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RESEARCH ARTICLE

Benefits of Preconditioning Cattle under Stochastic Feedlot Performance

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Abstract
Preconditioning cattle, a management practice of preparing cattle for feedlots as well as following a vaccination protocol for common diseases, has been shown to add value to cattle by reducing disease incidence and severity, yet it is not universally adopted. We estimated the benefits to a beef system of preconditioning weaned calves versus not preconditioning under stochastic returns. Purchasing preconditioned calves makes economic sense, but market efficiency requires complete information of the health status of the cattle, feedlot performance, along with the right market mechanisms, which may not be available in all markets.

Keywords: antimicrobial use; backgrounding; feedlot economics; preconditioning cattle; stochastic dominance

JEL classifications: Q12; Q13; Q16

1. Introduction

Preconditioning is a management practice that prepares weaned cattle for feedlots. This practice can be performed by calf producers or by other actors in the beef supply chain, such as backgrounders, and generally requires 45 days in which the cattle undergo a health protocol, are castrated, dehorned, and placed in housing conditions similar to the feedlot. The health protocol consists of administering vaccines against BRD[1] and deworming. Preconditioned calves have better immune functionality to cope with the initial feedlot stress which minimizes weight loss (Griebel et al., 2014) and have lower incidence of BRD than non-preconditioned calves (Thrift and Thrift, 2011). They are less susceptible to severe infections, have lower morbidity and mortality (Avent et al., 2004; Dhuyvetter et al., 2005; Williams et al., 2012), and experience less stress, especially during the shipping and receiving period, than non-preconditioned cattle (Lalman and Mourer, 2014). Feedlot operators may apply a metaphylactic treatment of antibiotics on arrival to protect incoming cattle against BRD, especially lighter weight cattle, which is at a higher risk of BRD (USDA, 2019). When both preconditioned and non-preconditioned cattle comingle in the feedlot, feedlot operators may use antimicrobials in both groups as a precaution.

Beef production constitutes a major use of antimicrobials in the US, with an estimated 2.5 thousand metric tons of medically important antimicrobials marketed for cattle in 2020 (USFDA,

[1]Bovine respiratory disease is the most common disease of feedlot cattle, causing increasing costs due to slower weight gain and treatment costs. Mortality risk also increases due to BRD.

2021). Excessive use of antimicrobials in food production is linked to antimicrobial resistance bacteria (Tang et al., 2017). Practices, such as preconditioning of calves that enter feedlots, have the potential to be implemented and contribute to a more judicious use of antimicrobials in US beef production; however, the amount of antimicrobial reduction due to preconditioning has not been estimated (Lhermie et al., 2019). Adoption of preconditioning practices must be incentivized to the preconditioner.

Evidence suggests that preconditioned cattle are less likely to become affected by diseases requiring antimicrobials use (Edwards, 2010); thus, preconditioning can be a way to reduce antimicrobials use in the beef production system compared to shipping newly weaned cattle to feedlots (Ives and Richeson, 2015).[2] Given the ongoing trend of antibiotic-free food consumption, consumers may value beef produced with fewer antimicrobials more than traditionally produced beef (Lusk et al., 2006), thereby paying a premium of which a share could be passed back to calf producers that perform preconditioning.

Preconditioners may follow an established preconditioning plan in order to obtain a preconditioning certification,[3] which allows them to receive a price premium for their cattle. Many preconditioning certification schemes in the US are administered by public and private entities (e.g., Oklahoma Quality Beef Network Vac-45 (OSU), Superior Livestock Vaccination Programs, and Iowa Cattlemen's Association Preconditioning Programs). The magnitude of the price premium paid to preconditioners depends on the estimated benefits to feedlots of preconditioned versus non-preconditioned cattle, particularly due to lower morbidity and mortality rates

Studies on the benefits of preconditioning are numerous. Schumacher et al. (2012) estimated that an identified health program is worth \$7.28/cwt to feedlots, and an extra \$2.37/cwt is added to the benefits if the certification agency is the USDA. Third-party certifications in Iowa auctions generate \$6.12/cwt in premium over \$3.35/cwt for non-certified claims of preconditioning (Bulut and Lawrence, 2007). The average price premium received for preconditioning cattle has been estimated to range between \$10.58 and \$19.35/cwt[4] over the years 2011–2019. Despite the benefits to the feedlot of introducing preconditioned over non-preconditioned cattle, the practice of preconditioning is not the dominant technology in cattle production.[5]

Preconditioned cattle can still experience disease, so the benefit of preconditioning is stochastic. We look at the return distributions that may occur, simulating the performance of preconditioned versus non-preconditioned cattle that enter feedlots, and use stochastic dominance techniques to determine feedlot operator preferences under different risk tolerances. The simulated cattle feedlot performance values were generated by fitting PERT distributions to published performance estimations.

The purpose of this paper is to estimate the economic incentive which makes producing preconditioned cattle attractive for cow-calf operators with backgrounding capacity. We used stochastic dominance analysis on the distributions of net returns per head of preconditioned and non-preconditioned animals at the feedlot, to determine the choice of preconditioning status given feedlot operator's risk appetite. We included the net return of preconditioned cattle with a price premium that covers the cost of preconditioning most of the time. Alternatively, using certainty equivalent analysis on the net return distributions, we estimated the price premium which would make feedlot operators indifferent between purchasing preconditioned and non-preconditioned cattle.

[2]It is estimated that 92.6% of all feedlots with capacity greater than 8,000 head apply metaphylactic treatment (USDA, 2013b), corresponding to 26% of incoming cattle to feedlots treated metaphylactically (USDA, 2013b).

[3]An example of a preconditioning program is the OQBN-VAC 45: http://oqbn.okstate.edu/oqbn-vac-45/oqbn-vac-45-requirements/

[4]https://extension.okstate.edu/programs/beef-extension/ranchers-thursday-lunchtime-series/vac45-program-opportunities-and-considerations.html

[5]Mitchell (2020) estimated that about 7% of all lots auctioned in AK were preconditioned from May 2019 to Aug 2020.

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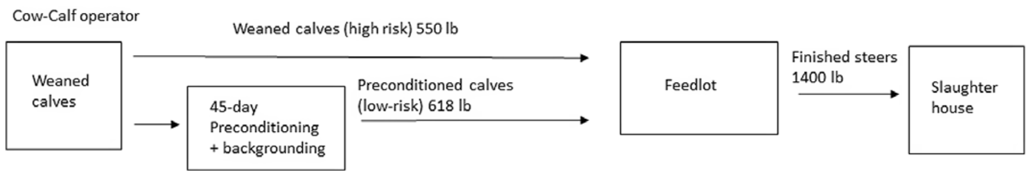

Figure 1. Relevant US beef production system for this study: cow-calf operator, backgrounders, feedlots, and slaughterhouse.

Our estimations can help determine the potential premium that might be passed back to cow-calf operators by feedlot managers from producing preconditioned calves under a heath protocol. Understanding this potential premium can shed light into the feasibility of efficient market-based mechanisms that decrease the susceptibility of BRD at feedlots.

