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Assessing the Sustainability of the Indonesian Halal Beef Supply Chain

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ABSTRACT

Assessing the halal beef chain's sustainability is crucial for the achievement of sustainable development goals in Indonesia. This study evaluates the economic, environmental, and social impact of the Indonesian halal beef supply chain. The economic indicator shows that cattle farmers incurred the highest costs, but earn a lower profit than the beef retailers. Cattle farmers produce higher carbon emissions and use more freshwater than other actors. However, cattle farmers contributed most significantly to hiring employees along the Indonesian halal beef supply chain. These indicate a gap between actors that impact the fragile sustainability of the supply chain.

Keywords: *Economic sustainability; Environmental sustainability; Social sustainability; Life cycle sustainable assessment; Halal beef.*

1 Introduction

Cattle and chicken are livestock that can be consumed by the Muslim community. They can only consume these livestock products if they have gone through a halal process. Generally, local cattle farmers provide halal chicken and beef products in Indonesia. For halal beef supply, Indonesia is still not self-sufficient. Local beef supply could meet 65% of the national halal beef demand in 2008 and 80% of national meat consumption in 2018 (Ministry of Agriculture, Republic of Indonesia, 2019). In this decade, cattle supply has reduced the deficit in halal beef demand.

Halal meat in Indonesia has rapidly expanded beyond ritual slaughter and other processes based on Islamic law. The sector's growth is driven by the development of technology, app innovation, and halal traceability software that connects the entire supply chain from farm to fork. The use of various technologies and platforms provides value to each actor in the Indonesian halal beef supply chain. Muslim consumers in Indonesia perceive the ability to trace a product's compliance with halal principles as useful and vital (Sayogo, 2018). For cattle farmers, beef wholesalers, and meat retailers, halal traceability implementation presents an initiative to minimize the cost of product rejection by the market (Mohammed et al. 2016).

All stakeholders must obtain a fair and equitable share of the added value to enhance the Indonesian halal beef chain's sustainability and mutual prosperity. According to Rivera et al. (2018), improving sustainability at the farm level has significantly contributed to creating a prosperous village economy. A prosperous society is the goal of sustainable development. Hoffman (2011), Donde et al. (2016), and Baourakis and Mattas (2019) stated that sustainable development involves environmental protection, including biodiversity, economic growth, and social equity, both within and between generations.

A halal beef supply chain can be an effective means to promote sustainable development, especially in the halal food sector (Rezai et al., 2015). Besides, Khan et al. (2018) and Haleem et al. (2020) explained that halal values along the supply chain require the implementation of fair trade, environment-friendly, animal rights, and ethical issues. A fair trade, eco-friendly, and animal welfare are the key determinants beyond the halal and quality assurance in the sustainable halal meat industry. Therefore, evaluating the sustainability performance of the halal beef chain is essential for the achievement of sustainable development goals in Indonesia.

We assess the sustainability of Indonesian halal beef supply chain, particularly, this study aims to identify the Indonesian halal beef supply chain's basic system and assess the economic, environmental, and social sustainability in the Indonesian halal beef supply chain. Halal beef's sustainability assessment serves to find a sustainable critical point in the Indonesian halal beef supply chain. The findings in this study can enhance each partner's innovation in the Indonesian halal beef supply chain.

Furthermore, the life-cycle sustainability assessment (LCSA) framework is suitable for evaluating sustainability along the Indonesian halal beef supply chain. Helbig et al. (2016), Kempen et al. (2017), Muñoz-Torrez et al. (2018), and Ferrari et al. (2019) explained that LCSA integrates the environmental dimension and the socio-economic dimension to calculate the impact of using natural resources in the product supply chain from producer to consumer.

The structure of this paper is as follows. The second section presents the research method that explains the research design and approach, research instrument, data collection, and analytical framework. In the third section, we explain the result and discussion that describe the Indonesian beef supply chain's basic system and illustrate the economic, environmental, and social sustainability. Finally, in the fourth section, we present the conclusion and implication. The conclusion section shows the key point of this study, while the implication section discusses policy implications and future research.

