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Sustainability of the Sugar Value Chain: An Emerging Country Perspective

Phuong Mai Nguyen [1] , ***Thu-Hanh-Huong Nguyen*** [1] , ***Ta Huy Hung*** [1*] , ***Manh Ha Nguyen*** [2]

[1] *International School, Vietnam National University Hanoi, Hanoi 100000, Vietnam*
[2] *BB Group, Hanoi 100000, Vietnam*

ABSTRACT

In recent decades, building a resilient and inclusive agricultural sector has become a major concern of many countries, particularly an emerging country like Vietnam. This paper seeks to analyze the sustainability of the Vietnamese sugar value chain through an integrated framework of the triple bottom line and value chain theory. The metrics for value chain sustainability were derived and modified from existing literature to create a three-dimensional analysis framework comprising 26 items. Data for analysis were obtained through a self-administered survey involving ten stakeholder groups within the Vietnamese sugar value chain. After six months, 473 valid responses were obtained. The analysis utilized SPSS software. Our findings indicate that stakeholder groups evaluate the economic sustainability of the sugar value chain at a lower score during the input stage, with average values of observed variables between 3.27 and 3.76, compared to the production and output stages, which have mean values ranging from 3.57 to 3.97. Furthermore, all stakeholder groups within the sugar value chain possess a favorable perspective on its social sustainability. Our research indicates that distributors and suppliers, who are not directly involved in the sugar production process, receive higher assessment ratings than other groups, with average values ranging from 3.90 to 4.13, in terms of environmental sustainability throughout the value chain. The findings provide methods to enhance the sustainability of the sugar value chain in Vietnam, necessitating the active participation of local government, sugar mills, and sugarcane growers.

Keywords: Sugar Industry; Sustainable Development; Triple Bottom Line; Value Chain Theory; Vietnam

*CORRESPONDING AUTHOR:
Ta Huy Hung, International School, Vietnam National University Hanoi, Hanoi 100000, Vietnam; Email: hungth@vnuis.edu.vn

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1. Introduction

In recent years, sustainability of the value chain has been a buzzword in many industries [1]. Optimal sustainability of the value chain is essential as it guarantees enduring economic viability, reduces environmental footprint, and improves social welfare. Implementing sustainability throughout the value chain is not only morally just, but also a crucial strategic necessity for ensuring the long-term viability of enterprises.

Regarding the sugar industry, it is apparent that this industry contributes substantially to the gross domestic product (GDP) of many countries, yet it faces volatility due to fluctuating market prices, trade policies, and climate change impacts [2, 3]. For example, in China, the production of sugarcane and cane sugar decreased dramatically in the recent two milling seasons, especially in Guangxi, because of continuous severe drought during the fast-growing season, leading to a considerable decline in cane sugar and total sugar production [4]. Moreover, this industry, one of the largest agricultural sectors globally, is resource-intensive, requiring vast amounts of water, energy, land and human labor. The sugar business plays a crucial role as a significant source of employment, especially in rural regions of developing nations where millions of smallholder farmers and workers depend on sugarcane cultivation for their livelihoods [5]. However, labor conditions within this sector frequently involve issues such as low wages, inadequate working conditions, and child labor [6, 7]. Meanwhile, the worldwide demand for sugar and its derivatives highlights the necessity for sustainable ways of production. The sustainability of the sugar value chain warrants thorough research due to its multifaceted environmental, social, and economic implications [3].

Vietnam is an emerging country with an unstable sugar industry. Vietnam's agricultural policies have had a significant impact on the sustainability of the sugar value chain. Historically, the government has promoted sugarcane cultivation through subsidies, protective tariffs, and support for local producers to ensure self-sufficiency and reduce reliance on imports [8]. However, these protectionist measures have also led to inefficiencies, as domestic producers struggled to compete with cheaper, higher-quality imports from countries like Thailand [9]. In recent years, Vietnam has shifted towards liberalizing the sector by joining international trade agreements, such as the ASEAN Trade in Goods Agreement (ATIGA), which eliminated tariffs on sugar imports. This policy change has exposed domestic producers to increased competition, highlighting the need for sustainable practices to enhance productivity and competitiveness [10]. Furthermore, sustainability initiatives, such as promoting crop diversification, efficient water usage, and adopting modern agricultural technologies, are being encouraged to improve environmental resilience and economic viability within the sugar value chain [11]. While these policies are a step towards sustainability, ongoing challenges, including limited access to technology and fluctuating global sugar prices, continue to affect the sector's long-term sustainability [12]. In the last five years, the Vietnamese sugar industry has suffered substantial financial losses due to the negative impact of an unbalanced economic climate. At present, Vietnam's sugar industry is undergoing a significant decrease in size. Insufficient supply of sugar in Vietnam necessitates the importation of a substantial quantity of sugar annually to compensate for the inadequate availability. The volume of imports has seen a substantial surge of around 340% in 2020 as compared to the values recorded in 2019. Furthermore, the recent decline of the sugar industry is also due to its low competitiveness, especially since Vietnam joined the ATIGA Agreement in 2019. As a result, there is a quest for maintaining the sustainability of the Vietnamese sugar industry.