2. Methods

2.1. Beef Production System Description

The cattle production system in the US is heterogeneous. It may involve few or many steps in the commercialization from birth to slaughter. Common beef production stages are cow-calf operation, backgrounder or stocker, and feedlot (Peel, 2003). Backgrounder and stocker operations consist of raising post-weaned calves to a higher weight to develop animal frame and muscle (Peel, 2003) before transfer to the feedlot.

Cow-calf operators can sell weaned cattle to backgrounders, sell directly to feedlots, or raise the weaned cattle to a higher weight and sell them to backgrounders or feedlots. Cow-calf operators can also retain ownership of their cattle when they are transferred to a backgrounder or a feedlot. Figure 1 shows the relevant US beef production system for this study, which depicts two possible paths, among many, for weaned cattle to feedlot: either weaned calves moving directly to a feedlot or first through a preconditioning program before movement to the feedlot.

Many weaned cattle go through a post-weaning growing program by a commercial backgrounder (Peel, 2003). Backgrounders are an important link in the beef industry; they consolidate and prepare young cattle before entering feedlots by providing low-energy high-forage starter rations under confinement. This feedlot preparation is also called preconditioning if it includes a health protocol such as common vaccinations, deworming, castration, and dehorning. Some cow-calf operators perform backgrounding operations if they have the capacity. Stocker operations where weaned calves are first feed outside the finishing feedlot using various available forages may include health protocols as well, effectively producing preconditioned cattle. We do not consider the case of stocker operations in this article[6].

In feedlots, cattle from many sources are fed in a confined environment until they reach a finished weight ranging between 1100 and 1400 lb (Comerford, Kime, and Harper, 2013), before being sent to a slaughterhouse. Transportation, social mixing, confinement, and new diets consisting of high-protein feed stress cattle placed into feedlots, which makes them more prone to acquire infections from other cattle and the environment (Aich et al., 2009; Griebel et al., 2014). Feedlots consider newly weaned and shipped cattle high-risk cattle, compared to preconditioned cattle which are considered low-risk cattle (Lalman and Mourer, 2014). We refer to preconditioned cattle as low risk and non-preconditioned cattle that are weaned and shipped to feedlots as high risk.

[6]Although there may be differences in feedlot performance from backgrounded and stocker cattle, due to differences in weight, our focus was not to compare these two post-weaned operations. We focus on the option to perform backgrounding for cow-calf operators that have installed capacity for it.

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Feedlot operators may be willing to pay premia for preconditioned cattle based on performance, such as higher average daily gain (ADG), and lower morbidity and mortality, which unfortunately is stochastic, and not known with certainty. If the premium is sufficiently high, cow-calf operators with backgrounding capacity, or backgrounders as a separate business entity, could be incentivized to precondition cattle. The return and thus the decision to precondition or not depends on many factors, including risk preference of the producer, preconditioning premium, cattle price and its price slide,[7] feed costs, and the benefits to feedlots. While the benefits to feedlots from introducing preconditioned cattle directly affects the premium offered to producers, the distribution of those benefits and the risk profile of the feedlot operator also plays an important role in determining the price premium offered to producers of preconditioned cattle.

2.2. Preconditioning Protocol

Many analyses of preconditioning benefits focus on 45-day preconditioning protocols[8] (Hilton and Olynk, 2011; McCollum and Gill, 2000). Cattle following a 45-day preconditioning program are sold to feedlots at a higher premium compared to shorter programs (Dhuyvetter et al., 2005; Dhuyvetter, 2004). Our analysis follows a 45-day program. These protocols require calves to be weaned for 45 days or longer before feedlot placement, be dehorned, castrated, and vaccinated. The protocol recommends deworming and feeding concentrate supplements for at least the last 7 days. During the 45-day period, calves are expected to gain about 1.50 lbs/day (Dhuyvetter et al., 2005; Donnell et al., 2008).

2.3. Data

2.3.1. Cost of Calf Production

In our model, the cow-calf operator produces calves and weans them at 550 lb. At that point, the calves are either sold to a feedlot or grown from 550 to 618 lb in 45 days following a preconditioning protocol and then sold to a feedlot. At the feedlot, calves are fed until they reach 1400 lb and then sold to a slaughterhouse.

Costs of production are estimated for weaned, and backgrounded calves, and finished cattle from Kansas State University (KSU) KFMA Enterprise Reports[9] 2019 (2014–2018 average). We obtained the expenses per pound for weaned calves (Beef Cows-Calves Report), backgrounded calves (Beef-Backgrounding Report), and finishing animals (Beef-Backgrounding/Finishing Report). All values are Kansas State averages. This location was selected because it is a major cattle-producing region. The costs of production include feed and pasture costs and other direct expenses, indirect expenses, and fixed costs. We included extra costs for preconditioning in the backgrounding budget. Preconditioning costs are additional to the backgrounding costs; it is an added process. Similar budget analyses include Brooks and Eirich (2014), Dhuyvetter et al. (2005), and Donnell et al. (2008).

We estimated the market prices for the specific cattle weights in the analysis using linear interpolation between the purchasing and selling prices of cattle from the Beef-Backgrounding Report. The finished price of cattle was obtained from the selling price of the Beef-Backgrounding/Finishing Report of the KFMA Enterprise Reports (2014–2018 average).

[7]Price slides refers to the adjustment in cattle price as cattle weight varies from a base price. For instance, a price slide of $5/cwt for each lb above 600 lb decreases the base price by five times the number of cwt above the base. Price slide is a common practice and reflects the cost of weight gain and gives certainty to buyers and sellers when the delivery weight is different from the contracted weight. Heavier cattle are sold at a lower price per head than lighter cattle.

[8]Examples of certified preconditioning protocols include VAC-45 of Superior Livestock Auction, OQBN VAC-45 of Oklahoma State University, and VAC-45 of Texas A&M University. All of which require the same vaccinations.

[9]https://www.agmanager.info/kfma/kfma-enterprise-reports

Preconditioning costs, which includes labor, facilities and equipment, vaccines, and marketing, are obtained from Dhuyvetter et al. (2005). Preconditioning expenses per head include vaccinations (Donnell et al., 2008), labor and equipment (Dhuyvetter et al., 2005), deworming (Dhuyvetter et al., 2005), and marketing. Mortality losses were included in the analysis.

Gallo and Berg (1995) found a reduction in morbidity in cattle treated with antimicrobials in feedlots of 25%. Nickell and White (2010) estimate a reduction of morbidity risk of metaphylaxis treatment of 50% compared to not administering metaphylaxis[10]. The cost of treating a sick animal is estimated at $30.82 USDA (2013a).

The parameter values for the budget analysis are summarized in Table 1. These values are the baseline to estimate the benefits of preconditioning in the system.