2 Materials and Methods

2.1 Research Design and Approach

This research uses a descriptive design to evaluate the environment and socio-economic impact along the Indonesian halal beef supply chain. Assessing sustainability requires producer and supplier surveys using a quantitative method. This approach provides a numeric description of trends, opinions, attitudes, or experiences of a population object (Cresswell, 2014). This sustainability research can reveal the additional cost, margin, value-added, profit, greenhouse gas emissions, freshwater use, and labor.

2.2 Research Instrument

The research variable consists of economic, environmental, and social dimensions composed of various indicators. Additional cost, margin, added value, and profit elaborate on the economic aspect. The measurement of these indicators identifies various attributes: buying price, selling price, production cost, and operational cost. Whereas, carbon and water footprints explain the environmental aspect that is identified by attributes that are CH_4, CO_2, N_2O, and freshwater use. Besides, the number of labor describes the social aspect shown by the attribute of amount labor. Each attribute has several open questions to explore the input and output in each actor's business activity along the Indonesian halal beef supply chain.

2.3 Data Collection

This research area's entry points are the four largest cities in Indonesia, which have different consumer preferences. In the field study, halal beef retailers, beef processors, and cattle farmers were interviewed from August to September 2019 in Jakarta and Surabaya and from January to March 2020 in Bandung and Lampung. The total respondents are 225 comprised of 100 of beef retailers, 25 of beef processors, and 100 middle-up scale cattle farmers.

2.4 Analytical Framework

This study utilized the LCSA framework, a mechanism to analyze and calculate the total economic, environmental, and social impact of a product in its life-cycle stage. Excessive inputs or materials will decrease material supply. In contrast, the output from the production system and supply chain could include a waste (solid, liquid, and air), which will have a significant negative impact on the economic environment. Life-cycle sustainability assessment is carried out in different phases, whose results are interdependent so that each phase informs the others. The phases are defining goal and scope, identifying stakeholders, life cycle inventory (LCI), life cycle sustainability impact assessment (LCSIA), and interpretation (figure 1).

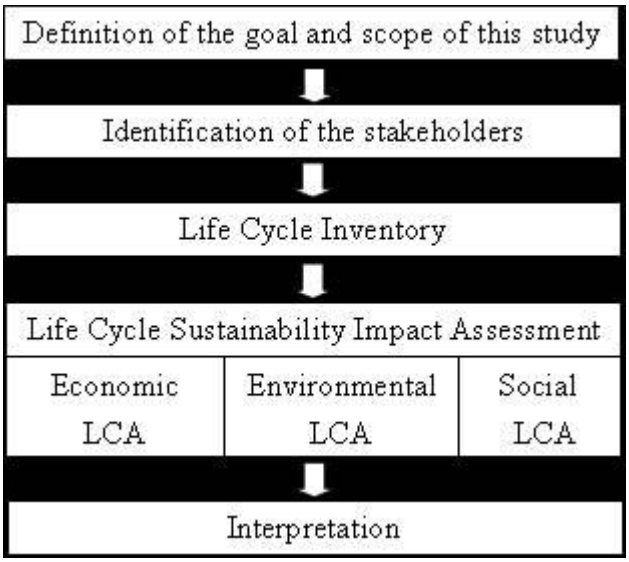

Figure 1. Flow of life-cycle sustainable assessment
Source: Adopted from Ferrari et al. (2019) and Liu et al. (2019)

The goals and scope of this study set its direction and boundary. The specified goals and scope affect the results of LCSA. The goals of this study determine the goal of the LCSA analysis. Our goal is to identify the economic, environmental, and social impacts along the halal beef supply chain. The scope of LCSA includes the processes of fattening cattle (for large-scale cattle farmers) and distributing cattle, slaughtering, and packaging, distributing, and displaying beef.

Describing a food product's production and distribution reveals the actors involved at each level along the halal food supply chain. Generally, each level consists of various actors. For example, meat distribution involves wholesalers and retailers. Identifying the actors along the halal meat supply chain allows us to find the factor that triggers their activities' costs and emissions. Calculating the costs and emissions at each level can illustrate their role in producing greenhouse gas emissions.

The life cycle sustainability inventory identifies the activities of actors and ingredients consumed by each along the halal beef supply chain. All cost, income, labor absorption, and emissions data are collected based on one product life-cycle period. According to Islam et al. (2016), LCSI is the crucial phase of LCSA, which deals with the quantification and accumulation of system input and output data. The three main currently available LCI methods are process-based modeling, input-output (IO) LCI, and a hybrid method. Different methods may provide different environmental impact results for the same product. This study uses a hybrid method that combines process-based modeling and input-output LCI.

