nature food

Supplementary information

https://doi.org/10.1038/s43016-026-01300-9

Distinct worldviews determine how meat producers navigate competing sustainability priorities in the United States

In the format provided by the authors and unedited

CONTENTS

Supplementary Discussion 1: Example interpretation

In developing an outreach campaign on animal welfare, one could look across statements related to animal wellbeing to assess which strategies might be met with full or partial consensus and which areas are low, medium, and high priorities for different groups. This exercise would yield findings such as: (i) Statements 21, 28, 18, and 34 do not have consensus. S28 (“Ensuring animals are respected and happy”) is a very high priority for AH and ES and a lower priority for BV. (ii) S12, about responsible use of vaccines and antibiotics, and S26, about optimal animal rations, are not particularly high priorities for any group, but least of all for ES. (iii) S9 (“Showing the public that production is safe and humane”) has consensus among all three groups as a moderate priority, and S32, “Ensuring the health of animals,” is a high priority for all three groups but is especially motivating for AH.

Supplementary Discussion 2: Strengths and limitations

Q methodology combines rigorous quantitative analysis with qualitative context to illuminate the complexity of subjective viewpoints. The forced-choice nature of the method encourages participants to express nuanced opinions on sensitive issues without feeling pressured to provide socially desirable responses. Limitations to the method include those related to the completeness of the statement set in covering the full range of views on a topic, and the diversity of participants recruited to represent a breadth of perspectives. In this study, the statement set was derived from interviews with experts and from well-evidenced frameworks on sustainability priorities in animal agriculture. Although all statements were designed to be species-neutral, portraying a full spectrum of sustainability priorities necessitated inclusion of some statements that were better aligned with certain scales (e.g., S14) or types (e.g., S26) of production). The participant sample covered a wide diversity of production types, scales, and geographies, but would have benefited from more large- and very large-scale producers, particularly of broilers. Despite this limitation, we were able to identify strikingly distinct worldviews among groups of meat producers that crossed traditional boundaries of scale and species, and to explore the forces driving tradeoffs between different sustainability priorities.

Supplementary Methods 1: Full methods

Concourse development

Concourse development was based on key informant interviews (KIIs) conducted with 14 industry and value chain stakeholders across beef, pork, and broiler industries. Interviewees included representatives of trade associations (5), producers and other supply chain entities (4), consumer-facing companies (3), and consultants (2). The KIIs followed a semi-structured interview guide in which interviewees were asked to discuss what they perceived to be key significant environmental impact and animal wellbeing priorities within their industries overall and for producers specifically. Interviewees were also invited to discuss other priorities beyond environmental impact and animal wellbeing (e.g., economic and other social considerations), and were asked to reflect on what they perceived as consumer priorities on these topics, including areas of alignment or misalignment between producers and consumers, and sources of trust or mistrust. Interviews also touched on drivers of producer decision-making, including the influence of tradeoffs and market pressures. KIIs were approximately an hour long and conducted via Zoom by the same trained interviewer. Thirteen interviewees provided verbal consent to have their interviews recorded. One interviewee declined to be recorded, and a member of the study team took notes instead.

Transcribed recordings and interview notes (for the interview that was not recorded) were coded in Dedoose. The codebook consisted of 18 codes representing different aspects of sustainability, developed based on review of industry standards, sustainability assessment metrics, an animal wellbeing conceptual framework, and current producer commitments related to animal handling[37-40]. Codes were distributed across economic, environmental, and societal pillars of sustainability with deliberate enrichment for environmental (8 codes) and animal welfare (3 of 6 societal codes) considerations. To evaluate the reliability of the codebook, two interviews were coded separately by two members of the study team. Double-coding was cross-checked and codebook definitions were adjusted accordingly. A third interview was then double-coded using the revised codebook to ensure codes were applied consistently prior to coding the remainder of the KIIs. Coded KII excerpts were extracted to yield a total of 538 statements, with a diversity of statements for each code. This collection of statements encompassing the breadth of expressions on the study topics comprised the study concourse.