The ADG is used to estimate the number of days spent in the feedlot by each animal type. Differences in the ADG will have an impact on feedlot costs, captured in non-feed costs per day. The weight produced in the feedlot are 872 lb and 797 lb for non-preconditioned and preconditioned cattle, respectively. These weights include shrinkage of 4 and 2.5%, respectively. At the expected daily gain of 2.56 and 2.93 lb, the expected days in feed are 332 and 264, for non-preconditioned and preconditioned cattle. With an estimated non-feed costs of $31.29/cwt of gain,[11] the non-feed cost per day at the feedlot are $0.81 and $0.92, for non-preconditioned and preconditioned cattle. To be conservative in our estimates, we assume a daily non-feed cost of $0.92 for both types of cattle.

2.3.2. Partial Budget Analysis

We present budget analyses based on Table 1 for the three types of operations, one for the cow-calf operation (no preconditioning), the preconditioning operation, and the third for the feedlot operation, who can buy either preconditioned or non-preconditioned calves. Table 2 contains the analysis of the cow-calf operation which sells a newly weaned calves to a feedlot (or to a backgrounder) without preconditioning. This operation loses $40 per calf sold given the budget parameters used; however, negative net returns in cattle production often occur and depends greatly on market conditions.

Table 3 shows the net return of the backgrounding operation following the preconditioning protocol.

Similar to selling newly weaned calves, selling backgrounded calves under a 45-day preconditioning protocol does not generate positive net results under the assumption that the producer does not receive a price premium for preconditioning. In this estimation, net returns become positive if the price premium is about 1% of the market price, or $1.86/cwt.

Next, we estimate the benefits to the feedlot when it introduces non-preconditioned or preconditioned calves based on the performance estimates from Table 1. This estimation does not include the stochastic analysis of feedlot performance, but only point estimates. The price premium, if any, that the feedlot can offer to purchase low-risk cattle given expected performance, prices and costs can be estimated from Table 4.

Under the baseline parameter values and no stochastic feedlot performance, preconditioned cattle return $46.19/head more than non-preconditioned cattle. This benefit translates to a maximum premium per head that the feedlot can pay for a low-risk animal of $7.26/cwt. This estimate is within the range of $6.98 and $10.97/cwt as estimated by Dhuyvetter et al. (2005).

[10]Nickell and White (2010) provide a summary of some performance values of using different types of antimicrobials as metaphylactic treatment. Morbidity values range from 3% to 68.1%, while mortality values range from 0.04% to 13.5%.

[11]2019 Kansas Farm Management Association, Annual ProfitLink Summary, Beef-Backgrounding/Finishing.

Table 1. Parameter values used in the baseline budget model for the beef production system described in this study

Parameter name	Value	Unit	Reference
Weaning weight	550	lb/head	Dhuyvetter et al. (2005)
Shrinkage	4[a], 2.5[b]	%	Dhuyvetter et al. (2005)
Backgrounded weight	618	lb/head	Estimated
Finished weight	1400	lb/head	Assumed
Weaned cattle market price	187.85	$/cwt	KSU[c]
Backgrounded cattle market price	181.03	$/cwt	KSU[c]
Finished cattle market price	128.05	$/cwt	KSU[c]
Days in backgrounding	45	Days	Assumed
Average daily gain in backgrounding	1.5	lb/head	Dhuyvetter et al. (2005)
Backgrounding death loss	1	%	Dhuyvetter et al. (2005)
Treatment of sick animals at feedlot	30.82[c]	$/case	USDA (2013a)
Expenses			
Feed weaned cattle	89.46	$/cwt	KSU[a]
Non-feed weaned cattle	98.15	$/cwt	KSU[a]
Feed backgrounded cattle	68.37	$/cwt	KSU[a]
Non-feed backgrounded cattle	49.54	$/cwt	KSU[a]
Feed finished cattle	67.15	$/cwt	KSU[a]
Non-feed finished cattle	31.35	$/cwt	KSU[a]
Preconditioning expenses (non-feed)			
Vaccinations	12.22[c]	$/head	Donnell et al. (2008)
Labor, equipment, and facilities	8.81[c]	$/head	Dhuyvetter et al. (2005)
Dewormer	0.65[c]	$/head	Dhuyvetter et al. (2005)
Marketing costs	3.92[c]	$/head	Dhuyvetter et al. (2005)

[a]Non-preconditioned cattle.
[b]Preconditioned cattle.
[c]Kansas State University (KSU) KFMA Enterprise Reports 2019 (2014–2018 average) (KSU, 2019). Adjusted for CPI Inflation to 2019 (https://www.bls.gov/data/inflation_calculator.htm).
Original values for treatment: $23.60; vaccinations: $10; labor, equip. and facil.: $6.75; dewormer: $0.50; marketing costs: $3. Marketing costs include preconditioning tags.

2.4. Stochastic Performance Parameters of Preconditioning

The stochastic benefits of preconditioned cattle to feedlots were estimated from data from Avent et al. (2004) surveys to feedlot managers. We focus on differences in morbidity, mortality, and ADG between preconditioned and non-preconditioned cattle.

The equation used to simulate net returns per animal at the feedlot is

$$\pi_{h,y} = P_y W - C_{h,y} - \widetilde{DR}_h C_{h,y} - F_y WG_h - \widetilde{SR}_h \mathrm{TR} - \widetilde{D}_h DC \tag{1}$$

where π is net revenue per animal at the feedlot, P is price per cwt of fed cattle, W is the weight of fed cattle sold (14 cwt), C is the cost of the animal purchased from the cow-calf producer, $\widetilde{\mathrm{DR}}$ is the simulated death rate of the animal, F is the feed cost per cwt, WG is the expected weight gain of the animal in the feedlot, $\widetilde{\mathrm{SR}}$ is the simulated sick rate of the animal, TR is the average

Table 2. Budget analysis of a cow-calf production systems which sell weaned calves

Cow-calf operator	$/cwt	$/head
Price	187.85	1033.19
Shrink		41.33
Revenue	180.34	991.87
Feed expenses	89.46	492.03
Non-feed expenses	98.15	539.83
Total costs	187.61	1031.86
Net return	−0.07	−39.99

Rounding errors may be present. Estimates were obtained from 2019 Kansas Farm Management Association, Annual ProfitLink Summary, Beef Cows-Calves (2014–2018). Shrink assumed at 4%. Newly weaned calf weight is 549 lb.

