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Report on the multiscale scoring method for socioeconomic sustainability assessment of value chains

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Pathways
FOR SUSTAINABLE FOOD

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Executive Summary

The global community faces complex challenges in security, health, climate, and economy, driven by interconnected crises. Over the past 50 years, these issues have spurred actions towards sustainability, inspired by the Club of Rome. Despite the United Nations' 2030 Agenda for Sustainable Development, only 17% of its targets have been achieved, with concerns about stagnation and regression.

Human well-being and development are closely linked to natural resource management, particularly in agriculture. Livestock production plays a dual role as both a contributor to and a solution for sustainability issues. Promoting sustainable livestock production is crucial to the European Green Deal, the Common Agricultural Policy, and the Farm to Fork Strategy.

The PATHWAYS project, funded by the Horizon 2020 program, aims to identify sustainable practices in the European livestock sector. The PATHWAYS project is grounded in three key concepts: Leverage Points, SAFA framework, and One Welfare. Work Package 7 focuses on innovations, policy levers, and business strategies to enhance sustainability and resilience in livestock value chains. This includes a report on current meat and dairy value chains and a forecast of future macro-scenario impacts.

The final goal of this study is to co-design a multiscale method to evaluate the socioeconomic sustainability of post-farm gate livestock value chains. This method, intended for researchers and policymakers, integrates economic and social sustainability performance through a sustainable governance system.

This work is rooted in the sustainability assessment field, which aims to define, plan, and measure progress toward sustainability. A sustainable food value chain (SFVC) is defined as a series of coordinated value-adding activities that are profitable, beneficial to society, and do not deplete natural resources. Livestock, and in general agri-food, supply chains are unique due to their biological production processes, product characteristics, and societal attitudes towards food safety, animal welfare, and environmental impact. Historically, sustainability assessments in agriculture have focused on environmental and technical issues, often neglecting the economic and social dimensions. Recent efforts have defined the objectives and duties of sustainability assessments, but their application remains complex due to the involvement of multiple systems and actors. Various frameworks have been already developed to provide comprehensive sustainability assessments, among them the SAFA framework has emerged for its flexibility, credibility, and compatibility with other certification tools.

This work departs form the concept of Earth system boundaries, emphasizing the need for structural changes in livestock farming systems to return within the "safe operating space for humanity". This involves starting from livestock farming practices and then recognizing the post-farm livestock value chain impacts on the economic, social, and governance sustainability. The study aims to develop a multiscale method to assess the economic and social sustainability of livestock value through a co-design process with European experts. The identification and prioritization of themes were achieved through an online two-round Delphi Study, since it was recognized as useful in selecting indicators dealing with complex sustainability issues.

The method considers three sustainability dimensions: Techno-Economic, Socio-Cultural, and Governance. For each of these dimensions, specific themes were identified during the first round of the Delphi study and ranked by importance in the second round. These themes were then associated with indicators, primarily based on the SAFA framework, introduced by the FAO.
In the first round of the Delphi study, open-ended questions were posed, and the responses were analysed using a qualitative method. The total number of experts reached was 316, with 98 experts responding, among which 50 experts completed the entire questionnaire. The purpose of the first Delphi round was to refine and select the most relevant themes for each dimension. Starting from an initial list of 28 themes, the list was reduced to 22 to avoid overlap and incorporate participants' suggestions. The same experts were subsequently invited to participate in the second round of the Delphi study. In the second round, a hierarchy of themes' importance was established using a best-worst scaling exercise. The results were analysed using both a counting exercise and a conditional logit model. Once an ordinal ranking of the themes was obtained, it was necessary to convert this ranking into a system of applicable numerical weights for the sustainability assessment metric. Among the various techniques which fall under the rank ordering criteria weighting methods, two approaches were suggested.
For each theme, one or two indicators were specified, resulting in a total of 31 indicators. Four levels were defined for rating their performance, namely “Good”, “Moderate”, “Limited” and “Unacceptable”.
Future improvements could include sharing the method with Delphi Study participants for feedback and further refinement. Moreover, empirical applications to animal product value chains at various geographical levels, combining different information sources and stakeholder interviews, will be beneficial to assess the concrete applicability of the method.

Introduction

The global community is currently grappling with multi-dimensional challenges, including security, health, climate, and economic issues, arising from multiple and interconnected crises at various levels (Bruyninckx, 2021; Lawrence et al., 2024). Over the past 50 years, these challenges have prompted civil society and institutions to reflect on and take action towards sustainability, inspired by the work of the Club of Rome (D. H. Meadows et al., 1972). Since 2015, the United Nations’ 2030 Agenda for Sustainable Development, comprising 17 Sustainable Development Goals (SDGs), has seen only 17% of its targets achieved (United Nations, 2024). This percentage doubles when considering instances of stagnation and regression, leading to concerns that the attainment of these goals is at risk (United Nations, 2024). Human livelihood, well-being, and development are intrinsically linked to natural resource management, which is closely tied to agricultural production. Livestock production, now and in the future, is recognized as both a contributor to and a solution for sustainability issues, given its various roles in different contexts, such as providing nutrition, supporting

economic activity, and conserving biodiversity. Promoting sustainable livestock production and its transformation is integral to the European Green Deal, the Common Agricultural Policy (CAP), and the Farm to Fork Strategy (F2F), all of which aim to establish a fair, healthy, and environmentally-friendly food system for people and the planet. PATHWAYS[3], a Horizon 2020 project, seeks to identify practices along the supply and production chains of the European livestock sector to inform research, businesses, and policy on transition pathways. In particular, the overall objectives of Work Package 7 consist of "identifying innovations, policy levers and business strategies that will support a transformational change towards more sustainability and resilience within livestock value chains in Europe". To achieve this goal, a report on current meat and dairy value chains was performed at country level (Task 7.1), and a forecast of future macro-scenarios impacts on the livestock sector will be outlined (Task 7.3).

The final goal of the present work is to "co-design quantitative multiscale method that enables the evaluation of the socioeconomic sustainability performances of the post-farm gate livestock value chains at different scales (local and European), combining existing food value chains sustainability assessment approaches"[4]. This means that neither environmental sustainability consideration nor the production and consumption phases are included in the scope of the metrics, as they have been the focus of other work packages. The expected final users are researchers and policymakers.

The multiscale method was originally structured around five socio-economic sustainability related themes, i.e., value creation, profitability, number and the quality of jobs provided, competitiveness, and mark-up distribution. The interpretation of these aspects of sustainability along the value chain was not exclusively accounting-based through financial information. However, the authors sought to address also the social sustainability performances of livestock value chains. The complex equilibrium between societal and economic sustainability performances can be achieved through the sustainable governance system. For instance, value creation is a term that represents the main functions of the enterprise, and its interpretation has changed over time to include additional items not related to financial performance, such as environmental, societal, and governance impacts (Venturelli, 2023). The broader consideration of the value creation paradigm has therefore led to the inclusion of impacts on the community, stakeholders, as well as the level of innovation, the culture and knowledge impact and the quality of the products provided. Profitability instead is a crucial indicator of a company's financial health and its ability to sustain and grow its business in the long term. Information on the number and quality of jobs has been captured by the impact that the company has on the local economy and the well-being of workers. Competitiveness refers to 'the ability to compete in markets for goods or services' and it 'is based on a combination of price and quality' (Black et al., 2017). It includes operational efficiency as well as adaptability to new market conditions. Finally, the mark-up distribution indicates the distribution of the profit margin along the value chain, which allows us to investigate the economic relationships among the actors in the value chain, including workers, and the

[3] https://pathways-project.com/
[4] https://pathways-project.com/about-pathways/work-packages/

governance of the chain. The decision was therefore made to define the dimensions of sustainability as Techno-Economic, Socio-Cultural, and Governance and in addition to the content already mentioned, other concepts were added, aiming to follow the fundamental concepts of the project.
The Pathways project is grounded upon three concepts, which are (1) “Leverage Points” concept inspired by the Donella Meadows (Abson et al., 2017), (2) the “Trade-offs in Sustainability” guidelines based on the FAO Sustainability Assessment of Food and Agriculture Systems (SAFA) (Food and Agriculture Organization of the United Nations, 2013), and (3) the holistic “One Welfare” concept (Röhrig et al., 2023). To ensure continuity and coherence with the project, the conceptualization of the method presented in this study also relies on these foundational concepts. Among several sustainability assessment methods (see Milestone 23) the SAFA method was adopted from the outset as a reference and baseline for describing the indicators.

The proposed method originates from the concept of planetary boundaries (Rockström, Steffen, Noone, et al., 2009) and the assumption that under current optimal conditions, humanity operates outside the safe operating space. This assumption also applies to livestock supply chains, which, like other anthropogenic activities, require significant transformation to return within the safe operating space. To this end, and in line with the concept of "leverage points" (D. Meadows, 1999), the sustainability assessment method proposed aims to identify sustainability indicators—spanning the techno-economic, the socio-cultural, and the governance dimensions—that are particularly effective in estimating the transformative capacity towards sustainability - the “fundamental changes in structural, functional, relational, and cognitive aspects of socio-technical-ecological systems that lead to new patterns of interactions and outcomes” (Patterson et al., 2017) - of a livestock supply chain. Moreover, the proposed method, following the “One Welfare” approach, explicitly addressed human health and animal welfare metrics in the effort to “highlight the interconnections between animal welfare, human wellbeing and the environment” (One Welfare CIC, 2018).

The document is organized in different sections, respectively dealing with a theoretical background (Background) leading to the problem statement and research proposal, the description of the chosen methods (Methodology) including the design of the Delphi Study and the process of data gathering from the research participants. The outputs of the data analysis (Results) and its discussion follow, providing the description of the multiscale metric (Discussion of results). Finally, a reflection on the research constrains and weaknesses (Limits of the study) and the expected future steps is provided, followed by conclusions (Conclusion and future developments).

Background

This work is rooted in the sustainability assessment field, which is carrying out the arduous task of defining, planning and measuring the progress toward sustainability (Gasparatos & Scolobig, 2012). Quoting Ness and colleagues "the purpose of sustainability assessment is to provide decision-makers with an evaluation of global to local integrated nature-society systems in short- and long-term perspectives in order to assist them to determine which actions should or should not be taken in an attempt to make society sustainable" (Ness et al., 2007).

For an extended period, sustainability assessments in agriculture have predominantly concentrated on environmental and technical issues, often overlooking the economic and, more importantly, the social dimensions of sustainability (Binder et al., 2010). Thanks to recent efforts, an agreed definition of the objectives and duties of a sustainability assessment seems to be defined, but its application remains a complex task, given that it deals with systems and numerous actors (Gasparatos et al., 2008). Several frameworks and tools with different approaches and metrics have been developed (see Milestone 23); thus, before starting the co-design a new method, we reviewed some literature to understand which dimensions were covered, which was the scale of the evaluation (farm, firm, value chain, region, etc..), and what was applicable to the livestock sector. In the middle of Figure 1, recurring keywords in four selected references works were represented by the VOSviewer software (www.vosviewer.com). The investigation conducted to the results of only five out of hundred methodologies, i.e., AgBalance™, Aviculture Biologique (AVIBIO), Hot-Spot Analysis (HSA), Sustainability Assessment of Food and Agriculture Systems (SAFA), Life Cycle Sustainability Assessment (LCSA), all of which take a value chain (VC) approach and cover all of three (or even four) dimensions of sustainability: environmental, economic, social and governance[5].

[5] More information in PATHWAYS Milestone 23. Table 1 "List of sources consulted to build the literature review", Table 2 "List of 111 (frameworks and tools) in alphabetic order", Figure 1 "The selection criteria" and Section 3 "The selected tools".

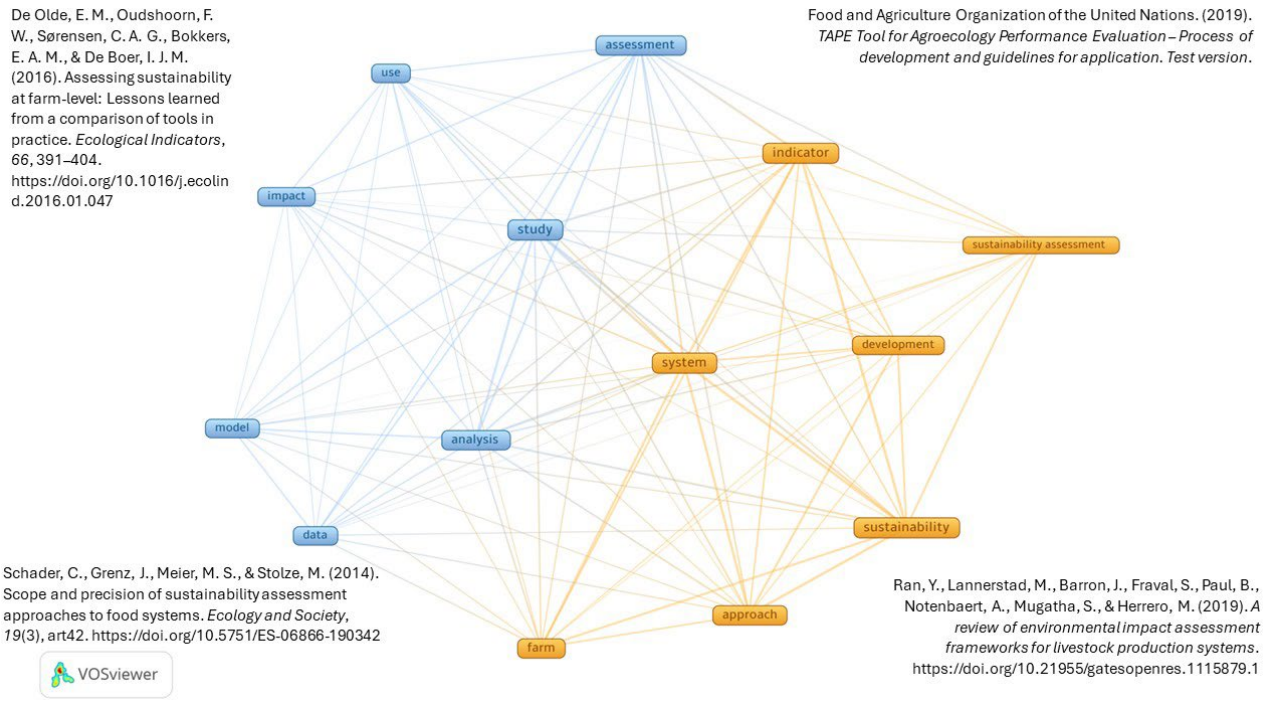


Figure 1: Network visualization of the literature sources consulted. *(Source: Elaboration of the authors using VOSviewer software).*

These results confirmed that taking the value chain as target of the sustainability evaluation is challenging and more awareness on value chain is needed, starting from its definition.

Literature exploration

In this paragraph will deal with the broader literature on evaluation of value chains performances, particularly in the food sector. Starting from its multiple definitions, studies either have a descriptive/structural approach (what a VC is) or normative/strategic aim (how VC should be) (Neven, 2014). Adapting the definition of Kaplinsky and Morris (2000)[6], a sustainable food value chain (SFVC) is defined as "the full range of farms and

[6] "The value chain describes the full range of activities which are required to bring a product or service from conception, through the different phases of production (involving a combination of physical transformation and the input of various producer services), delivery to final consumers, and final disposal after use."(Kaplinsky & Morris, 2000). In Kaplinsky and Morris (2000) manual and in FAO SFVC guidelines (2014) a clarification on other concepts used in the value chain literature is proposed, namely Porter's term *value stream*, the French scholars' *filiere* and the term introduced by Gereffi of *global commodity chains*. In his work, Gereffi has particularly focused on industrial organization in the global market, power relations, and value chain governance (Gereffi et al., 2005).

firms and their successive coordinated value-adding activities that produce particular raw agricultural materials and transform them into particular food products that are sold to final consumers and disposed of after use, in a manner that is profitable throughout, has broad-based benefits for society and does not permanently deplete natural resources". According to Aramyan et al. (2006) what characterizes and distinguishes the agri-food supply chains from other supply chains is "(1) the nature of production, which is partly based on biological processes, thus increasing variability and risk; (2) the nature of the product, which has specific characteristics like perishability and bulkiness that require a certain type of supply chain; and (3) the societal and consumer attitudes towards issues like food safety, animal welfare and environmental pressure".