Furthermore, life-cycle sustainability impact assessment (LCSIA) evaluates the impact produced during one life-cycle period of beef not only on the environmental aspect or life cycle assessment (LCA) but also on the socio-economic aspect (Social life cycle assessment or S-LCA) and Life cycle costing (LCC). For the environmental aspect, this study focuses on carbon and freshwater footprints. These two types are the largest ecological footprints for climate change. For the social aspect, this study focuses on the number of employees. The following is a conceptual formula:

LCSA = (environmental) LCA + LCC + S-LCA (1)

Where:

LCSA: Life-cycle sustainability assessment

LCA: Life-cycle assessment

LCC: Life-cycle costing

S-LCA: Social life-cycle assessment

Neugebauer et al. (2016) extended the scope of a sustainable economic assessment beyond the life cycle cost considering the profitability indicator, including cost, added value, and margin. This scope was called economic LCA. Besides, Liu et al. (2019) redefined the formula as

LCSA = Economic LCA + Environmental LCA + Social LCA (2)

One period of beef life cycle extends from the production process to beef sales. The final calculation was converted in terms of one kilogram of beef (boneless weight equivalent or BWE) unit and constructed by equation model as follows:

a) Economic LCA

The economic LCA dimension calculates added unit costs, margin, added value, and total profit. The equation model of the added unit costs as follows:

AC = OC + TC + RC + IC (3)

Added unit costs (AC) refer to the added costs at each stage of the supply chain, including operating costs, both variable and fixed (OC), transaction costs (TC), regulatory costs (RC), and investment costs (IC). Whereas, the formula to calculate the margin as follows:

M = SP – BP (4)

P = SP – BP – AC (5)

Margin (M) refers to the difference between the selling price (SP) and the buying price (BP) at each stage of the supply chain. In contrast, profit (P) refers to the selling price (SP) minus buying price (BP) and added unit costs (AC) in each actor in the Indonesian halal beef supply chain. The equation model of the value-added adopted the formula of Hayami (1987) as follows:

VA = OV – AC – BP (6)

Value-added (VA) equal to the output value (OV) minus the added unit cost (AC) and buying price (BP), while the output value equals the selling price multiplied by the conversion factor from the output divided by the input.

b) Environmental LCA

The environmental LCA dimension calculates carbon and freshwater use footprint. The carbon footprint consists of CO_2, NH_4, and N_2O, converted into the unit of CO_2 equivalent. The equation model of the carbon footprint refers to the equation in the IPCC (2006), the formulation is as follows:

Emissions per BWE = AD x $EF_{\text{electricity, fuel, etc}}$ (7)

Various activities to produce halal beef need to use electricity and fuel that cause CO_2, NH_4, and N_2O emissions. Electricity and fuel have different CO_2, NH_4, and N_2O emission factors. The emissions of BWE refer to activity data (AD) that multiplied by the emission factor of electricity and fuel ($EF_{electricity, fuel, etc.}$). In the farm levels, enteric fermentation and manure cause CH4 emissions, the equation model as follows:

CH_4 emissions per BWE = ($HC_{fermentation}$ x $EF_{fermentation}$) + (HC_{manure} x EF_{manure}) / BWE per a head cattle (8)

The CH_4 emissions of BWE refer to the fermentation of one head cattle in one period ($HC_{fermentation}$) multiplied by the emission factor of fermentation ($EF_{fermentation}$). In addition, the manure of one head cattle in one period (HC_{manure}) multiplied by the emission factors of manure (EF_{manure}). The sum of these two calculation divided by BWE per head cattle. Furthermore, this study adopted Mekonnen and Hoekstra (2012) equation to calculate the freshwater use footprint of the halal beef production process as follows:

$WF(f, p, r) = WF_{act1}(f, p, r) + WF_{act2}(f, p, r) + WF_{act3}(f, p, r)$ (9)

Water footprint (WF) refers to each activity of cattle farmers (f), beef processors (p), and beef retailer (r) that uses water in the halal beef production. For example, the water footprint at the farm level refers to the water footprint of feed added by the water footprint to drink cattle, and the water footprint of cattle maintenance.