Table 3. Budget analysis of a preconditioning operation for a cow-calf production system

Preconditioning of a cow-calf operator	$/cwt	$/head
Price	181.03	1118.74
Shrink		27.97
Death loss		9.92
Cost of weaned calf	180.34	991.87
Gross income	130.86	88.98
Feed expenses	68.37	46.49
Non-feed expenses	49.54	33.69
Preconditioning costs	37.65	25.60
Total costs	117.91	105.78
Net return	−24.70	−16.80

Rounding errors may be present. Preconditioning is assumed to be conducted in cow-calf operations that have backgrounding capacity. Preconditioned calves are sold at 618 lb. The number of lb produced in the preconditioning operation is 68. Shrink is 2.5% and death loss is 1%. Gross income in $/cwt is for weight produced. Estimates were obtained from 2019 Kansas Farm Management Association, Annual ProfitLink Summary, Beef-Backgrounding (2014–2018).

treatment cost of a sick animal, $\widetilde{D}$ is the simulated days in feedlot, which is a function, $\widetilde{D}_h = \text{WeightGained}_h/\widetilde{\text{ADG}}_h$, of WeightGained (expected weight gained at feedlot) and $\widetilde{\text{ADG}}$, simulated average daily weight gain of the animal, and DC is the non-feed feedlot daily costs per animal. The subscript h refers to the health status of the animals: preconditioned or non-preconditioned, y is an indicator of the year, or period, when prices are observed. $\widetilde{\text{DR}}_{h,y}$, SR_h, and $\widetilde{\text{ADG}}_h$ are the simulated PERT random variables, which depend on h.

From the parameter estimates of Avent, Ward, and Lalman (2004) (mean, minimum, maximum, and standard deviation), we fitted a PERT distribution to each variable to incorporate a stochastic component into the analysis. These parameter estimates were used because they compare the performance of preconditioned and non-preconditioned cattle at various feedlots during the same period. Although there are many studies that estimate performance of preconditioned and non-preconditioned cattle at the feedlot, most parameter estimations are point estimates (Lalman and Mourer, 2014; Lalman and Ward, 2005, Mathis et al., 2008). Fitting a PERT

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Table 4. Partial budget analysis of a non-preconditioned and preconditioned cattle in a feedlot

Feedlot	$/cwt	Non-preconditioned $/head	Preconditioned $/head
Revenue	128.05	1792.70	1792.70
Cost of animal		991.87	1090.77
Death loss		42.35	16.36
Gross income		758.48	685.57
Feed expenses	67.15	585.55	535.49
Non-feed expenses		312.16	249.54
Treatment cost for sick animals		8.60	2.18
Total costs		906.30	787.21
Net return		−147.82	−101.64

Rounding errors may be present. Cost of animal includes shrink. Non-preconditioned calves enter the feedlot at 550 lb. Preconditioned calves enter the feedlot at 618 lb. Fed animals are finished at 1400 lb. Feedlot performance parameters for non-preconditioned and preconditioned cattle were obtained from the average values of Avent et al. (2004).

Table 5. Distribution parameters used to fit a PERT distribution on feedlot performance variables

Performance variables	Average	Min	Mode	Max	SD	Lambda
ADG (lbs), preconditioned	2.93	2.34	2.78	3.59	0. 337	0.429
ADG (lbs), non-preconditioned	2.56	1.70	2.67	3.31	0.375	1.516
% Sick, preconditioned	9.23	1.5	2	25	5.447	1.11
% Sick, non-preconditioned	36.43	12.5	26.8	70	14.172	1
% Dead, preconditioned	1.57	0.5	0.5	3	0.678	0.333
% Dead, non-preconditioned	4.26	2	2	10	1.694	1.53

Average, minimum, and maximum were obtained from Avent et al. (2004). Mode and Lambda were calibrated to fit each PERT distribution to the values estimated by Avent et al. Standard deviation (SD) is the result of the PERT distribution estimated. See the Appendix for more information on the distribution estimation process.

distribution is pragmatic when there is limited information about stochastic outcomes since it only requires three data points: minimum, maximum, and mode. PERT is similar to a triangular distribution but with more weight around its mode compared to its extreme values. Using a normal distribution may not be appropriate in this case because of the small sample size ($n = 16$ feedlots sampled) and because its unboundedness may create outliers. Fitting the PERT distributions in this analysis required the estimation of the mode of the distribution and the shape parameter, Lambda, to match the PERT mean with the observed mean by Avent et al.

To capture some of the variability in the performance measures of preconditioned and non-preconditioned animals in the feedlot, we simulated 1,000 observations of death rate, sick rate, and ADG using PERT distributions with parameters from Table 5. Each performance variable was independently drawn from each other using the function rpert from the library mc2d in R. From the results of the performance simulation, we obtained distributions of net returns per head at the feedlot for each type of cattle using equation (1).

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2.5. Stochastic Dominance

Stochastic dominance is a decision criterion used when the variable of interest is stochastic and decision-makers are expected utility maximizers. Implementing this method requires only the cumulative distribution function (CDF) of the competing choices. Although the 1,000 simulations produce normally distributed results, and the mean and variance could therefore be used in the stochastic dominance analysis, we elect to use the entire distribution for analysis. Stochastic dominance rules provide a visual comparison of the competing outcomes, including a qualitatively assessment of risk preferences in choosing competing outcomes when neither dominates the other. Graphically, when the CDF of a choice lies to the right of another competing choice without crossing, the CDF at the right is said to stochastically dominate the other distribution in first order, and it will be preferred over the dominated choice regardless of the risk preferences of the decision-maker. If the CDF of the choice that starts on the left eventually crosses the CDF of the other choice, while having a larger area under the CDF, the CDF of the choice that started on the right is said to second-order stochastically dominate the other choice, and the dominant choice will be preferred by a risk-averse decision-maker. A risk-seeking decision-maker, however, may prefer a choice that is second-order stochastically dominated.

2.6. Certainty Equivalence

The minimum amount of money a decision-maker is willing to pay in order to avoid a gamble, or stochastic outcome, with a potential higher expected value is the certainty equivalent (CE) to the gamble. The CE is a way to place a sole monetary value on the utility of a stochastic choice. A decision-maker will select the choice, among many stochastic choices, that generates the highest CE. The CE provides the same utility to the decision-maker than the gamble: $U(\text{CE}) = E[U(\tilde{x})]$, where $U()$ is a utility function, $E[]$ is the expectation operator, and $\tilde{x}$ is a stochastic variable representing the gamble. Utility functions are monotonically increasing (more is preferred to less) and for risk-averse individuals, concave, indicating decreasing marginal utility. The CE of a gamble depends on the decision-maker's risk preferences. Risk preferences are captured by the Arrow–Pratt risk aversion coefficient, which measures the shape of the individual's utility function, more specifically, its curvature. The Arrow–Pratt risk aversion coefficient is the negative of the ratio of the second derivative of the utility function to its first derivative: $r = -\frac{U''(\,)}{U'(\,)}$. A commonly used utility function is the exponential utility function: $U(x) = e^{-rx}$. The formula of the CE for this function is $\text{CE}(x) = E[\tilde{x}] - \frac{r\sigma^2}{2}$, where $E[\tilde{x}]$ is the expected value of the random outcome and σ^2 is the variance of the random outcome. The CE formula is valid under normality assumptions. Our simulated net returns are assumed to have a normal distribution due to the large number of iterations ($n = 1{,}000$). When $r = 0$, the decision-maker is risk-neutral and the only decision criteria is the expected value of the stochastic outcome. Higher values of r, assuming $\sigma^2 > 0$, would lower the CE value, indicating that the decision-maker is more risk-averse.