For the mentioned reasons, this research aims to evaluate the sustainability of the sugar value chain in Vietnam to suggest solutions for tackling environmental deterioration, enhancing social circumstances, and ensuring economic stability.

2. Theoretical Background and Research Problem

2.1. Value Chain and Triple Bottom Line Theory

The value chain theory and triple bottom line theory serve as the foundation for the present study. The value chain theory, created by Michael Porter, is a strate-

gic management framework that outlines the complete set of actions necessary for the creation of a product or service. The activities are categorized into primary and support functions, highlighting the interdependence of each component and their combined influence on overall value generation [13]. The main tasks include of incoming logistics, operations, outbound logistics, marketing and sales, and service. Additionally, there are support activities such as firm infrastructure, human resource management, technological development, and procurement. Through a comprehensive analysis of each component in the sequence, enterprises can pinpoint opportunities for enhancement, expense reduction, and distinctiveness, ultimately strengthening their competitive edge and providing increased value to their clientele.

The concept of the triple bottom line (TBL) was initially established by Elkington in 1994, suggesting that businesses must demonstrate three elements (3P: profit, people, planet) when evaluating their activities: 1) corporate profit, 2) people (corporate social responsibility), and 3) planet (environmental responsibility) [14, 15]. TBL theory is an analytical framework that encompasses the sustainable development of enterprises, focusing on not only financial returns but also the well-being of society (people) and the preservation of the environment (planet) [16]. TBL perspective assists companies in not only taking into account the economic value they generate, but also in integrating environmental and social values that can have a multiplying or diminishing effect on the assessment of their operations. This aligns with the premise that while firms are dedicated to creating value, they are also engaged in practices that undermine particular values.

The three pillars of sustainability serve as a framework for evaluating and disclosing a company's performance in terms of business, social, and environmental indicators [17]. In its most comprehensive definition, the TBL concept refers to including all the values, concerns, and procedures that a corporation must consider to avoid any detrimental impacts on its operations while also generating economic, social, and environmental benefits. This entails having a distinct understanding of the company's mission and considering the requirements and anticipations of stakeholders in the company's policies and activities [18]. The TBL theory is based on the idea that a company should measure its performance concerning stakeholders, including local communities and governments, not just those stakeholders it has direct transactional relationships (such as employees, suppliers, and customers).

2.2. Sustainability of the Sugar Value Chain

The value chain approach in the agriculture industry offers a methodical approach to enhance market connectivity for farmers [19]. The framework facilitates the identification of crucial limitations and the exploration of suitable remedies. The successful resolution of these limitations and remedies involves a synchronized effort from various entities involved in the process, which in turn requires a foundation of confidence and a readiness to work together [20]. The value chain approach allows for a comprehensive understanding of the link between farmers and traders, the dynamics of power, and the distribution of advantages [21]. It is also argued that value chain analysis is crucial for comprehending markets, their interconnections, the involvement of various stakeholders, and the significant limitations that hinder the expansion of agricultural production and, consequently, the competitiveness of small-scale farmers [22]. Currently, these farmers only receive a small portion of the whole worth of their produce.

The sugar industry globally operates as a "push chain" system, in which sugarcane is processed through a chain to generate raw sugar [5]. This raw sugar is then sold as a bulk commodity without much variation in the product and at market value. A typical sugar value chain comprises the following sectors: cultivation, harvesting, transportation of cane, milling, transportation of sugar, and storage/shipping/marketing.

In recent decades, scholars and practitioners have been mainly concerned with the sustainability of the value chain in different industries, including the sugar industry [2, 6, 7]. Consequently, a range of concerns pertaining to the value chain have been deliberated. For example, Koilo investigated the maritime industry and suggested solutions to implement digital twins for the sustainability of this industry [23]. Higgins & Laredo conducted a study on the Australian sugar industry [2]. They

developed an analytical framework to represent the different parts of the process involved in harvesting and transporting sugar cane products across the value chain.

