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Determinants of Feedlot Cattle Death Loss Rates

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ABSTRACT

Death loss in feedlot cattle can have significant impacts on feedlot profitability. Not only does death loss result in foregone revenue, but the operation still incurs the costs to date associated with those animals. This study uses pen-level feedlot data from a private feedlot in the Southern Great Plains. Both company-owned and customer retained ownership cattle are included in the data set. A Tobit model is used to analyze pen characteristics' influence on death loss in feedlot cattle, including cattle characteristics, source characteristics, management characteristics, and treatment incidence. Results imply that several pen characteristics impact death loss and that cattle source, in terms of both cattle source geographic location and market source type, has a significant influence on death loss rate.

KEYWORDS

feedlot, death loss, beef cattle, Tobit analysis

INTRODUCTION

Death loss in feedlot cattle can have significant impacts on feedlot profitability. Not only does death loss result in foregone revenue, but the operation also incurs the costs associated with those animals. Death loss contributes to economic losses through unrecovered feed cost, medical cost, increased labor, manure disposal, animal disposal, and other increased costs (Loneragan et al., 2001). Economic loss from death loss is highly correlated with morbidity (sickness) (Roeber et al., 2001). Irsik et al. (2006) estimate that a 1% increase in death loss per pen increased feedlot cost by $1 per head and that death loss per pen would increase by 0.14% for one percentage increase in number of medical treatments.

Many factors may influence feedlot death loss rates. Some, such as weather and policy, are uncontrollable. Extreme weather may increase animal stress and lead to higher death loss rates. Policy changes may inadvertently influence death loss. For example, when the Renewable Fuels Standard Program was introduced in 2005 and expanded in 2007, corn prices increased significantly. In response, feedlot diets for cattle began to include significant amounts of distillers' grain and new feed additives, potentially exposing cattle to sulfur toxicity that could lead to polioencephalomalacia, a neurologic disease (Crawford, 2012; Drewnoski et al., 2014). Feed additives introduced to increase animal efficiency such as zilpaterol hydrochloride, a beta-agonist drug that enhances the natural ability of cattle to convert feed into lean meat, might cause ambulatory problems in cattle that could lead to death (Loneragan et al., 2014; Waters, 2013).

Controllable factors such as cattle source may also influence death loss rates. Feeder cattle come from different market sources including sale barns, country ranches, growing yards, and other backgrounding operations. Compared to ranch-sourced steers, sale barn–sourced steers are treated more often for bovine respiratory disease and have higher death loss rates (Step et al., 2008). Meanwhile, cattle brought from locations far from the feedlot could experience greater stress and potential exposure to disease than those sourced from closer distances. Death loss rates may also be influenced by cattle type (steer, heifer, dairy, etc.). For example, research suggests that steers have lower death loss rates compared to heifers (Babcock et al., 2006; Vogel et al., 2015).

Causes of death for feeder cattle can be classified into predator-related and non-predator-related.

Non-predator-related deaths cost the beef cattle industry more than $2.35 billion per year (USDA, 2011). Bovine respiratory disease (BRD) is the primary reason for death loss in feedlots (Brooks et al., 2011; Loneragan et al., 2001; Smith, 1998; Snowder et al., 2006). BRD is caused by pathogen attacks on the animal's respiratory tract. A single pathogen or a variety of pathogens interact with the animal's immune system, leading to a full-blown disease. Vogel et al. (2015) found that average days on feed at death caused by respiratory disease is day 62 for both steers and heifers. Factors that may influence BRD susceptibility include initial animal placement weight, transportation process, commingling, and feedlot personnel experience (Lechtenberg et al., 1998; Loneragan et al., 2001).