With the simulated net returns per head of preconditioned and non-preconditioned animal in the feedlot, we can estimate their CEs: $\text{CE}(\text{prec})$ and $\text{CE}(\text{non} - \text{prec})$. The difference is an estimate of the preconditioning premium that the feedlot operator is willing to pay, depending on the operator's risk aversion.

In the following section, we present the results of the stochastic performance of cattle at the feedlot and the resulting preconditioning price premia obtained from cost analysis to the producer and from using certainty equivalent on the feedlot operation.

3. Results and Discussion

Since preconditioned cattle produce greater benefits than non-preconditioned cattle to the feedlot, the question is why introducing preconditioned cattle in a feedlot is not the dominant practice?

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Table 6. Net returns, in $/head, for each production type at the cow-calf production and feedlot level by year

Year	Cow-calf operator		Feedlot		Max premium $/cwt	Max premium $/head
	Non-preconditioned	Preconditioned	Non-preconditioned	Preconditioned		
2014–2018[a]	−39.99	−16.80	−150.45	−102.30	7.79	48.15
2019	−294.49	−35.43	−143.96	−87.91	9.07	56.05
2018	−206.58	−26.98	−86.51	−39.83	7.55	46.68
2017	−144.47	−20.63	−36.27	9.34	7.38	45.61
2016	−144.28	−15.67	1.10	44.67	7.05	43.57
2015	31.35	6.26	−88.11	−35.98	8.44	52.13
2014	218.37	−18.04	−232.66	−159.61	11.82	73.05
2013	−105.52	−39.99	−248.89	−170.86	12.63	78.03
2012	−31.00	−27.12	−201.42	−132.75	11.11	68.67
2011	−112.78	−36.81	−288.62	−216.42	11.68	72.20
2010	−117.36	−29.45	−196.44	−126.94	11.25	69.50

[a]Average of these years.

After all, the mechanisms exist for feedlots to incentivize cow-calf operators to follow a preconditioning protocol by offering a price premium. Preconditioning protocols can be certified by third parties to provide assurance to the buyer. To answer that question, we perform stochastic analysis on the distribution of returns from preconditioning and non-preconditioning. According to Lalman and Mourer (2014), 27.2% of all cattle lots sold through Superior Livestock Video Auction in 2012 were preconditioned certified (VAC-45). However, for the market to operate efficiently, all information related to potential benefits of preconditioning and the health status of incoming animals to the feedlot should be available to all market participants. Preconditioned cattle, when placed in a pen along non-preconditioned, high-risk cattle, may have morbidity and mortality rates like the high-risk cattle (Hilton, 2014). Feedlots have significant risk in accepting cattle as preconditioned if there is no perfect information on the distribution of preconditioned cattle performance and net return per head. Moreover, feedlots can treat incoming cattle with a metaphylaxis treatment to minimize losses from incoming high-risk cattle.

To incentivize producers to precondition post-weaned cattle, the price premium received by producers should compensate the costs and the risks associated to preconditioning, given their risk preferences. In this analysis, using equation(1), we set a price premium that covers the health protocol costs of preconditioning. This value is calculated at $25.60/head (from Table 1) and is assumed to be the minimum amount for a preconditioning premium. Net returns per year for each scenario are shown in Table 6.

The average maximum premium per head and the 95% confidence interval for the sample period are $60.55 (52.49, 68.61), which corresponds to a maximum premium per cwt of preconditioned cattle of $9.79 (8.49, 11.10). The maximum premium represents the net total benefits to the feedlot from purchasing preconditioned cattle without any precondition price premium. The average net benefit of preconditioning ($60.55) per head in our estimation is about the same expected net benefit of using a metaphylaxis treatment with "lower-tier" antimicrobials,[12]

[12]Timilcosin is considered a "lower-tier" antimicrobials, while Tulathromycin is considered an "upper-tier" antimicrobial (Abell et al., 2017).

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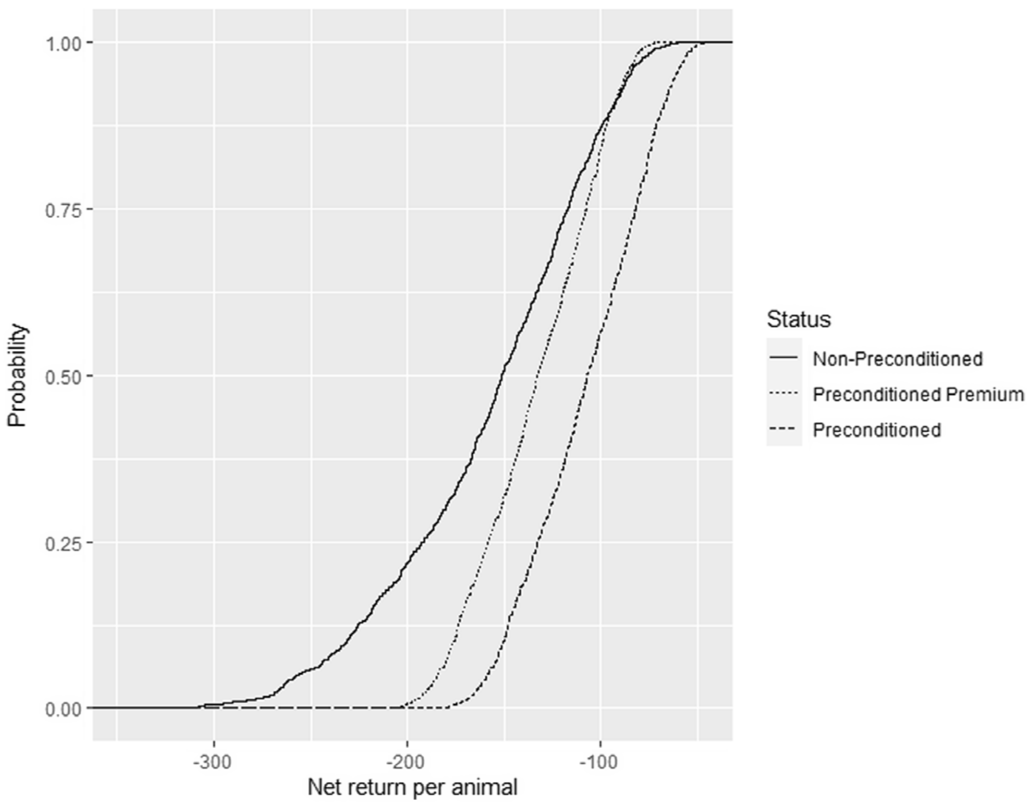

Figure 2. CDF of net returns of non-preconditioned and preconditioned animals with and without a price premium at the feedlot. Preconditioned price premium is $25.60 per head, corresponding to the costs of the health protocol of the preconditioning operation. Average of 2014–2018 prices. The required price premium is less than half the net benefits to the feedlot and more than the preconditioning cost to the producer.

$58.05, while the average net benefit of using an "upper-tier" antimicrobials is estimated at $109.31 (Dennis et al., 2020). Dennis et al. do not consider random variation in feedlot performance for preconditioned and non-preconditioned cattle as we have done.