c) Social LCA

The Social LCA dimension calculates the number of employees at each level along the halal beef supply chain. The amount of employee describes the opportunity to create new jobs. a new entrepreneur along the beef supply chain causes an opportunity to increase employment

Finally, this stage assesses the effect of variations in process data, model selection, and other variables. Besides, conclusions and recommendations are drawn based on the results. A combination of results from the life cycle inventory and life cycle impact assessment is used to interpret the findings and draw conclusions from the previously identified goals and scopes. This phase consists of several steps: (1) Determining whether the assumptions, methods, models, and data are consistent with the study's aims and scope regarding product life cycles and other options. (2) Ensuring that all relevant information and data needed for the interpretation phase are fully available. (3) Calculating the overall contribution of various factors to the results (this analysis answers questions about the contribution of specific processes and their impact on the final score. (4) Analyzing disorders by studying the effects of small changes in the system from the LCA results. (5) Performing sensitivity and uncertainty analysis.

3 Results and Discussions

3.1 Basic System of Indonesian Halal Beef Supply Chain

Beef supply is sourced from various breeds of cattle developed and scattered in rural areas in Indonesia. These include Bali (red-striped skin), cross-bred Ongole (white skin), Sumba Ongole (white skin), Madura (red skin), and local cattle cross-bred with superior cattle from abroad (especially Limousin, Simmental, and Brahman). The supply chain pattern is different in each region, depending on stakeholders' involvement from upstream to downstream. In cattle-farming centers such as East Java, the halal beef supply chain relatively longer because each of its parts includes many stakeholders from various districts.

The Indonesian beef supply chain starts from cattle owned by farmers who sell to local traders. In a very short time, they sell cattle to cattle traders or butchers in the cattle market categorized as halal beef processors or wholesalers. These processors slaughter cattle in the abattoir, which is majority-owned by the government, and distribute it to their beef retailers, mainly in the traditional market. Halal principles are followed in the beef supply chain, from cattle farming to beef processing to slaughtering to beef retailing, including distribution and display in stores.

Cattle-farming is the first echelon of the Indonesian halal beef supply chain map (figure 2). In Indonesia, there are local and imported cattle. Peranakan Ongole (PO), Bali, and Madura are local cattle. They are mainly found in East Java (Surabaya), Central Java (Semarang), and West Java (Bandung). Imported cattle and their crosses include Brahman, Angus, Ongole, and Siemental bred by artificial insemination (AI). They are chiefly found in the Lampung (Bandar Lampung) region. The cattle population in Indonesia is around 17 million. An estimated two million head were slaughtered in 2019, accounting for a gross value of production around IDR 79.2 trillion or USD 5.7 billion (Ministry of Agriculture of the Republic of Indonesia, 2019). The activities in this echelon include breeding, rearing, and fattening. Generally, Indonesia uses an intensive cultivation system. According to Maman et al. (2017), cattle farming's critical halal aspect

concerns animal welfare, regular provision of feed and water, including good supplements, and proper livestock health care without causing stress to the cattle, among others. Halal principles uphold animal welfare (Farouk et al., 2016). In addition, Velarde et al. (2015), Aghwan et al. (2016), and Gallo et al. (2018) found that animal handling affects not only animal welfare but also the quality of the meat produced.