In a similar study, Archer et al. evaluated the sugar value chain, focusing on its limitations and identifying strategies for enhancing its development [24]. They compared the sugar industries in Australia and South Africa and emphasized the importance of collaborative engagement and disruptive changes [24]. Kalinda & Chisanga examined the sugar value chain in Zambia [6] while Perlata & Navarrete developed a model for generating shared value in the sector [25]. Manda et al. investigated factors affecting farmers' involvement in the sugar value chain and analyzed the conditions for obtaining benefits and participation [26]. Srichanthamit & Tippayawong developed criteria to assess the performance of the sugar value chain [4]. In addition, Khalid explored the impact of free market mechanisms on sugar prices and value chain analysis in Pakistan [27]. Using both quantitative and qualitative research methods, Khalid confirmed that rather than interference in the sugar market, if the government had left the market free, consumers would have enjoyed lower prices and the government would have saved the cost incurred in terms of subsidy [27]. Furthermore, Ghafeer applied several quantitative economic forecasting models to examine the value chain diversification in the South African sugar industry [28]. Based on the research results, Ghafeer suggested that sugar mills should form a strategic partnership with key players in the beverages' industry, exploring alternative production routes, and future work should use other time series models to validate the results of his study [28].

Despite these studies, none have specifically focused on assessing the sustainability of the sugar value chain. While studies have been undertaken on the sugar business in Vietnam, there is a lack of comprehensive research on the sugar value chain and its sustainability.

2.3. Sugar Industry in Vietnam and Challenges for Its Sustainability

It is undeniable that the sugar industry in Vietnam holds significant importance and plays a pivotal role in the agriculture-based sectors. Sugar production in Vietnam has undergone significant transformations, shaped by both domestic policies and international market dynamics. Traditionally, the Vietnamese sugar industry has been characterized by smallholder farming and state-owned enterprises, with the government playing a pivotal role in protecting the sector through tariffs, subsidies, and support programs. This protectionist stance aimed to secure national self-sufficiency, but it also led to inefficiencies, such as higher production costs, inconsistent quality, and low competitiveness compared to international counterparts [10]. However, the landscape of sugar production and trade in Vietnam has evolved significantly with the country's deeper integration into the global economy, particularly through participation in regional and international trade agreements. Moreover, the sugar value chain in Vietnam has also been developing from short and simple value chain into multiple stakeholders' value chain and sugar mills play an important role in the value chain governance [29].

Vietnam's sugarcane cultivation area, once over 300,000 hectares, has been transformed into various crops, necessitating land reclamation. The industry aims to increase the area to 250,000 hectares by 2025 and 300,000 hectares by 2028 [30]. However, the industry faces challenges such as an imbalanced economic environment, devaluation of sugar from Thailand, and abundant local sugar products. The domestic sugar price is falling below production costs, causing significant losses. Additionally, climate change poses challenges, and the utilization of by-products generated during sugar manufacturing is limited. The industry must address these issues to ensure sustainable development.

The signing of the ASEAN Trade in Goods Agreement (ATIGA) marked a turning point for Vietnam's sugar industry. Under ATIGA, Vietnam was required to eliminate tariffs on sugar imports from other ASEAN countries, particularly from Thailand, which is one of the world's largest sugar producers and exporters. As a result, cheaper Thai sugar flooded the Vietnamese market, forcing local producers to compete directly with imported sugar that was often of higher quality and produced at lower costs due to more advanced technology and larger-scale production [10]. This shift exposed the inefficiencies within Vietnam's sugar value chain, highlighting the need for structural reforms to enhance com-

petitiveness and sustainability. The increased competition led to significant restructuring within the sector, including the closure of some sugar mills and a push towards modernization and efficiency improvements [31]. During the processing season of 2022/2023, there are 24 sugar mills in operation. These mills have a combined design capacity of 122,200 tons of sugarcane per day [30]. The cumulative yield since the start of the season has reached 9.7 million tons of sugarcane, resulting in a production of over 941,000 tons of various types of sugar. The sugarcane crushing output and sugar output for the current season exceeded those of the 2021/2022 season by 144% and 136%, respectively [30]. Despite a significant rise in domestic production output, it only satisfied one-third of the consumption demand in 2023.

Linkages to international markets have had mixed effects on the sustainability of Vietnam's sugar value chain. On one hand, exposure to global markets has driven the need for improved practices, such as adopting modern agricultural technologies, optimizing water usage, and diversifying crops to ensure a more resilient and sustainable production system [32]. Sugarcane farmers have been encouraged to adopt sustainable agricultural practices to reduce costs and improve yields, aligning with global trends toward environmentally friendly and socially responsible production. Additionally, integration with international markets has provided local producers access to advanced technology, new farming methods, and better management practices, fostering a gradual shift towards sustainability [33].

