			Yes	Yes
Output pricing information shown:										
CME price?		Yes		Yes		Yes	Yes	Yes	Yes	Yes
Expected local basis?		Yes					Yes		Yes	
Ambiguous local basis?						Yes		Yes		Yes
Forward contract basis?				Yes			Yes	Yes	Yes	Yes

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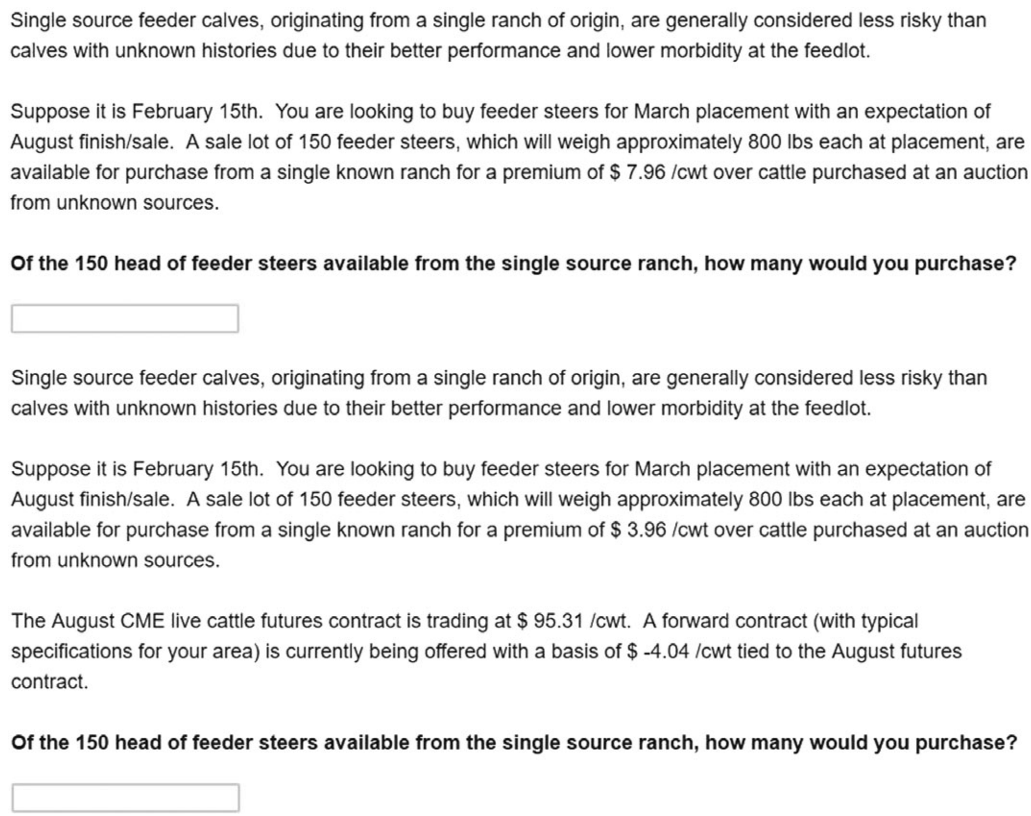

Single source feeder calves, originating from a single ranch of origin, are generally considered less risky than calves with unknown histories due to their better performance and lower morbidity at the feedlot.

Suppose it is February 15th. You are looking to buy feeder steers for March placement with an expectation of August finish/sale. A sale lot of 150 feeder steers, which will weigh approximately 800 lbs each at placement, are available for purchase from a single known ranch for a premium of $ 7.96 /cwt over cattle purchased at an auction from unknown sources.

Of the 150 head of feeder steers available from the single source ranch, how many would you purchase?

Single source feeder calves, originating from a single ranch of origin, are generally considered less risky than calves with unknown histories due to their better performance and lower morbidity at the feedlot.