Q set development and refinement

The concourse excerpts were systematically winnowed and refined to arrive at a representative set of statements (the Q set) describing producer-relevant sustainability priorities that could be sorted against one another. Through four initial cycles of refinement, concourse excerpts were evaluated and excluded from further consideration if they did not describe a priority (e.g., if they were about specific practices), were not within a producer's purview, were species-specific, were too broad or narrow, were compound (i.e., describing multiple priorities together), described tradeoffs, could not be sorted against other statements, or duplicated other statements (in which case the clearest excerpt was retained and duplicates were excluded). Concurrently with this process, retained excerpts were rephrased where necessary to improve clarity and were further

categorized to capture subthemes that emerged within codes. For example, “land stewardship” and “farmland preservation” emerged as subthemes within the “land” code, and statements reflecting each were retained through the refinement process in order to preserve these distinct priorities within the final Q set.

After four initial cycles of refinement, 79 possible Q statements remained. These were cross-checked against the 3 pillars of sustainability and 18 codes, all of which were represented. At this stage it was noted that the majority of statements addressing economic sustainability framed it as part of the rationale for prioritizing or de-prioritizing other (environmental or societal) sustainability considerations and decisions. Because such cross-linking between priorities would not allow them to be cleanly sorted against one another, explicitly economic statements were excluded from the set of possible Q statements, and instead “economics” was included as a potential decision-making driver explored in the post-sort interview (see *Q sort procedure*, below). However, a number of statements that were not explicitly economic yet fit broadly within the concept of economic sustainability of a farm business (e.g., those addressing risk mitigation and operational viability) and that did not exhibit cross-linking were retained. Remaining statements underwent three additional cycles of refinement, with exclusion criteria similar to the first four cycles, to yield a pool of 45 possible Q statements distributed across all 18 codes. The wording of these 45 statements was further refined so that each was a succinct statement of priority with a consistent format across the set (e.g., “increasing water use efficiency” and “ensuring the health of animals”).

The 45 possible Q statements were then piloted in mock Q sorts, three conducted with members of the study team and three with individuals external to the study team (a small-scale beef producer, a small-scale diversified producer, and a pork industry representative). Through these mock Q sorts the possible Q statements were further refined for clarity based on participant feedback, and an additional seven statements were removed that did not work well during the mock sorting exercise (e.g., statements that pilot participants found inactionable, confusing, or redundant with others). The result was a final Q set of 38 statements distributed across all 18 original codes, but enriched for statements pertaining to environmental impacts (12 statements) and animal wellbeing (13 statements) (Fig. 1a). The six mock Q sorts also served as a means for refining the sorting methodology and interview guide based on pilot participant feedback, with adjustments made to improve the clarity of instructions and flow of activities.

P set recruitment

Minimum participant inclusion criteria were individuals age 18 or older who were farm owners, operators, or other cognizant representatives of operations actively producing beef, pork, and/or broilers in the U.S. Because in Q methodology the participants are considered the variables and *not* the sample (the sample is comprised of the participants’ sorts), best practices suggest the inclusion of a limited number of participants[41], expected to represent the diversity of perspectives on a topic. In the present study, therefore, participants were selected to maximize variation in scale, geographic location, and species (Supplementary Tables 1 and 2). Participant recommendations were solicited from the study’s advisory committee (consisting of animal agriculture and consumer-facing industry representatives across species, scales, and sectors),

KII interviewees, and study team members. Additional recruitment outreach was conducted via network nodes (e.g., state veterinarians, industry stakeholders, listserv managers), species-specific industry organizations, and targeted snowball sampling.

Recruitment materials included a brief study description; information about format, time commitment, and compensation; and a link to an intake survey where potential participants could indicate their interest and provide an email address so that the study team could contact them. The intake form also asked for a farm/operation name and state, and for a brief description of the farm/operation (e.g., size, species, other key information they wished to share). This information allowed the study team to select participants for maximum variation across the criteria described above. All participants selected for the study were contacted by email. The participant invitation email included a link to schedule an interview and also repeated the recruitment information described above. Once participants had scheduled an interview, they received a virtual meeting invitation with an access link and informed consent language via email to examine prior to participating in the Q sort. Informed consent language included a description of the study purpose, procedures, compensation, risks, and benefits.

