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A Latent Class Analysis of Stocker Cattle Producer Purchasing Preferences

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The stocker industry plays numerous critical roles in the cattle industry and is the most flexible—yet complicated—segment of the beef supply chain. Stocker producers' calf-purchasing decisions have historically been diverse and difficult to characterize. This study uses data from a unique survey to analyze factors affecting stocker producers' calf-purchasing decisions. Latent class analysis is used to classify stocker producers into subgroups based on cattle-purchasing preferences. Results indicate that stocker producers can be divided into four distinct latent classes according to calf-purchasing preferences.

Key words: beef supply chain, buyer behavior, farm management, livestock

Introduction

The United States is the biggest producer of beef in the world, with the largest fed-cattle industry, producing high-quality grain-fed beef for both domestic and export use (US Department of Agriculture, 2019). In 2017, the value of all US cattle and calves was $103.90 billion, with 93.71 million head (US Department of Agriculture, 2018). The US beef cattle industry is complex and involves diverse production systems utilizing diverse resources around the country (Peel, 2021). Commercial beef cattle production consists of three stages: (i) the cow–calf segment, which produces weaned feeder calves for further grazing and/or feeding; (ii) the backgrounding or stocker phase of production, which includes weaned calves intended for sale as feeder cattle but not yet placed in the feedlot (Peel, 2003); and (iii) the finishing phase, in which cattle are fattened for slaughter.

The second phase, stocker operations, is the focus of this article. Stocker production is defined as "the process of growing and developing calves from weaning weights (450–600 lb) to yearling weights of 700–850 lb when the cattle are ready to enter a feedyard" (Gadberry et al., 2015, p. 9). Stocker cattle production adds value between the cow–calf and finishing phases. (Peel, 2003; Johnson et al., 2010). This phase is focused on increasing calves' frame, weight, and quality using forage-based production systems, while sometimes adjusting stocker cattle feeding periods to adapt to market signals. Tonsor, Hill, and Blasi (2015) found an average daily gain for stockers of 1.77 lb and an average net return of approximately $76.57/head. Both measures exhibited notable variation across producers, reflecting the diversity and flexibility of stocker operation production settings. The stocker phase provides several economic functions in the beef industry, including production

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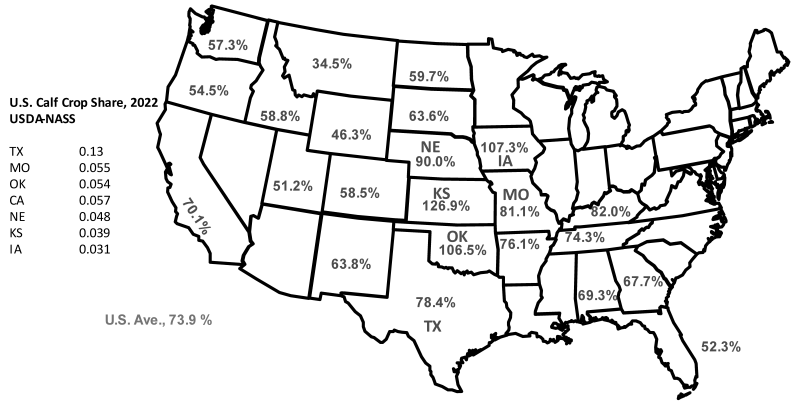


Figure 1. Average Stocker Ratio, January 1, 2013–2022 and 2022 US Calf Crop Share, Selected States

(growing calves), assembly and sorting of cattle into larger marketing groups, changing timing of cattle production, balancing excess forage production, and balancing forage–feed grain markets. In other words, the flexible nature of stocker production provides essential arbitrage for the cattle industry with respect to variability in cattle numbers within and across years, forage conditions, and grain markets. These functions are accomplished across a wide range of production resources and environments with a variety of producers, each of whom may be responding to different stocker production motivations.

The stocker industry generally has two operation scenarios. It may be a component of a cow–calf operation where the producer retains ownership of weaned calves in a post-weaning growing program until those calves are suitable for feed lot placement. The other possibility is that the stocker operation is a separate commercial enterprise (Johnson et al., 2010). As an independent commercial enterprise, stocker operators buy weaned calves, grow them on forage, and sell them to cattle feeders at heavier weights for feedlot placement. Some operators may purchase poorly managed calves and work to upgrade cattle quality and performance after purchase to add value, making them more attractive to possible buyers. Assembling and sorting calves to be sold in larger and more uniform groups adds value as well. Regional differences in forage across the United States determine whether stocker cattle can be grazed seasonally or year-round. In summer grazing programs, cattle may be grazed season-long or placed in pastures at twice the stocking density and marketed earlier. Winter production systems typically employ either perennial or annual cool-season forages, such as small grains pasture (Phillips et al., 2006).

The stocker industry is difficult to define, understand, or even identify and is considered the most flexible and complicated part of the beef cattle supply chain (Peel, 2017). The calf purchase decision is obviously complex. Many factors influence stocker operator decisions, such as market signals in weaned calf and feeder calf markets, cost of inputs such as forage, and weather conditions that affect grass quality and the price of alternatives. Stocker operator decision making represents a range of purchase strategies, production strategies, and risk tolerance. Since little data exist about stocker production and feeder cattle movement around the country, there is limited research regarding the purchasing behavior of stocker producers. One important study is by Tonsor (2018), who used prospect theory to frame purchase decisions of stocker/backgrounder producers in a choice experiment and found that producers tended to make purchase price decisions based on a comparison of predicted performance and their best past performance experience.

The fluid nature of the stocker cattle industry makes it difficult to capture data in standard USDA National Agricultural Statistics Service (NASS) cattle surveys, as those surveys capture data and inventory at a point in time. One proxy of stocker production intensity by state is the ratio of the USDA's January 1 feeder calf inventory to the preceding year's calf crop number. This ratio captures

the percentage of the previous year's calf crop available as feeder supply after replacement heifers, veal slaughter, and feedlot placements are accounted for and is a measure of relative inflow or outflow of weaned calves (Peel, 2003). Kansas, Iowa, and Oklahoma have the highest relative inflow of feeder calves from outside of the state (Figure 1). When US calf crop shares and the stocker ratio are considered together, it implies that Texas, Oklahoma, and Kansas have a significant presence of stocker cattle. In a recent industry-supported survey, 45% of stocker producers indicated that they own and manage the majority of their stocker cattle in Kansas, Nebraska, Missouri, Oklahoma, and Texas (Beef Magazine, 2021). Oklahoma is in the heart of the US stocker industry, with diverse and regionally distinct topography, climate, and forage bases where each quadrant of the state is uniquely comparable to significant parts of neighboring stocker states.