The literature on value chain analysis in the agri-food sector presents research that can aid policy formulation, sector development and global challenges, addressing both performance in terms of efficiency and effectiveness of the supply chain (Aramyan et al., 2006) and sustainability (profit, planet, people), concept on which a plurality of different visions stands out (F. Galli et al., 2016). Both kinds of performances are affected by the element of governance of the value chain, because it entails the "process through which decisions are made and implemented (United Nations Economic and Social Commission for Asia and the Pacific, 2009) in the economic, environmental, and social spheres" (D. Galli et al., 2023).

The governance structure refers to the manner in which the transactions are organized within the chain (Rota et al., 2014), and different structures fit in different types of food chain (Carbone, 2017; Pomarici, 2019). An aspect of governance that emerges as key to sustainability performance is coordination, which allows for "economic utility, social welfare, and ecological resilience" (Formentini & Taticchi, 2016; Moreno-Miranda & Dries, 2022). The value chain, being the precursor of food system (Stefanovic et al., 2020), is also studied by those observing the transformation process of the food system, for a transition toward sustainable development (Caron, 2018). Thus, food VC development is an object of a rethinking process, as for example the novel transformative value chain perspective advanced by Mechri and colleagues (Mechri et al., 2023). Value chains remain a complex target for a holistic sustainability performance assessment, nonetheless some attempts have been made to provide a comprehensive assessment framework. For instance, Ivo de Carvalho et al. (2022), identify and characterize the most significant sustainable-related performance areas and subcategories that should be measured and monitored in the agri-Food supply chain (AF-SSC), while Allali et al. (2024) develop an holistic framework combining the SAFA and the Agri-food Evaluation Framework (TEEB)", validating it to the chestnut sector. In the last case, as in other applications (D. Galli et al., 2023), the SAFA framework is taken as reference because of its flexibility, high credibility, user-friendliness, comprehensiveness, and compatibility with other certification tools (Bonisoli et al., 2019; D. Galli et al., 2023).

Objectives and research questions

The conceptual framework we built and the research questions which guided us are reported in Figure 2. From left to right, the first picture reports the current status of control variables for all nine planetary boundaries (Richardson et al., 2023), showing the urgent need to implement efforts to come back to the so called “safe operating space for humanity”. The livestock sector, with many different systems of production and value chains, has its role, too. For livestock farming systems to fall within—or at least contribute to—the process of returning to the safe operating space, structural changes in farming systems and practices to produce animal-derived products are necessary. These changes can follow different pathways such as agroecology, organic farming, etc., whose environmental sustainability has been scientifically demonstrated. However, it is necessary to extend the performance evaluation to socio-economic aspects and to the whole livestock value chains, including the processing and distribution phases. Given the extensive literature and the urgent need to consider not only the environmental, but also the economic, the social and the governance dimensions of sustainability and recognizing that the vast body of sustainability literature narrows when focusing on value chains, this study aims to develop a multiscale method to assess the economic and social sustainability of livestock value chains. Building on existing work, particularly the SAFA assessment framework, we aim to customize this method for the livestock sector and its transformation, involving European experts in a process of co-design. Furthermore, the objective is to rank performance areas to prioritize certain theme while maintaining a comprehensive overview. This approach allows us to determine the most and least important themes when assessing the sustainability performance of the post-farm gate livestock value chain.

The present study aims not only to describe the sustainability evaluation method developed, but above all the process followed to achieve this result, through a Delphi Study.

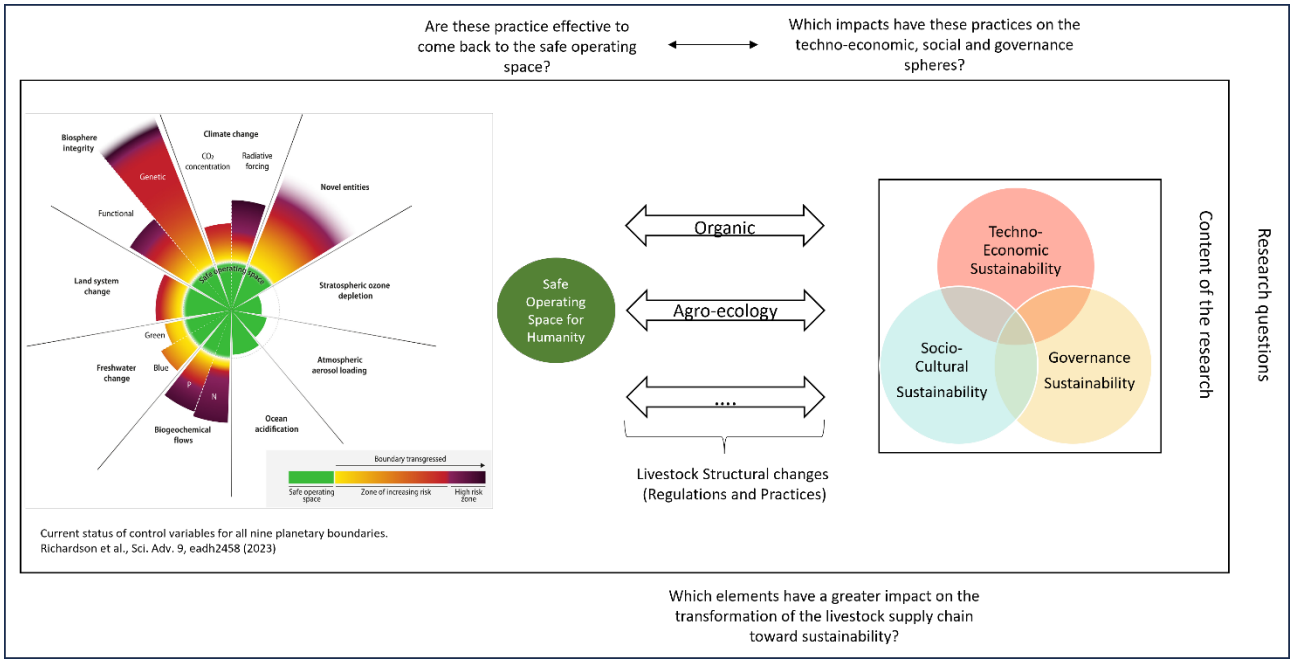


Figure 2: Schematization of the research questions and content (*Source: Own elaboration*).

Methodology

In this section, we will explain the different methodologies chosen, then the data collection process and finally the data analysis with the detailed description of the method application. As a multi-stage process, Figure 3 facilitates its comprehension by illustrating the methods, results, direction of the process, and the number of experts involved.

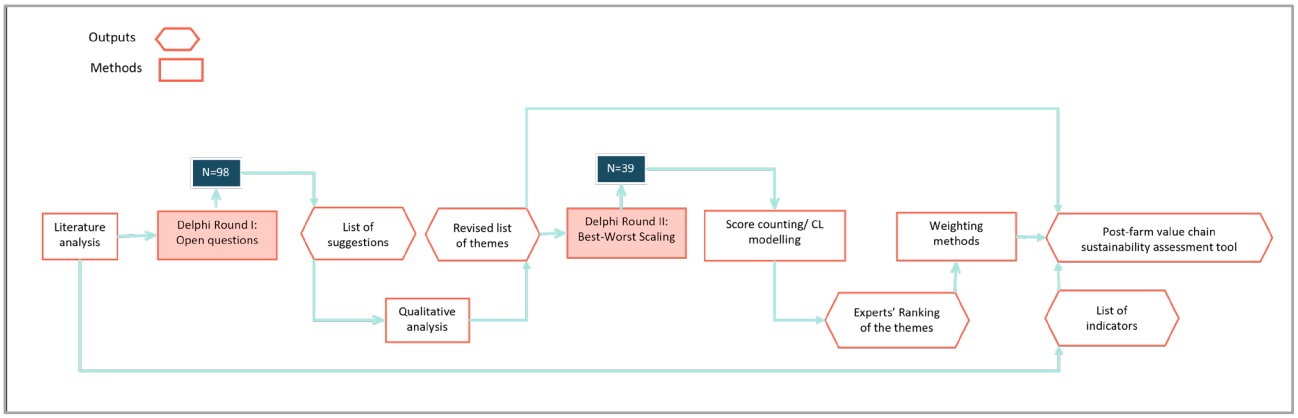


Figure 3: Flowchart research steps *(Source: Own elaboration).*

Methods

DELPHI STUDY METHODOLOGY

The chosen methodology to set up the co-designing process was a Delphi Study, since it was recognized as useful in selecting indicators dealing with complex sustainability issues (Frewer et al., 2011; Van Schoubroeck et al., 2019). In this kind of study, experts are iteratively facilitated and engaged to anonymously express their opinions to reach a group consensus, which could then support the decision-making process (Hasson et al., 2000). In the present study, a two-round Delphi survey has been conducted with both open and closed questions with the aims to: i) list sustainability themes for the evaluation of the socio-economic-governance sustainability of livestock value chains, and ii) identify those which are more critical in promoting their transformations towards sustainability. The contribution of experts was therefore requested in two phases (rounds), involving only those who have fully completed the first-round questionnaire in the second phase. The selection of the list of indicators to measure the socio-economic sustainability performance was carried out by the authors, based on existing metrics and approaches reviewed in Milestone 23, as will be explained later in this manuscript. The interaction with experts will also require a final consideration of the overall results. The questionnaires were created in Qualtrics Software (© 2018 Qualtrics ®) and were distributed by e-mail to experts.

COUNTING METHODOLOGY

During the second round of the Delphi study, a best-worst scaling exercise was used to generate a ranking of the themes comprising the sustainability assessment method. The results were analysed using a counting exercise and a conditional logit model.

The Best-Worst Scaling analysis

The Best-Worst Scaling (BWS) data analysis was initially performed using the counting technique, where the frequency of each theme being selected as the most or least important is recorded. The counting exercises provides three scores, namely the B (best), the W (worst), and the BW (best-worst) (Marley & Flynn, 2015; Van Schoubroeck et al., 2019). The BW score of a theme is computed according to equation (1):

$$(1)\quad BW_n score = \sum B_n - \sum W_n$$

Conditional logit analysis

Secondly, a Conditional Logit (CL) model was estimated, based on the theoretical assumption that the respondents have a certain level of utility (v) given by the characteristics of the alternative items, this case, the different themes. The CL model computes the average preference $(\Pr)$ for a certain theme among the individuals (Van Schoubroeck et al., 2023). Based on the CL model and for ease of interpretation, the "share of preference" (SP) can be computed for each item. In the present study, both the CL model and the share of preferences were computed using the theme with the lowest $B - W$ score as control. According to equation (2) (Cohen & Neira, 2004), SP_i is the share of preference of theme i on a ratio scale, the sum of the SP_i is 1 and if SP_i is twice SP_t, it would mean that theme i is twice preferred to theme t, where i and t indicate two generic themes (Lusk & Briggeman, 2009).

$$(2)\quad SP_i = \frac{\exp(v_i)}{\sum_{t=1}^{T} \exp(v_t)}$$

The BWS facilitated the ranking of themes within each dimension of sustainability by their level of importance. This relative ranking was determined by the CL model, and the share of preferences subsequently served as a reference for the definition of the theme's relative weight in the evaluation method.

Data collection

EXPERTS' RECRUITMENT

Participants were gathered from two European Research Projects, and thus included specialists from research institutes, agri-food organizations, including associations with expertise in the livestock sector, and additional contacts from academic networks. Given that the number and expertise composition of the participant group are critical for the successful completion of the Delphi study, a snowball sampling technique was employed. The first round remained open for six weeks during which respondents were solicited submit the questionnaire and to provide additional contacts. Expecting a dropout rate between the first and the second round. Starting from a list of 233 potential respondents, other 83 contacts were reached through the snowball approach. The final number of experts invited to submit the Delphi Study in round I was 316.

The data analysis

DELPHI ROUND I

The design of the questionnaire

The first-round questionnaire was made of two sections, which correspond to different sustainability dimensions: an environmental part, linked to the Planetary Boundaries framework and a socio-economic part. The objective of the environmental part of the Delphi Study was twofold. On one hand, it asked the experts to express their views of the effectiveness of alternative animal husbandry systems to come back to the "safe operating space for the humanity" (Rockström, Steffen, Persson, et al., 2009). On the other hand, those reflections, being at the beginning of the survey, could also help the participants in assuming the perspective of a restructuring of the livestock sector, which was the starting point for the second part of the Delphi Study (right hand side of the Figure 2)[7].

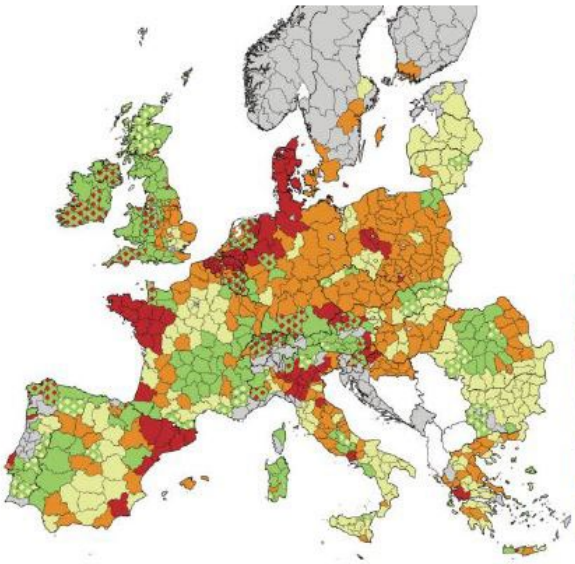
The environmental sustainability section

In this section, experts were asked to express the effectiveness (from "not effective at all" to "extremely effective") of five animal husbandry systems in transitioning back to the safe operation space for humanity, for each of the four selected planetary boundaries. The boundaries particularly affected by livestock production and value chains are the climate change, the biogeochemical flows and the land-change, but also the change in biosphere integrity, as suggested in the literature (Bowles et al., 2019).
The animal husbandry systems presented were five, here we report the name, and the sources consulted for their characterization[7]:

- Intensive livestock system (Mpofu, 2020; Organisation des Nations Unies pour l'alimentation et l'agriculture & International livestock research institute, 2011).
- Sustainable Intensive (SI) livestock system (Garnett, 2009; Poux & Aubert, 2018; Sijpestijn et al., 2022).
- Extensive livestock system (Horsin et al., 2018).
- Organic livestock system (REGULATION (EU) 2018/848 on Organic Production and Labelling of Organic Products and Repealing Council Regulation (EC) No 834/2007, 2018).
- Agroecological livestock system (Botreau et al., 2014; Gliessman, 2007; Poux & Aubert, 2018).

[7] More information can be found in Pathways Milestone 42.

To account for the heterogeneity of European regions in terms of animal species, livestock density and proportion of grassland on total agricultural areas their judgements, experts were asked to specify the typology of areas for which their evaluation is valid. The areas classification adopted is reported in Figure 4.



	Agricultural area million ha	% total	Livestock population million LU	% total	Stocking rate (LU/ha)
	18.9	10.5	40.8	29.5	2.15
	12.0	6.7	20.1	14.6	1.70
	34.7	19.3	25.6	18.5	0.75
	12.2	6.8	2.9	2.1	0.25
	56.8	31.6	36.8	26.6	1.20
	44.9	25.0	11.9	8.6	0.30

Figure 4: Typology and localisation of European livestock system *(European Commission, Directorate General for Agriculture and Rural Development, 2020).*

The socio-economic sustainability section

In the second section, participants were provided with a list of themes regarding critical aspects in the transformation of livestock value chains toward sustainability, that they had to integrate or modify. The three dimensions were Techno-Economic, Socio-cultural and Governance, which relate to the indirect drivers of change (IPBES, 2013).

We chose to evaluate the techno-economic sustainability, instead of just economic sustainability, by considering both the technical and economic feasibility of transitioning towards sustainability. This decision was based on the observation that themes dealing with firms' productivity and efficiency, are inherently linked to both dimensions, meaning their interpretation involves both technical and economic aspects. We included for example the cost of the energy supply, the level of Total Factor Productivity, the businesses' R&D expenditure, the level of digitalisation, the logistics and transport infrastructure. The complete list of themes selected for the techno-economic dimension and their definition is provided in Table 1.