A total of 63 potential participants were initially contacted, 42 of which resulted in successful scheduling of interviews. After conducting the Q sort interviews (see *Q sort procedure*, below), four of these participants were determined to be ineligible, either because they were not actively farming or were from the same operation as a previous participant. These participants' data were excluded from analysis, yielding a usable P set of 38 (Supplementary Table 1).

Q sort procedure

Each Q sort interview was conducted using the Q Method Software online platform and administered virtually via Zoom by the same trained facilitator, accompanied by a second member of the study team as a notetaker. The facilitator followed a consistent interview guide with all participants. Following introductions and a description of the study and procedure, the facilitator confirmed that the participant had received, read, and understood consent language sent beforehand via email, repeating the information if necessary. The facilitator then asked the participant for approval to audio record the interview so that the study team could accurately capture the participants' explanations and discussion. All participants agreed to the audio recording. Prior to beginning the sorting exercise, participants were asked to describe their operation and their role within it. The facilitator probed to determine/confirm farm location (state), species raised, farm size (in head or animal units), primary customer (e.g., direct-to-consumer, wholesale, etc.), and the participant's role (e.g., owner, operator, manager).

In the sorting phase of the interview, the facilitator first explained what to expect, then told participants that after completing the sorting exercise they would be asked what factors drove how they ranked highest and lowest priorities. Participants were provided with a list of potential drivers (described as "influences") both verbally and in the Zoom chat, and asked to keep them in mind as they sorted but not to feel constrained to the list, and to share any others that were relevant for them after the sorting exercise. The listed influences were:

- REGULATORY (e.g., governmental mandates on manure storage)
- INDUSTRY/BUYER (i.e., customer purchase stipulations)
- CONSUMER/EATER (i.e., general public demands)
- OPERATION/BRAND (i.e., values pertaining to the brand of the product, company pressures)
- PERSONAL (i.e., values pertaining to the producer's personal perspectives)
- ECONOMIC (i.e., pertaining to the need to be financially stable)

Participants next completed a pre-sort, in which they read each Q set statement and provisionally categorized it as a "lower," "moderate," or "higher" priority within the online platform, providing comments and asking questions as needed. After the pre-sort, the main sorting exercise commenced, in which participants moved statements from the provisional categories to a pyramidal grid with 13 columns (Supplementary Fig. 1), in which the far-right column received their highest priorities, while the far-left column received their lowest priorities. It was explained that only horizontal positioning mattered (i.e., statements in the same vertical column would receive the same scores).

Prior to beginning this sort, each participant received the following condition of instruction: "Go ahead and read each statement. When it comes to the current decisions you make on your operation, rank the statements appropriately to reflect your lowest, moderate, and highest priorities." Because of the shape of the grid, more spaces were available for moderately-ranked statements than for higher and lower priorities, and it was explained that while participants may well consider all or most statements to be priorities, for the purposes of this exercise not all priorities can receive the highest rank. It was also emphasized that although a participant may personally value a priority, they were to rank based only on their current ability to actually prioritize the statements on their operation, not their aspirational goals. Participants were encouraged to discuss their decision-making processes while they sorted statements. Participants did not encounter any significant technical challenges with the online platform.

Once participants had sorted all statements (filling the grid), and were satisfied that the completed sort reflected their current operational priorities, a 4-question post-sort interview was conducted in which participants were asked about their experience sorting the Q-set, to expand on the drivers that influenced their sorting decisions, and to consider how their prioritization would have changed without any constraints. Question 1 asked for an open-ended reply of initial reactions to the Q-sort exercise: *"So what did you think?"* Question 2 reiterated the six drivers emphasized in the beginning of the interview and then asked explicitly what drives the higher prioritization of statements in their last four columns of the sort: *"Looking at these 4 columns, or your highest priorities, what drives this prioritization?"* Question 3 asked for the influence of the same drivers on the lower prioritization of statements: *"Looking at these last four columns, or your lowest priorities, what drives this ordering?"* Finally, Question 4 asked for producers to describe their hypothetical ideal prioritization of the Q-set in the absence of external drivers: "*In an ideal world, and keeping within this grid, without any of these influences putting pressure on you, would you have sorted these priorities differently?"* The post-sort interviews allowed producers to freely

share the influences and tradeoffs of their decision-making, allowing the interviewers to both explore emerging topics and probe for drivers.