The CDFs of net returns per preconditioned animal, with and without a price premium, and non-preconditioned animal at the feedlot is shown in Figure 2.

When no price premium is paid for preconditioned animals, the net returns of preconditioned cattle stochastically dominate by first degree the returns of non-preconditioned cattle at the feedlot. However, under a scenario in which feedlots pay a price premium that covers the cost of the health protocol in the preconditioning operation, the CDFs of the net returns of preconditioned with premium and non-preconditioned cattle to the feedlot cross once. In this case, no distribution stochastically dominates in the first degree, but net returns from preconditioned cattle with premium second-order stochastically dominate net returns of non-preconditioned cattle. These results imply that risk-neutral feedlot operations would select preconditioning under the specified price premium and assumptions. A feedlot operator with sufficiently high risk-seeking preferences may prefer non-preconditioned cattle, since they provide a small probability of higher net returns. However, this conclusion would be sensitive to expected preconditioning premium, which incentivizes the cow-calf operator to precondition, and parameters of the stochastic event, discussed next.

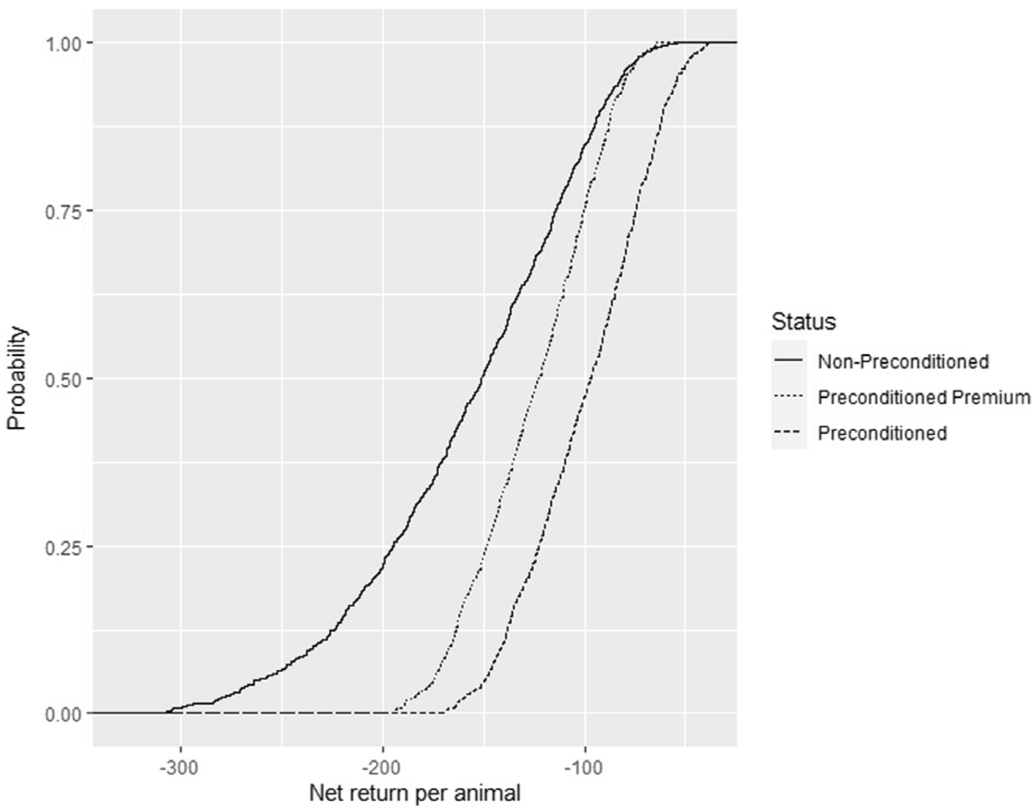

Figure 3. Year 2014 CDF of net returns of preconditioned and non-preconditioned animals at the feedlot including a preconditioning price premium of $25.60 per head, corresponding to the costs of the health protocol of the preconditioning operation.

The differences in prices between weaned and fed cattle, as well as the cost of production, also contribute to the feedlot expected benefits of purchasing preconditioned cattle. We compared the benefits of preconditioned and non-preconditioned cattle at the feedlot for the years 2014 and 2010, which corresponds to a year where the ratio of prices of fed cattle to weaned cattle was at its lowest (0.656) and highest (0.849) of our sample, respectively. The ratio of total costs for fed cattle to weaned cattle was also lowest in 2014 (0.64), while in 2010 was the second highest (0.77).

The CDFs for years 2014 (Figure 3) and 2010 (Figure 4) are similar to that of years 2014–2018. Preconditioned cattle with premium paid continue to dominate stochastically non-preconditioned cattle net returns at the feedlot (second order in 2014 and first order in 2010). Similar to Figure 2, non-preconditioned cattle have a small probability of generating higher net returns than preconditioned cattle, and thus a risk-seeking feedlot manager may prefer non-preconditioned cattle.

The preference for preconditioned cattle at the feedlot will be affected by the expected price premium, but this price premium is dependent on the expected net benefits at the feedlot over non-preconditioned cattle. In all the sample years analyzed, net benefits of preconditioning to the feedlot, without a price premium, were always positive. Preconditioning generates additional net benefits to the beef production system analyzed in this study. Benefits to the feedlot after paying a preconditioning price premium of $25.60/head result in $22.55 higher net return over non-preconditioned cattle for the average of 2014–2018 prices.