Table 1: Indicators of Techno-Economic Sustainability and related definition for the Delphi Study round I.

Indicators of Techno-Economic Sustainability and related definition	
Cost of the energy supply	Economic cost of energy supply includes the full value of the supply chain from the upstream to the point of energy consumption.
Farm reliance on the market for inputs	Ratio of purchased inputs on total inputs.
Distribution of remuneration	Adequate remuneration of invested resources in each stage of the supply chain.
Economic advantages provided by public institutions	Grants, contributions, subsidies, economic advantages provided by public institutions both independent and/or subjected to specific outcomes.
Mortality rate of small farms or companies	Number of enterprise deaths as a percentage of the population of active enterprises, in a given reference period.
Level of Total Factor Productivity	It measures how efficiently production inputs, such as labour and capital, are being used in an economy to produce a given level of output.
Business and enterprises R&D Expenditure	Research and experimental development (R&D) performed in the Business.
Capital expenditure	Amount of money spent by a business or organization on acquiring or maintaining fixed assets, such as land, buildings, and equipment.
Financial services	It involves the transaction required to obtain the financial good. The financial sector covers many different types of transactions in such areas as real estate, consumer finance, banking, and insurance, investment funding, including securities.
Digitalisation	Refers to the adoption or increase in use of digital or computer technology (by an organisation, an industry, or a country) and therefore describes more generally the way digitisation is affecting economy and society.
Transport logistics infrastructure	Includes measures and conditions enabling physical movement of persons and goods, in order to ensure continuity of production and services.
Level of global trade	Defined as the transactions in goods and services between residents and non-residents.

With regard to the socio-cultural dimension, we merged two class of sustainability descriptors: the social and the cultural, with the objective to go beyond the legislative obligations and capture the feature and dynamics of occupation, SDGs achievement and value-chain actors' perspectives (Blair et al., 2024). For instance, we listed animal welfare, human wellbeing, overall employment rate, food security, and job occupation change. The complete list of themes selected for the socio-cultural dimension and their definition is shown in Table 2.

Table 2: Indicators of Socio-Cultural Sustainability and related definition for the Delphi Study round I.

Indicators of the Socio-Cultural Sustainability and related definition	
Animal welfare	The physical and mental state of an animal in relation to the conditions in which it lives and dies.
Human wellbeing	A state of existence that fulfils various human needs, including material living conditions and quality of life, as well as the ability to pursue one's goals, to thrive, and feel satisfied with one's life.
Overall Employment rate	Employed people aged 25-64, as a share of the population of the same age.
Food security	When all people, at all times, have physical and economic access to sufficient safe and nutritious food that meets their dietary needs and food preferences for an active and healthy life.
Human-Nature connectedness	Material connections such as resource extraction and use; (2) experiential connections such as recreational activities in green environments; (3) cognitive connections such as knowledge, beliefs and attitudes; (4) emotional attachments and affective responses; and (5) philosophical perspectives on humanity's relationship to the natural world.
Job occupation change	Occupational change describes how job structures are changing across occupations, sectors, and the wage distribution.

Finally, considering its role in transformative change, we included the governance dimension of a value chain. The term referred to "both the process by which particular players in the chain exert control over other participants and how these leading firms appropriate or distribute the value that is created along the chain" (Hochachka, 2023). It dealt with networking and social organizations, knowledge and culture, access to natural ecosystems, fairness and equity, market infrastructure, and level of horizontal and vertical integration. The complete list of themes selected for the governance dimension and their definition is provided in Table 3.

Table 3: Indicators of Governance Sustainability and related definition for the Delphi Study round I.

Indicators of the Governance sustainability	
Networking and social organizations	Participation of the local community, coordinating actions, policy initiatives and decentralizing governance.
Knowledge and Culture	"Traditional knowledge systems (including language and practices, ceremonies, oral traditions, and intergenerational relations and the way knowledge is conceived, produced, and distributed in formal institutions"
Sustainable behaviour	Existence and adoption of certification systems that demonstrate concrete sustainability objectives.
System of exchange	Systems of exchange in food systems include the systems and processes by which: (a) agricultural products move from producers to the various users and

	consumers of these products; (b) the ways food producers acquire production inputs.
Access to Natural Ecosystems	"The access, control, use, and shape or configure land and physical territory consisting of communities, infrastructure, soil, water, biodiversity, air, mountains, valleys, plains, rivers, and coasts".
Fairness and equity	Equal right of access to productive resources and decision making, and to fair profit distribution, independently from gender, age, class and caste, religion, health, and race.
Level of vertical integration	Form of business organization in which all stages of production of a good, from the acquisition of raw materials to the retailing of the final product, are controlled by one company, in order to create a single economic complex and thus achieve a more efficient and convenient organisation of the production cycle.
Level of horizontal integration	Coordination, merger, concentration of businesses, which can take place either between companies carrying out the same processing stage, to reduce costs or to dominate the market.
Market infrastructure	Perfect competition, monopolistic competition, monopoly, oligopoly, duopoly.
Food safety and quality measures	The presence of production disciplinary and labelling specifications.

Data analysis used a qualitative approach. For each indicator and each sustainability dimension, we asked expert to judge if:

1. the indicators captured the potential impacts of the different animal husbandry systems presented, remembering that the impacts dealt with all the different stages of the value chains (farming, processing, distribution, consumption);
2. the indicators had the capacity to inform about relevant aspects in the process of transformation of livestock value chains toward sustainability;
3. any indicator was missing from the list;
4. any indicator was mis defined and/or misplaced across the three sustainability dimensions.

The questions were open-ended, requiring responses that included justifications, suggestions, and relevant references from the literature. We then organized 12 documents, one for each of the four questions and each sustainability dimension, to compare and synthetise the respondents' contributions. The respondent code was also retained to allow for tracking the survey responses if needed.

The texts were read multiple times, and the following types of information were highlighted:

- The suggestions (missing, mis defined and misplaced sustainability themes);
- Literature references;
- Methodological reflections;

- Declaration of the level of agreement (agreement, neither agreement nor disagreement, disagreement);
- Hardness of the comprehension.

These categories were identified by the authors deductively from the contents and the structure of the survey. However, inductive coding was also applied to account for the suggestions emerging from the participants, such as piece of information which ex-ante were not coded. The ultimate objective was to feed the second round of the Delphi study, explained in the following section, where a revised list of themes was proposed. To achieve this result, we matched the answers from the Delphi round I with the initial set of themes, added the new themes integrated the meanings, and considered the option to move items form one thematic section to the others. The criteria used to select the themes for the second round, and to write their short descriptions, were:

- Relevance of the theme;
- Clarity of the definitions;
- No overlaps between the meanings of the themes;
- Possibility of intervention by the firm/farm;
- Synthesis.

DELPHI ROUND II

The design of the questionnaire

The second round of the survey was organized in five sections. After a short introduction recalling the research objectives and explaining the Best-Worst Scaling (BWS) methodology, applied in the second round, to obtain a ranking of the sustainability themes, resulting from the participant consultation of the first round (Van Schoubroeck et al., 2019).

Before starting the survey, its structure was anticipated and a complete list of the themes for each sustainability dimension was provided (Table 6). For each dimension, Techno-Economic, Socio-Cultural and Governance, expert respondents were asked to select the most important (or the best) and the least important (or the worst) items among a subset of themes. The BWS methodology was firstly developed by Louviere and Woodworth (1991) to elicit stakeholders' preferences. It is simpler to execute than a full ranking method and it circumvents the interpretation difficulties associated with conventional rating scales (Van Schoubroeck et al., 2023).

The BWS used a balanced incomplete block design (BIBD) (Auger et al., 2007; Marley & Flynn, 2015). In a BIBD there is a set of treatments and a set of blocks, but not all treatments are present in every block. However, the design is balanced in such a way that each pair of treatments appears together in the same number of blocks. Each item t appears r times, and each pairwise comparison occurs with frequency λ. The design of the questionnaires was created in R-Studio and it is reported in Table 4, showing the number of

blocks (questions) and the correspondent items (answers). To avoid positional bias, in each sustainability dimension, both the order of the blocks and the alternatives within each block were randomized. The number of blocks and alternatives for each question were defined to ensure the functionality of the methodology. Therefore, to avoid participants' fatigue, efforts were made to limit the total number of questions and not to add more than four alternatives for each question.

Table 4: Balanced incomplete block design for the three dimensions.

Block	Items			
Techno-Economic themes				
1	1	2	5	7
2	1	2	6	8
3	1	2	3	4
4	4	6	7	8
5	2	3	7	8
6	1	4	5	6
7	2	5	6	7
8	3	4	5	7
9	2	3	4	6
10	1	3	5	8
11	2	4	5	8
12	1	3	6	7
13	1	4	7	8
14	3	5	6	8
Socio-Cultural themes				
1	3	6	7	
2	1	2	6	
3	4	5	6	
4	2	3	5	
5	1	5	7	
6	1	3	4	
7	2	4	7	
Governance themes				
1	5	6	7	
2	1	3	7	
3	2	3	5	
4	1	2	6	
5	1	4	5	
6	2	4	7	

7	3	4	6	

Figure 2 shows the BWS question for the techno-economic dimensions to exemplify the BWS questions' formulations in the survey.

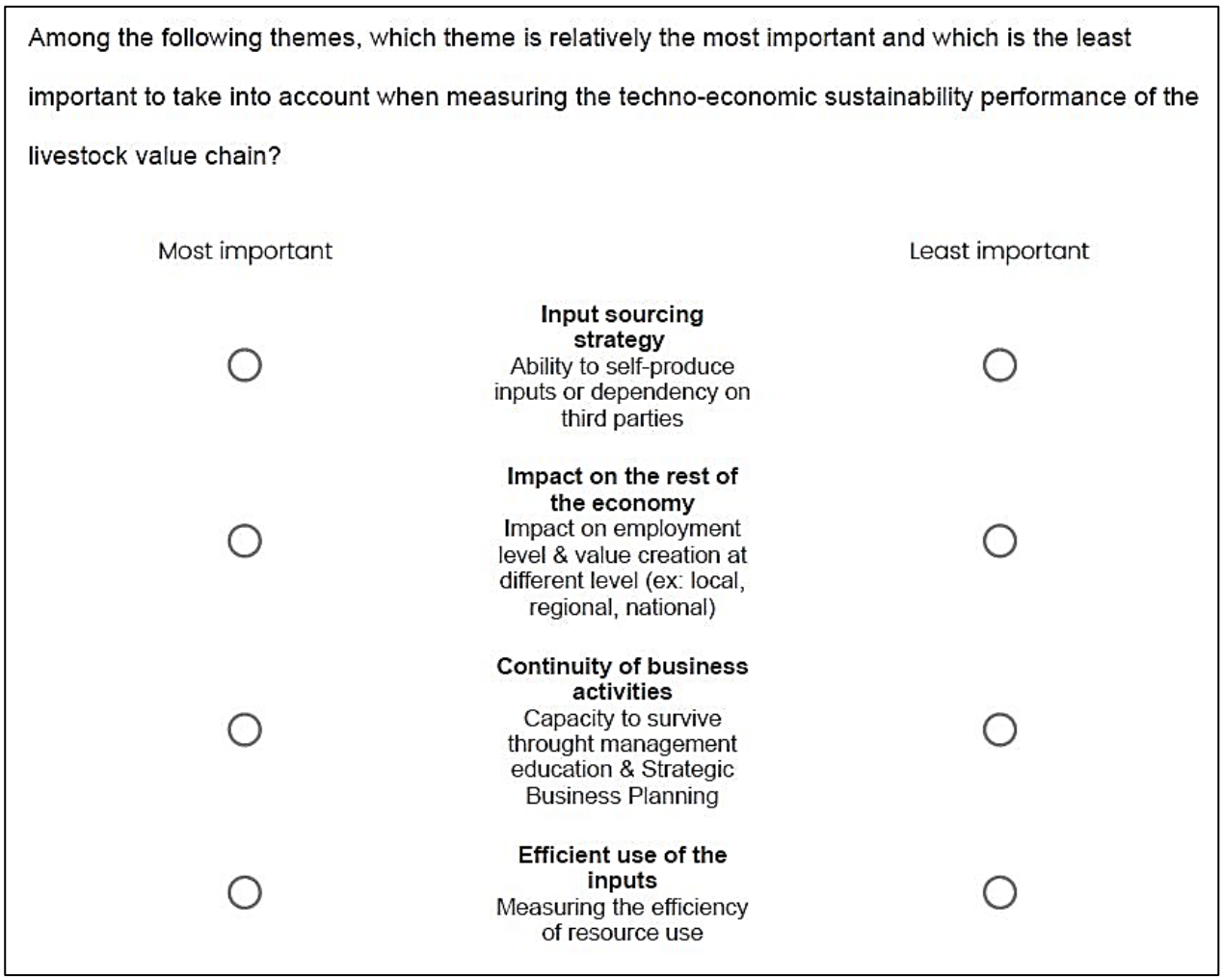


Figure 5: An example of a Best-Worst question of the Second Delphi Round *(Source: Own elaboration).*

After the BWS exercise, a final feedback on the level of comfort and on its motivation was asked.

The following section deals with the characteristics of sampled experts, based on the non-compulsory personal questions asked at the end of the Delphi round I.

RESPONDENTS CHARACTERIZATION

The total number of experts reached was 316. As shown in Figure 6, the respondents included 98 experts (response rate: 31%) among which 50 experts completed the whole questionnaire (complete response rate: 15,8%). The latter were also invited later to take part to the second Delphi round.

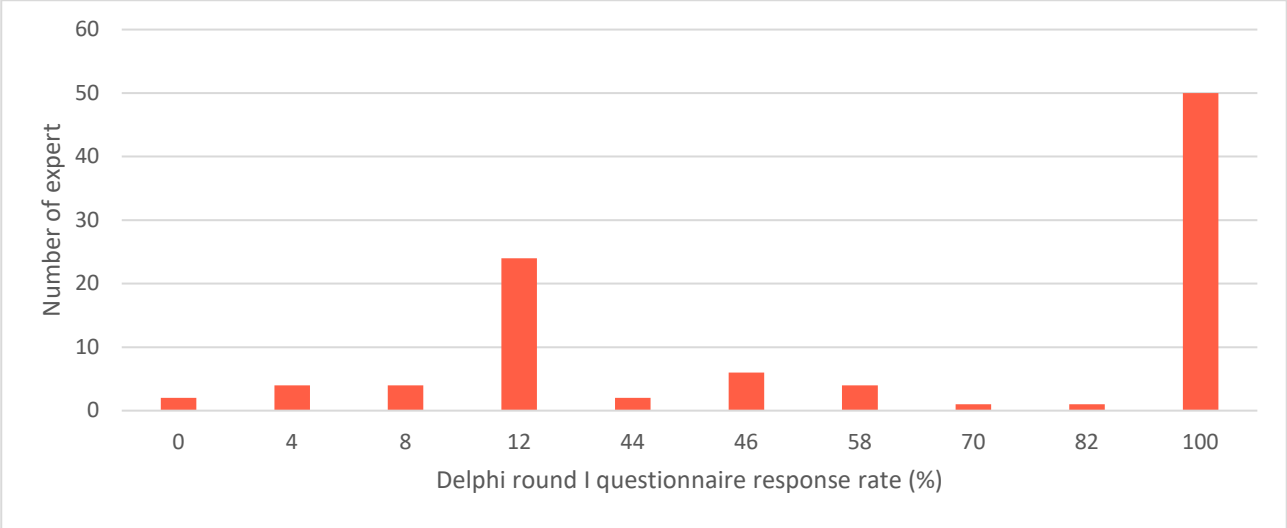


Figure 6: Number of respondents per level of completeness of the First Delphi round *(Source: Own elaboration).*

Of the 98 participants, 41% declared expertise in the livestock sector, 25% in the food sector and in decreasing order in environmental (34%), economic (14%), social (11%), and governance (8%) sustainability (Figure 7). Among other competences (11%), there are heterogeneous topics, in the field of agriculture science (i.e., grassland and arable plant production, agroecology), animal and human health (i.e., animal welfare, public health, broiler genetics), policy implementation (i.e., Common Agricultural Policy, Food Industry policies, Livestock policies), climate change and its mitigation (i.e., ecological processes, climate change, circular economy, sustainable transition to the post-fossil fuel based societies, true cost accounting), food chain assessment, project management, communication, and dissemination.