Before concluding the interview, participants were asked if there were any additional aspects of their sort they wished to elaborate on or anything else they wanted to share. To supplement recordings and facilitate the interpretation of results, both study team members took contemporaneous notes during the interview and made operational and analytical notes afterwards. Recorded interviews were transcribed using Microsoft Word's transcription feature. Final transcripts were de-identified and edited for readability, including inserting punctuation to reflect pauses in speech and removing duplicate words.

Statistical analysis

The 38 Q sorts were analyzed essentially as described by Zabala[42], using principal component analysis and varimax rotation with the R package "qmethod" (R Development Core Team, 2021). Three factors were extracted based on examination of eigenvalues, number of Q sorts loading, and percent of explained variance. The three factors explained 49% of total variance, consistent with expected ranges of 40-70% seen in other Q method studies[43]. Thirty-five Q sorts loading significantly onto only one of the three factors at the $p < 0.05$ level and for which the squared loading for a factor was higher than the sum of the squared loadings for the other factors[57] were automatically flagged for inclusion in further analysis as belonging to the factor with which they demonstrated greatest affinity. Three Q sorts did not meet this criteria, showing affinity for more than one factor ("confounded" Q Sorts), and were excluded from further analysis following manual inspection to confirm factor membership determinations.

Within each factor, statements received z-scores (the weighted average of the values given to that statement by the Q sorts most closely related to that factor) and factor scores (integer values derived from the placement of the statements into an archetypical Q sort for the factor, based on their relative z-scores). An archetypical factor Q sort, representing the hypothetical sort of an individual who is most closely aligned with that factor's perspective, was generated for each of the three factors (Supplementary Fig. 2). Statements' z-scores and factor scores were utilized in further analysis.

Distinguishing statements for each factor, and consensus statements across factors, were determined based on z-scores: Statements whose z-score for one factor differed significantly ($p < 0.05$) from its z-score for the other two factors were identified as distinguishing statements for that factor. Statements whose z-scores were not significantly different across the three factors were identified as consensus statements (Supplementary Fig. 2).

Qualitative interpretation

To facilitate interpretation, each factor was further characterized by its highest-ranked statements (those with factor scores of +5 and +6), its lowest-ranked statements (those with factor scores of -5 and -6), the statements with higher factor scores for that factor than the other two factors, and

the statements with lower factor scores for that factor than the other two factors. This 'crib sheet' approach[44] allows for examination of each statement for each factor, in the context of the other two factors, and was utilized to develop initial factor narratives based on emergent themes from each factor crib sheet. Once the initial factor narratives had been developed, participant characteristics (Supplementary Table 1) were incorporated into the factor interpretation process, as were interviewer field notes.

Additionally and described in detail below, interview transcripts were coded by statement, excerpts were organized by factor, and this qualitative dataset was used to further inform factor interpretation. As is typical with Q-methodology, qualitative analysis allowed for the identification of illustrative quotes that contextualize the discourse suggested by each factor grouping[30].

Coding began with an open phase followed by two focused phases to reduce qualitative data into themes[45]. An initial codebook was drafted with definitions and descriptions for each code based on existing conceptual frameworks of social and environmental sustainability, predefined drivers, and post-sort interview questions. Coding decisions and codebook changes were documented in detail in an audit trail and debriefed between two investigators. To achieve intercoder reliability, a subset of five interviews were co-coded by two investigators. After the codebook was refined, each transcript was coded using Dedoose software in a first phase referred to as "open coding," a common method employed in qualitative analysis[45]. During this phase, codes were split, added, merged, or refined inductively. For example, codes that emerged during open coding include, "general ethos," "inapplicable," "geography," "driver: animal wellbeing," "driver: environmental stewardship," "operational resilience," "driver: operational resilience," and "synergies." Some initially emergent drivers were ultimately merged with one another or with other codes. When codes were changed or added, transcripts were re-coded to reflect the new codebook in its entirety. Applying codes allowed researchers to form connections between interviews regarding drivers of priorities on their operations, tradeoffs, as well as other salient themes. Detailed notes were taken during coding for each transcript. Notes and memos were created periodically during open coding and referred to in later phases of analysis, providing a useful resource for identifying emerging themes[46].