This paper utilizes data from a unique survey of Oklahoma stocker producers to characterize stocker producers based on purchasing preferences, including specific breed of cattle, general animal type (frame or muscling), animal size/weight, certified preconditioned cattle, purchasing or avoiding cattle from specific geographic origins, distance shipped, avoidance of trader cattle, and source/method of purchase (auction or direct).[1] Geographic origin is not limited to in-state purchases. Latent class analysis is used to categorize stocker producers according to the purchasing preferences listed above.

Data

Data are sourced from the 2017 Oklahoma Beef Calf/Stocker Movement Survey, a comprehensive survey of Oklahoma cattle producers conducted by Oklahoma State University in conjunction with USDA's Animal and Plant Health Inspection Service (APHIS) and NASS. The primary objective of the survey was to augment the scarce available data on stocker production, decision making, marketing, and animal movement. The stocker cattle production phase includes many producers who have no breeding herd and specialize in purchasing and growing calves with forage. A producer may have stocker cattle or multiple groups of stocker cattle during the year, may vary how long they graze groups of stocker cattle from a few weeks to several months, and may have no cattle inventory on January 1. While NASS maintains a list of people who own cattle, there is no distinction for stocker cattle producers. Additionally, some cattle producers are involved in the stocker phase as part of their operation but may not self-identify as stockers. To obtain a sample that is representative of the state's population of cattlemen, including stocker producers, we chose to have NASS use probability sampling of the population of Oklahoma cattlemen rather than convenience sampling. The survey contained a series of questions to guide all producers participating in the stocker phase to the appropriate segments. The survey was promoted heavily to the population of producers through existing Oklahoma Cooperative Extension Service newsletters (mail and email) and through newspaper articles, radio spots, Oklahoma Cattlemen's Association publications, producer meetings, conferences, and presurvey postcards. The NASS sample comprised 4,844 survey questionnaires distributed to Oklahoma cattle producers. A total of 1,461 usable surveys were completed via mail or phone, resulting in a 30.2% survey response rate. Of those respondents, 207 identified as specialized commercial stocker producers or as other cattle producers who also incorporate some phase of purchased stocker production within their operation. Based on NASS population sampling and response, the data are statistically representative of the state at a 95% confidence interval. As part of the survey, these Oklahoma stocker operators were asked to rate the importance of nine characteristics of stocker cattle when making a purchase decision. This paper uses these stocker purchase preference data to characterize groups of stocker producers who purchase cattle for their operations.

[1] The phrase trader cattle refers to cattle that are sold multiple times over a short period and are often comingled with cattle from multiple ranches, resulting in increased likelihood of exposure to disease and higher stress levels for the animals.

Table 1. Demographic Characteristics of Survey Respondents

Characteristic	Description	% of Respondents
Region	Northwest	32.8
	Northeast	21.2
	Southwest	24.7
	Southeast	21.3
Education level	High school	29.6
	Vocational, technical, or 2-year degree	14.3
	Bachelor's degree	42.9
	Graduate degree	10.2
	None of these	3.1
Multicounty	Yes	38.9
	No	61.1
Producer age	<25	0
	25–34	8.7
	35–44	12.2
	45–54	15.8
	55–64	33.7
	65–74	18.9
	>75	10.7
Primary operation type	Cow/calf, retain calves through feedlot	3.4
	Cow/calf: and stocker/background calves	34.3
	Cow/calf, sell calves at weaning	19.1
	Stocker/background, retain calves through feedlot	3.4
	Stocker/backgrounder	33.1
	Custom feeder	1.7
	Purebred seedstock	1.7
	Freezer beef	1.7
	Other	1.7
Annual capacity	1–100	26.6
	101–500	39.2
	501–2,500	28.1
	>2,500	6.1

Table 1 reports demographic characteristics of stocker producers, including production region, educational level, single or multiple county operation, age, types of operation, and annual capacity. Respondents are distributed relatively evenly across the state's four quadrants, with 21.2% from the Northeast, 24.7% from the Southwest, 21.3% in the Southeast, and 32.8% from the Northwest. Regarding highest education attained, 42.9% of respondents have bachelor's degrees and 29.6% have high school diplomas, while 14.3% and 10.2% have 2-year degrees or graduate degrees, respectively. Approximately 38.9% of respondents have operations on land in multiple counties. The majority of respondents (63.3%) are 55 and over. Stocker operations are evenly split between primary operation type, where 37.7% of respondents are cow–calf producers who retain ownership of the weaned cattle before they are sold to feedlots and 36.5% operate as a separate commercial stocker operation. Other respondents primarily operate elsewhere in the beef supply chain but occasionally purchase stocker cattle. Operation size is distributed relatively evenly, with 26.6% having annual capacities of less than 100 head, 39.2% having annual capacities of 101–500 head, and 34.2% having annual capacities of over 500 head.

Methods

Latent Class Analysis Model

Latent class analysis (LCA) is often used to identify and describe unobserved subgroups, called latent classes, within a population based on responses to a set of observed indicators, such as a questionnaire response (Lazarsfeld, 1950; Collins and Lanza, 2010). LCA results can be used to classify individuals into their most likely (latent) class, with classes based on a categorical latent variable (LV) (Agresti, 2002). LCA estimates class membership probabilities and item response probabilities. Class membership probabilities represent the probability that an individual is a member of a specific class. Item response probabilities are conditional upon class membership and represent the probability that an individual gives a specific response. Following Porcu and Giambona (2017), the latent class model can be expressed as

$$\text{(1)} \qquad \mathrm{P}(Y = y) = \sum_{c=1}^{C} \gamma_c \prod_{j=1}^{J} \prod_{k=1}^{R_j} \rho_{j,k|c}^{I(y_j=k)},$$

where $I(y_j = k)$ equals 1 when the response to item $y = k$ and 0 otherwise. Let $j = 1, \ldots, J$ be observed categorical items with $k = 1,\ldots, R_j$ denoting response categories; $\boldsymbol{Y}$ and y represent a vector and a particular response pattern; C is number of latent classes, where $c = 1, \ldots, C$; γ_c is probability of membership in latent class c (class membership probabilities), and ρ is item-response probability conditional on latent class membership. In our case, $j = 1, \ldots, 9$ stocker purchase characteristics and $k = 1, \ldots, 5$ response categories reflect the producer's importance ranking of individual characteristics on a scale from 1 (very important) to 5 (not important). Latent class membership probability (γ_c) indicates the probability that a randomly selected producer is a member of a specific latent class. Latent class membership probabilities sum to 1 across classes and are mutually exclusive and exhaustive. Item-response probability reflects the likelihood that a stocker producer in the selected class gives that specific response regarding a specific purchase preference (Law and Harrington, 2016). Item response probability, ρ, expresses the relationship between each factor and each latent class and indicates how well each individual stocker producer can be classified into specific latent classes. Item-response probabilities for a specific characteristic sum to 1 within a class (Collins and Lanza, 2010).