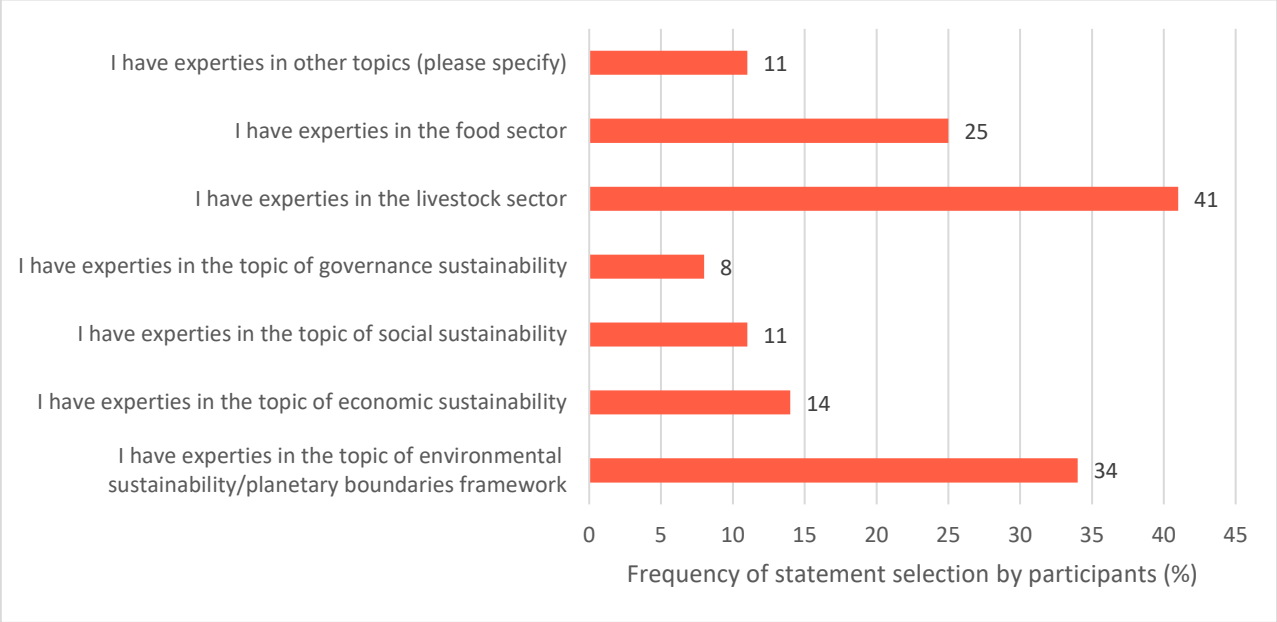


Figure 7: Statements participants declared to agree with (multiple answers admitted) *(Source: Own elaboration).*

Regarding the representation of expertise, which was a not compulsory question in the survey, more than one third of the 98 respondents did not answer, and they are counted as "not available" (NA) (39,8%). Among the available data, in decreasing order there were the experts in ruminants (18,4%), ruminants and monogastric animal (15,3%), other competences (13,3%), only monogastric (6,1%), ruminants, monogastric and other competences (4,1%), monogastric and other competences (2%) and ruminants and other competence (1%) (Figure 8).

Other competences included general animal welfare, operational management, broiler, breeding growing, processing, farm economics, food system, grassland management, nature conservation, Montado/Dehesa system[8], and poultry.

[8] "The dehesa-montado is an agro-sylvo-pastoral system, based on three essential elements: the trees (mainly cork oak and holm oak, with an inferior layer of pasture and/or bush), the animals (livestock and wild species) and the Man." (*PRODEHESA-MONTADO Project*, 2024)

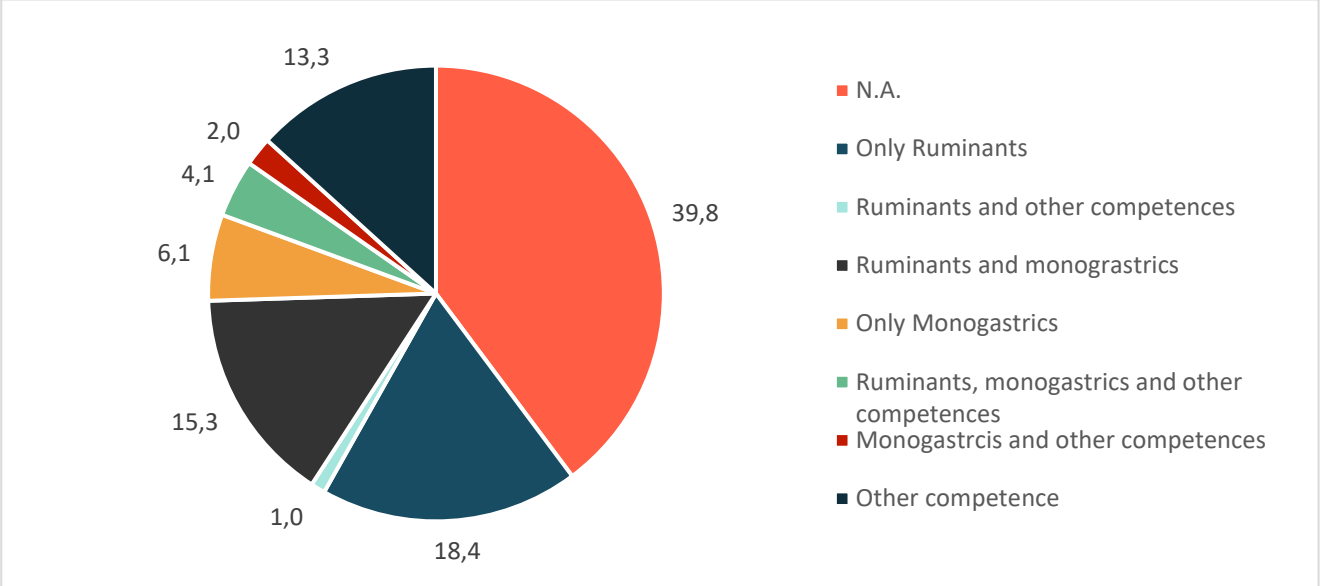


Figure 8: On which animal categories the participants felt to have the most expertise in *(Source: Own elaboration).*

Figure 9 shows that most of the experts come from research organisations; mainly from academic institutions (23%) and independent research institutes (10%). Non-profit organisations (15,3%) are more represented than for-profit companies (3,1%). Public institutions were scarcely represented (around 1%). However, the 10,2% of respondents – choosing the "other" option reported to work for international organization (NGO, EU CAP Network and UN Agency), in the field of cooperation and trade, and in the consultancy business. The countries of competence of respondents covered a big portion all Europe, with a higher proportion coming from Italy and France (Figure 10).

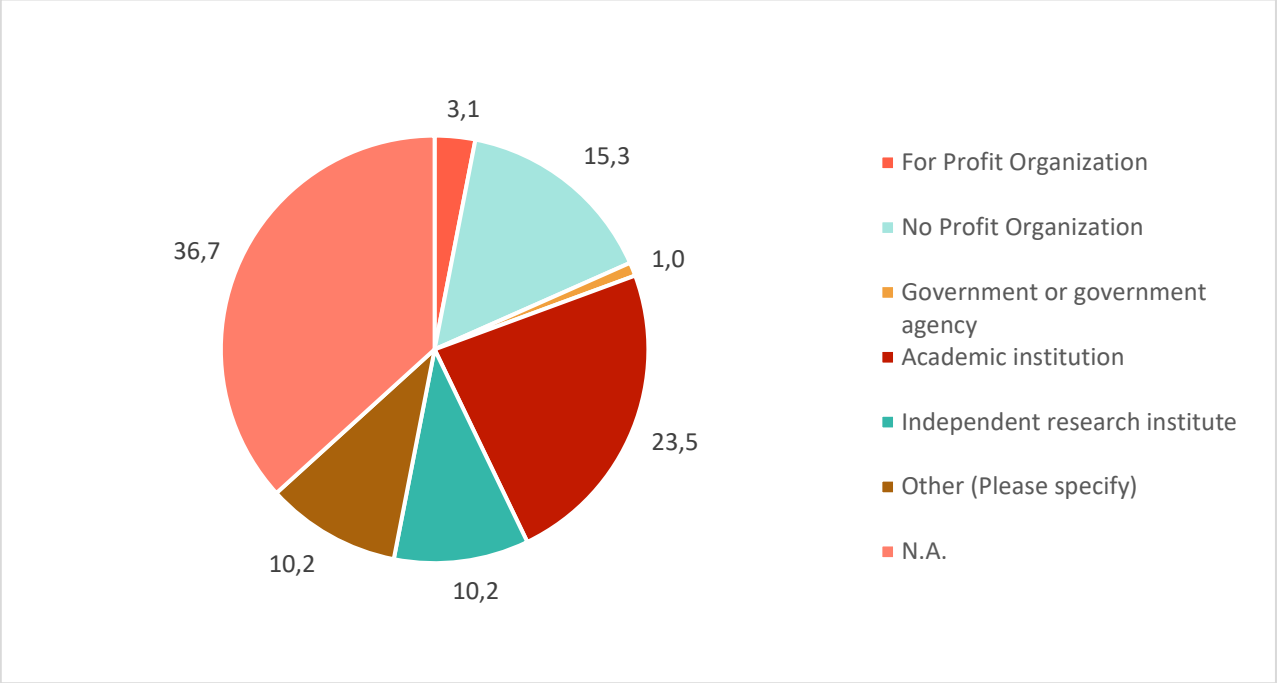


Figure 9: What best describes the type of organization the participants work for *(Source: Own elaboration).*

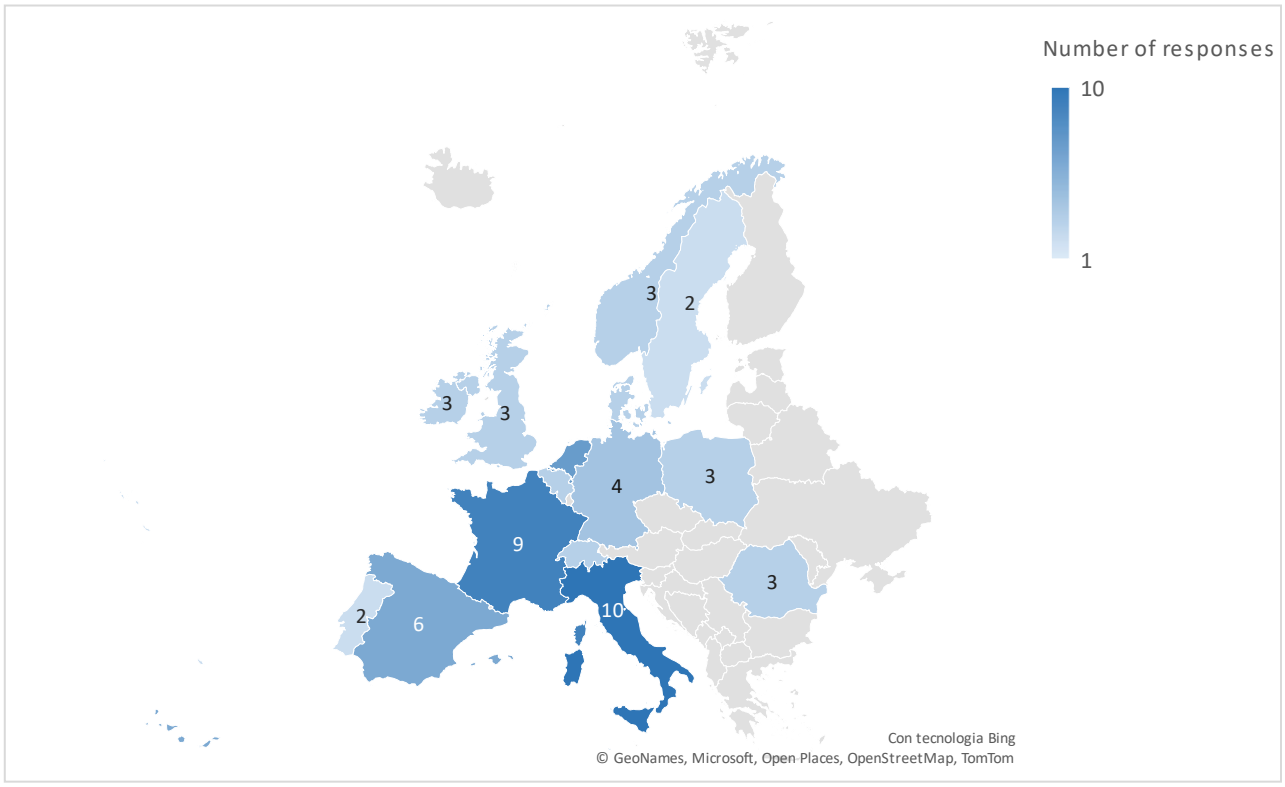


Figure 10: Distribution of responses by country of competence *(Source: Own elaboration).*

Of the 50 experts involved in the Second Delphi round, only 39 answers (response rate: 78%) were completed at the 100% percent. The role of respondents in the livestock sector is heterogeneous, the sample includes academics (14), and members of non-profit organizations (9), independent research institutes (6), consultants (2), for profit organizations (1), non-government organisations (1), cooperative (1), and government or government agency (1). Two respondents were a private farm manager and a retiree.

To ensure good results of the BWS exercise, "bad respondents" were identified and investigated following the criteria of Van Schoubroeck et al., (2023), which are based on time to complete the survey and straight-lining behaviour, i.e., consistency of the answers. The time required to complete the survey was recorded automatically. The lowest value recorded was 7 minutes. Given the possibility to complete the survey in multiple sessions, saving the responses and restoring the session later, the upper bound is not relevant. To exclude "bad respondents" based on the criterion of low accuracy of responses, estimated by the insufficient time invested, we observed that no responses were given in less than 5 minutes. The second check was to verify if any respondent scored item i as "most" and item j as "least" in subset x, and scored item j as "most" and item i as "least" in subset y. Consistency checks were performed for each set of answers. Both on the techno-economic and the socio-cultural sections, only one respondent resulted incoherent for the ranking of a couple of items, while in the governance BWS exercise, any contradictory answer was given. The third criterion of exclusion was if experts scored two or more themes as both "most" and "least" during the full

survey. In this case, three “bad respondents” appear only for the techno-economic part, and only if we consider themes that were selected as best and as worst for two or more times.

METRIC BUILDING

In the following paragraph, the rating and the weighting of the themes for each sustainability dimension are explained.

Rating methodology

The indicators evaluation system is based on the approach proposed in the SAFA, where the performance is measured in 5-point scale including the following terms: “Best”, “Good”, “Moderate”, “Limited, and “Unacceptable”, corresponding to specific scoring bands. To simplify the evaluation system, in this study, we chose to retain only four levels, as shown in Table 5. Using a 4-levels scale in sustainability assessment results in a loss of granularity and detail, but it also offers several advantages, including increased simplicity for designers in defining each level and ease of understanding for those who need to apply it, as well as simplified data analysis.

Table 5: Rating systems.

RATING	SCORE	PERCENTAGE SCORE
GOOD	4	75-100 percent
MODEARATE	3	50-75 percent
LIMITED	2	25-50 percent
UNACCEPTABLE	1	0-25 percent

In themes with multiple indicators, following the procedures indicated in SAFA, we assigned a score to each indicator using the arithmetic mean or the lower value between the two scores.

Weighting Methodology

Once an ordinal ranking of the themes from the analysis of Delphi Study round II was obtained, the ranking was converted into a system of applicable numerical weights for the sustainability assessment metric. In general terms, either the actual weight of the criteria is known, or it may be unknown, and therefore estimated or approximated (Roszkowska, 2013). Various techniques fall under the rank ordering criteria weighting methods and propose different approaches.

For the selection of the method to follow, we will briefly present some theoretical alternatives here, discuss their application in the results section, and finally, the suggested choice will be discussed in the metric design.