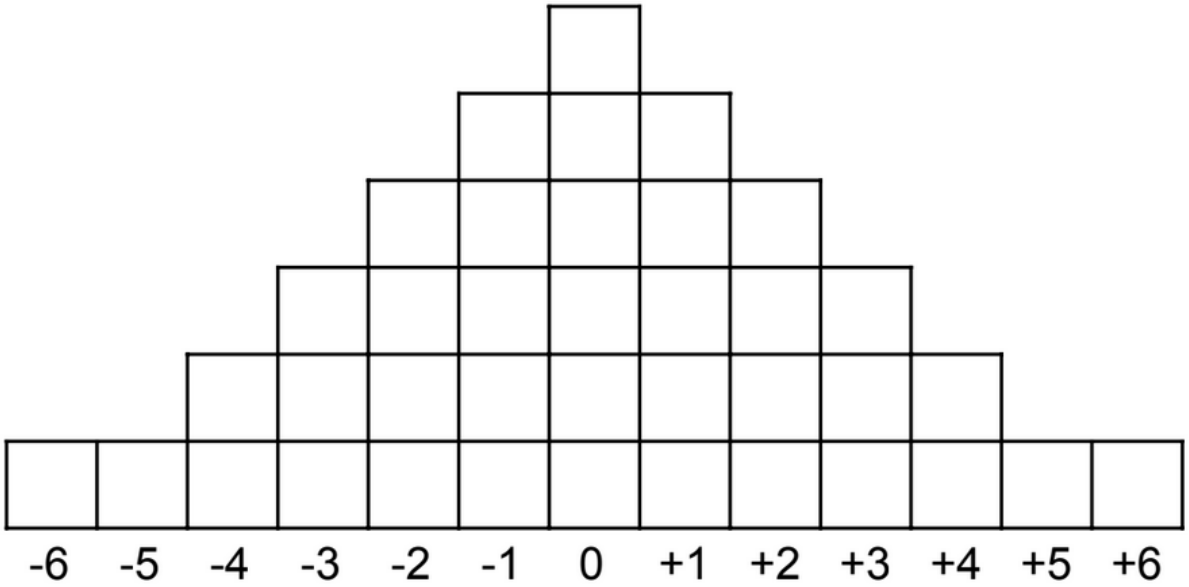
After the open coding phase, each transcript was reviewed again to add excerpts and generate new themes using the constant comparison method[47] where themes found in open coding were repeatedly cross-checked with the discourses suggested by the Q-sort factor groupings, distinguishing statements, and the body of literature related to a topic. Themes within each transcript were compared within and between the factor group associated with each Q sort as a way to refine the discourse suggested by the factor's archetypical Q-sort, providing essential detail not available through analysis of quantitative data alone. For example, statements that were ranked as low priorities for a factor may not have been ranked low by all producers in that factor. Excerpts were pulled out throughout focused coding that illustrated overall themes found in each transcript into a data reduction matrix that grouped interview characteristics by factor (see Tolley et al., page 206 for example)[46]. After the first phase of focused coding, coded excerpts for each transcript were pulled from Dedoose software into a data reduction matrix (one for each code) and analyzed for patterns and themes between factors. The themes and patterns revealed from

the coded excerpts were then compared to (1) the initial themes found during open coding of the interview transcripts, (2) the themes found during focused coding, which considered both the interview transcripts and the factor discourses revealed in the quantitative analysis, and (3) the themes of each discourse as suggested by the quantitative analysis.

The descriptions of the three worldviews in the Results section represent both our quantitative analysis of the Q sorts and our qualitative analysis of insights shared by participants during and after completing the sorting exercise.