The procedure of determining the number of classes in the LCA is called class enumeration. Multiple tests are used to determine class enumeration, including Bayesian information criterion (BIC), sample-size-adjusted Bayesian information criterion (SBIC), Akaike information criterion (AIC), and consistent Akaike information criterion (CAIC), with smaller criteria values pointing to a better fit (e.g., Yang, 2006; Nylund, Asparouhov, and Muthén, 2007; Dziak, Lanza, and Tan, 2014). Generally, fit index values do not all point to one option and must be jointly considered to decide the number of latent classes. This process illuminates how well classes differentiate among the individuals considered (Law and Harrington, 2016). While the "true" correct class number is not known in any given data analysis, fit indices have been shown to work well in simulation studies.

Multiple-Group Latent Class Analysis

Multiple-group LCA tests whether differences exist in item-response probability or class membership probability across different populations (Goodman, 1974; Collins and Lanza, 2010). Differences in these probabilities can indicate that the latent structure is not the same across the populations tested. For example, there may be interest in whether differences in latent structure exist across production region or producer age. When group variable g is included, both latent class

membership (γ_c) and item-response probabilities (ρ) are conditioned on group, expressed as

$$\text{(2)} \qquad \mathrm{P}(\mathrm{Y}=\mathrm{y}\mid g)=\sum_{c=1}^{C}\gamma_{c\mid g}\prod_{j=1}^{J}\prod_{k=1}^{R_j}\rho_{j,k\mid cg}^{I(y_j=k)}.$$

Lanza et al. (2007) recommended establishing whether item-response probability measurement invariance across groups holds before testing class membership probabilities across different groups. This can be accomplished by comparing fit of two nested latent class models, where Model 1 allows ρ parameters to vary across groups and Model 2 restricts the ρ parameters to be equal across groups. Model fit is compared by the likelihood ratio difference test:

$$\text{(3)} \qquad \left(G_2^2-G_1^2\right)\sim\chi^2_{|DF_2-DF_1|},$$

where H_0 is that item-response probabilities do not differ across groups (Collins and Lanza, 2010). If the null hypothesis is rejected, this implies that latent classes may differ across groups to some extent, and caution is recommended in interpreting group differences in latent class membership probabilities. The ρ parameters in the unconstrained model (Model 1) give a benchmark for interpreting the latent variables regarding the nature and extent of group differences. If the measurement of group differences is severe, it may be beneficial to model groups separately, providing group-specific interpretations of latent classes (Lanza et al., 2007).

Descriptive analysis is used to determine whether demographics impact importance rankings of stocker producers for purchase characteristics. Chi-square tests are used to statistically test independence between individual demographic characteristics and the nine stocker purchase attribute ratings. For example, the chi-square test will indicate whether stocker producer region is independent from their importance rankings of the nine stocker characteristics.

Results

Table 2 reports producer rankings of the importance of the nine stocker cattle-purchase characteristics. Stocker producers were asked to rate the importance of each factor as very important, important, indifferent, slightly important, and not important. Recall that the nine characteristics include specific breed of cattle, general animal type (frame and muscling), animal size/weight, certified preconditioned cattle, purchasing cattle from a specific geographic origin, avoiding cattle from a specific geographic origin, distance shipped, avoidance of trader cattle, and source/method of purchase (auction or direct). Certified preconditioned cattle are managed by producers in a specific protocol verified by a third party before they sell their calves to the next stage, with practices such as castrating, dehorning, administering a health program, longer weaning periods, and vaccinating (Schumacher, Schroeder, and Tonsor, 2011).

Results indicate, not surprisingly, that stocker operators emphasize the physical aspects of calves. Nearly 69% of stocker producers rated specific breed as important and very important, but 15% of them think it is not important at all. More than 90% of stocker producers think general animal type is important in purchase decisions. Similarly, 83% chose animal size and weight as important or very important in their purchasing. Certified preconditioning, a bundle of calf health management practices certified by a third party, is not rated as highly as the physical characteristics in that only 28% of stocker producers consider it important or very important; however, 36% rate it as not important at all. Note that calves may be marketed as preconditioned without third-party certification, so this question captures only buyer preference for certified preconditioned rather than for preconditioned calves overall. Ratings of purchasing or avoiding cattle from a specific origin are comparatively even. Distance shipped of cattle is a relatively important factor in stocker producer purchasing behavior as 63.41% of them consider it important or very important. Stocker producers consider avoiding trader cattle important or very important at a rate of 86%. Source or method of

Table 2. Importance Ratings of Purchase Characteristics in Stocker Purchase Decisions

Description	Value	%	Mean	Std. Dev.
Specific breed	1 = Very important	31.13		
	2 = Important	37.74		
	3 = Indifferent	8.02	2.42	1.4
	4 = Slightly important	8.02		
	5 = Not important	15.09		
General animal type (frame/muscling)	1 = Very important	46.95		
	2 = Important	43.19		
	3 = Indifferent	2.82	1.74	0.948
	4 = Slightly important	3.76		
	5 = Not important	3.29		
Animal size/ weight	1 = Very important	39.72		
	2 = Important	43.93		
	3 = Indifferent	7.01	1.92	1.047
	4 = Slightly important	4.67		
	5 = Not important	4.67		
Certified preconditioned cattle	1 = Very important	10.14		
	2 = Important	17.39		
	3 = Indifferent	21.74	3.49	1.389
	4 = Slightly important	14.98		
	5 = Not important	35.75		
Purchasing animals from a specific geographic region	1 = Very important	20.39		
	2 = Important	25.73		
	3 = Indifferent	15.53	2.97	1.503
	4 = Slightly important	12.14		
	5 = Not important	26.21		
Avoiding animals from a specific geographic region	1 = Very important	24.27		
	2 = Important	22.33		
	3 = Indifferent	14.56	2.9	1.526
	4 = Slightly important	13.11		
	5 = Not important	25.73		
Distance shipped	1 = Very important	23.41		
	2 = Important	40.00		
	3 = Indifferent	16.59	2.46	1.283
	4 = Slightly important	7.32		
	5 = Not important	12.68		
Avoiding trader cattle	1 = Very important	73.43		
	2 = Important	12.08		
	3 = Indifferent	6.28	1.54	1.061
	4 = Slightly important	3.38		
	5 = Not important	4.83		
Source/method of purchase	1 = Very important	25.25		
	2 = Important	36.36		
	3 = Indifferent	22.72	2.4	1.177
	4 = Slightly important	7.58		
	5 = Not important	8.08		