Suppose it is February 15th. You are looking to buy feeder steers for March placement with an expectation of August finish/sale. A sale lot of 150 feeder steers, which will weigh approximately 800 lbs each at placement, are available for purchase from a single known ranch for a premium of $ 3.96 /cwt over cattle purchased at an auction from unknown sources.

The August CME live cattle futures contract is trading at $ 95.31 /cwt. A forward contract (with typical specifications for your area) is currently being offered with a basis of $ -4.04 /cwt tied to the August futures contract.

Of the 150 head of feeder steers available from the single source ranch, how many would you purchase?

Figure 1. Treatment 2 example.
Note: The two questions were presented on successive screens and not simultaneously.

presented two ways: unambiguous (e.g., −$1.00/cwt) or ambiguous (e.g., 35% chance of being less than −$1.00/cwt and 65% chance of being greater than −$1.00/cwt) (Di Mauro and Maffioletti, 2004). Basis ambiguity was included to understand how producers form their price expectations and how basis uncertainty might alter risk mitigation decisions.

Each participant was randomly assigned to one of the seven treatments (Table 6). Treatments fall into two broad categories consistent with the initial assessment of past behavior: feeder cattle procurement (treatments 1–3) or live cattle marketing (treatments 4–7). Treatments 1–3 consisted of two choice scenarios about procuring a lot of feeder steers, see Figure 1 for an example of treatment 2. Participants were given the following information:

> "Single source feeder calves, originating from a single ranch of origin, are generally considered less risky than calves with unknown histories due to their better performance and lower morbidity at the feedlot. Suppose it is February 15th. You are looking to buy feeder steers for March placement with an expectation of August finish/sale. A sale lot of 150 feeder steers, which will weigh approximately 800 lbs each at placement, are available for purchase from a single known ranch for a premium of *${random premium}*/cwt over cattle purchased at an auction from unknown sources."

Then they were asked,

> "Of the 150 head of feeder steers available from the single source ranch, how many would you purchase?"

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Single source feeder calves, originating from a single ranch of origin, are generally considered less risky than calves with unknown histories due to their better performance and lower morbidity at the feedlot.

Suppose it is February 15th. You just purchased a lot of 150 feeder steers weighing approximately 800 lbs each for March placement with an expectation of August finish/sale. The steers were sourced from a single known ranch for a premium of $ 7.96/cwt over cattle purchased at an auction from unknown sources.

The August CME live cattle futures contract is trading at $ 95.31 /cwt (CME contract is for 40,000lb of live cattle).

How many head would you place under each of the following output pricing strategies?

A forward contract (with typical specifications for your area) with a basis of $ -4.04 /cwt tied to the August futures contract.	0	head
A futures hedge where the expected local August basis has a 54% chance of being less (weaker) than $ 2.13, and a 46% chance of being greater (stronger) than $ 2.13.	0	head
Other output pricing strategy (e.g., options, Livestock Risk Protection, formula pricing, etc.)	0	head
I would accept the local cash price at time of sale in August	0	head
Total	0	head

Figure 2. Treatment 7 example.

In this first question, no output pricing information is given and the exact same initial question is given in treatments 1–3. However, in the second question additional potential output pricing information is provided as an information shock. In treatments 1 and 3, participants are provided information needed for a futures hedge, including the August CME live cattle futures contract price and expected local basis. In treatment 1, the futures basis is unambiguous, but is ambiguous in treatment 3. In treatment 2, information for a forward contract, including the August CME live cattle futures contract price and offered basis, is provided. By comparing responses across the two questions, we can test our core hypothesis as it relates to feeder cattle procurement.