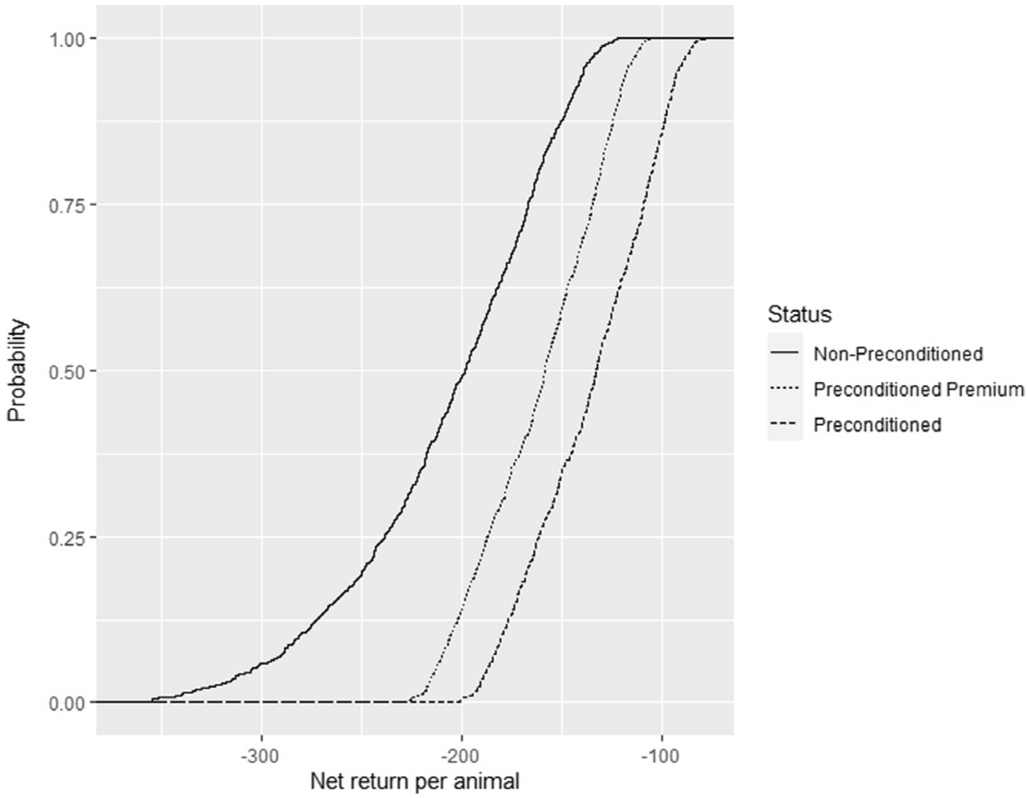

Figure 4. Year 2010 CDF of net returns of preconditioned and non-preconditioned animals at the feedlot including a preconditioning price premium of $25.60 per head, corresponding to the costs of the health protocol of the preconditioning operation.

The summary statistics of the net returns for each of the three time periods are presented in Table 7.

Our current analyses do not consider a positive net return for the operator that sells preconditioned cattle, rather an expected breakeven net return for preconditioning cattle. The extent of the

Table 7. Simulated net return sample statistics by period in $/head ($n = 1000$)

Period and preconditioning status	Mean	SD	Min	Max
2014–2018				
Preconditioned	−108.49	30.04	−178.61	−47.65
Non-preconditioned	−158.51	53.96	−322.50	−63.48
2014				
Preconditioned	−100.62	30.46	−173.79	−37.45
Non-preconditioned	−159.19	55.39	−332.04	−59.11
2010				
Preconditioned	−137.10	29.53	−202.11	−80.15
Non-preconditioned	−209.65	52.28	−361.91	−120.84

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Table 8. Certainty equivalent estimation and price premium for preconditioned cattle estimated by different degrees of risk aversion

	Certainty equivalent value (CE)		
Risk aversion coefficient (*r*)	Preconditioned	Non-preconditioned	Price premium (difference in CE)
0 (Risk-neutral)	−108.49	−158.51	50.02
0.01 (Low risk aversion)	−113.00	−173.06	60.06
0.02 (Moderate risk aversion)	−117.52	−187.62	70.10
0.04 (High risk aversion)	−126.54	−216.73	90.19

excess net return for the preconditioner depends on local market conditions, like market power of the feedlot over producers, information asymmetries, and the net benefits of performing metaphylaxis treatment on arrival to all incoming cattle. From the net benefits of metaphylaxis from Dennis et al. (2020), even using a "lower-tier" antimicrobials treatment result in similar expected benefits than purchasing preconditioned animals in feedlots without paying a price premium. When a conservative price premium is paid, that allows preconditioners to have zero net returns from preconditioning, the net benefits of preconditioning fall below from that of metaphylactic treatment.

3.1. Premium Estimate Using Certainty Equivalent Analysis

Once the CDFs of the net returns per preconditioned and non-preconditioned animal at the feedlot are simulated from the PERT distribution estimations, we can calculate the CE of each net return distribution. Under a normality assumption, only the mean and variance of the net return distribution are needed to estimate the CE, as well as a value of *r*. Babcock et al. (1993) provide a review of estimates of *r*. We use four scenarios of risk preference of the feedlot operator: 0, 0.01, 0.02, and 0.04. These represent risk neutrality, low, moderate, and high risk aversion. These estimations are the CDF estimates correspond to the average prices of 2014–2018. The mean and variance of the net returns of non-preconditioned cattle are −158.51 and 2911.28, respectively, while those from preconditioned cattle are −108.49 and 902.27, respectively. The estimated CE and price premium at different levels of risk aversion are shown in Table 8.

For a risk-neutral feedlot operator, the price premium willing to pay for preconditioned cattle is $50.02/head, essentially the difference of the expected net returns. This figure is higher than the of $25.60/head premium calculated in the stochastic dominance example, since that value represents an amount to cover the health protocol expenses of preconditioning and is not related to actual feedlot net benefits. As the risk aversion of the feedlot operator increases, the CE decreases (the utility from a random outcome decreases) and the price premium for preconditioned cattle increases, indicating a desire to decrease net revenue risk. At higher levels of risk aversion, for instance 0.04, the price premium for preconditioned cattle is $90.19/head.

Hilton and Olynk (2011) estimated the yearly preconditioning premium from years 1999 to 2009 in Indiana to range from −$3.51 to $11.34/cwt, with net return to preconditioning ranging from $26.04 to $116.48/head. Thrift and Thrift (2011) summarized the results from various studies and found that preconditioning price premia range between $1.40 and $6.12/cwt, but the net profit per head ranged from −$89.92 to $53.71. Qian (2014) estimated the preconditioning premium at cattle auctions in NY State to be $3.11/cwt. Lalman and Mourer (2014) found that VAC-45 certified cattle had a premium of $12.06/cwt in 2012 at the Superior Livestock Video Auctions. Schumacher, Schroeder, and Tonsor (2012) estimated that the value to feedlots in Kansas for cattle with a certified health program is between $6.98 to $11.97/cwt. Williams et al. (2012) estimated that The Oklahoma Quality Beef Network certification program adds $3.40 to $5.71/cwt in price premium. The benefits of preconditioning depend on market conditions as well as on its increase performance over non-preconditioned cattle and managerial practices of feedlot operators. Garber et al. (2022) conclude that even when preconditioning (Virginia Quality Assured certification) does not have a large price effect, it still has a positive effect on producer profitability.

4. Conclusion

We estimated the net return distribution of fed cattle under a preconditioning program and non-preconditioned cattle following a metaphylaxis treatment on arrival to the feedlot. We found that preconditioned cattle generate net returns of about $48.15/head to the feedlot over weaned cattle. This extra benefit to the feedlot represents the maximum amount that a feedlot is able to pay for preconditioned cattle, which translates to a maximum price premium of $7.79/cwt for a 618 lb animal. Our results indicate that introducing preconditioned cattle to a feedlot, with a price premium that generates nonnegative returns to cow-calf operators with preconditioning capacity, is the stochastic dominant strategy for feedlots. The use of preconditioning of cattle would also reduce the use of medically important antimicrobials in beef production, which has been estimated to be 2.5 thousand metric tons (USFDA, 2021).

The transfer of part of the maximum price premium back to the backgrounder is contingent on the preconditioning information available to feedlot managers, the cost of preconditioning, and the risk preferences of feedlot operators. If there is perfect information on the preconditioning status and performance of preconditioned animals across the beef value chain, we should expect all preconditioned animals to receive a price premium sufficiently high to incentivize preconditioning.