Equal weight method (EW)

When the decision maker has no information on the weight's distribution, the information can be represented by a uniform probability density function. Thus, the weight of the j-criterion w_j could be computed using the following formula:

$$w_j(EW) = \frac{1}{n}$$
$$where\ n\ is\ the\ number\ of\ the\ j\ crtiteria\ to\ be\ ranked,\ \ j = 1, \dots, n$$

Rank exponent weight method (RE)

The rank exponent weight method (RE) is a generalization of the "Rank Sum weight method" approach introduced by (Stillwell et al., 1981), where "individual ranks are normalized by dividing by the sum of the ranks" (Roszkowska, 2013). The weight of the j-criterion is computed following the following formula:

$$w_j(RE) = \frac{(n - r_j + 1)^p}{\sum_{k=1}^{n}(n - r_k + 1)^p}$$
$$where\ r_j\ is\ the\ rank\ of\ the\ j^{th}\ criterion, j = 1, \dots, n$$
$$p\ is\ the\ parameter\ describing\ the\ weights$$

When $p = 0$, the rank exponent results are the same of the equal weight method. When p increases, the distribution of the weights becomes steeper. In our case we have chosen three cases, $p = 0.5,\ p = 1, and\ p = 2$.

Rank Order centroid weight method (ROC)

The rank-order centroid weight is a method where the weights "reflect the centroid (centre of mass) of the simplex defined by the ranking of the criteria". In fact, this approach "minimizes the maximum error of each weight by identifying the centroid of all possible weights, maintaining the rank order of objective importance" (Roszkowska, 2013). Barron and Barret (1996) showed that the expected value of the weights can be found with the following formula:

$$w_j(ROC) = \frac{1}{n}\sum_{k=j}^{n}\frac{1}{r_k}$$
$$where\ r_k\ is\ the\ rank\ of\ the\ k^{\ th}\ criterion,\ k = j, \dots, n\ and\ j = 1, \dots, n$$

Results

Delphi Round I

The qualitative analysis of the responses to the first round of the Delphi study allowed to reconsider the definition and categorisation, of each proposed sustainability dimension. As described earlier in the section (The design of the questionnaire) we used specific criteria to be able to arrive at our final list of themes. The revised set of themes are reported in Table 6.

Table 6: List of the themes for the three categories (Techno-Economic, Socio-Cultural, Governance) and the relative description.

Techno-Economic Themes		
1	Efficient use of the inputs	Measuring the efficiency of resource use
2	Input sourcing strategy	Ability to self-produce inputs or dependency on third parties
3	Level of productivity	Productivity level of production factors (ex: labor, livestock)
4	Financial stability	Capacity of being solvent, access to loans and manage risk
5	Profitability assessment	Capacity to generate and increase profits over the long run
6	Continuity of business activities	Capacity to survive through management education and Strategic Business Planning
7	Capacity of innovation	Private/public investment on R&D and innovation adoption
8	Impact on the rest of the economy	Impact on the level of employment & value creation at different level (ex: local, regional, national)
Socio-Cultural Themes		
1	Animal Welfare and Health	Practices to ensure animal health and animal welfare
2	Knowledge impact	Promotion of training and exchange of knowledge, good practices, advice
3	Culture impact	Enhancement of local culture, products and traditional customs
4	Food safety, food quality	Contribution of the value chain to food safety, food security and food quality
5	Local living conditions	Impact on local living conditions (ex: health)

6	Sustainability certification	Adoption of systems of sustainability reporting and/or certifications (voluntary and obligatory)
7	Employees' wellbeing	Practices to guarantee wellbeing for the employees (ex: moral and physical welfare)
Governance Themes		
1	Just value chain	Fair working and commercial contracts among and inside the businesses of the value chain
2	Level of integration of the value chain	The length of the value chain, level of coordination & collaboration among actors
3	Marketing capabilities	Ability to analyse and access to new markets
4	Loss of product during the whole supply chain process	The food loss and the waste production occurring along the value chain stages.
5	Communication	Communication of the adopted practices (ex: B2B, B2C, B2G)
6	Stakeholder engagement	Identify, dialogue, and engage with all those affected by the activities of the firm
7	Mindset	Corporate ethics (ex: Code of conduct)

TECHNO-ECONOMIC DIMENSION

For the Techno-Economic dimension, the initial focus was on the cost of energy supply, which was redefined to include all process inputs and the corporate efficiency in their use. The cost of energy alone was deemed insufficient and misleading as information. Indeed, attention was directed towards the level of use of fossil fuels, the technical progress, the energy poverty, but also the resilience to market price changes. This is why the theme "input source strategy" was also maintained, to observe the vulnerability among supply chain actors, specifically the level of dependence/self-sufficiency and uncertainty/stability in their supply channels. The "level of productivity" was also retained, acknowledging that it did not, by itself, fully capture the evaluation of the created value output. On the "financial stability" theme, there was no disagreement, so the ability to access the credit system and make long-term investments, which was represented by capital expenditure in the draft list, and the ability to be solvent were summarised. The "profitability theme" which did not appear in the first list, was supplemented after the first round of Delphi by gathering participants' suggestions on indicators of company results (i.e., Long Term Profitability, Net Income), while "business continuity" incorporated suggestions regarding business demographics. The "innovation capacity" theme captures both R&D expenditure and the level of adoption and readiness in relation with new technologies, not only digital. Finally, the "impact on the rest of the economy" theme emerged from the participants'

suggestions to observe the contribution of livestock value chains in terms of employment on different territorial scale.

SOCIO-CULTURAL DIMENSION

In the socio-cultural dimension, the theme “Animal welfare and health” integrates with the concepts of animal health, precisely according to the concept of One Heath and One Welfare, emphasising the need for a more precise definition. The impacts generated on culture and knowledge (“Culture impact” and “Knowledge impact” themes, respectively were moved from the governance dimension following experts’ suggestions. The theme “knowledge impact” focused on the creation, development and sharing of skills and expertise, such as consultancy or training, while the “culture impact” theme encompasses the assessment the livestock sector’s role on local food traditions and local customs. The theme “food quality and food security” was initially positioned in the governance dimension and was moved to the socio-cultural dimension to replace the theme “food security information” according to experts’ suggestions. In this regard, the relevance of including indicators related to the availability (volume) of food (food security) was overall acknowledged. However, it was emphasised that for European livestock value chains this factor is less relevant since Europe is a net exporter and therefore nutritional value, and affordability should rather be observed (food safety and quality). The theme of local living conditions, on the other hand, encompassed the impact of companies in the value chain on the community, through e.g. investment programmes for example on infrastructure, facilities, health services, youth education, community development funding. The term 'Sustainability certification' encompasses the concept of 'sustainable behaviour' introduced at the beginning, while 'Employees’ wellbeing' addresses all aspects of working conditions, including safety, health, wages, and representation.

GOVERNANCE DIMENSION

Looking at the Governance dimension, the theme of justice and equity have been reinterpreted as the power dynamics within the value chain. To capture this value chain’s attribute, the theme of just value chain was defined. The level of integration in the value chain was initially distinguished into horizontal and vertical integration, while in the revision it was considered as a single theme, emphasising practices of collaboration, cooperation, and trusts. The theme of market infrastructure is accounted for by assessing the possibilities of access new markets and the ability to introduce a new product. Following experts’ suggestions, the theme related to food loss and food waste along the value chain has been introduced in the list. The theme of corporate communication was also suggested by the experts which remarked how greater transparency can support the transformation towards sustainability. Additionally, experts also highlighted the importance of assessing value chain’s actors commitment in stakeholder engagement activities, which is linked to their

reliance on networking and social organization. The importance of mindset was highlighted in the section on the socio-cultural dimension, recognizing its potential to enhance sustainability. Consequently, the company's commitment to sustainability was included in the governance dimension, following the SAFA framework.

Delphi Round II

Table 7, Table 8 and Table 9 report the results of the counting analysis and of the CL model for each of the sustainability dimension. In the first column, the number of times each theme (listed in the rows) was chosen as 'Most important' is reported. In the second column, the number of times the theme was chosen as 'Least important' is indicated. The third column, 'Most-least important,' represents the difference between the first two. This final number allows us to compare the preferences expressed by the participants. The order of the rows in the following tables is based on the descending value of the 'Most-Least' criterion, allowing the ranking emerging from the participants to be readily discerned. In the fourth and fifth columns, the outputs of the CL model (mean value, standard deviation, and p-value) and the share of preference are reported, which respectively estimate the average preference for a certain theme among the individuals (Van Schoubroeck et al., 2023) and forecasts the probability that each theme is picked as most important (Lusk & Briggeman, 2009). The theme taken as control is the one that presented the minimum value of the difference between most and least, and indeed the theme that appears in the last row has a zero mean for the CL. The number of responses considered, net of the 'bad respondents', is reported in parentheses. For each dimension of sustainability, the shares of preferences, based on the results of the CL model, are also graphically represented through histograms (Figures 11, 12, and 13), where the themes are arranged from least preferred (left) to most preferred (right).

Table 7: Results of Delphi Study round II for the Techno-Economic section (n=35).

	Counting analysis			**Conditional Logit Model**	
	Most	**Least**	**Most-Least**	**Mean (Standard Error)**	**Shares of preferences**
Profitability assessment	95	39	56	0.745*** (0.125)	0.182
Efficient use of the inputs	86	40	46	0.669*** (0.124)	0.169
Level of productivity	67	46	21	0.482*** (0.123)	0.140

Financial stability	57	39	18	0.460*** (0.123)	0.137
Input sourcing strategy	49	74	-25	0.142 (0.122)	0.100
Continuity of business activities	49	83	-34	0.076 (0.122)	0.093
Impact on the rest of the economy	50	88	-38	0.045 (0.122)	0.091
Capacity of innovation	37	81	-44	0	0.087

*p<0.1; **p<0.05; ***p<0.01

Table 8: Results of Delphi Study round II for the Socio-Cultural section (n=38).

	Counting analysis			**Conditional Logit Model**	
	Most	**Least**	**Most-Least**	**Mean (Standard Error)**	**Shares of preference**
Employees' wellbeing	53	20	33	1.061*** (0.173)	0.201
Animal Welfare and Health	54	23	31	1.036*** (0.172)	0.195
Food security, food safety, food quality	52	22	30	1.023*** (0.172)	0.192
Local living conditions	43	32	11	0.784*** (0.168)	0.152
Knowledge impact	28	39	-11	0.514*** (0.166)	0.116
Culture impact	20	64	-44	0.086 (0.169)	0.075
Sustainability certification	16	66	-50	0	0.070

*p<0.1; **p<0.05; ***p<0.01

Table 9: Results of Delphi Study round II for the Governance section (n=39).

	Counting analysis			**Conditional Logit Model**	
	Most	**Least**	**Most-Least**	**Mean (Standard Error)**	**Shares of preference**
Just value chain	67	17	50	1.099*** (0.170)	0.247
Stakeholder engagement	52	21	31	0.852*** (0.163)	0.193
Loss of product during the whole supply chain process	37	31	6	0.553*** (0.159)	0.143
Level of integration of the value chain	42	43	-1	0.471***	0.132

				(0.158)	
Marketing capabilities	33	50	-17	0.283* (0.158)	0.110
Mindset	25	54	-29	0.138 (0.159)	0.094
Communication	17	57	-40	0	0.082

*p<0.1; **p<0.05; ***p<0.01

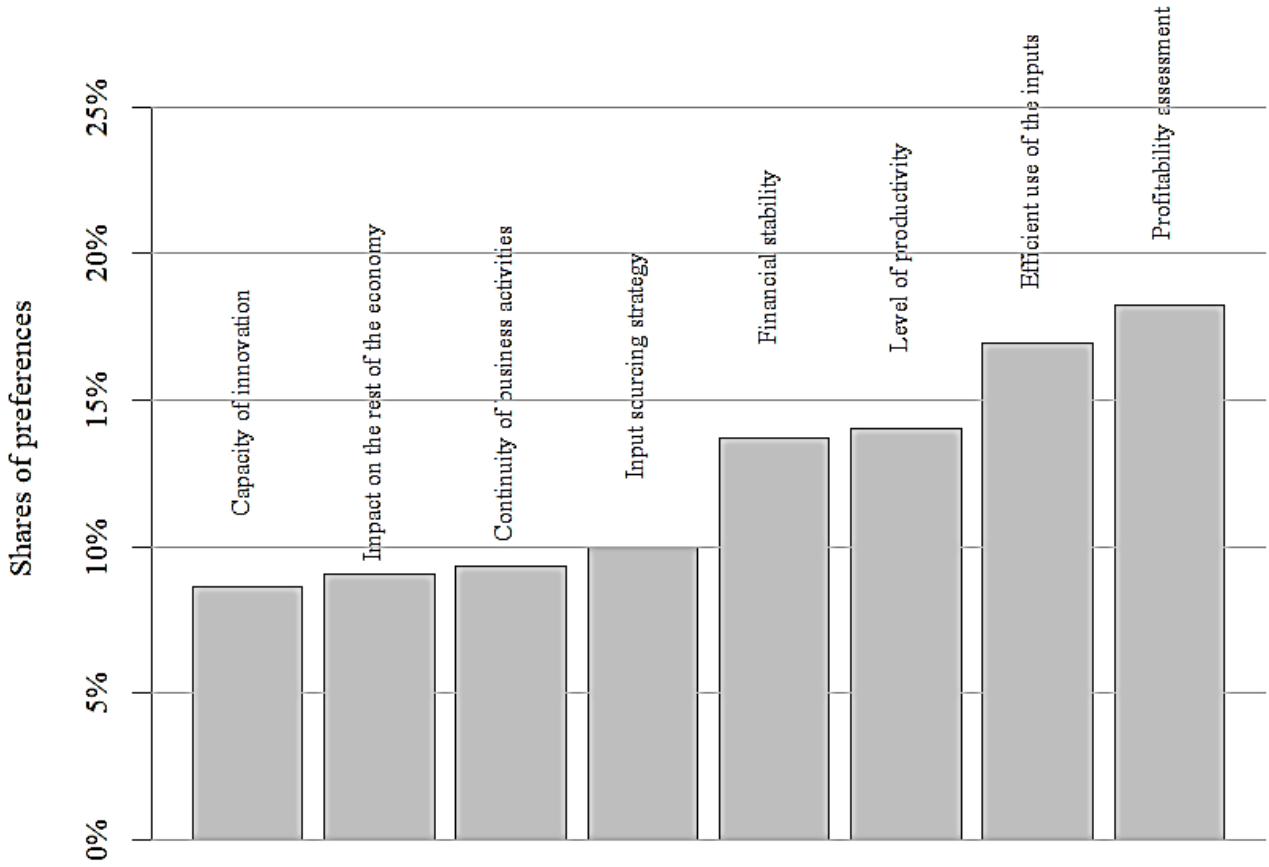


Figure 11: Share of preferences for the Techno-Economic sustainability themes *(Source: Own elaboration).*