Treatments 4–7 each include one scenario where the participant was told they just purchased 150 head of feeder steers for March placement which they expected to sell in August (Figure 2). A random August CME live cattle futures contract price was also provided. Treatments 4 and 5 are the base treatments where no feeder cattle source information was given. In treatments 6 and 7, participants were also told the steers were purchased from a single source and given a random premium paid (information shock). After this introductory information, participants were asked how many head they would place in each of the four output pricing strategies provided—futures hedge, forward contract, other output price strategy, or accept local cash price at the time of sale. In treatments 5 and 7, an ambiguous live cattle basis for futures hedges was presented while basis was unambiguous in treatments 4 and 6. By comparing responses across treatments, we can understand if/how producers alter decisions when animal health and price risks are individually versus jointly examined. In particular, treatments 4 and 6 (non-ambiguous basis) can be compared, and treatments 5 and 7 (ambiguous basis) can be compared. To keep the manuscript concise, methods and results for treatments 4–7 can be found in online supplementary Appendix C.

Values of key variables in the choice design were randomly drawn for each participant from a range selected to match current market conditions. The source premium shown ranged from $1.00 to $10.00/cwt (Blank, Saitone, and Sexton, 2016), the August CME live cattle futures contract price ranged from $95.00 to $110.00/cwt (consistent with the market as of January 9, 2017), all basis numbers ranged from −$5.00 to $5.00/cwt (consistent with historical basis numbers from the Livestock Marketing Information Center [LMIC] [2016]), and the random ambiguous basis percent ranged from 1 to 99%.

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The choice experiments were hypothetical; however, our instructions specifically stated, "[. . .]. It is important that you make your selection as if you were actually facing these choices in operation of your feed yard." Cheap talk scripts, such as the one provided, have been shown to reduce hypothetical bias in choice experiment research (Cummings and Taylor, 1999; Lusk, 2003; Tonsor and Shupp, 2011). Furthermore, Lusk and Schroeder (2004) found that although total willingness to pay was overstated in hypothetical choice experiments, marginal willingness to pay was not statistically different across hypothetical and actual payment scenarios. Thus, hypothetical bias concerns are mitigated since our core hypotheses tests depend on net differences across treatments (Tonsor, 2011).

Econometrically, systems of Tobit models are utilized because the dependent variables (either feeder cattle purchased or head placed in each output price risk strategy) are continuous but censored between 0 and 150. Using these methods, marginal effects can be calculated and compared across designs to identify if relationships exist between animal health risk mitigation and output price risk mitigation.

5.1. Feeder Cattle Placement Scenarios (Treatments 1–3)

For treatments 1–3, the two latent variables of interest (indicated with a * subscript) are the total head purchased when output pricing information is not shown ($feederheadA_i^*$) and total head purchased when output price information is shown ($feederheadB_i^*$). These variables can be modeled as:

$$feederheadA_i^* = \boldsymbol{X'}_{A,i}\boldsymbol{\beta}_A + \varepsilon_{A,i} \tag{8}$$

$$feederheadB_i^* = \boldsymbol{X'}_{B,i}\boldsymbol{\beta}_B + \varepsilon_{B,i} \tag{9}$$

where the relationships between the latent variables and the observed variables are

$$feederheadA_i = \begin{cases} feederheadA_i^* & if\ 0 \leq feederheadA_i^* \leq 150 \\ 0 & if\ feederheadA_i^* < 0 \\ 150 & if\ feederheadA_i^* > 150 \end{cases} \tag{10}$$

$$feederheadB_i = \begin{cases} feederheadB_i^* & if\ 0 \leq feederheadB_i^* \leq 150 \\ 0 & if\ feederheadB_i^* < 0 \\ 150 & if\ feederheadB_i^* > 150. \end{cases}$$

In equations (8) and (9), $\boldsymbol{X}'_{k,i}$ (where $k = A,\ B$) is a vector of information given in the question (e.g., source premium, CME price, basis) and explanatory variables for each individual i, $\boldsymbol{\beta}_k$ are coefficient estimate vectors, and $\varepsilon_{k,i} \sim N\left(0, \sigma_k^2\right)$. Equations (8) and (9) are modeled jointly with maximum likelihood. The error terms $\varepsilon_{A,i}$ and $\varepsilon_{B,i}$ are specified following a bivariate normal distribution with zero mean, standard deviations σ_A^2 and σ_B^2, and correlation ρ. By estimating these equations jointly, we can test if unobservable factors are impacting total head purchased in each question. If ρ is zero, then the equations can be estimated independently (Cornick, Cox, and Gould, 1994).