Table 3. Chi-Square Tests of Independence between Producer Demographic Information and Cattle Purchase Characteristics

	Region		Educational Level		Multiple County	
Cattle-Purchase Characteristic	χ^2	***p*-value**	χ^2	***p*-value**	χ^2	***p*-value**
Specific breed	1.32	0.72	10.74	**0.03**	0.00	0.99
General animal type (frame/muscling)	5.72	0.13	5.16	0.27	0.65	0.42
Animal size/weight	0.42	0.94	8.33	0.08	0.20	0.65
Certified preconditioned cattle	11.11	0.01	1.43	0.84	0.95	0.33
Purchasing animals from specific geographic origin	3.36	0.34	2.96	0.57	2.02	0.15
Avoiding animals from specific geographic origin	0.36	0.95	1.30	0.86	1.27	0.26
Distance shipped	1.01	0.80	1.21	0.88	0.30	0.58
Avoiding trader cattle	1.32	0.73	6.22	0.18	2.21	0.14
Source of purchase	0.49	0.92	0.54	0.97	0.12	0.72

	Age		Operation Type		Annual Capacity	
Cattle-Purchase Characteristic	χ^2	***p*-value**	χ^2	***p*-value**	χ^2	***p*-value**
Specific breed	2.01	0.85	8.26	0.41	0.27	0.97
General animal type (frame/muscling)	0.21	0.99	17.21	**0.03**	6.80	0.08
Animal size/weight	2.08	0.84	9.28	0.33	5.73	0.13
Certified preconditioned cattle	8.32	0.14	15.12	0.06	1.39	0.71
Purchasing animals from specific geographic origin	8.55	0.13	13.46	0.097	2.55	0.47
Avoiding animals from specific geographic origin	4.29	0.51	10.19	0.25	4.94	0.18
Distance shipped	1.17	**0.04**	17.51	**0.03**	2.52	0.47
Avoiding trader cattle	2.45	0.78	21.98	**0.01**	9.55	**0.02**
Source of purchase	0.25	0.39	8.64	0.37	1.60	0.66

Notes: Bold values indicate p-values at or below the 5% significance level.

purchase is important or very important to 61.6% of stocker producers. Table 2 reports the mean and standard deviation of importance scores for the nine cattle-purchase characteristics across all stocker producers. In general, the factors that stocker producers consider most important when they purchase cattle are general animal type, animal size and weight, and avoiding trader cattle. The purchase characteristic with the lowest overall importance rating is certified preconditioned cattle.

Independence Test between Demographics and Factor Importance Ratings

Table 3 reports the results of the chi-square tests used to determine whether producer ratings of importance for the nine purchase characteristics are independent across six demographic categories, including production region, educational level, single or multiple counties, age, type of operation, and annual capacity. Across the possible 54 interactions, the null hypothesis of independence of importance ratings is only rejected for six interactions, including producer region and certified preconditioned cattle ($chi^2 = 11.11$, $p = 0.011$), breed and producer education level ($chi^2 = 10.74$, $p = 0.030$), stocker producer age and distance shipped ($chi^2 = 1.17$, $p = 0.045$), operation type and general animal type ($chi^2 = 17.21$, $p = 0.028$), operation type and distance shipped ($chi^2 = 17.51$, $p = 0.025$), operation type and avoiding trader cattle ($chi^2 = 21.98$, $p = 0.005$), and annual capacity/operation size and avoiding trader cattle ($chi^2 = 9.55$, $p = 0.02$). The results imply that importance ratings are relatively independent of influence from the demographic factors considered. Not surprisingly, the demographic factor with the most influence on ratings is operation type.

Table 4. Latent Class Model Enumeration Fit Indices for 5-Point and 2-Point Scales

Number of Classes (k)	Log-Likelihood	Akaike Information Criterion (AIC)	Bayesian Information Criterion (BIC)	Consistent AIC	Sample-Size Adjusted BIC	Entropy
5-point						
1-class	−2,468.25	2,847.11	2,967.09	3,003.09	2,853.02	1.00
2-class	−2,341.64	2,667.89	2,911.18	2,984.18	2,679.88	0.90
3-class	−2,257.13	2,572.88	2,939.48	3,049.48	2,590.95	0.87
4-class	−2,199.14	2,530.89	3,020.80	3,167.80	2,555.04	0.88
5-class	−2,186.39	2,579.40	3,192.68	3,376.63	2,609.63	0.89
2-point						
1-class	−1,025.98	461.43	491.42	500.42	462.90	1.00
2-class	−940.58	310.62	373.94	392.94	313.74	0.78
3-class	−918.63	286.73	383.38	412.38	291.50	0.81
4-class	−905.83	281.13	411.11	450.11	287.54	0.77
5-class	−895.54	281.55	443.85	492.85	288.60	0.79

Notes: Values in bold are the "best" fit for each respective statistic. Entropy is an omnibus index where values > 0.80 indicate "good" classification of individual cases into classes.

Class Enumeration

Exploratory LCA models are estimated using MLE in SAS 9.4. To facilitate class enumeration of stocker producer importance ratings for cattle purchase characteristics, models are estimated for up to five classes. Class enumeration models were estimated for the original data's 5-point importance scale and for a 2-point scale rating, where the Important group includes 1 (very important) and 2 (important). The other three importance ratings of 3 (indifferent), 4 (slightly important), and 5 (not important) are placed in the Unimportant group. Table 4 reports class enumeration results for the 5-point (1–5) and the 2-point (1–2) scales.

According to the class enumeration literature, smaller criteria values indicate a better fit. In Table 4, smaller values for each information criteria are bolded to indicate best fit. Model fit results for the 5-point and 2-point scales are consistent. BIC and CAIC statistics point to the two-class latent class model, while the AIC and SBIC statistics indicate the four-class model. Since Nylund, Asparouhov, and Muthén (2007) indicate that the BIC underestimates the number of classes when samples are small, the SBIC is preferred here due to the relatively small sample size. Overall, four-class enumeration is concluded to be the best fit for both the 5-point scale data and the 2-point scale data.