Digestive disorders are related to what cattle eat, including feed and feed additives. The most common digestive disorders are acidosis and bloat (Glock & Degroot, 1998). Acidosis happens when the pH of the rumen becomes acidic for an extended period of time, possibly caused by excess high energy feeds and feed particle size. Acidosis leads to low feed consumption and dehydration and may lead to death (Owens et al., 1998). Bloat occurs when fermentation gases build up in the rumen, causing breathing difficulty and possible death (Cheng et al., 1998). Animals that die of digestive disorders usually do so at later stages of the feeding period (Loneragan et al., 2001). Vogel et al. (2015) found that average days on feed at death caused by digestive disorders are day 99 for steers and day 98 for heifers. Loneragan, Thomson, and Scott (2014) associated death close to the end of feeding periods with the use of beta-agonist drugs in cattle confinement. However, Maday (2016) suggested that the beta-agonist drug zilpaterol hydrochloride had only small impacts on death loss as death loss rates actually increased after its withdrawal from the market. Past research investigated death loss from the perspective of animal health (Engler et al., 2014; Irsik et al., 2006; Loneragan et al., 2001; Smith, 1998). However, no distinction in sources of cattle were included in these studies.

The purpose of this study is to examine factors that appear to influence death loss in feedlot cattle, including cattle characteristics, management characteristics, and treatment incidence. Important cattle characteristics for consideration include geographic source, sex, and market source. Death loss may also be impacted by management characteristics such as decisions regarding cattle weight at placement, efforts to control shrinkage, and how many cattle are placed in the feedlot pen. The incidence of treatments for respiratory and digestive illnesses may also be important factors in death loss rates. In this study, pen-level feedlot data is analyzed using a Tobit model to examine the influence of these factors on feedlot death rates. A discussion of the data, Tobit model implementation, and model results follows.

DATA

This study uses pen-level feedlot data from a large private feedlot in the Southern Great Plains. While any private feedlot has its own management strategies that are unique, the challenges faced are similar to those faced by other feedlots in that region. Certainly some regional uniqueness will exist as well, but generally, the data are representative of large commercial U.S. cattle feeding operations. Both company-owned and customer retained ownership cattle are included in the data set. Data include overall death loss percentage; death loss by cause of death (respiratory disease, digestive disorders, others); number of cattle treated for respiratory disease, digestive disorders, and others; number of deads; placement head count (pen size); in-weight (placement weight after shrink); days on feed; feed to gain ratio; shrink percentage; sick head days; cattle type; market source; and geographic state of origin. Pen-level data are included from 5,773 pens with closeout dates from May 2009 to January 2017. Each observation is the average value among cattle in each pen. Placement head count for the observed time period is 636,042 with a closeout head count at 623,291.

Year and month refer to closeout date. Pen type includes steers, heifers, and other type. Other type consists of steer and heifer mix, Holstein, and cow. Cattle market source includes sale barn, country ranch, combination of sale barn and other (country ranch, wheat pasture, growing yard), and other sources. The category for Other market source consists of wheat pasture, growing yard, and backgrounding program. State of origin is used to compile a geographic region origin variable comprised of Southern Great Plains, Northern Great

Plains, Midwest, West, and East. Summary statistics across pens are presented in Table 1.

MODEL AND PROCEDURES

Since death loss is observed as a censored variable taking on only values that are zero or positive, a Tobit model is considered for analysis. According to Wooldridge (2002), Tobit regression is applicable when data are censored on the left. In this case, since the dependent variable, death loss (*DL*), is observable, it may be more appropriate to refer to this model as a corner solution model rather than a censored regression model. At pen level, *DL* takes the value of zero with positive probability and a continuous variable with only positive values. The model implies that the producer is solving a mathematical optimization problem where the optimal solution will be the corner, *DL* = 0.[1] There is no exact definition for latent variable *DL** in this study because death loss *DL* is observable. The interest of this study is to estimate the expected *DL,* which is non-negative, as well as the probability that *DL* is not zero.

In Tobit regression, the likelihood function is comprised of two parts. The first part is related to the classical regression of the uncensored observations (*DL* > 0). The second part takes into account the relevant probabilities that an observation is censored. The likelihood function for the Tobit model is

(1)

$$L(\beta,\sigma)=\prod_{DL_i>0}\left[(2\pi\sigma^2(z_i\eta))^{\frac{-1}{2}}\exp\left(\frac{-1}{2\sigma^2(z_i\eta)}(DL_i-\boldsymbol{x}_i'\beta)^2\right)\right]\times\prod_{DL_i=0}\left[1-\Phi\left(\frac{\boldsymbol{x}_i'\beta}{\sigma^2(z_i\eta)}\right)\right]$$

where DL_i is the dependent variable, $\boldsymbol{x}_i$ is the vector of explanatory variables, z_i contains explanatory variables that affect the variance, and Φ is the normal cumulative distribution function (CDF).