6. Results and Discussion: Choice Experiment

Summary statistics by treatment are shown in Table 1. Responses per treatment ranged from 36 to 42.

For the following models, AMEs are reported in the article; however, model coefficient estimates are in online supplementary online supplementary Appendix E.

6.1. Purchasing Feeder Cattle (Treatment 1–3)

Recall, the difference between question A and question B is participants were presented additional information (an information shock) on potential output price risk mitigation strategies in

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Table 7. Pooled feeder cattle purchasing treatments average marginal effects (treatments 1–3)

	Model E		Model F	
	Question A	Question B	Question A	Question B
Source premium	−10.32***	−7.81***	−10.56***	−7.81***
	(1.18)	(1.20)	(1.18)	(1.22)
	[−12.64, −8.00]	[−10.17, −5.45]	[−12.86, −8.25]	[−10.21, −5.42]
P value for test if source premium AME statistically different	0.11		0.09	
CME price		0.09		0.21
		(0.77)		(0.81)
		[−1.42, 1.61]		[−1.37, 1.79]
Basis		4.42***		4.44***
		(0.98)		(0.98)
		[2.50, 6.35]		[2.52, 6.37]
Capacity 1,000+			−15.83*	−14.52*
			(9.32)	(8.35)
			[−34.10, 2.45]	[−30.87, 1.84]
Custom feeder			37.05***	16.74
			(12.84)	(12.51)
			[11.89, 62.20]	[−7.77, 41.25]
Risk averse			3.62	0.27
			(8.70)	(8.46)
			[−13.43, 20.67]	[−16.32, 16.86]
Purchased single source before			−0.58	3.88
			(9.05)	(8.81)
			[−18.31, 17.15]	[−13.39, 21.15]

Notes: Standard errors are reported in parenthesis. 95% confidence intervals are reported in square brackets. * $P < 0.10$, ** $P < 0.05$, *** $P < 0.01$.

question B (futures hedge information with non-ambiguous basis in treatment 1, forward contract in treatment 2, or futures hedge with ambiguous basis in treatment 3). Likelihood ratio tests were conducted to determine if observations from treatments 1–3 could be pooled. The hypothesis that observations from the three treatments could be pooled was not rejected $(X^2 = 7.06,\ P\ \text{value}\ 0.99)$. Therefore, there are no differences in responses to question B based on the output price risk mitigation information given or the ambiguous versus non-ambiguous basis presentation.

The bivariate model AME from the pooled feeder cattle procurement questions (treatments 1, 2, and 3) is in Table 7. The statistically significant ρ (see online supplementary Appendix Table E.3) indicates there is a relationship between question A and B residuals. Thus, these questions should be estimated jointly. Model E is the base model with explanatory variables only for the information shown (source premium, CME price, and basis). Model F includes additional explanatory variables: binary variables for operation size, custom feeder, risk aversion, and if they have purchased single source cattle before.

The source premium AMEs are negative, statistically significant, and similar across both models E and F. Focusing on model F, a \$1.00/cwt increase in the source premium decreases feeder steers purchased (from a maximum of 150) by 10.56 and 7.81 head in questions A and B, respectively. This indicates the willingness to purchase feeder cattle decreases as source premium increases. To test our hypothesis that a relationship exists between animal health and price risk mitigation strategies, we test if the source premium AMEs in questions A (no output price risk mitigation information) and B (output price risk mitigation information is given) are statistically different. The source premium marginal effects in questions A and B are statistically different from each other ($P\,value = 0.09$) in model F and marginally different from each other ($P\,value = 0.11$) in model E. Thus, there is evidence that a relationship exists between animal health and price risk mitigation as operators were less sensitive to increases in source premium whenever output price risk mitigation information (CME price and basis) is given.