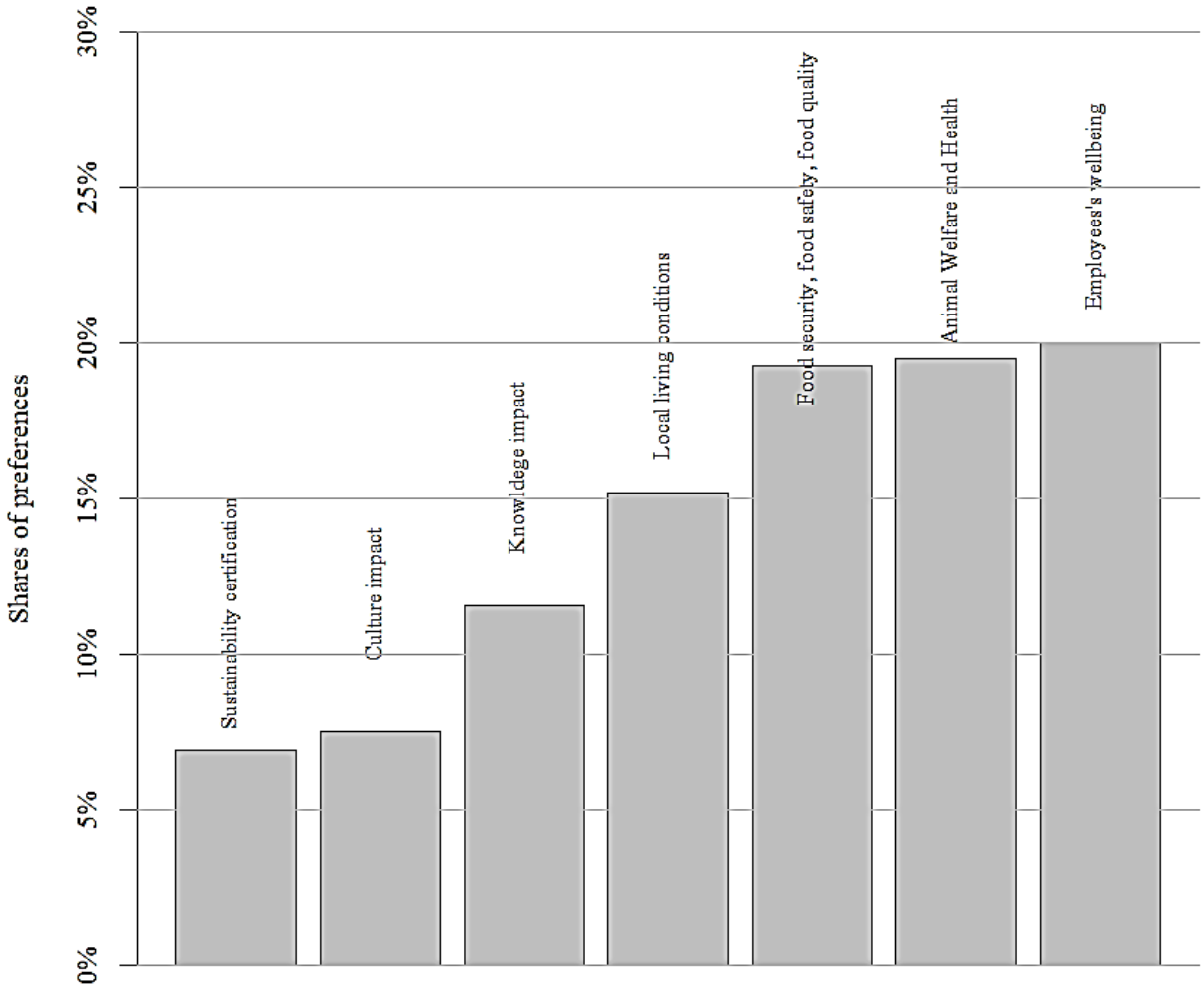


Figure 12: Share of preferences for the Socio-Cultural sustainability themes *(Source: Own elaboration).*

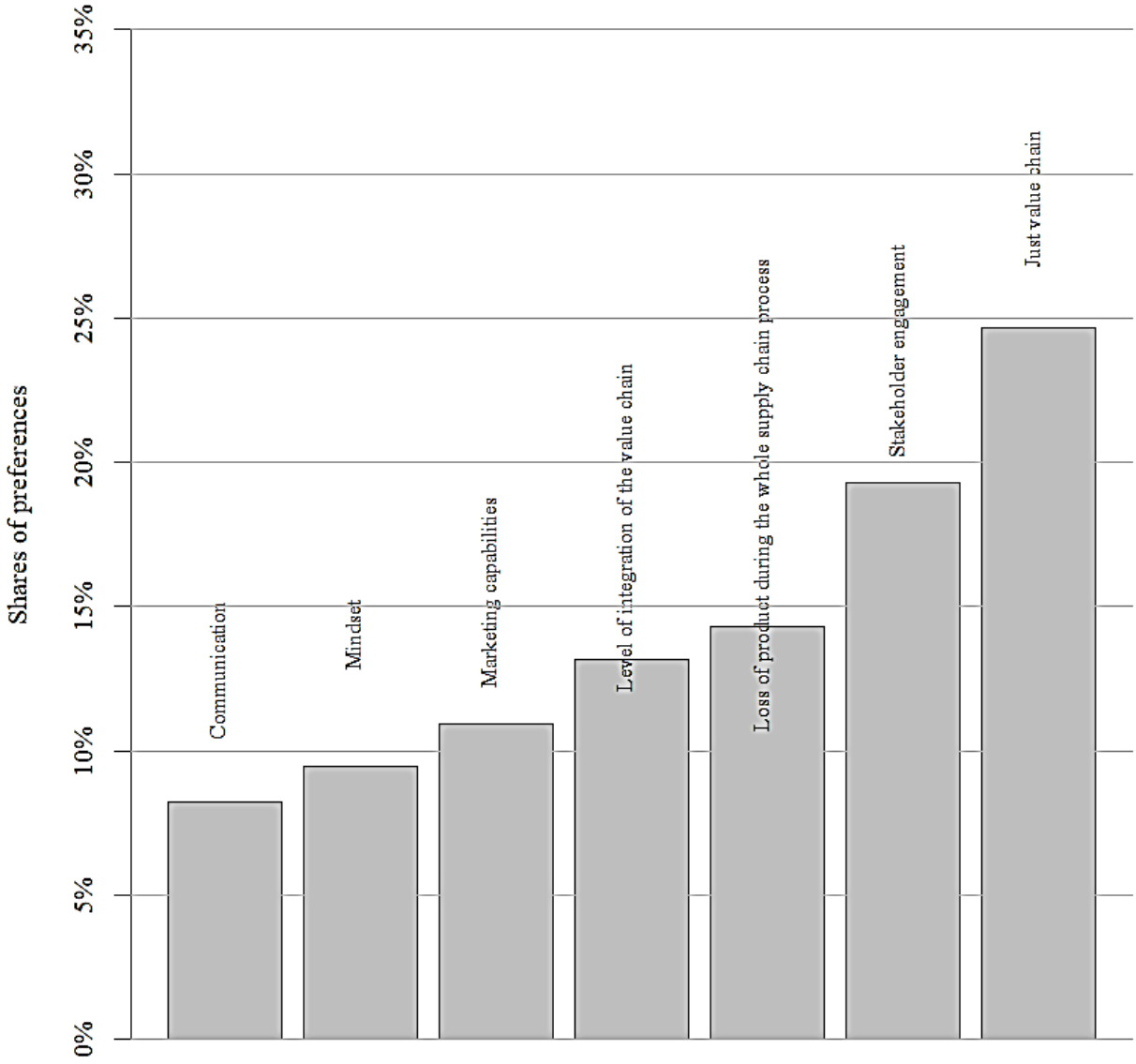


Figure 13: Share of preferences for the Governance sustainability themes *(Source: Own elaboration).*

Feedback from the participants

Upon completion of the surveys, participants were requested to articulate their level of comfort, rating on a five-point Likert scale, form “extremely comfortable” to “extremely uncomfortable”. In the first round, respondents’ feedback on their level of comfort in the survey is clearly recognized as “neither uncomfortable

neither comfortable" (Figure 14). The reasons for the recorded uncomfortable and extremely uncomfortable choices were the high complexity of the topics and the design of the questionnaire.

In the second round (Figure 15), most of the sample was divided between the options "somewhat comfortable" (39,5%) and "somewhat uncomfortable" (31,5%). Participants expressed discomfort for several reasons, such as the difficulty in comparing elements due to their interconnectedness and the perceived importance. Additionally, the unclear definitions and distinctions of some elements, largely due to their interdependencies, increased the complexity of the exercise. The lack of a time horizon specification was identified as a factor contributing to response uncertainty, while the extensive length of the text and repetitive questioning posed barriers to completion. The questionnaire's structure also caused discomfort, and the introduction of a single ranking system for the items was proposed. Lastly, a lack of confidence in "ability to respond" emerged, with many participants citing insufficient experience.

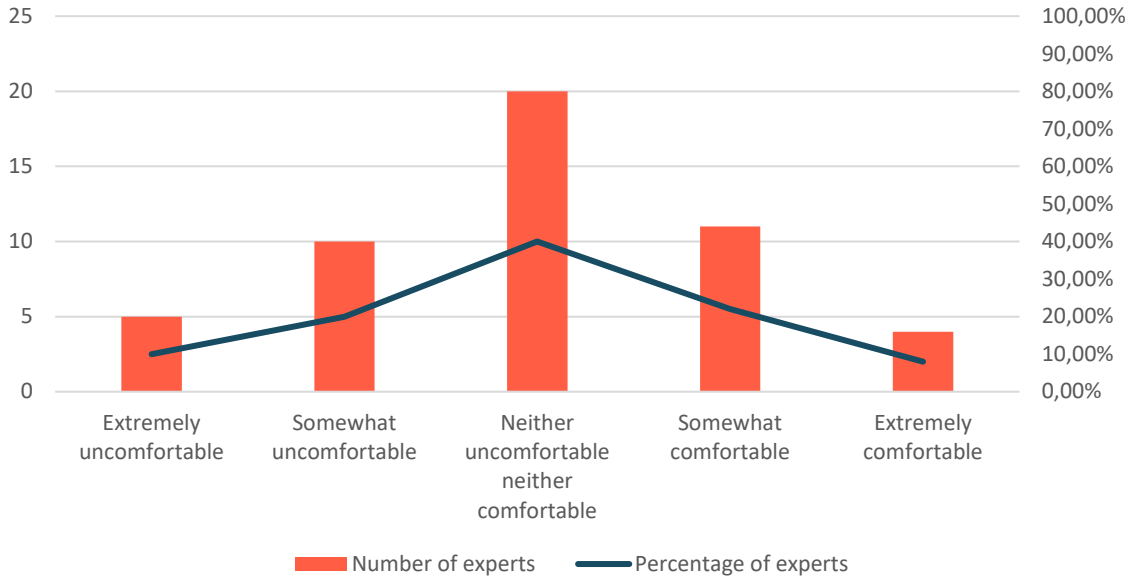


Figure 14: Comfort level feedback from participants in the Delphi round I *(Source: Own elaboration).*

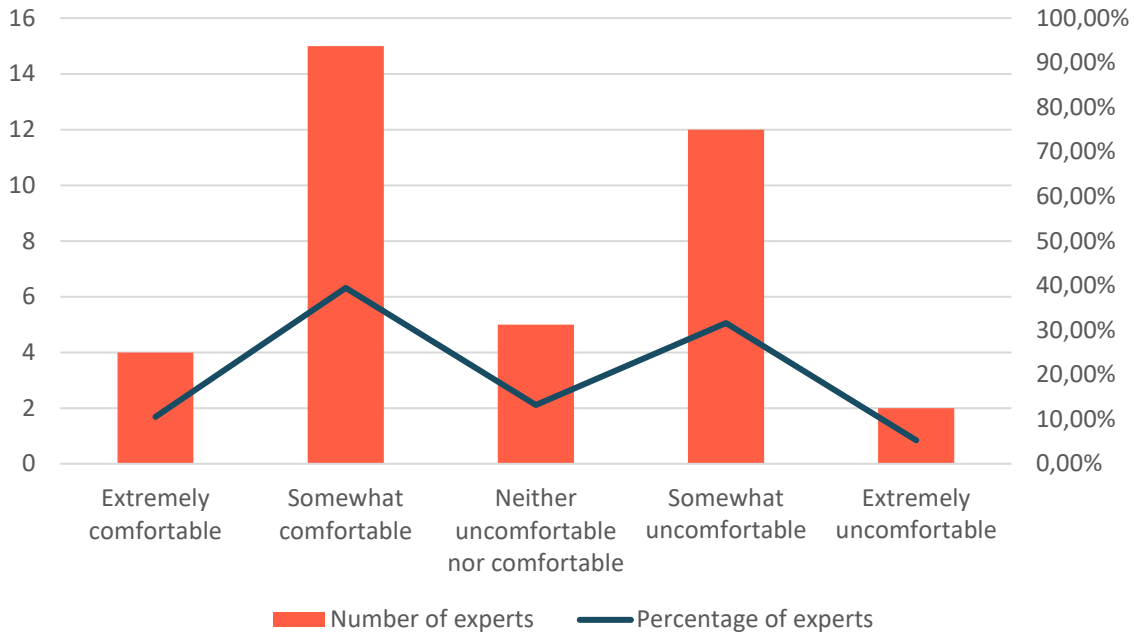


Figure 15: Comfort level expressed by participants to Delphi round II *(Source: Own elaboration)**.***

Metric

Departing from the literature analysis, and going through two rounds of Delphi study, we identified 22 themes. This list of indicators associated to the 22 themes was refined after a careful analysis and review of the indicators proposed in the SAFA and TAPE frameworks. Finally, we defined 31 indicators of interest related to the themes including measurable and verifiable performance-based, and the corresponding practice-based, and target-based indicators to be used in case of contextual data limitations. The criteria used for selecting the indicators were:

- Common keywords, between themes' title and themes' definitions;
- Relevance to the themes

At the basis of the framework and the assessment, SAFA reports that "indicators provide evidence that a condition exists, or certain results have or have not been achieved, and can be either quantitative or qualitative" and that "a metric refers to a unit of measurement that is quantitative" (Scialabba, 2014).

Figure 16 outlines the structure of the sustainability assessment method, derived from the analysis presented in this deliverable. From left to right, the dimensions of sustainability, the observed themes, and the

indicators selected for measurement are reported. The method aims to consider the performance of all actors and stages in the livestock post-farm gate value chain. Thus, as shown in the last column of Figure 16, most themes can be applied to all actors, with the exception of animal health and welfare, which pertain to the transport and slaughter phases, and market capabilities and product loss along the chain, which are more relevant to the processing and distribution phases.

Table 10 and Table 11, and the related Figure 17 and Figure 18, report the application of the systems of numerical weights, applicable in the sustainability assessment metric, and introduced in the Weighting Methodology section. On the rows, and the x-axis, the themes are listed in decreasing order for the criteria “Share of preference”. On the columns, and on the y-axis, the results of “Share of preference” and the weighting technique are represented, by “Rank exponent (p=0.5)”, “Rank exponent (p=1)”, “Rank exponent (p=2)”, “Centroid weight”, and “Equal weight”.

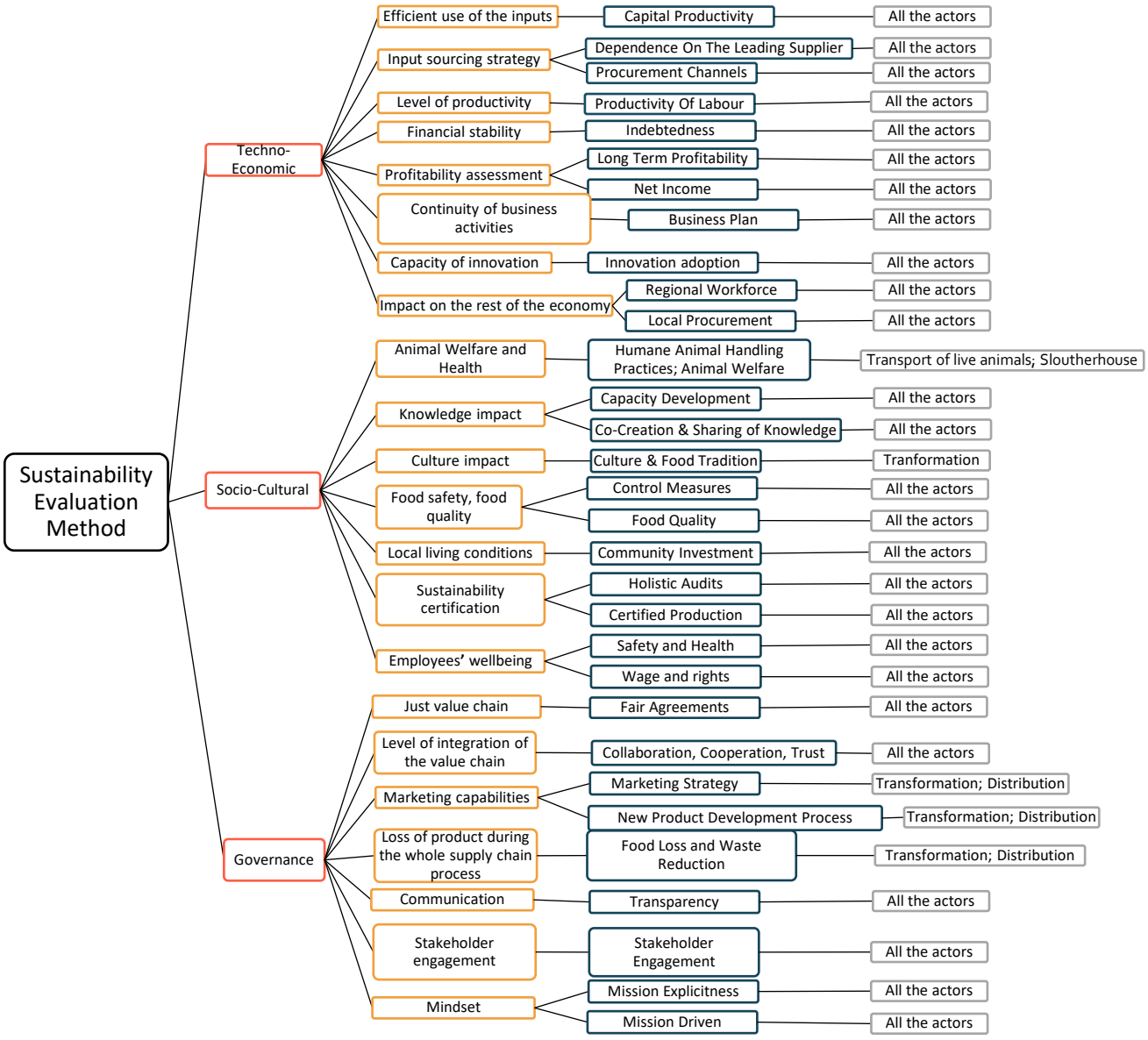


Figure 16: Structure of the co-designed socio-economic sustainability metrics for the livestock value-chain *(Source: Own elaboration).*

Table 10: Application of Ranking Ordering methods to the Techno-Economic Themes.