Supplementary References

1. Broom, D. M. *Broom and Fraser's Domestic Animal Behaviour and Welfare, Sixth Edition* (CABI, 2021). https://doi.org/10.1017/S096272860001006X
2. Nguyen, H. *Sustainable food systems: concept and framework* (FAO, 2018). https://openknowledge.fao.org/server/api/core/bitstreams/b620989c-407b-4caf-a152-f790f55fec71/content
3. Fraser, D. Understanding animal welfare. *Acta Veterinaria Scandinavica*, 50, 1 (2008). https://doi.org/10.1186/1751-0147-50-S1-S1
4. *2017 Cattleman's stewardship review* (NCBA, 2018). https://www.beefitswhatsfordinner.com/Media/BIWFD/Docs/beef-csr-report-2017-final.pdf
5. Webler, T., Danielson, S., & Tuler, S. *Using Q method to reveal social perspectives in environmental research* (Greenfield MA: Social and Environmental Research Institute, 2009). http://www.seri-us.org/sites/default/files/Qprimer.pdf
6. Zabala, A. Qmethod: a package to explore human perspectives using Q methodology. *The R Journal*, 6(2), 163 (2014). https://doi.org/10.32614/RJ-2014-032
7. Zabala, A., Sandbrook, C., & Mukherjee, N. When and how to use Q methodology to understand perspectives in conservation research. *Conservation Biology*, 32(5), 1185–1194 (2018). https://doi.org/10.1111/cobi.13123
8. Watts, S. & Stenner, P. *Doing Q Methodological Research: Theory, Method and Interpretation* (SAGE Publications Ltd., 2012). https://doi.org/10.4135/9781446251911
9. Charmaz, K. *Constructing Grounded Theory: A Practical Guide Through Qualitative Analysis* (SAGE Publications, 2006).
10. Tolley E. E. *Qualitative Methods in Public Health: A Field Guide for Applied Research* (Wiley, 2016). http://ebookcentral.proquest.com/lib/washington/detail.action?docID=7104122
11. Glaser, B. & Strauss, A. *The discovery of grounded theory: strategies for qualitative research* (Sociology Press, 1967).
12. U.S. Census Bureau. *Geographic Levels*. (2025). https://www.census.gov/programs-surveys/economic-census/guidance-geographies/levels.html#par_textimage_34



Supplementary Fig. 1: The Q sort grid. Statements were sorted into a pyramidal grid, with each box able to accommodate one statement. The scale at the bottom depicts statement priority rankings from -6 (lowest priority) to +6 (highest priority). Vertical placement had no significance (e.g., statements placed at the top and the bottom of the “0” column received an equal priority of 0).

A

						27						
					35	24	12					
				37	31	23	13	7				
			29	36	30	20	21	8	9			
		15	17	11	25	5	33	14	18	4		
22	3	10	6	1	16	2	34	38	26	19	32	28
-6	-5	-4	-3	-2	-1	0	+1	+2	+3	+4	+5	+6

B

						4						
					37	26	33					
				11	30	16	9	5				
			1	29	20	23	6	19	7			
		12	15	31	17	18	3	14	28	8		
10	25	2	13	22	35	24	36	21	27	32	34	38
-6	-5	-4	-3	-2	-1	0	+1	+2	+3	+4	+5	+6

C

						15						
					17	29	6					
				3	2	11	16	1				
			22	27	20	23	25	30	37			
		10	36	13	14	12	9	33	5	8		
21	24	35	31	18	28	38	19	26	4	32	34	7
-6	-5	-4	-3	-2	-1	0	+1	+2	+3	+4	+5	+6

Supplementary Fig. 2: Archetypical factor Q sorts. A, Archetypical Q sort for the factor associated with the *Animal husbandry, first and foremost* discourse. **B,** Archetypical Q sort for the factor associated with the *Environmental stewardship, a holistic approach* discourse. **C,** Archetypical Q sort for the factor associated with the *Business viability, a balancing act* discourse. Numbers in boxes correspond to statement numbers (see Fig. 1a). The scale at the bottom depicts statement priority rankings from -6 (lowest priority) to +6 (highest priority). Black-filled boxes represent consensus statements. Gray-filled boxes represent distinguishing statements.