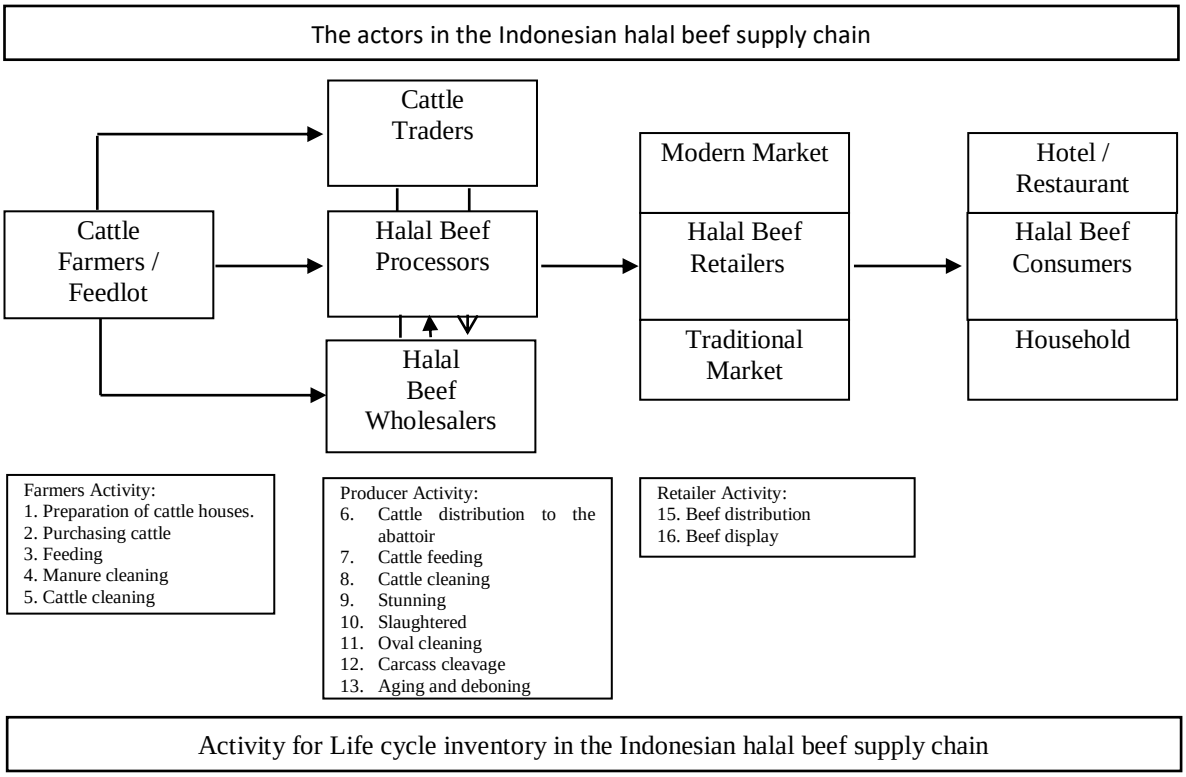

Figure 2. Basic system of the Indonesian halal beef supply chain

Beef processing begins when cattle are traded after the fattening stage. In the beef processing phase, cattle are moved to various traders in different regions. In Indonesia, cattle farmers sell their cattle to small or large cattle traders. Small-scale traders purchase cattle only from the closest region, but large-scale traders purchase cattle not only from their region but also from other regions – a cross-the district, and even a cross-the island. Usually, large-scale traders obtain cattle from small-scale traders in various areas. Then, these traders sell cattle to butchers. In the Indonesian context, they are categorized as beef wholesalers because they buy and slaughter cattle for sale. According to Maman (2018), the greatest halal-critical point in beef processing is the cattle slaughter process and its elements: stunning, the knife, the slaughter person, the slaughter method, invocation, and packaging. Halal beef packaging protects against contamination from something unlawful, especially in shipping. Soon et al. (2017) explained that halal meat is not cross-contaminated with haram products or methods, with no ill intents throughout the process and delivery of halal beef from producers to retailers and consumers.

Beef retailing is the last activity in the halal beef supply chain before consumers consume it. The main activity in this echelon is beef distribution and display. These activities have the high risk of haram product contamination. Beef could be contaminated while being distributed to retailers or while on display in retail stores (Yusof et al., 2015). Halal products are placed separately from non-halal products when sold in stores (Shahijan et al., 2014). In Indonesia, haram meats (i.e., pork) are separated from other meats and displayed on separate chillers or rooms in supermarkets. In wet markets, retailers sell only halal meat, especially in Muslim minority areas; halal and non-halal meat traders are separated. According to Hashim et al. (2014), Muslim retailers should display halal certificates in their stores. Customers would most likely patronize the halal products of such stores. Suki and Salleh (2018) and Meixner et al. (2018) stated that the store has a halal image wins customer loyalty. In addition, Muhammad et al. (2019) explained that attitude has the most significant effect on Muslim customers' intention to purchase halal food products in halal stores.