If OLS is used to estimate *DL* using the whole sample or only the uncensored sample, estimates will be biased and inconsistent. Expected *DL* for the whole sample is a nonlinear function of explanatory variables, corresponding coefficients, and sigma, but OLS assumes linearity. OLS using

Table 1. Pen Average Summary Statistics for Private Southern Plains Feedlot, 2009–2017

Variable	Unit	Mean	Std. Dev.	Minimum	Maximum
Continuous					
All Pens (*n* = 5,573)					
Death Loss	%	2.28	3.22	0.00	50.00
In-Weight	lbs.	697.91	117.18	262.76	1,388.85
Pen Size	head	110	54	2	389
Sick Head Days	%	0.84	1.46	0.00	67.33
Cattle treated with Antibiotic for Respiratory Disease	%	12.08	12.70	0.00	91.11
Cattle Treated for Digestive Disorder	%	6.13	10.22	0.00	79.73
Non-Zero Death Loss Pens (*n* = 4,267)					
Death Loss	%	3.09	3.40	0.35	50.00
In-Weight	lbs.	685.66	114.32	262.76	1,095.09
Pen Size	head	119	53	2	389
Sick Head Days	%	0.94	1.27	0.00	24.18
Cattle Treated with Antibiotic for Respiratory Disease	%	13.75	13.40	0.00	91.11
Cattle Treated for Digestive Disorder	%	6.86	10.87	0.00	79.73

Table 1. Pen Average Summary Statistics for Private Southern Plains Feedlot, 2009–2017 (cont.)

Variable	Description	% of Pens in Category
Categorical		
Shrink		
Shrink > 5.5 percent	Outlier shrink	9.87
Shrink <= 5.5 percent	Normal shrink	90.13
Region Origin		
Southern Plains	Cattle sourced from Southern Plains	90.40
Other Region	Cattle sourced from other region	9.60
Pen Type (Cattle Type)		
Other Cattle	Other cattle including cows, Holsteins, and mix of steers and heifers	5.13
Heifer	Heifers	35.49
Steer	Steers	59.38
Market Source		
Other Source	Cattle sourced from wheat pasture, growing yard, or backgrounding program	4.94
Sale Barn & Other	Cattle sourced from combination of sale barn and country ranch, wheat pasture, or growing yard	2.27
Country	Cattle sourced from country ranches	32.53
Sale Barn	Cattle sourced from sale barn	60.26
Closeout Month		
January	Closeout in January	10.24
February	Closeout in February	7.40
March	Closeout in March	7.34
April	Closeout in April	8.70
May	Closeout in May	8.05
June	Closeout in June	7.57
July	Closeout in July	10.57
August	Closeout in August	8.73
September	Closeout in September	8.63
October	Closeout in October	7.78
November	Closeout in November	7.38
December	Closeout in December	7.62

Note: Variable category in *italics* is used as reference in the estimations.

only the uncensored sample omits sigma in the regression, leading to correlation between explanatory variables and the error term.

The Tobit regression in this study is quite similar to the Tobit model for death loss by Belasco et al. (2009). However, death loss is modeled with heteroskedasticity in this study under the assumption that variance is different by in-weight. The log-likelihood function from the death loss Tobit model can be written as:

(2)

$$LnL = \sum_{DL_i > 0} \frac{-1}{2}\left[Ln2\pi + Ln(\sigma^2) + INWT_i\eta + \frac{DL_i - \boldsymbol{x}_i'\beta}{\sigma^2.\exp(INWT_i\eta)}\right] + \sum_{DL_i = 0} Ln\left[\Phi\left(\frac{\boldsymbol{x}_i'\beta}{\sigma^2.\exp(INWT_i\eta)}\right)\right]$$

where,

(3)

$$x_i'\beta = \beta_0 + \beta_1 INWT_i + \beta_2 PSIZE_i + \beta_3 SHD_i + \beta_4 CTRES_i + \beta_5 CTDIG_i + \beta_6 SHRINK_i + \beta_7 REGION_i + \sum_{k=1}^{2} \alpha_k CTYPE_{ik} + \sum_{l=1}^{3} \gamma_l ORIGIN_{il} + \sum_{q=1}^{11} \delta_q MD_{iq}$$