A caveat of this study is our assumption on the performance of preconditioned and non-preconditioned cattle at the feedlot. We assume perfect stochastic information in the system: health status and preconditioning benefits. More studies are required to have a better understanding of the feedlot performance; despite the current estimations available, there is much uncertainty in the outcome to help decision-makers.

Reliable certification programs or reputation of the backgrounder are ways to inform feedlot managers on the preconditioning status of the cattle. Performance may also vary by backgrounder and would have to be ascertained by feedlot production records. It is estimated that 25.9% of managers of feedlots with capacity of 8,000 head or more have pre-arrival processing information of the cattle all the time (USDA, 2013b).

Metaphylactic use of antibiotics on arrival conditional on Veterinarian approval is a low-cost strategy to feedlots, which may decrease the desirability for purchasing preconditioned cattle. The net return of metaphylactic use of antibiotics to the U.S. feeder industry is at least $532 million (Dennis et al., 2018). The status quo does not allow market mechanisms to fully adopt preconditioning practices in the beef system. Further analysis on the net benefits of metaphylaxis on arrival versus preconditioning is needed to assess the sustainability of preconditioning programs in the US.

Author contributions. Conceptualization, L.J.V.C., L.W.T., and Y.T.G.; Methodology, L.J.V.C., L.W.T., K.K., G.L., and Y.T.G.; Formal Analysis, L.J.V.C.; Data Curation, L.J.V.C.; Writing—Original Draft, L.J.V.C. Writing—Review and Editing, L.W.T., and Y.T.G.; Supervision, L.W.T., and Y.T.G.; Funding Acquisition, L.W.T., and Y.T.G.

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Conflict of interest. The authors report there are no competing interests to declare.

Data availability statement. The data that support the findings of this study are available from the corresponding author, L. V., upon reasonable request.

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Appendix A

PERT Distribution

PERT fitting are often used when only expert opinion about stochastic outcomes is available. The PERT distribution is similar to a triangular distribution, which is bounded (min and max) and unimodal. PERT distribution is parameterized by a minimum and maximum possible values, the mode (most likely value), and a shape parameter Lambda. PERT distributions are used when limited information is available to construct a distribution of a random variable. From Avent et al. (2004), we used the minimum and maximum values as input of the estimated PERT distributions. The PERT mean was estimated from mean $= \frac{\max + \min + \text{mode}*\lambda}{(2+\lambda)}$, and the PERT variance from $= \frac{(\max - \min - \text{mode}*\lambda)(\max + \text{mode}*\lambda - \min(1+\lambda))}{(2+\lambda)^2(3+\lambda)}$. We estimated the values of mode and λ such that our estimates of mean and var were similar to those reported by Avent et al. (2004). As a reference, the mean and SD reported by Avent et al. (2004) were as follows: ADG Prec., 2.94 (0.337); ADG Non-Prec. 2.57 (0.375); % Sick Prec., 9.235 (6.4); % Sick Non-Prec., 36.44 (18.64); % Dead Prec., 1.5 (0.816); and % Dead Non-Prec., 4.269 (1.886).

Net Returns to Feedlot by Purchasing Backgrounded Cattle Without Health Protocol

For completeness in our analysis, in addition to our net return estimations to the feedlot by purchasing preconditioned (backgrounded and a health protocol) and non-preconditioned (weaned calves), we also included the scenario of backgrounded calves without any health protocol sold to a feedlot. Because feedlot performance estimates are not available for each possible management scenario of calves produced by cow-calves operators, which is the objective of our study, we assumed that the feedlot performance estimate of backgrounded calves but without administered a preconditioning health protocol is the same as weaned calves at feedlot.

This management strategy generates higher income to the cow-calf operator in general due to the weight gain of the calves, but the net benefits to the feedlot are similar than purchasing weaned calves, depending on relative prices the difference in net returns may become larger. The following figure shows the CDF of the net returns per animal at the feedlot for the average prices of 2014–2018.

The mean and standard deviation of the net returns shown in Figure A1 are the following: non-preconditioned: −158.51, 53.95; non-preconditioned but backgrounded: −184.40, 50.44; and preconditioned: −108.49, 30.04.

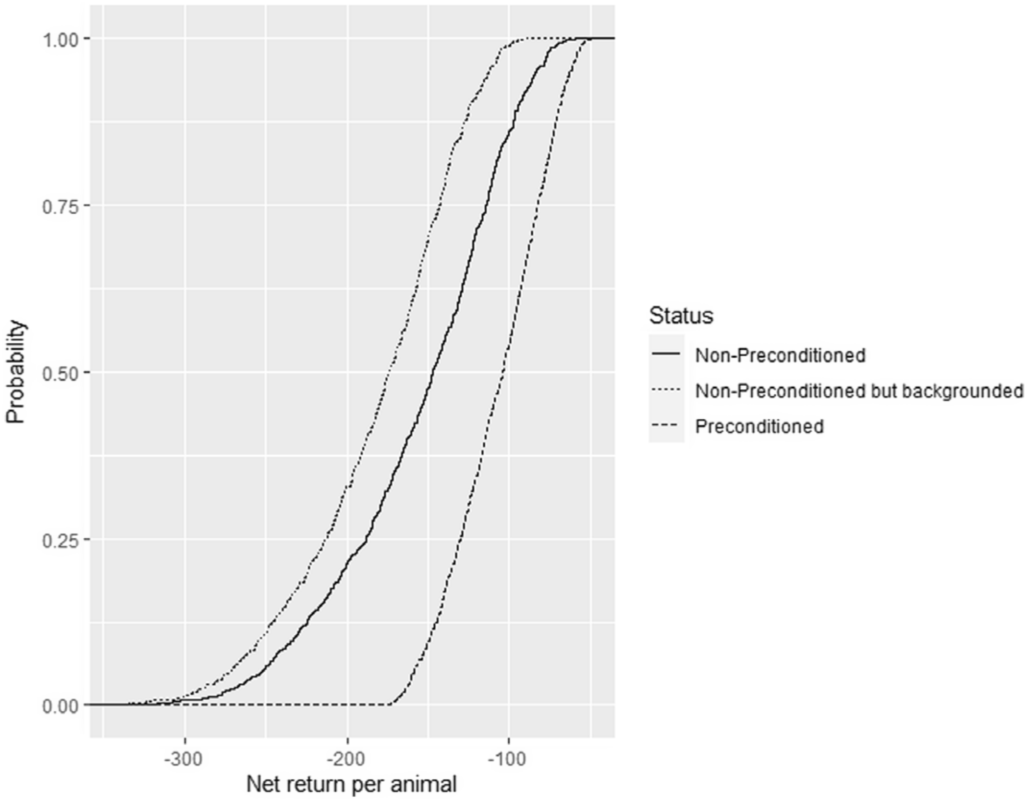

Figure A1. CDF of net returns of non-preconditioned, non-reconditioned but backgrounded, and preconditioned animals at the feedlot. Average of 2014-2018 prices.

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