3.2 The economic sustainability of the Indonesian halal beef supply chain.

Economic sustainability is often interpreted as a development activity that provides positive benefits to some community economies in utilizing the natural resource economy and the surrounding environment without disturbing other communities. According to Bayramoglu et al. (2018), agribusiness will be economically sustainable if every actor in the agribusiness sub-system has sufficient income to meet his or her needs. Majewski et al. (2013) stated, in more detail, that agricultural development would be economically sustainable when economic performance is associated with low costs, low negative environmental effects, and high social impact. Even Bhattacharjee and Cruz (2015) confirmed that economic sustainability is the key to achieving environmental sustainability. In addition, Xu and Gursoy (2015) explained that focusing only on a supply chain's economic sustainability is insufficient in this era because of the increasing pressure placed on companies not only from consumers, shareholders, competitors, and governments but also from the grassroots and community organizations. In addition, economic sustainability can be measured by profitability (Checcini et al., 2016 and Hooks et al., 2017). The distribution of additional cost, value-added, margins, and profits of each actor in the halal beef supply chain illustrates the supply chain's economic sustainability. A Kruskal-Wallis test expressed a significant difference in each indicator between actors, with a p-value of 0.000 (figure 3).

Figure 3 shows the added cost distribution along the halal beef supply chain. Cattle farmers' costs (78%) are higher than those of halal beef processors (10%) and retailers (12%). At the farmer level, feed cost is the highest, around 67%-86% of the total added cost. According to Wantasen and Paputungan (2017), forage expenses are 75% of the total added costs for cattle farms in the Minahasa Regency, North Sulawesi Province, Indonesia. Cattle farming systems affect the use of feed. Achmad et al. (2019) explained that forage and concentrate feed contributed 75% of the added cost for self-owned farms and 67% for partnership farms in Yogyakarta, Indonesia. Forage and concentrate feed together determine feed cost. In addition, the source of forage feed determines its cost. Forage feed usually includes grass that grows wild on the edge of a rice field or dry field, elephant grass cultivation, or other farmers' grass. In addition, this study found that labor cost is approximately 35%-60% of the total added cost at the halal beef processor and retailer level. Beef processors engage labor to slaughter cattle and supervise them for quality control and halal processes in the abattoir. In addition, retailers recruit laborers to manage transportation and display beef products, and they are paid daily. The distribution is a key factor for the retailer because they should get beef early in the morning and sell it later in the morning. Fresh halal beef that has not been sold until noon can lose its quality to decrease the price and margins.

The distribution of halal beef margins along the halal beef supply chain is 54% for cattle farmers, 19% for beef processors, and 27% for retailers (figure 3). Farmers receive a high margin because they keep cattle for four to six months, with an average increase of one kilogram of cattle's live weight per day. This increase in cattle weight causes a significant margin difference when the selling and the buying per head of cattle. Although the price per kilogram may be the same at the purchase and sale of beef, the total amount differs. In addition, beef processors and retailers receive a low margin because they handle beef in a short time with a maximum of a day. The margin for the beef retailer is lower in Indonesia than in Turkey that was 35.75% (Aral et al., 2016).

Furthermore, cattle farmers also account for the largest share in the distribution of value-added in the halal beef supply chain: 43% for cattle farmers, 21% for beef processors, and 37% for retailers (figure 3). However, the disparity between actors is smaller for value-added than the margin. Cattle farmers enhance the added value through the process of rearing and fattening the cattle. processors and retailers slaughter cattle, distribute and display beef following halal principles completed by a halal certificate from the Indonesian halal certification body (MUI). Moreover, agricultural products, including beef, are used as raw materials for producing processed food products with higher value-added (Scholten et al., 2016). For example, Halal beef is the main raw material of traditional Indonesian dishes such as meatballs, rendang (a dry curry without much sauce), and *semur* (a meat dish processed in dark brown broth). Besides increasing value-added, various halal beef processed products also can increase profits in the Indonesian halal beef chain.