and where DL_i is percentage of death loss observed in pen i, $INWT_i$ is pen i's average in-weight, $PSIZE_i$ is pen size and represents the number of cattle in the pen, SHD_i is sick head days percentage for pen i, $CTRES_i$ is percentage of cattle treated with antibiotics for respiratory disease in pen i, $CTDIG_i$ is percentage of cattle treated for digestive disorders in pen i, $SHRINK_i$ equals one for pens with shrinkage of more than 5.5 percent and zero otherwise, $REGION_i$ equals one for cattle sourced from the Southern Plains and zero otherwise, $CTYPE_{ik}$ is pen type k where $k = \left\{\begin{smallmatrix} 0 & \text{Steers} & 2 & \text{Other Cattle} \\ 1 & \text{Heifers} & & \end{smallmatrix}\right\}$, $MSOURCE_{il}$ indicates cattle market source, l, for pen i where $l = \left\{\begin{smallmatrix} 0 & \text{Sale barn} & 2 & \text{Sale barn \& Other} \\ 1 & \text{Country} & 3 & \text{Other Source} \end{smallmatrix}\right\}$, and MD_{iq} are monthly dummy variables from October to August. Days on feed is not included as an explanatory variable because it is highly correlated with in-weight (> 0.8). As discussed by Stehle, Peel, and Riley (2018), cattle availability and feeding cost of gain heavily influence feedlot placement weights, which impacts days on feed directly.

Death loss percentage may differ among cattle market sources. Sale barn pens represent the majority of cattle sourcing at more than 60% (see Table 1) and are used as the base for the market source category. Cattle from sale barns may be exposed to more viruses as they mingle with cattle from multiple ranches and may experience greater stress prior to feedlot arrival that could lead to higher death loss risk relative to other sources. Similarly, cattle that travel further or longer may be more prone to stress and sickness that could lead to higher death rates, while death loss for cattle sourced from the Southern Plains may be lower than for cattle from other regions given feedlot location. "Other regions" is used as the base for cattle origin. Abnormal shrink, that is, shrink greater than 5.5% of initial body weight, may indicate cattle under high stress that may be more prone to death. Higher percentages of cattle treated for respiratory disease in a pen may lead to lower death loss; however, it may also be a sign that disease has spread, leading to higher death loss. Treatment for digestive disorders may lessen death loss caused by digestion problems.

Approximately 19% of the feedlot's cattle, that is, 1,062 of the 5,573 pens, are customer cattle with customer ownership retained. Customer cattle do appear to have a lower average death rate relative to company-owned cattle at 1.97% and 2.35%, respectively. However, market source and ownership characteristics are highly correlated and, thus, ownership is omitted from the model. Approximately 61% of customer cattle are sourced directly from the country while 78% of feedlot-owned cattle are sourced from sale barns.

Since the dependent variable of death loss rate is observable with a minimum value of zero (i.e., a pen with no death loss), there is no clear interpretation for the value of coefficient estimates. Instead, the effects of explanatory variables on the observed variable are explained by the marginal effects computed as:

(4)

$$\frac{\partial E(DL \mid x)}{\partial x} = Prob(DL > 0)\frac{\partial E(DL \mid x, DL > 0)}{\partial x} + E(DL \mid x, DL > 0)\frac{\partial Prob(DL > 0)}{\partial x}$$

These marginal effects account for the fact that changes in explanatory variables affect both the conditional mean of death loss percentage as well as the probability that a pen has death loss.

RESULTS

As noted earlier, not all pens necessarily have death loss. Table 1 reports that of the 5,573 total pens, 4,267 pens have a nonzero rate of death loss while 1,306, or approximately 23% of pens, have zero death loss. Interestingly, 199 pens in the sample actually have zero sick head days. Figure 1 illustrates average annual death loss percentages for closeouts in years 2010 through 2016. The years 2009 and 2017 are omitted from the figure since the full year of closeout data is not available for those years. From 2010 to 2015, annual death loss percentage doubles from 1.75 to 3.60, though it drops to 2.86 in 2016. Respiratory disease represents the majority of death loss in the feedlot across all years.