6.2. Discussion of Core Hypotheses in Treatments 1–3

Investigating the AMEs, there is evidence of a complementary relationship. Finding that the source premium AME when no output pricing information is given (question A) is larger in magnitude (more elastic) than when output price hedging information is given (question B) supports this conclusion. An increase in source premium would decrease profit per head. Overall, the output hedging information shocks decrease the sensitivity to an increase in source premium.

In consumer choice studies, willingness to pay estimates vary depending on the number and mix of attributes shown (Pozo, Tonsor, and Schroeder, 2012; Gao and Schroeder, 2009). Therefore, we recognize that having more information presented (output price risk management information) could influence coefficients and marginal effects. However, the identified relationship between source premium and output price risk mitigation information is rational. If output prices are considered strong, then more feedlots will be interested in placing feeder steers and would potentially consider paying a premium for single source steers. By purchasing single source steers, producers reduce uncertainty on the animals' performance, which in turn increases the likelihood of actually receiving higher output prices. Conversely, if output prices are weak, then feedlots will place fewer cattle and potentially ignore single source cattle premiums.

6.3. Discussion of Core Hypotheses in Treatments 4–7

Results for treatments 4–7 are in online supplementary Appendix C. To test the core hypothesis that a relationship between animal health risk and output price risk exists, the 95% confidence intervals from the decomposed AMEs are compared across the base treatments and those with the single source information shock.[9] There is no evidence that the single source information shock changes the AME of the output hedging information.

Multiple explanations for little evidence of a relationship between incoming cattle health risk and output pricing strategies exist. First of all, the hypothetical nature of the survey and how historical seasonality in profits partially align with any one-time assessment (Schulz, 2019) cannot be ignored. Furthermore, livestock producers do not necessarily hedge at the time of placement but can hedge at any time during the feeding period; this is especially true if the net price from the hedge is less than the breakeven price (Schulz, 2016). Our findings suggest that incoming cattle characteristics do not impact output hedging decisions (at least the source of cattle in our

[9]Schenker and Gentleman (2001) found that comparison of 95% confidence intervals is more conservative than standard methods of significance testing when the null hypothesis is true and falsely rejects the null hypothesis more frequently when the null hypothesis is false.

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experiment). Potentially, feedlot operators largely ignore incoming cattle characteristics because the decision is already made, likely reflecting pre-existing business relationships, and cannot be changed. Thus, this sunk decision is not considered moving forward. Furthermore, potentially animal health and price risk mitigation are handled by different managers at the feedlot. Therefore, these risks are managed independently even if they could potentially be managed jointly. This issue of risks not being considered jointly in complex systems was noted in Pate-Cornell (1996) when discussing tiles for space shuttles.

Alternatively, persistence of past behavior and existing relationships with live cattle buyers was present. There could be a high cost in switching output pricing or output risk management strategies. This could be a reason for little evidence of animal health risk mitigation information impacting output hedging decisions. In the U.S., there are approximately 729,000 operations with beef cows, over 30,000 feedlots (USDA-NASS, 2019a), and 650 beef packing plants, 179 of which harvest more than 1,000 head (USDA, 2017). Therefore, there are more options to buy feeder cattle than to sell these cattle once finished. This would support our finding of a relationship between incoming cattle and output pricing risk in the feeder cattle purchasing scenarios (treatments 1–3) but no relationship in the output pricing scenarios (treatments 4–7).

7. Conclusion and Implications

To the best of our knowledge, this is the first study seeking to understand feedlot operators' decision-making regarding both animal health and output price risk management. Our objective was to determine if feedlot operators manage these two risks jointly or independently. The animal health practice of interest was single source steers while the output price risk management strategies were futures contracts, forward contracts, other, and none (accept cash price at the time of sale). An online survey was utilized to collect primary data from feedlot operators about their use of risk management tools, producer and operation characteristics, and views on risk mitigation. A split-sample choice experiment was used, placing feedlot operators in a forward-looking mindset to better understand their risk management decision-making. Treatments 1–3 asked operators feeder steer procurement oriented questions while treatments 4–7 were output pricing oriented scenarios.