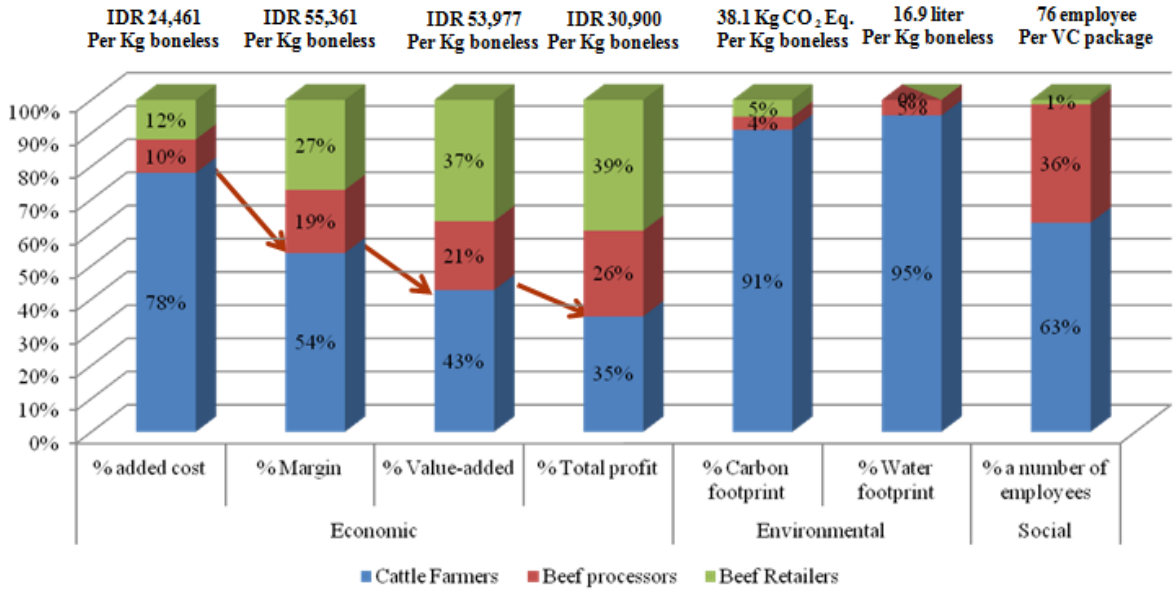

Figure 3. the sustainability of the Indonesian halal beef supply chain
Notes: p-value = 0.000 (<0.05 significance level).

The distribution of halal beef profits along the halal beef supply chain is as follows: 35% for cattle farmers, 26% for beef processors, and 39% for retailers (figure 3). Cattle farmers' profit share is lower than that of beef retailers. This study finds that each actor's average profit rate in the Indonesian halal beef chain is approximately 11% -14%. Various methods were adopted to increase the profits of actors along the supply chain – for example integration of upstream and downstream businesses, as with the big feedlots in Jakarta; partnerships between actors along the supply chain, such as in Tuban East Java; cattle raising through art and cultural approaches, for example, the Sonok cattle tradition in Madura Island; and a group system such as in a livestock village in Tuban and a farmer women's group in Central Lampung.

3.3. Environmental sustainability of the Indonesian halal beef supply chain

Environmental sustainability is the use of resources for present and future generations without causing environmental damage or low emissions. Severo et al. (2015) and Rijsberman (2017) stated that environmental degradation could disrupt the ecosystem. Even Boggia et al. (2018) argued that human activities cause significant pressure on environmental resources. Measuring environmental sustainability has become a challenge in business, particularly with all industrial activities throughout the supply chain, leaving behind both carbon footprint and freshwater use footprints.

Indonesian halal beef production contributes to greenhouse gas (GHG) through three main facets: methane (CH_4), - mostly from enteric fermentation, nitrous oxide (N_2O) – from manure application and storage, and carbon dioxide (CO_2) – from fossil fuel consumption. Indonesia is not an efficient beef producer concerning GHG emissions, with a total footprint of 38.1 kg of carbon dioxide equivalents (kg CO_2 eq.) of packed boneless beef. This carbon footprint is higher than that of Canada's beef system, with only 30.8 kg CO_2 eq. Per kg of packed boneless beef (CRSB, 2016), but lower than that of the USA's beef system, 48.4 CO_2 eq. Per kg of boneless beef (Asem-Hiablie et al., 2019). According to De Vries and De Boer (2010) and Hyland et al. (2017), beef has the highest greenhouse gas (GHG) emissions among farm products. However, organic and non-organic beef's global warming potential is similar (De Vries et al. 2015). The farming stage accounts for 91% of the industry's total carbon footprint, followed by retail and processing at 5.1% and 3.9% (figure 3). Cattle dung significantly contributed to the carbon footprint at the cattle farm level. Livestock waste is generally only used as manure and is not yet widely used for biogas.