We examine whether differences in latent class structure exists among regions of the state by adding Region to the four-class model as a grouping variable. This is of particular interest in Oklahoma, given the distinct climates and topography across the four quadrants of the state. Oklahoma, defined as a geographic transition zone, is geographically and climatically diverse with variation in vegetation that represents a wide range of cattle production environments (Tyrl et al., 2007). The state contains ten distinct ecological regions, more per square mile than any other state. Oklahoma climate varies from humid subtropical in the southeast, with annual average precipitation of 56 inches, to semi-arid in the northwest, with only 17 inches of annual average precipitation. Elevation also changes significantly from southeast (272 feet) to northwest (4,978). Oklahoma's topography transitions east to west from mountains to rolling prairie to southern plains and high plains. The results could also be interesting beyond the border, given the geographic similarities of different state quadrants to specific neighboring stocker states. To test whether item-response probabilities differ across regions, Model 1 is estimated with unrestricted parameters and again with parameters constrained to be equal across regions. The resulting G^2 statistic of 123.27 is distributed

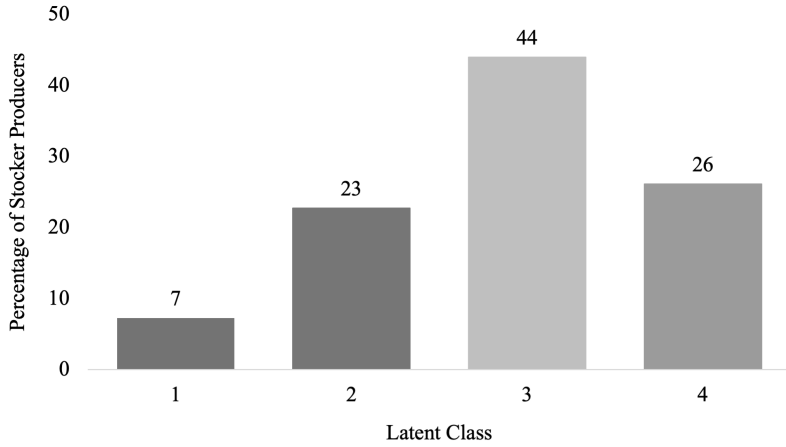


Figure 2. Latent Class Membership Probabilities for Stocker Operators Based on Purchasing Preferences

χ^2_{108}. The p-value of 0.15 indicates that we fail to reject the null hypothesis that item-response probabilities, and thus latent class structures, are equal across region. This does not suggest that class membership or item response is equally distributed across regions but rather that a specific producer's item-responses—here, importance ratings of the nine stocker purchase preferences—would result in the same class membership probability, regardless of region.

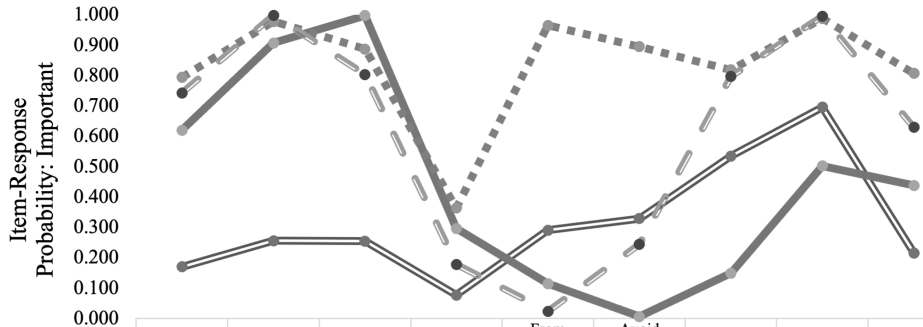
Interpreting Latent Class Analysis

LCA suggests that stocker producers can be divided into four classes based on purchase preferences. Since results for class enumeration are consistent for the 2-point and 5-point scale data, latent class membership probabilities (γ_c) and item-response probabilities (ρ) are estimated for the four-class model using 2-point scale data for easier interpretation and explanation of results. Figure 2 illustrates the percentage of producers in each latent class. Class 1 has the lowest membership at 7.25%, while Class 3 has highest percentage of producers at 43.96%. Classes 2 and 4 have a similar prevalence of producers at 22.71% and 26.09%, respectively.

Item-Response Probabilities

The item-response probabilities, illustrated in Figure 3, can be used to characterize membership within a specific class and highlight similarities and differences that distinguish the classes. Stocker producers in all four latent classes have high probabilities of avoiding trader cattle, with probabilities of deeming it important ranging from 0.50 to 0.99. Source of purchase indicates where producers buy calves, for example, from live auction or through other methods. Stocker producers' importance ratings fall across the spectrum on this characteristic. Classes 3 and 4 consider source of purchase to be important, at probabilities of .81 and .63, respectively. Meanwhile, Class 1 and 2 stocker producers consider source to be important at lower rates of .22 and .44, respectively. While research and extension efforts promote preconditioning calves prior to marketing, stocker producers across all classes exhibit relatively low probabilities of rating preconditioning as important.

One interesting distinction is the differing levels of importance that groups of stocker producers place on the physical characteristics of cattle. Here, producers in Classes 2, 3, and 4 have high probabilities of rating the physical characteristics of cattle as important with size/weight at 0.99, 0.89, and 0.80, respectively, and animal type at 0.91, 0.98, and 0.99, respectively. The pattern of probabilities is similar for cattle breed. Producers in Classes 2, 3 and 4 also have a relatively high probability of rating cattle breed as important at 0.62, 0.79, and 0.74, respectively. Meanwhile,



	Breed	Cattle type	Size/weight	Certified pre-conditioned	From specific geographic origin	Avoid specific geographic origin	Distance shipped	Avoid "trader" cattle	Purchase source
C1 - Risk Taker	0.171	0.257	0.255	0.078	0.291	0.329	0.535	0.697	0.217
C2 - Amazon Shopper	0.620	0.908	0.998	0.297	0.115	0.007	0.150	0.503	0.439
C3 - Risk Avoider	0.794	0.978	0.887	0.364	0.965	0.896	0.819	0.989	0.807
C4 - Upscale Shopper	0.743	0.999	0.804	0.179	0.024	0.245	0.798	0.996	0.630

Purchase Preference Attributes

Figure 3. Item-Response Probabilities for "Important" across Stocker Purchase Characteristics and Latent Classes

Class 1 producers have relatively low probabilities of rating breed (0.17), animal type (0.26), and size/weight (0.26) as important. They are also not likely to rate purchasing from or avoiding a specific region or purchase source as important at 0.29, 0.33 and 0.22, respectively. In fact, the only factors for which Class 1 producers exhibit a probability of more than 0.50 of rating as important are avoiding trader cattle and distance shipped, making them perhaps the most distinctive class among the four. Overall, these stocker producers are not picky about the details. Since stocker producers in Class 1 seem to be the least risk averse, we label Class 1 as the "Risk Taker" group. Note that Class 1 has the smallest membership, at 7.5% of stocker producers.