Supplementary Table 1. Participant Characteristics.

Participant	Scale[a]			Region[b]	Marketing channels[c]	Years of experience[d]	Discourse membership[e]
	Beef	Pork	Broilers				
P1	-	-	Very small	West	D	0–4	AH
P2	Small	Medium	-	Midwest	D, W	ND	ES
P3	Small	Small	Small	West	W	10–24	BV
P4	Small	Small	Small	West	D	5–9	AH
P5	Small	-	-	Northeast	D	0–4	AH
P6	-	Small	Small	West	D, W	5–9	AH
P7	-	Very small	Very small	Midwest	D ,W	0–4	ES
P8	Small	-	Very small	Midwest	D	5–9	ES
P9	-	-	Medium	West	D, W	10–24	ES
P10	-	Small	-	Midwest	D	5–9	AH
P11	-	Very large	-	Midwest	W	10–24	BV
P12	Medium	-	-	West	C	≥ 25	AH
P13	-	Small	-	West	D, W	5–9	AH
P14	Medium	Very small	-	West	D	10–24	AH
P15	-	-	Very small	Midwest	D	5–9	Confounded (AH, ES)
P16	Large	-	-	West	C	≥ 25	Confounded (AH, BV)
P17	-	Very small	-	West	D, W	ND	AH
P18	-	Very large	-	Midwest	C	≥ 25	BV

P19	-	Very large	-	Midwest	C	ND	BV
P20	Medium	Small	-	West	D	5–9	ES
P21	Medium	-	-	West	D, C	ND	AH
P22	Large	-	-	West	C	≥ 25	AH
P23	Small	-	-	South	D, W	ND	ES
P24	-	-	Small	Midwest	D	0–4	BV
P25	-	Small	-	West	D, W	10–24	Confounded (AH, ES)
P26	Medium	Medium	-	Midwest	W	≥ 25	ES
P27	-	-	Very small	Midwest	D	5–9	ES
P28	Small	-	-	West	D	10–24	AH
P30	Small	Small	Small	South	D	0–4	ES
P31	Very small	-	Very small	Midwest	D, W	5–9	ES
P32	-	Very large	-	Midwest	W	≥ 25	BV
P33	Large	-	-	West	D, C	10–24	AH
P34	Small	Small	-	South	D	0–4	AH
P35	-	Very small	-	Midwest	D	5–9	ES
P39	Small	Very small	Very small	South	D, W	5–9	ES
P40	-	Large	-	Midwest	W	10–24	BV
P41	-	Small	-	Midwest	D	5–9	AH
P42	Small	Small	Small	Midwest	D	5–9	ES

[a]Operation scale is shown for each species raised (e.g., an operation that raised beef at a small scale and pork at a very small scale, based on animal units (see Supplementary Table 2), is shown as such).

[b]Farm locations are grouped by U.S. Census Region[12] to preserve anonymity. In the event that an operation spanned regions, the region in which it had the greatest presence is listed.
[c]D = direct to consumer, W = wholesale, C = commodity.
[d]Years of experience as expressed by participants are grouped into ranges to preserve anonymity. ND = no data (participant did not disclose).
[e]Discourses are the interpretations of the factors extracted from principal component analysis. AH = animal husbandry, first and foremost, ES = environmental sustainability, a holistic approach, BV = business viability, a balancing act. Confounded sorts showed affinity for more than one factor and were excluded from further analysis (see Methods).

Supplementary Table 2. Operation size categories used in this study.

		Number of Animals[b]		
Size	**AU[a]**	**Beef**	**Pork**	**Broilers**
Very small	1-9	1-9	1-24	1-999
Small	10-99	10-99	25-249	1,000-9,999
Medium	100-499	100-499	250-1,249	10,000-49,999
Large	500-999	500-999	1,250-2,499	50,000-99,999
Very large	≥1,000	≥1,000	≥2,500	≥100,000

[a]Animal Units.

[b]Operation sizes were categorized by AU, which corresponds to different numbers of animals for different species. Numbers are inclusive of all life stages (e.g., hogs, pigs, and sows; cattle and calves).