				Rank Ordering methods				
			Share of preference	Rank exponent (p=0.5)	Rank exponent (p=1)	Rank exponent (p=2)	Centroid weight	Equal weight
Techno-Economic Themes	1	Profitability assessment	0,182	0,173	0,222	0,314	0,340	0,125
	2	Efficient use of the inputs	0,169	0,162	0,194	0,240	0,215	0,125
	3	Level of productivity	0,140	0,150	0,167	0,176	0,152	0,125
	4	Financial stability	0,137	0,137	0,139	0,123	0,111	0,125
	5	Input sourcing strategy	0,100	0,123	0,111	0,078	0,079	0,125
	6	Continuity of business activities	0,093	0,106	0,083	0,044	0,054	0,125
	7	Impact on the rest of the economy	0,091	0,087	0,056	0,020	0,033	0,125
	8	Capacity of innovation	0,087	0,061	0,028	0,005	0,016	0,125

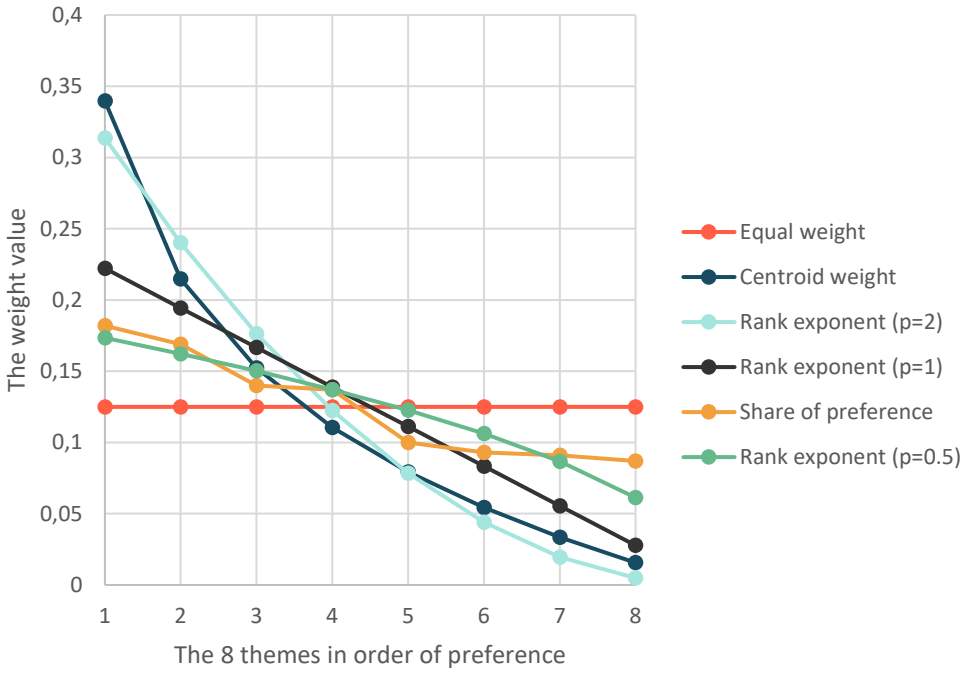


Figure 17: The weight value distribution among eight ranked themes according to different weighting methods *(Source: Own elaboration).*

Table 11: Application of Ranking Ordering methods to the Socio-Cultural and the Governance Themes.

Socio-Cultural Themes/Governance Themes			Shares of preference socio-cultural	Shares of preference governance	Rank exponent (p=0.5)	Rank exponent (p=1)	Rank exponent (p=2)	Centroid weight	Equal weight
	1	Employees' wellbeing Just value chain	0,201	0,247	0,196	0,250	0,350	0,370	0,143
	2	Animal Welfare and Health Stakeholder engagement	0,195	0,193	0,182	0,214	0,257	0,228	0,143
	3	Food security, food safety, food quality Loss of product during the whole supply chain process	0,192	0,143	0,166	0,179	0,179	0,156	0,143
	4	Local living conditions Level of integration of the value chain	0,152	0,132	0,148	0,143	0,114	0,109	0,143
	5	Knowledge impact Marketing capabilities	0,116	0,11	0,129	0,107	0,064	0,073	0,143
	6	Culture impact Mindset	0,075	0,094	0,105	0,071	0,029	0,044	0,143
	7	Sustainability certification Communication	0,070	0,082	0,074	0,036	0,007	0,020	0,143

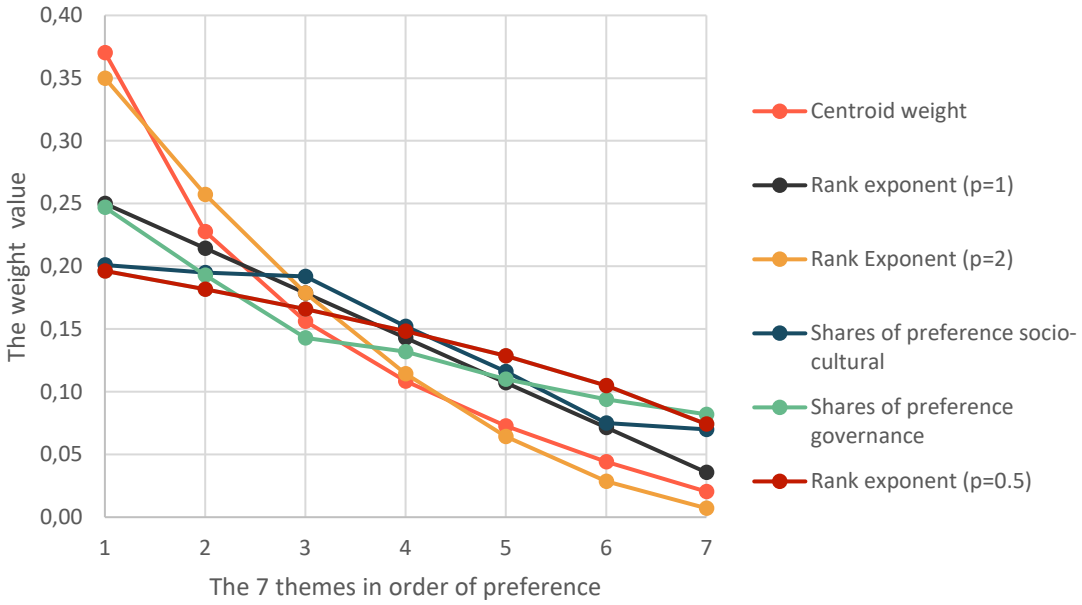


Figure 18: The weight value distribution among seven ranked themes according to different weighting methods *(Source: Own elaboration).*

The fundamental choice is between adopting a system of equal or differential weights, and the recommended criterion for the researcher is to carefully consider the quality of the available information and the process followed to obtain it. The choice will depend on the proximity of the distribution with the preferences gathered.

In the next paragraph for each theme, the corresponding indicators and their rating levels will be explained. For evaluating sustainability performances, four levels have been introduced: 'Good', 'Moderate', 'Limited', and 'Unacceptable', each corresponding to a colour, as shown in Table 5, recalled here by the colour of the bullet point. Wherever the indicator has been taken from SAFA, the definitions have been adopted from the SAFA too and the related references are reported in brackets. It should be noted that in SAFA, definitions are provided for the extreme levels but not for the intermediate ones, which were therefore established to ensure a gradual progression of performance.

TECHNO-ECONOMIC

Theme: Efficient use of the inputs

Indicator: Following the guidelines provided by Eurostat, various indicators are used to measure capital productivity (CAPIs) [9]. The choice of which indicator to apply here depends on the availability of data and the level of analysis chosen.

Theme: Input sourcing strategy

Indicator: Dependence On the Leading Supplier (C 2.2.3)

- The enterprise has conducted a risk analysis of its supply chain to identify its level of vulnerability to certain input supplies and suppliers; and the enterprise has developed and implemented a strategy to minimize the supply risk and to establish a diversified supply structure when it is more appropriate; and for the cases in which supply diversification is recommended, the share of the input supplies that come from the leading supplier does not exceed the 25%.

- The enterprise has developed and implemented a strategy to minimize the supply risk and to establish a diversified supply structure when it is more appropriate. The share of the input supplies that come from the leading supplier is between the 25% and the 50%.

[9](Eurostat, 2024).

- The enterprise has implemented some steps towards reducing its supply risk. The share of the input supplies that come from the leading supplier is between the 50% and the 75%.

- There are records that reveal that the enterprise has an unfavourable level of vulnerability to certain input supplies and suppliers; or the enterprise has not implemented any steps towards reducing its supply risk.

Indicator: Procurement Channels (C 2.2.1)

- The actions and mechanisms implemented have targeted maintaining business relationships with a number of suppliers that could guarantee the required input supply; and the actions and mechanisms implemented enable the access to alternative procurement channels, in case current suppliers fail to provide the required inputs; and since the implementation of such actions and mechanisms, there are no records of input supply shortages, or periods during which the enterprise has failed to meet the expected volume of production on time, or to deliver the service offered.

- Some actions and mechanisms have been implemented to guarantee the required input supply, the records of consistent input supply shortages that have undermined the production process and the delivery of products and services to the market are still present but rare.

- Some actions and mechanisms have been implemented to guarantee the required input supply, nonetheless there are records of consistent input supply shortages that have undermined the production process and the delivery of products and services to the market.

- No actions and mechanisms have been implemented to guarantee the required input supply; or there are records of input supply shortages that have undermined the production process and the delivery of products and services to the market.

Theme: Level of labour productivity

Indicator: Following the guidelines provided by Eurostat, various indicators are used to measure labour productivity (LPIs) [10]. The choice of which indicator to apply here depends on the availability of data and the level of analysis chosen, being a multi-level evaluation.

[10](Eurostat, 2024)

Theme: Financial stability

Indicator: Indebtedness

- No debt.
- Debt is limited and capacity to reimburse is total.
- Debt is more than half of the income. Capacity to reimburse is limited.
- Debt is higher than income.

Theme: Profitability assessment

Indicator: Long Term Profitability (C 1.3.1)

- The enterprise has done investments that aim to generate profits over a period of at least five years; and the enterprise has done investments to generate profits in the short-term and has met completely its financial needs and obligations of the current year.
- The enterprise has done investments that aim to generate profits over a period of at least a year.
- The enterprise invests only to maximize its profit in the short term.
- The enterprise has not done any investment that aim to generate profits over a period of at least a year; or the enterprise has not done any investment that aim to generate profits over a period of at least five years; or the enterprise invests only to maximize its profit in the short term.

Indicator: Net Income (C 1.4.1)

- The net income grows from one year to the other, or within the 5-year period.
- The resulting net income is greater than 0 in each year of the last five years.
- The resulting net income is negative in some of the last five years and positive on the rest.
- The resulting net income is 0 or below (negative) in each year of the last five years.

Theme: Continuity of business activities

Indicator: Business Plan (C 1.3.2)

- The enterprise has a complete and up-to-date business plan that outlines the strategy to be implemented and objectives to achieve for at least a minimum 5 year period; and the enterprise has deployed steps towards progressing in its long-term strategic, business and financial objectives; and all the employees know the business plan, its objectives and targets, and their respective annual operating plan is designed in alignment with the business plan.

- The enterprise has a complete and up-to-date business plan that outlines the strategy to be implemented and objectives to achieve for at least a minimum 5 year period; and the enterprise has implemented steps towards progressing in its long-term strategic, business and financial objectives; and all the employees know the business plan, its objectives and targets, and their respective annual operating plan is designed in alignment with the business plan.

- A written or otherwise documented business plan may not be in place, but the enterprise has implemented steps towards planning for the future, that at least addresses the next few years.

- The enterprise does not have a business plan or an up-to-date document articulating revenue streams, growth plan, and an operational action plan that projects the generation of financial resources for the future.

Theme: Capacity of innovation

Indicator: Innovation Capacity; Innovation Adoption

- Higher R&D expenditure. The individual or organization becomes aware of the innovation, assesses the sustainability, implements it (trial or fully).

- Stable R&D Expenditure; The individual or organization becomes aware of the innovation, collect information, benefits and challenges of the innovation are assessed.

- Decreasing R&D expenditure. The individual or organization becomes aware of the innovation but lacks detailed information.

- Null R&D expenditure. The individual or organization is not aware of the innovation.

Theme: Impact on the rest of the economy

Indicators: Regional Workforce (C 4.1.1); Local Procurement (C 4.2.1)

- The enterprise has a human resources policy that prioritizes hiring regional employees when similar skills, profile and conditions are offered in relation to other candidates; the enterprise has developed and applied a procurement policy that prioritizes the purchase of inputs, products and ingredients from local suppliers.

- During the last 5 years, in half of applicable cases, the enterprise has hired regional when external candidates offer similar skills, profile and conditions; the enterprise has developed, but not applied yet a procurement policy that prioritizes the purchase of inputs, products and ingredients from local suppliers.

- During the last 5 years, in half of applicable cases, the enterprise has hired non-regional or external candidates when regional candidates offer similar skills, profile and conditions; the enterprise is developing a policy that prioritizes the purchase of inputs, products and ingredients from local suppliers.

- The enterprise does not have a human resources policy that prioritizes hiring employees when similar skills, profile and conditions are offered in relation to other candidates; or in most cases where local suppliers can provide the required inputs to the enterprise, under equal of similar conditions in comparison to non-local, the enterprise has selected non-local suppliers.

SOCIO-CULTURAL

Theme: Animal Welfare and Health

Indicators: Humane Animal Handling Practices (E 6.2.1); Animal Welfare (E 6)

- Animals do not suffer from stress, hunger, thirst, pain, or diseases during the transportation and decent slaughtering practices, in a way to avoid unnecessary pain are guaranteed.

- Some practices to reduce suffer and stress are put in practice both in the transportation and slaughter phases.

- Animals can suffer and experience stress during the transportation and especially at slaughter.

- Inhumane and illegal treatment of animals, such as butchering with a dull knife, or unnecessarily long transport without sufficient space and water.

Theme: Knowledge impact

Indicator: Capacity Development (S 1.2.1)

- Employees may attend trainings, conferences, or other learning and networking events; employees may discuss opportunities for advancement openly with management and may develop plans for acquisition of necessary skills; employees can give examples of colleagues, or their own experience, of being promoted fairly, or of being given by the enterprise, opportunities for career development.

- Employers offers to some of their workers the chance to advance through learning and networking events. Nonetheless they have no chance to discuss openly on the opportunity to advance.

- Employers rarely give their own workers the chance to advance through learning events, they still prefer to hire form outside the needed skills. Employees cannot discuss opportunities for advancement openly with management and cannot develop plans for acquisition of necessary skills.

- Employers hire from outside their enterprise when they want new skills or greater capacity, and do not give their own workers the chance to advance.

Indicator: Co-Creation & Sharing of Knowledge

- Several well established and functioning platforms for the co-creation and transfer of knowledge are available and widespread within the community, including women.