In stark contrast, Class 3 producers exhibit high probabilities of rating each characteristic as important, except for certified preconditioned cattle, which at 0.36 is their only probability below 0.80 and is the highest probability of a rating of important across all groups for certified preconditioning. Class 3 producers are also the only class that exhibits a high probability of rating purchasing cattle from a specific source as important, at 0.97, as compared to the other classes where that probability is 0.29 and below. Geographic region of origin of stocker calves is obviously considered important by producers in Class 3, as the pattern of exhibiting the highest probability among classes also holds for avoiding specific regions of origins when purchasing stocker cattle. Thus, we label Class 3 as the "Risk Avoider" group. Recall that it is the largest class at approximately 44% of producers.

Classes 2 and 4 both have high probabilities of rating specific breed, animal type and the size/weight important; that is, they place much importance on the physical characteristics of the cattle. Interestingly, both Class 2 and 4 rate the importance of sourcing from a specific geographic origin as relatively unimportant, but Class 4 producers have a higher probability of stating that avoidance of a specific region is important (0.25), whereas Class 2 producers place nearly no importance on avoiding a specific region (0.007). However, Class 4 producers are more likely than Class 2 producers to rate the distance shipped of cattle, avoiding trader cattle and the cattle source to also be very important. Class 2 producers care primarily about physical attributes when they purchase cattle, without other strong preferences. Class 2 is the least likely to place importance on avoiding trader cattle, though that probability is still at 0.50. Producers in the other three classes are significantly more likely to place importance on avoiding trader cattle. We describe Class 2 as the "Amazon Shopper" group, as they care more about the type and function of the cattle but less about where they were sourced or the sale venue. They want what they want regarding physical

Table 5. Estimated Probabilities of Class Membership for a Sample of Individual Stocker Producers (N = 1–10)

	Cattle Purchase Attribute Importance Ranking 1 = Important, 2 = Not Important									Class Membership Probability				
ID	Breed	General Animal Type (frame/muscling)	Size/Weight	Certified Pre-Conditioned	Specific Geographic Region	Avoid Geographic Origin	Distance Shipped	Avoid Trader Cattle	PurchaseSsource	Class 1 Risk Taker	Class 2 Amazon Shopper	Class 3 Risk-Avoider	Class 4 Upscale Shopper	Best Class Fit
1	2	2	2	2	2	2	2	1	2	0.999	0	0	0	1
2	2	1	1	2	1	1	2	1	.	0.018	0.002	0.973	0.007	3
3	1	1	1	1	2	2	2	1	1	0	0.687	0.007	0.305	2
4	1	1	1	2	2	1	1	1	1	0.001	0.001	0.203	0.795	4
5	2	2	1	2	2	2	2	2	1	0.186	0.814	0	0	2
6	2	1	1	1	1	1	1	1	1	0	0	0.998	0.002	3
7	1	1	1	1	1	1	1	1	1	0	0	0.999	0.001	3
8	1	1	1	2	1	1	1	1	1	0	0	0.996	0.003	3
9	1	1	1	2	1	2	1	1	1	0.001	0.022	0.894	0.082	3
10	2	1	1	2	1	2	2	1	2	0.121	0.754	0.092	0.032	2

cattle attributes but exhibit flexibility regarding where those cattle actually come from. Class 4 is consistent with Class 2 in regarding physical attributes of cattle as important, but Class 4 producers place some importance on cattle geographic attributes and market source. We label Class 4 as the "Upscale Shopper" group. These stocker producers also want specific physical cattle characteristics but, unlike the Amazon Shoppers of Class 2, the Upscale Shoppers of Class 4 also have preferences about where those cattle come from. Note that Classes 2 and 4 are similar with respect to class size, given the likelihood of producer membership at approximately 23% and 26%.

Probability of Class Membership for an Individual Stocker Producer

The procedure PROC LCA (Lanza et al., 2007) can be used to predict class membership for an individual stocker producer. To illustrate the class selection process, Table 5 shows importance ratings from the first ten stocker observations in the original data along with estimated probabilities for specific class membership. For example, the first stocker producer in the sample responded to all items as unimportant, with the exception of avoiding trader cattle. These preferences place stocker producer 1 in Class 1 as a Risk Taker with 0.999 probability. That is, the best estimate is that this stocker belongs to Class 1. Other stocker producers can be categorized using the same kind of rule, where they are placed into the class for which they exhibit the highest probability of class membership, based on item responses.

Demographic Distributions within Classes

Figure 4 illustrates latent class membership by region. Stocker producers classified as Risk Avoiders (Class 3) are the dominant class by region, excluding the Southwest. While Class 3 represents just over 40% of stocker producers in the Northeast, Northwest, and Southeast regions, only 24% of stocker producers in the Southwest region are considered Risk Avoiders. In fact, the Southwest region exhibits the most distinct latent class membership patterns relative to the statewide