On the other hand, the increased exposure to global competition has also brought challenges that threaten the sustainability of the sector. For instance, the volatility of global sugar prices has made it difficult for Vietnamese producers to maintain stable income levels, leading to financial instability for many smallholder farmers [34]. Additionally, the dependency on a single crop can make the value chain vulnerable to environmental shocks, such as droughts or floods, which are becoming more frequent due to climate change. In this context, the over-reliance on sugarcane cultivation without adequate diversification of income sources can undermine the resilience of the entire value chain, making it less sustainable in the long term.

Moreover, Vietnam's sugar industry has faced criticism over issues related to land use, labor conditions, and environmental sustainability. Large-scale sugarcane production often involves extensive use of water, fertilizers, and pesticides, which can lead to soil degradation, water scarcity, and pollution. To address these challenges, the Vietnamese government has been encouraging the adoption of more sustainable farming practices, including the use of organic fertilizers, integrated pest management, and water-saving irrigation technologies [35]. Nevertheless, the transition to more sustainable practices is slow, primarily due to limited access to technology, high costs, and the small-scale nature of most sugarcane farms.

In conclusion, the dynamics of sugar production, trade, and market linkages to international markets have profoundly influenced the sustainability of Vietnam's sugar value chain. While integration into the global market has spurred improvements in efficiency and encouraged the adoption of sustainable practices, it has also exposed the sector to new challenges, including increased competition, price volatility, and environmental concerns. For Vietnam's sugar industry to remain sustainable, continued efforts are needed to enhance productivity, improve environmental practices, and ensure that smallholder farmers can adapt to these new market realities. This may include policy measures aimed at supporting sustainable agricultural practices, diversifying income sources, and promoting technological innovation across the value chain.

In summary, literature review shows that the sustainability of the Vietnamese sugar value chain has not yet been adequately addressed in previous studies. Thus, it is important to analyze the sustainability of the Vietnamese sugar value chain to suggest some solutions for the long-term development of the industry.

3. Methodology

3.1. Measurements

In this study, the measurements of sustainability of a value chain were adopted from existing studies. By integrating the TBL and value chain approach, three dimensions to assess the sustainability of the sugar value

chain were chosen. For the economic dimension, seven items from the study of Fearne et al. and Perlata & Navarrete were selected [25, 36]. The social dimension measurement was captured from Nguyen and Sarker, Vurro et al. and Labuschange and Van Erck [37–39]. This measurement has 13 items. Finally, the environmental aspect was measured using 6 items collected from Darmawan et al., Gebre and Rik [40, 41].

3.2. Sampling Methods and Data Collection

In order to assess the sustainability of the sugar value chain in Vietnam, Nghe An province, a large area in the North of the country, was selected as a representative sample. This province exhibits the average characteristics commonly found in other sugar chain locations across Vietnam. In this study, contact information of the sugar value chain's stakeholders was gathered through the support of officials from Vietnamese Sugarcane and Sugar Association (VSSA). The questionnaire was randomly sent to stakeholders, including individual farmers, employees in sugar mills, cooperative farmers, suppliers, distributors and local governments, and they were invited to participate in both our online survey via email and paper-pencil-based survey. We started the survey in August 2023 and ended it in January 2024.

Using the convenient sampling method, 473 valid responses from 10 groups of stakeholders in the sugar value chain were received after six months. **Table 1** below shows the sample characteristics.

4. Findings and Discussions

4.1. Preliminary Results

To check the data for further analysis, the reliability and validity test of the measurements were run. The results are presented in **Table 2** below.

As shown in **Table 2**, the economic sustainability factor (ECO) is measured by 7 observed variables. The factor loading coefficients range from 0.697 to 0.763 (all greater than 0.45). This scale achieves a Cronbach's alpha reliability coefficient of 0.840 (greater than 0.7). The corrected item - total correlation coefficients range from 0.640 to 0.810 (greater than 0.3). The second scale is the social sustainability factor (SOC) with 13 observed variables all with high corrected item - total correlation coefficients of 0.60 or higher. All 13 observed variables were loaded on the same factor with factor loadings ranging from 0.616 to 0.821. Finally, for the environmental sustainability scale (ENV), Cronbach's alpha coefficient reached 0.76 and the corrected item - total correlation coefficients of the 6 observed variables were all higher than 0.7. EFA analysis shows that all 6 observed variables are loaded on the same factor with high loading coefficients of 0.684 or higher. Thus, all observed variables of three measurements meet the requirements for further analysis.