Model estimation results using equations 2 and 3 are presented in Table 2. The model was estimated with SAS Enterprise Guide 6.1 using the PROC QLIM (qualitative and limited dependent variable

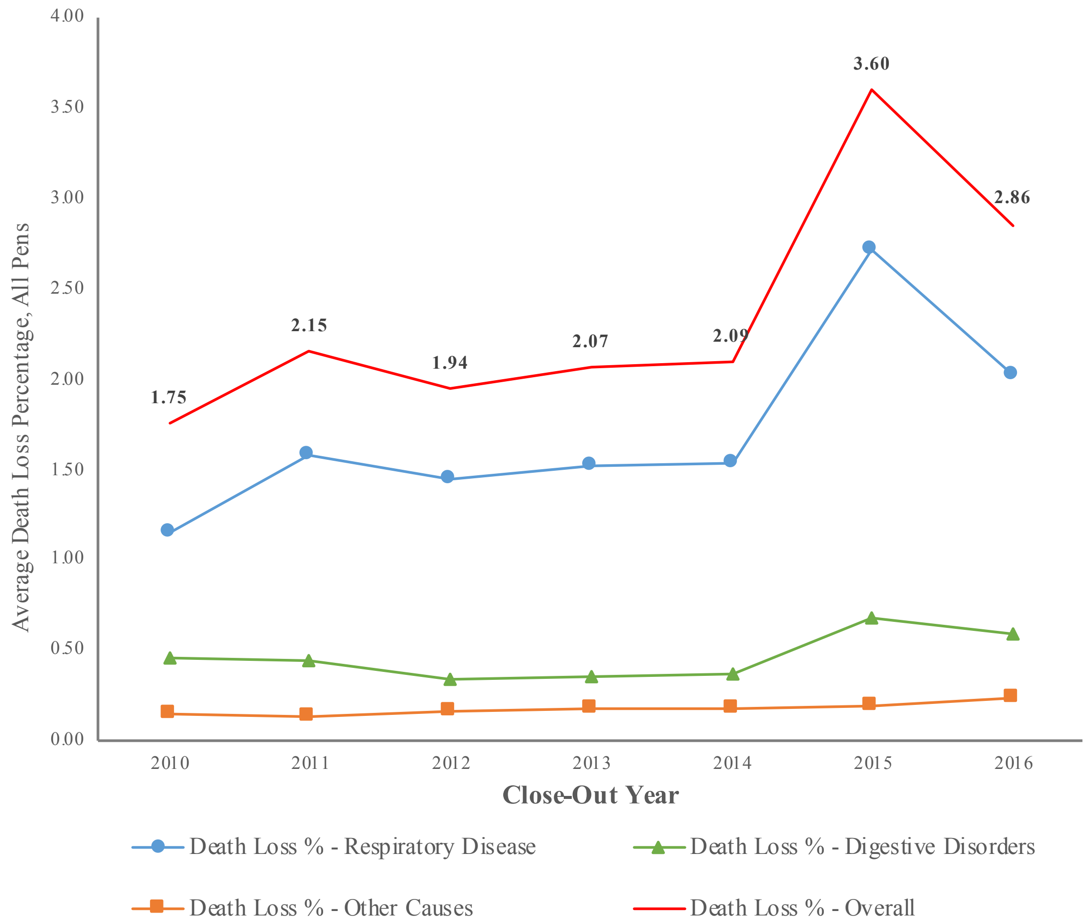

Figure 1. Average Pen-Level Feedlot Death Loss by Close-Out Year and Cause

model) procedure as a Tobit regression with heteroskedastic adjustment by in-weight. In Table 2, coefficients refer to the effects of explanatory variables on the latent variable *DL**. Marginal effects from equation 4 are also reported in Table 2.

Coefficient estimates of all continuous explanatory variables are significant at a 5% level. As expected, the marginal effect for in-weight is negative, indicating that pens with lighter in-weights have higher death loss rates. A hundredweight increase of in-weight will decrease death loss percentage by 0.2. This suggests that moving from an in-weight of 450 pounds to an in-weight of 850 pounds decreases death loss rate by 0.8, all else equal. Marginal effects for pen size and sick head days are positive, suggesting that larger pen size and more sick head days contribute to a higher death loss rate. More cattle in a pen translates to more cattle exposed and possibly infected by sickness, potentially leading to higher rates of death loss. Death loss percentage increases by 0.4 for each additional hundred head of cattle in a pen. More sick head days indicates that a pen has higher risk of more cattle getting sick, eventually leading to death loss. A 1% increase in sick head days increased death loss rate by 0.185.