- One or several platforms for the co-creation and transfer of knowledge exist, are functioning and are used to share knowledge, including women.

- At least one platform for the co-creation and transfer of knowledge exists but does not function well and/or is not used in practices.

- No platforms for co-creation and transfer of knowledge are available to producers.

Theme: Culture impact

Indicator: Culture & Food Tradition

- Local or traditional identity strongly felt and protected, high respect for traditions and/or rituals. Several local varieties/breeds are produced and consumed. Traditional knowledge and practices for food preparation are identified, applied and recognised in official frameworks and/ or specific events.

- Good awareness of local or traditional identity and respect of traditions or rituals overall. Most of the food consumed comes from local varieties/breeds and traditional knowledge and practices for food preparation are implemented.

- Little awareness of local or traditional identity. Most of the exotic/introduced varieties/breeds are consumed, or there is little use of traditional knowledge and practices for food preparation.

- No local or traditional (peasant/indigenous) identity felt. No use of local varieties/breeds nor traditional knowledge for food preparation.

Theme: Food safety, food quality

Indicator: Control Measures

- There are mechanisms in operation that fully comply with correspondent regulations to prevent and control food hazards and food contamination; there are no records of food contamination incidents since the mechanisms are in place.

- There are few mechanisms in place to prevent and control neither food hazards nor food contamination; there were rare records of food contamination incidents in the last five years.

- The enterprise is taking steps to prevent and control neither food hazards nor food contamination; there were decreasing records of food contamination incidents in the last five years.

- There are no mechanisms in place to prevent and control neither food hazards nor food contamination; there are records of food contamination incidents in the last five years.

Indicator: Food Quality (C 3.2.1)

- 100% of the volume of production has successfully passed the quality control that measures the required and highest nutritional standards the product needs to meet.

- More than half of production passed the quality control that measures the required nutritional standards the product needs to meet.

- Less than half of production passed the quality control that measures the required nutritional standards the product needs to meet.

- Any amount of the production has not passed the quality control that measures the required nutritional standards the product needs to meet.

Theme: Local living conditions

Indicator: Community Investment

- The enterprise has already implemented a community investment programme and measure its impacts.

- The enterprise has already implemented a community investment programme, but with no clear impacts yet.

- The enterprise has started a process of planning of at least one corporate investment

- The enterprise has never considered the possibility to make investments in their business models.

Theme: Sustainability certification

Indicator: Holistic Audits (G 2.1.1)

- The enterprise has a regular sustainability audit using a recognized tool and evidence that this is reviewed by governance body and peer reviewed. If the enterprise is a small-scale operation, it has used a systematic approach of their own, or with the assistance of an outside partner, to regularly review their sustainability performance.

- The enterprise has evidence of formal sustainability auditing, which is not under a peer review process.

- The enterprise has evidence of informal sustainability auditing; the enterprise is engaged to address known deficiencies emerged in sustainability audits.

- The enterprise has no evidence of sustainability auditing, either formal or informal; the enterprise has sustainability audits which are found to be falsified or consistently fail to address known deficiencies.

Indicator: Certified Production (C 3.3.3)

- The enterprise keeps a procurement record which identifies the certification status for all procurement, distribution and production; the enterprise is able to provide evidence of assessments for any non-certifiable procurement, distribution or production, and this assessment details the problem, reason for the decision, plan to remedy and date for review; the enterprise has evidence that it transparently reports its progress towards certified procurement, distribution and production to its stakeholders.

- The enterprise has records of the certification only for the 50%-75% of its procurement, distribution or production; the enterprise has evidence that it partially transparent reports its progress towards certified procurement, distribution and production to its stakeholders.

- The enterprise has records of the certification only for the 25%-50% of its procurement, distribution or production; the enterprise's claims to stakeholders regarding certified supply can be substantiated, albeit with some challenges.

- The enterprise has no records of certification of its procurement, distribution or production; the records of certified procurement, distribution or production are not independently verified or are self-awarded; the enterprise' claims to stakeholders of certified supply cannot be proven.

Theme: Employees' wellbeing

Indicator: Safety and Health Trainings (S 5.1.1); Safety of Workplace, Operations and Facilities (S 5.1.2)

- The enterprise ensures a safe, clean and healthy workplace for employees by determining if facilities and structures, equipment, practices and food offered are safe and meet employee needs for healthy lifestyles.

- The enterprise has a lower rate of accident compared to the industry average. The enterprise ensures the legal requirements of safe facilities and working conditions and practise.

- The enterprise has a rate of accidents equal to the industry average. The enterprise respects the legal requirements of safe facilities and working conditions and practise.

- The enterprise has a higher rate of accidents than industry average; buildings are compromised or unsafe; employees do not follow safety protocols, or none exist, for employees when using toxic

materials, hazardous materials or inputs; sanitation facilities, transportation or housing are filthy and unsafe for employees using them.

Indicator: Wage Level (S 1.1.2) Freedom of Association and Right to Bargaining (S 3.4.1)

- 100% of employees and personnel involved in the enterprise are paid more than the living wage. The rights to freedom of association and collective bargaining are fully established and understood by all employees involved and employers provide training in their legal rights for all employees.

- The rights to freedom of association and collective bargaining are fully established and understood by all employees. 100% of employees and personnel involved in the enterprise are paid a living wage.

- Legal requirement between employees and employers are respected. 100% of employees and personnel involved in the enterprise are paid a wage equal to the one of the same industries.

- Employer retaliation against employees for initiating the rights and freedoms, including cancelling of contracts/subcontracts and verbal threats against labour; or restrictions on transparency and negotiations; or refusal to allow employees to have representative of their choice present during any negotiations; paying employees below the prevailing average rate for the same industry.

GOVERNANCE

Theme: Just value chain

Indicator: Fair Pricing and Fair Contracts /Agreements

- 100% of trade deals with suppliers are based on contracts with buyers that include the rights to negotiate the terms of trade, a conflict resolution process for resolving differences, and the agreement that trade relations will not be terminated, except for just causes.

- More than 50% of trade deals with suppliers are based on contracts with buyers that include the rights to negotiate the terms of trade, a conflict resolution process for resolving differences, and the agreement that trade relations will not be terminated, except for just causes.

- Less than 50% of trade deals with suppliers are based on contracts with buyers that include the rights to negotiate the terms of trade, a conflict resolution process for resolving differences, and the agreement that trade relations will not be terminated, except for just cause.

- Buyers set prices without consultation with suppliers; or buyers retaliate against suppliers who raise issues, or complaints about the terms of trade; or buyers terminate trade agreements with suppliers without just causes; or the agreements lack of a mutual understanding on the conflict resolution process.

Theme: Level of integration of the value chain

Indicator: Collaboration, Cooperation, Trust

- Long lasting collaborations with partners (+10 years), vibrant association/cooperative membership, frequent and regular sharing of information.

- Established collaborations and membership in associations/cooperatives, occasional level of information sharing.

- Few initiatives of collaboration with partners, steps taken toward association/cooperative membership, low level of information sharing.

- No initiatives of collaboration with partners, no memberships in associations and cooperatives, no sharing of information.

Theme: Marketing capabilities

Indicator: Marketing Strategy

- The enterprise has well developed marketing strategy, with marketing analysis, planning and audit.

- The enterprise has recently implemented a structured marketing strategy.

- The enterprise has started a process of marketing analysis but has not developed a marketing planning.

- The enterprise has no marketing strategy.

Indicator: New Product Development Process

- New product development is well established in the company from many years. Innovations is a pillar of the business activities.

- New product development process has already started, and first results have already benefited the company.

- New product development is a novelty in the company and has not given results yet.

- New product development is out of the interest of the company.

Theme: Loss of product during the whole supply chain process

Indicator: Food Loss and Waste Reduction (E.5.3.4)

- Food loss and waste do not exceed an inevitable minimum over the entire sphere of influence of the analysed enterprise; where losses cannot be prevented, all concerned food is put into use via other channels (e.g. charities, feed, compost, bioenergy).

- The enterprise has set a target for food wastage reduction and invests in food wastage reduction measures.

- Food loss and waste is a concern of the enterprise, which has started to investigate on how to better them.

- Food loss and waste in the sphere of influence of the enterprise have increased over the past years or the share of loss and waste is higher than usual in the same sector.

Theme: Communication

Indicator: Transparency (G 2.3.1)

- The enterprise has explicit and open policies to deal with requests for information. it anticipates the information stakeholders will need and makes this available in a timely and accurate manner via channels which are appropriate and accessible to its stakeholders. The enterprise regularly assesses its performance and invites stakeholders to rate the performance and comment on how this could be improved. It can show a consistent history of improvement in its transparency.

- The enterprise has recently implemented transparency policy.

- The enterprise upon request provides the needed and true information.

- The enterprise regularly and deliberately withholds information from key stakeholders or provides information that is not fully accurate.

Theme: Stakeholder engagement

Indicator: Stakeholder Engagement (G 3.1.2)

- The enterprise has a clear commitment to stakeholder engagement and participation when it has achieved satisfactory engagement with 80% of identified stakeholders, including all vulnerable stakeholders and those unable to claim their rights.

- The enterprise is poorly able to describe the process of stakeholders' engagement. The 50% of the stakeholders, including the most vulnerable, have been engaged.

- The enterprise is poorly able to describe the process of stakeholders' engagement. The 30% of the stakeholders, or 50% of the stakeholders who are the most vulnerable, have been engaged.

- The enterprise is unable or unwilling to describe the process used for engaging with stakeholders or the process of engagement or excludes the most vulnerable and those unable to claim their rights; or less than 30% of stakeholders, or less than 50% of stakeholders who are among the most vulnerable and those unable to claim their rights, have been engaged.

Theme: Mindset

Indicator: Mission Explicitness (G.1.1.)

- 100% of employees, or members of a group of small-scale producers, can explain the enterprise's mission and identify how it influences the work which they do.

- More than half of the employees, or members of a group of small-scale producers, can explain the enterprise mission and identify how it influences the work which they do.

- Less than half of the employees, or members of a group of small-scale producers, can explain the enterprise mission and identify how it influences the work which they do.

- The enterprise or group of producers has no articulated mission; or the mission of the enterprise or group of producers does not address sustainability; or the key planning and reporting documents of the enterprise, or undocumented rituals of the group of producers, have no evidence of sustainability principles.

Indicator: Mission Driven (G 1.1.2)

- 100% of governance body and senior management can identify the influence of the mission sustainability commitments in the key decisions and processes of the enterprise.

- More than half of the governance body members and senior management can identify examples of mission driven decision making. The enterprise in staking steps to close the gaps between decisions taken and mission stated.

- Less than half of the governance body members and senior management can identify examples of mission driven decision making. There is still predominance of incoherency between decisions taken and mission stated.

- The governance body and senior management are unable to identify any examples of mission driven decision making; or significant decisions of the enterprise and its practices are contrary to mission.

Discussion of results

First round of the Delphi study

After the Delphi first round and the qualitative analysis of the answers, the list of themes was reduced from 28 to 22 themes. The smaller number is a result of a synthesis made to avoid overlapping and to incorporate similar suggestions in the same theme. One research challenge faced was how to disentangle the complex relationships between the themes inside the sustainability categories and between them. For instance, some Techno-Economic themes could be linked to value-chain organization ("Input-sourcing strategy"), or to the firm managerial context and generational turn-over ("Capacity of innovation" and "Continuity of business activity"). Socio-Cultural items could be interpreted also as building-block of economic or environmental resilience, i.e., "Sustainability certification" and "Animal welfare and health" was allocated into the Socio-Cultural dimension, but in SAFA they are respectively in the Economic and Environmental sections. Connections between Socio-Cultural and Governance dimensions are also evident. For example, "Mindset" was placed in the Governance, as suggested also in SAFA but, it was suggested as a theme belonging to the sustainability culture. In the end, Governance has multiple meanings and could influences all the activities performed, for example "Market capabilities" could also fit within the economic domain.

Second round of the Delphi study

The BWS experiment generated a hierarchy of themes' importance accounting for experts' judgment and preferences. For the Techno-Economic dimension, according to the "Most-Least" scores, there were three scoring class, where "Profitability assessment" (56) and the "Efficient use of the inputs" (46) were judged as the relatively most important. "Level of productivity" (21) and "Financial stability" (18) followed with and intermediate score, and at the bottom of the rank "Input sourcing strategy" (-25), "Continuity of business activities" (-34), "Impact on the rest of the economy" (-38) and "Capacity of innovation" (-44) were valued as relatively least important. The CL model's outputs confirm the order of the counting analysis, even if only half of the coefficient are significant (p-value <0,01), probably due to the small sample.

Moving to the Socio-Cultural dimension, "Employees' wellbeing" (33), "Animal Welfare and Health" (31) and "Food safety, food quality" (30) are the highest in the ranking, followed by "Local living conditions" (11), with a smaller but still positive difference between "Most" and "Least". With a negative sign "Knowledge impact" (-11), "Culture impact" (-44) and "Sustainability certification" (-50) close the list. It is particularly interesting the result on the "Sustainability certification" which means it was valued as relatively least important to consider when measuring the socio-cultural sustainability performance of livestock value chains. The CL model's outputs confirm the order of the counting analysis, and coefficients are all significant (p-value <0,01) except for "Culture impact".

Dealing with the Governance dimension, the ranking resulted more straightforward, "Just value chain" (50), "Stakeholder engagement" (31), "Loss of product during the whole supply chain process" (6), "Level of integration of the value chain" (-1), "Marketing capabilities" (-17), "Mindset" (-29) and "Communication" (-40). The CL model's output confirms the order of the counting analysis, and coefficients are all significant (p-value <0,01) except for "Mindset".

The metric design

Once the ordinal ranking of the themes was available, several systems of numerical weights were compared. Since the results were not always significant, for the three themes, a safe choice could be to adopt the "Equal weight method". On the other hand, to valorise the prioritization made by participants, the "Rank exponent method" with $p = 0{,}5$ or with $p = 1$ seem the best fitting options (Figure 17, Figure 18). This weight values will be used in the evaluation method to give relative weight to the themes, as shown in Figure 19. For each theme, instead, the weight is distributed evenly among indicators, as in the SAFA framework.

Figure 19: Outer circle with the three dimensions of sustainability and the themes characterizing them. The sectors' areas are proportional to the theme's relative weight *(Source: Own elaboration).*

Limits of the study

At technical level, the choice of administering the questionnaire online made it possible to reach a larger number of experts but made communication between the parties more difficult, even if the box for comments was always available and reference email was spread for further clarifications. In terms of the Delphi study, the rate of adherence to both the first and second rounds was not high, which also explains the small p-values of the CL's model. However it was still possible to apply the BSW experiment, as found in the literature (Mühlbacher et al., 2016). Participants' feedback indicated a risk that experts might not feel sufficiently competent when questions required knowledge beyond their area of expertise. This situation, which can always occur, was exacerbated by the complexity of the exercise and the attempt to synthesize several topics. This is also why we opted for an online Delphi method, aiming to reach a large number of respondents to cover the various specializations needed, and encouraging the involvement of colleagues with the required competences.

Conclusion and future developments

In a context of growing concern for the sustainability transition of the European food system, the sustainability assessment of livestock value chains is a complex exercise that can shed lights of the actions that need to be taken. Focusing on multiple dimensions, avoiding a reductionist approach, and involving different expertise along livestock value chains can help to assess the whole sector, in his systemic understating, contribution to the transition toward sustainability.

In our study, we developed a novel sustainability evaluation method, which considers the Techno-Economic, the Socio-Cultural and the Governance performances of livestock value chains, based on SAFA framework. However, the method focuses solely on the post-farm stages of livestock supply chains and only on their socio-economic aspects. Consequently, the method proposed represents an acceptable simplification of the SAFA, and reducing the rating values to four (instead of five) and the load of information to be gathered, makes it easier to be applied.

The process of identification of the themes and their prioritization was realized within an online two-round Delphi Study. Several steps can be taken in the future to improve the results obtained. Firstly, the method could be shared with the Delphi Study participants, who could comment on and check the overall ranking of the themes. Lastly, the refinement of the metric can be realized through an empirical application to animal product value-chains, which we aim to engage into at various geographical levels, combining different sources of information, particularly existing databases, and through interviews with stakeholders.

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