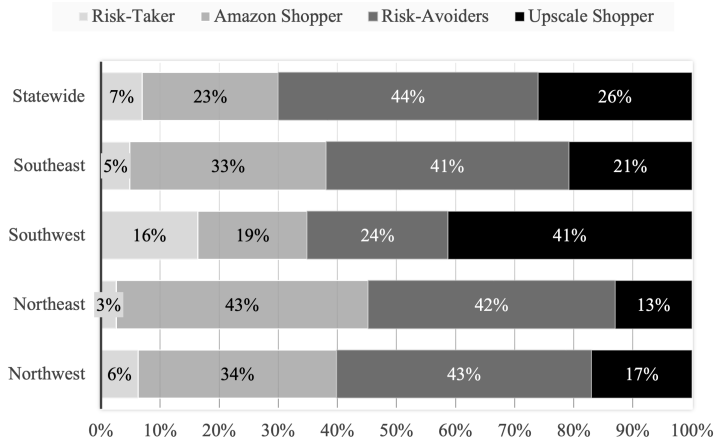


Figure 4. Class Membership Probabilities by Region

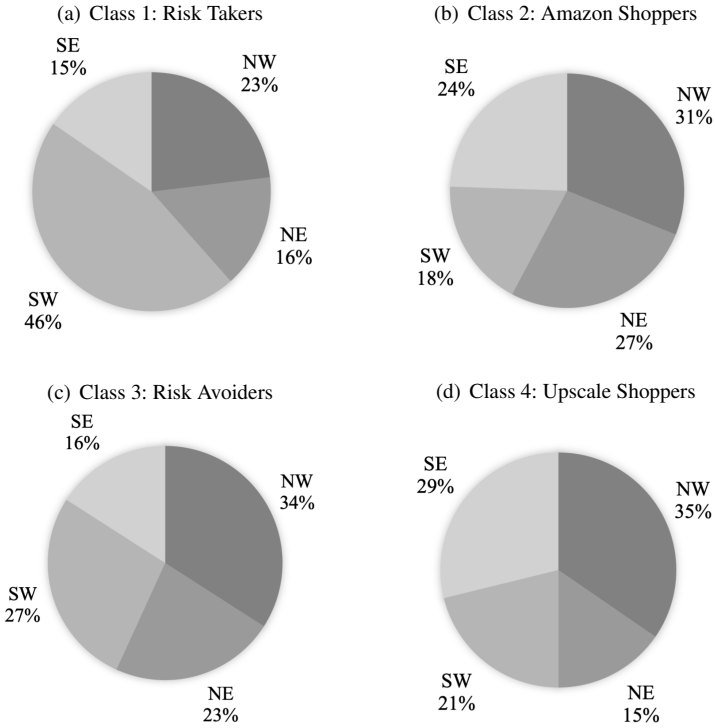


Figure 5. Distribution across State Quadrants within Latent Classes

distribution. While the proportion of Risk Takers (Class 1) is relatively small statewide at only 6% of producers, the Southwest region has the highest proportion of stocker producers described as Risk Takers (16%). Producers labeled as Upscale Shoppers (Class 4) comprise 41% of producers in the Southwest region compared to 21% or less in the other three regions. Oklahoma's Southwest region arguably has the most unpredictable weather and, thus, highly variable forage availability and forage quality, all of which make stocker production inherently riskier and may play a role in the distinctiveness of the region's latent class membership patterns. The Northeast region is nearly dichotomous, with most producers classified as either Amazon Shoppers (43%) or Risk Avoiders (42%).

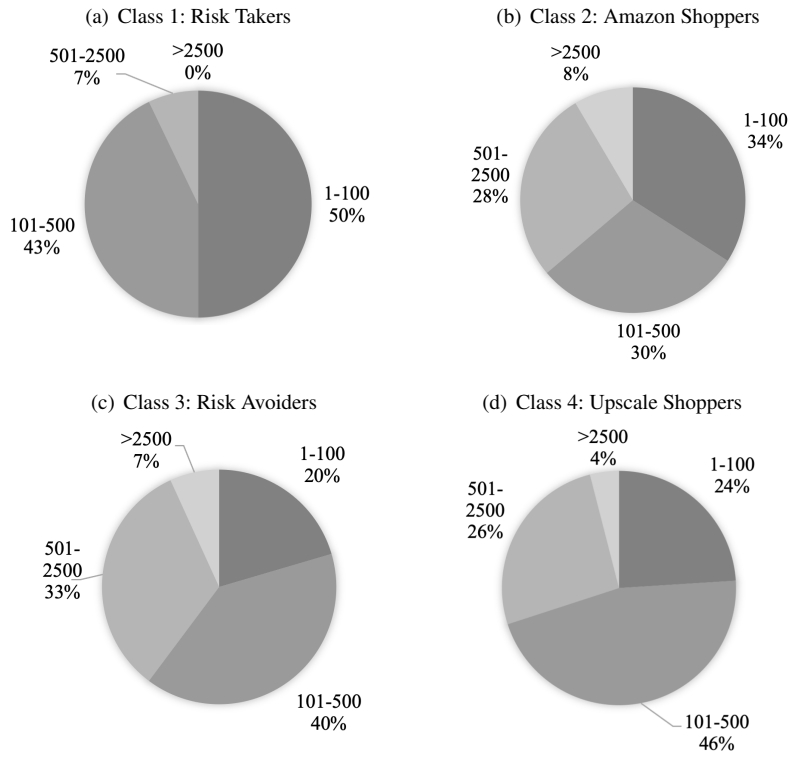


Figure 6. Distribution of Annual Capacity within Latent Classes

Demographic distributions within classes also raise some interesting points of discussion. Figure 5 reports class distribution across regions for each latent class identified by the model. Recall that the latent classes are of varying sizes, with Class 1 (Risk Takers) being the smallest at 7% of producers, followed by Class 2 (Amazon Shoppers) at 23%, Class 3 (Risk Avoiders) at 44%, and Class 4 (Upscale Shoppers) at 26%. Of the 7% of producers described as Risk Takers, nearly half are in the Southwest region. The rest are relatively evenly distributed across the other three regions. In contrast to Risk Takers, Class 2 (Amazon Shoppers, 23% of total producers) has only 18% of its membership comprised by producers from the Southwest region. Class 2 contains relatively more producers from the Northwest (31%), Northeast (27%), and Southeast (24%) regions. Roughly one-third of Risk Avoiders and Upscale Shoppers (34% and 35%, respectively) are from the Northwest region. Class 4's (Upscale Shoppers) highest proportion of producers is from the Southeast (29%) region, and the Northeast region nrepresents the smallest proportion within the class (15%).

Figure 6 illustrates capacity distributions within each class. Interestingly, Class 1 (Risk Takers) comprises 50% small (1–100 head) operations, 43% medium (101–500 head) operations, 7% large operations (501–2,500 head), and no very large operations (> 2,500 head). Class 2 (Amazon Shoppers) has the largest percentage of very large operations (8%) and contains fewer small and medium operations (34% and 30%, respectively) compared to other classes. One-third of Class 3 (Risk Avoiders) producers are large operations, the highest of the four classes. Almost half of Class 4 (Upscale Shoppers) producers (46%) are medium operations.