Marginal effects for respiratory disease treatment and digestive disorder treatment have opposite signs. The marginal effect for percentage of cattle treated for respiratory disease is positive, indicating that a higher percentage of cattle treated for respiratory disease in a pen is a precursor to greater death loss in that pen, likely because respiratory disease is highly infectious. Here, percentage of cattle treated for respiratory disease may be a proxy for the incidence of respiratory disease instead of the treatment outcome itself. Death loss percentage for a pen increases by 0.126 with a 1% increase in incidence of respiratory disease. The marginal effect for percentage of cattle treated

Table 2. Tobit Model Estimation Results

Variable	Coefficients	Std. Error	Marginal Effects
Intercept	1.520	0.424**	
Continuous			
In-Weight	–0.003	0.000**	–0.002
Pen Size	0.006	0.001**	0.004
Sick Head Days	0.280	0.033**	0.185
Cattle Treated with Antibiotic for Respiratory Disease	0.190	0.005**	0.126
Cattle Treated for Digestive Disorder	–0.088	0.005**	–0.058
Categorical			
Shrink			
Shrink > 5.5 percent	0.015	0.154	0.010
Shrink <= 5.5 percent	–	–	–
Region Origin			
Southern Plains	–0.841	0.156**	–0.557
Other Region	–	–	–
Pen Type (Cattle Type)			
Other Cattle	0.957	0.225**	0.634
Heifer	0.002	0.981	0.002
Steer	–	–	–
Market Source			
Other Source	0.729	0.210**	0.483
Sale Barn & Other	–0.444	0.270	–0.294
Country	–0.488	0.095**	–0.323
Sale Barn	–	–	–
Month			
January	0.197	0.190	0.130
February	–0.038	0.207	–0.025
March	0.221	0.209	0.146
April	0.350	0.200*	0.232
May	0.218	0.204	0.145
June	0.509	0.204**	0.337
July	0.114	0.188	0.076
August	0.204	0.196	0.135
September	–	–	–
October	0.135	0.202	0.089
November	0.345	0.206*	0.228
December	0.028	0.205	0.018
Conditional Variance			
Constant (σ)	2.780	0.070**	
In-Weight (η)	–0.003	0.001**	
Log-Likelihood	–11820		

Note: Double and single asterisks (**, *) indicate significant at 5% and 10% level.

for digestive disorders is negative, suggesting that this treatment reduces death loss in a pen, though the magnitude is relatively small. A 1% increase in cattle treated for digestive disorders reduces the pen's death loss rate by 0.058%.

Estimates of categorical explanatory variables highlight the influence of region origin, pen type, and market source. The coefficient for pens with shrink greater than 5.5% is not statistically significant. As expected, pens with cattle sourced from the Southern Plains have lower death loss rates compared to other more distant regions, likely because cattle that travel further or longer are more prone to stress and sickness. The death loss percentage for cattle sourced from the Southern Plains is 0.557 less than for cattle sourced from other regions.

The death loss rate for pens with cattle sourced directly from country ranches is significantly lower than for sale barn cattle, supporting the suggestion that cattle from the sale barn may be exposed to more viruses and greater stress as they come through the process. They may also be more likely to be commingled in pens with other cattle from different ranches. Cattle sourced directly from country ranches have death loss rates 0.323% lower than cattle sourced from sale barns. In contrast, the death loss rate for pens with cattle sourced from other market sources (wheat pasture, growing yard, or backgrounding program) is significantly higher than for sale barn cattle with death loss of 0.483% more than for sale barn pens.

In terms of pen type (cattle type in the pen), the coefficient for heifers is not statistically significant, indicating no difference in death loss between steer pens and heifer pens. However, cattle categorized as other (cows, Holsteins, or a mix of steers and heifers) have a death loss percentage that is 0.634 higher than for steer pens.