Furthermore, halal beef supply chain activity consumes 16.9 liters of fresh water per kilogram of boneless meat, mostly consumed by cattle farming (figure 3). Halal beef is high in the use of freshwater. According to Mekonnen and Hoekstra (2012), animal products have a greater freshwater footprint than other agricultural products. Even Gerbens-Leenes et al. (2013) stated that beef's freshwater footprint is higher than that of chicken meat, while Murphy et al. (2018) explained that beef production significantly contributed to freshwater scarcity. The availability of water affects livestock drinking's behavior and

distribution (Malan et al., 2020). Furthermore, the extent to which beef contributes to depleting freshwater depends on the production system. Huerta et al. (2016) explained that intensive systems have a 25% lower risk of freshwater eutrophication than extensive systems.

Carbon and freshwater use footprints in the Indonesian halal beef supply chain are still high, whereas the beef product must be Muslim friendly and environment friendly. Accordingly, the halal concept in animal meat production must minimize the carbon footprint and freshwater use. Islamic law requires that products must be not only halal and tayyib (good) but also produce low emission. Meanwhile, Mangunjaya and Praharati (2019) explained that Islamic law is not a positive law but a moral law in Indonesia.

3.4 Social sustainability of the Indonesian halal beef supply chain

The social sustainability aspect has obtained less attention in the supply chain than the environmental and economic aspects (Munny et al. 2019). In addition, Zortea et al. (2018) stated that the social aspect implies the higher potential for improvement. One of the parameters of social sustainability is the number of employees recruited for its supply chain activities. Employee recruitment specifically supports human resource practices for supply chain management (Jabbour and Jabbour, 2016). It means that supply chain management based on sustainable social aspects provides the broadest employment opportunities and develops attitudes, knowledge, and human resource skills. In the halal beef case, the halal meat supply chain's key success is the availability of halal-trained employees in each company (Ab Talib et al., 2015).

The Indonesian halal beef supply chain hires 76 employees per value chain group, 63% at the farm level, 36% at the processor level, and only 1% at the retailer level (figure 3). Large-scale farmers recruited approximately 48 employees. An employee tends to several cattle heads every day for 4-6 months. The work involves two routine activities; cleaning the cattle pens and providing a feed of forage and concentrates on cattle three times a day. Every day, cattle need 10%-12% of forage feed, and 1%-2% concentrate feed depending on their body weight.

Furthermore, employees at the processor level are mainly recruited to manage pre-slaughter, slaughter, and post-slaughter activities. The pre-slaughter stage focuses on buying cattle from trader and distribution, both from the cattle market to pens and from pens to the abattoir. The slaughter includes stunning and slaughtering in the abattoir. This stage has the most halal-critical points along the halal beef chain (Maman et al., 2018). For example, in the stunning process, an electric stun can be properly done to meet both halal and animal welfare requirements (Sabow et al., 2018). Furthermore, the post-slaughter stage consists of oval cleaning, carcass cleavage, aging and deboning, packing, and drying waste.

4 Conclusions and Implications

The economic indicator shows that cattle farmers incur the highest costs. They also account for the highest margin and value-added but earn a lower profit than beef retailers. Furthermore, cattle farmers produce higher carbon emissions and use more freshwater than other actors. However, they contribute most significantly to hiring employees along the Indonesian halal beef supply chain.

These phenomena indicate a gap between actors that can impact the Indonesian halal beef supply chain's fragile sustainability. Each actor in the Indonesian halal beef supply chain requires innovation to ensure its sustainability. Collaborative innovation could be developed between cattle farmers and between actors along the Indonesian halal beef supply chain. Beef retailer and beef processor should share their knowledge, technological, and managerial skills toward cattle farmers to minimize cost, maximize profit, and reduce carbon and water footprint.

Furthermore, future research must assess the information flow and relationships between actors along the Indonesian halal beef supply chain. Assessing the sustainability, information flow, and relationship among actors is more comprehensive when integrated through a food system dynamic approach. Finally, future research can explore a sustainable value chain innovation.

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