In Figure 7, age distributions are similar among the four classes, except for the Risk Taker class, which has no producers younger than 34 years old. This is intuitive, as younger producers are more likely highly leveraged and thus more financially vulnerable. Figure 8 reports producer education distributions; again, distributions are similar among classes except for the Risk Taker class. There are no producers with a graduate degree in the Risk Taker class, and this class contains the highest proportion of producers with a high school diploma as the highest level of education attained. Class 3

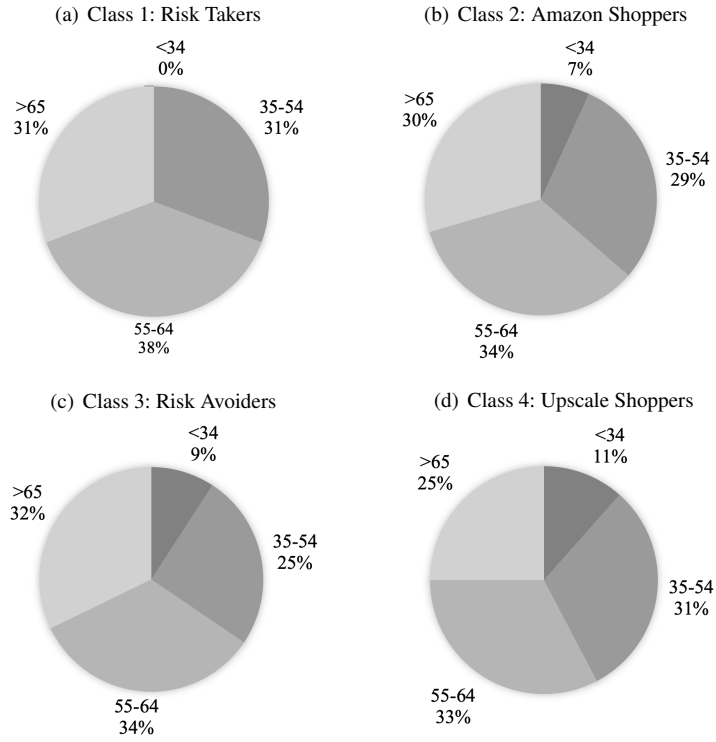


Figure 7. Distribution of Producer Age within Latent Classes

(Risk Avoiders), on the other hand, has the highest proportion of producers with a graduate degree, while Class 4 (Upscale Shoppers) has the highest proportion of producers whose highest level of education is a bachelor's degree.

The lack of importance of certified preconditioning programs among stocker producers may be somewhat surprising at first glance. While certified preconditioning programs are promoted heavily and research indicates market premiums for such cattle (Avent, Ward, and Lalman, 2004; Williams et al., 2012), the majority of stocker producers in this study place less importance on it than on other purchase characteristics. Historically, some stocker producers, specifically risk takers, have been motivated to earn a return by purchasing mismanaged cattle and upgrading them, thus providing the health management included in preconditioning programs. Other stocker producers may consider preconditioning in general to be important, as cattle can be marketed as preconditioned without having third-party verification, but either trust the credence information provided or are unwilling to pay an additional premium for third party verification. Stocker producers in this survey were asked only about certified preconditioning, rather than preconditioning in general.

Conclusions

The stocker segment of the cattle industry adds critical economic flexibility to the beef supply chain, yet it is the least documented and least understood segment. The stocker segment includes a vast array of arbitrage activities across cattle markets and forage/feed grain markets (Peel and Riley, 2018). It is also an inherently risky margin business. Anecdotal evidence from the industry has long suggested that stocker producer strategies vary greatly and that flexibility with respect to those strategies varies greatly as well. This variation and flexibility in strategy is what allows the stocker phase to fulfill its industry role.

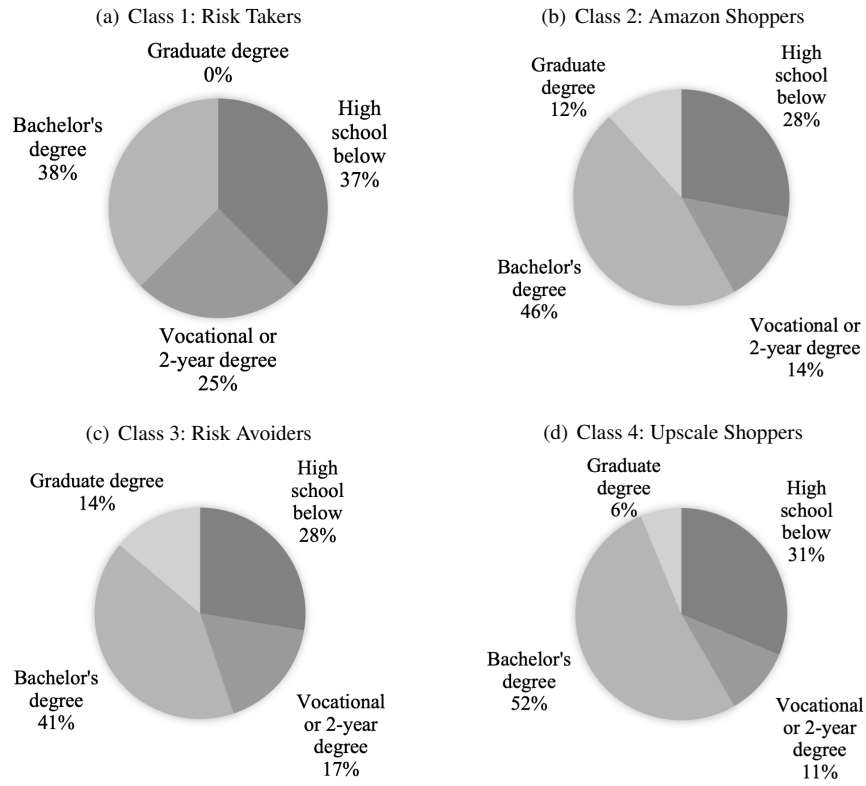


Figure 8. Distribution of Producer Education Groups within Latent Classes

One aspect of strategy is calf-purchase preferences. This study uses unique data to document differing stocker purchase strategies with respect to calf attributes. While the stocker sector collectively provides a wide range of production and economic functions, individual producers frequently focus or specialize on specific activities based on their individual risk preferences, financial situation, resources available, and production environments. Some stocker producers emphasize animal production with high-quality animals, some focus on upgrading "bargain" cattle, some have fixed resource bases that limit them to seasonal production and a specific calf type, and others have multiple and variable forages sources that permit a wide variety of stocker production enterprises and a greater ability to react to variable market conditions. Additionally, when making purchase decisions, producers likely incorporate their assessment of predicted animal performance based on attributes compared to their own best outcomes from past purchases (Tonsor, 2018). This study's results place stocker producers into one of four latent classes, described here as Risk Takers, Risk Avoiders, Amazon Shoppers, and Upscale Shoppers. These groupings illustrate divergent strategies in purchase preferences, representing only one aspect of the flexibility necessary for the stocker sector to fulfill its role in the beef supply chain.

Stocker production occurs in numerous locations in the country and utilizes a wide range of production environments and types of resources. Oklahoma's geographic and climatic variability is representative of stocker production in many other regions of the country. The analysis presented here is based on a survey that encompasses a diverse set of stocker producers representing a wide range of stocker enterprises. Arguably, the four latent classes of producers identified here based on variable stocker purchase preferences are indicative of the range of stocker production enterprises across the country.

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