A simple plot of average death loss by month in Figure 2 suggests a seasonal pattern in feedlot

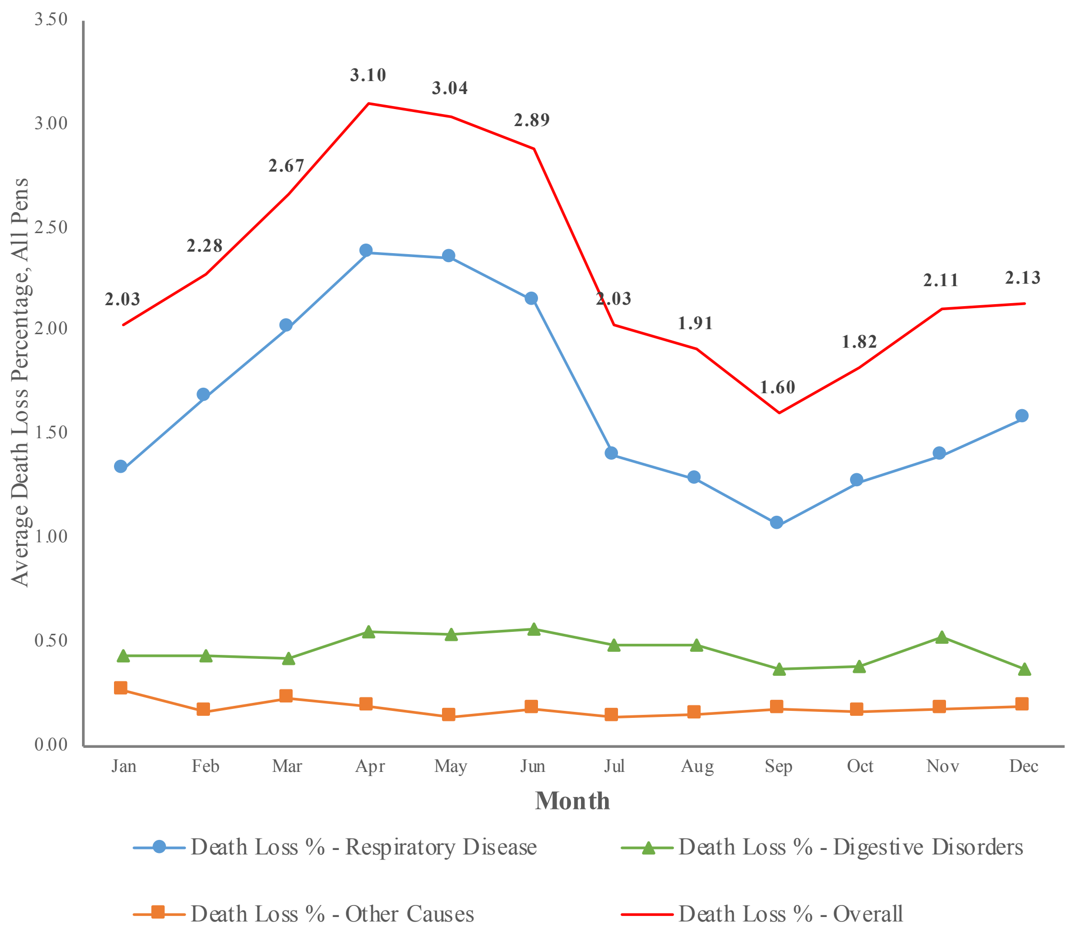

Figure 2. Average Pen-Level Feedlot Death Loss by Close-Out Month and Cause

death loss with September as the seasonal low. The estimated model indicates at least some degree of seasonality unexplained by other variables. Both April and November have statistically significant death loss rates greater than September at 0.232 and 0.228, respectively. Death loss rates peak in June, which is 0.337 greater than in September. Higher death loss percentages for late spring and summer (April, May, June) closeouts corresponds to cattle placed during fall and winter, while the seasonal low death loss percentage is for September closeouts, corresponding to spring cattle placement.

CONCLUSIONS

In-weight, pen size, percentage of sick head days, percentage of cattle treated for respiratory disease, and percentage of cattle treated for digestive disorders are all statistically significant determinants of feedlot cattle death loss rates. Distribution of these variables may be varied throughout the sample period, which may contribute to different death loss rates over time. The results also imply that cattle source, in terms of both cattle source geographic location and market source type, plays an important role in managing death loss rate. Relative increases in death loss percentage may suggest differences in how feedlots sourced cattle across the data period, which included a significant drought.