Simple Tobit models of past feeder cattle procurement and output hedging identified a negative relationship between past purchases of feeder animals from a single source and sole use of spot markets in marketing (no price risk mitigation). Therefore, a positive relationship is implied between animal health and output price risk mitigation. The split-sample choice experiment allowed for a deeper understanding of this relationship.

Using treatments 1–3, evidence of a complementary relationship between willingness to pay a source premium and output pricing information was found. Willingness to purchase single source cattle was more inelastic when output pricing information was provided. This complementary relationship could be one reason why producers do not hedge output price risk as much as analysts expect. Potentially, if more single source cattle were available, or offered at a lower premium, producers would increase their use of output price hedging. Furthermore, since there is less uncertainty in single source feeder steers performance in the feedlot (e.g., finish weight, death loss, etc.), producers could more confidently match their production to futures and forward contract specifications.

No evidence of a relationship was found between information on feeder cattle source and output pricing risk mitigation strategies in treatments 4–7. All of the AMEs for price risk management variables were not statistically different across treatments whether single source information was given or not, and many were insignificant. Potentially, these findings suggest that feedlot operators view the feeder cattle purchase as a "sunk decision" when deciding how to manage output price risk. Therefore, producers only consider another risk mitigation strategy when that

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decision is still applicable. Additionally, there was evidence of persistent behavior in output price hedging. This could be the result of existing relationships with cattle buyers and the relatively limited number of outlets to sell finished cattle. Potentially, this persistence could also stem from unfamiliarity with other output pricing strategies and high switching cost. The lack of a relationship between single source information and output pricing strategies could also be a function of the mitigation strategies considered. In the live cattle marketing options, no distinction was made regarding cattle quality. Conceivably, single source cattle might grade better at harvest and receive quality premiums (for those using grid pricing); however, this was not accounted for in our scenarios.

Our study is the first to look at the relationship in feedlot producers' decision-making regarding animal health and price risk. However, there are limitations. First, a hypothetical choice experiment and self-reported survey data were used. However, by making comparisons across treatments, hypothetical bias concerns are minimized (Lusk and Schroeder, 2004; Tonsor, 2011). Additionally, we recognize choice experiment findings are a function of the attributes chosen—here animal health and risk mitigation strategies (Gao and Schroeder, 2009; Pozo, Tonsor, and Schroeder, 2012). Feedlots animal health risk mitigation strategies can be complex and dynamic. To keep the survey manageable for producer participants, we chose to proxy animal health risk mitigation with single source cattle procurement. Furthermore, there could be other benefits of single source cattle, such as lower transaction costs, that are not accounted for in this analysis. Future research could consider more complex designs to capture producers' trade-offs in risk management decisions, or if available, use information on feedlots' actual usage of different risk mitigation strategies.

Our findings are relevant to ongoing policy discussions regarding livestock producers' use of LGM and LRP programs. In 2019, increased subsidy rates and other enhancements were made to these programs to better suit livestock producers needs with the hope of increasing participation. For example, effective July 1, 2019, the LRP subsidy rate increased from 13% for all coverage levels to 20–35% based on selected coverage level (Feedstuffs, 2019). Additional changes to premiums are being considered in 2020 for the 2021 marketing year (Willis, 2020). Our results suggest that the effectiveness of these subsidy rates at incentivizing participation will also depend on other risk mitigation strategies in place. For example, the sensitivity of participation to the subsidy rates might be less than expected if producers are also managing animal health risk. Therefore, it is important to consider other types of risk mitigation efforts that an operation may be using in addition to price risk mitigation when designing policy instruments and estimating participation.

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