Across the data period, the average death loss rate was lowest in 2010 and highest in 2015 (Figure 1). The results imply that increased respiratory disease incidence explains much of the high death loss rate in 2015 at 3.60% as compared to the low death loss rate in 2010 at 1.75% when disease incidence was also lower. In 2015, cattle were placed at heavier in-weights and in smaller pen sizes than in 2010, both of which are shown to be negatively related to death loss rates, but with relatively lower marginal effects than respiratory disease treatments. Figure 3 indicates that cattle were also sourced more heavily from auction barns in 2015 than in 2010, resulting in a pool of cattle likely more susceptible to disease exposure. Together with the model results, these variables help explain the high death loss in 2015.

For future research, it may be helpful to look at the death loss percentage by timing and cause of death. The frequency of treatment received by an animal may also be considered when estimating

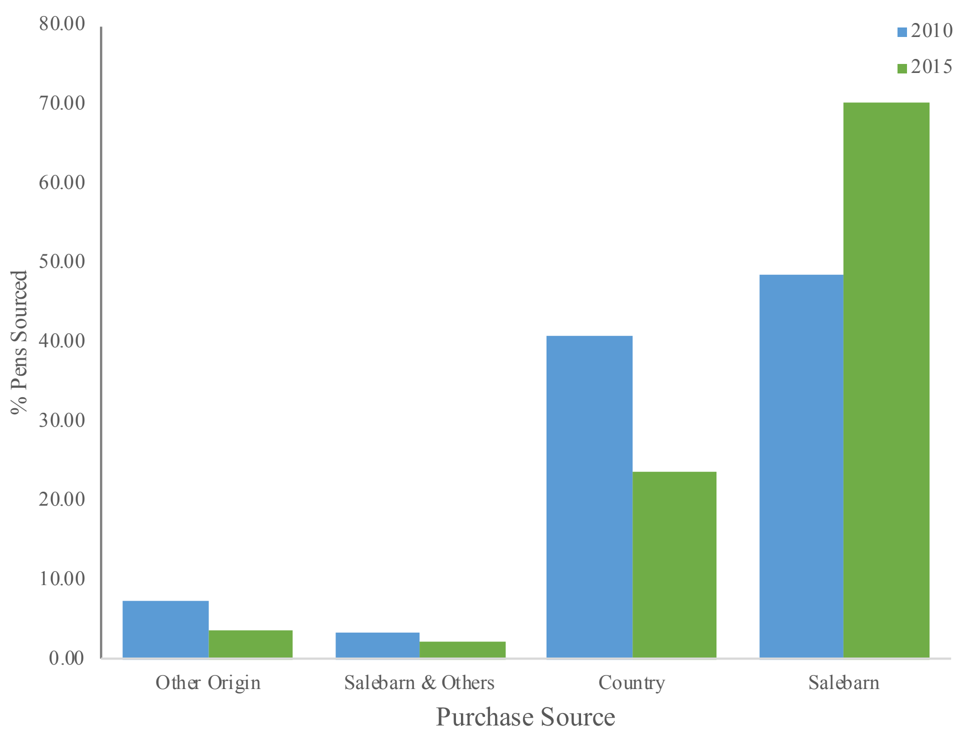

Figure 3. Distribution of Feedlot Cattle Market Source in 2010 and 2015

death loss rate. This study uses only the percentage of cattle treated in a pen and does not explicitly capture the number of treatments per animal. Treatment frequency by head could provide better estimates. Future research could also consider performance measures such as feed to gain ratio and average daily gain, perhaps categorizing death loss by these performance measures to examine the relationship between increased physical performance and death loss.

Death loss, or "percent deads," is only one of many factors that feedlots must balance when making placement decisions. Such factors include a range of other production parameters as well as the availability of cattle by size, capacity utilization needs, and various other market factors. While zero death loss may seem a worthy goal, in reality, feedlot managers make decisions in a constant state of cost-benefit analysis where economic optimization leads to managing for a death loss rate that is "acceptable." An increased understanding of feedlot death loss influences can inform those management decisions.

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NOTE

1. An economically optimal death loss rate may in fact approach zero, but still be positive, based on the marginal costs and benefits of reducing death loss.

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