4.2. Research Results

Upon checking the reliability and validity of the measurements, we ran the data description analysis in SPSS software for three measurements to examine how stakeholders in the Vietnamese sugar value chain assess the sustainability of the chain. First of all, we look into the economic sustainability of the the value chain. **Table 3** shows our findings.

For the economic sustainability scale, the average values of the observed variables in this measurement are all greater than 3.5. This shows that the parties involved in the value chain have slightly different assessments on sustainability and economic efficiency in several aspects, such as (1) effective transportation costs, (2) guaranteed income levels of workers in the sugar industry that ensure essential needs, and (3) stages in the sugar value chain are creating added value. However, participants in the value chain believed that the production costs and labor productivity are not very much effective. This finding is attributed to the fact that the cultivation of sugarcane and the production of sugar in Vietnam predominantly rely on human labor, without any yet automated methods. Consequently, the productivity of sugarcane remains low and the costs of production maintain high due to the fact that farmers continue to cultivate sugarcane on a small scale inside their households, rather than aggregating it on a big scale through cooperative cultivation.

Moreover, as shown in **Table 3**, the economic sustainability of the value chain is assessed at a high average

Table 1. Sample characteristics (N = 473).

No.	Sample Information	Frequency (Person)	Percentage (%)
1	*Stakeholders*		
	Cooperative farmers	101	21.4
	Group leaders	98	20.7
	Individual farmers	55	11.6
	Material and tool suppliers	10	2.1
	Local government	20	4.2
	Agricultural advisors	20	4.2
	Sugar mill employees	112	23.7
	Transporters	26	5.5
	Wholesalers	21	15.0
	Retailers	10	4.5
2	*Gender*		
	Male	339	71.7
	Female	134	28.3
3	*Age*		
	From 18 to 27 years old	15	3.2
	From 28 to 37 years old	124	26.2
	From 38 to 47 years old	217	45.9
	From 48 to 57 years old	94	19.9
	Over 57 years old	23	5.0
4	*Educational level*		
	Primary school	55	11.6
	Secondary school	183	38.7
	College	132	27.9
	University and higher	103	21.8

level by groups related to the input stage with average values of observed variables ranging from 3.27 to 3.76 and no criterion has a value above 4.00. Meanwhile, at the production stage, the economic sustainability of the value chain is assessed at a medium-high level. Sugar mills play a key role in this stage, so they reflect relatively accurately the level of sustainability of the value chain at this stage with the average value of observed variables ranging from 3.23 to 3.83. Among them, the observed variable with the highest average value is "participating in the value chain is the main source of income for the majority of stakeholders" (Eco6). When considering economic sustainability at the output stage, the stakeholders at this stage evaluate sustainability at a relatively high level with the average value of the observed variables of the scale ranging from 3.57 to 3.97. Our findings about the different evaluation of these stakeholder groups on the economic sustainability criteria can be explained due to their level of involvement in the sugar value chain. It seems that the transporters and distributors are more optimistic about the economic sustainability of the chain as they are getting more benefits in the value chain. The farmers, who are receiving little benefits from the value chain, do not highly appreciate its economic sustainability.

The ANOVA test was run to further check the differences between stakeholder groups in their assessments on the economic sustainability of the Vietnamese sugar value chain. **Table 4** below shows the details.

Nevertheless, the majority of groups engaged in the production of raw materials, including cooperative farmers, farmer group leaders, and agricultural advisors, see the economic sustainability as inferior compared to the appraisal of the mill group. The sugar mills exhibit significant differences in the coefficient values between various groups. The coefficient between the cooperative farmers and the mill is $\gamma = -0.39$, SE = 0.074, $p < 0.000$. The coefficient between the farmer group leaders and the mill is $\gamma = -0.22$, SE = 0.075, $p = 0.003$. Lastly, the coefficient between agricultural advisors and the mill is $\gamma = -0.32$, SE = 0.131, $p = 0.013$. Wholesale and retail companies have a greater appreciation for economic sus-

Table 2. Reliability and validity of measurements.

Construct	Item	Corrected Item - Total Correlation	Factor Loading
Economic sustainability (ECO) (Cronbach's alpha: 0.840)	Eco1	0.79	0.763
	Eco2	0.81	0.762
	Eco3	0.72	0.736
	Eco4	0.74	0.734
	Eco5	0.73	0.712
	Eco6	0.69	0.698
	Eco7	0.64	0.697
Social sustainability (SOC) (Cronbach's alpha: 0.920)	Soc1	0.70	0.689
	Soc2	0.69	0.616
	Soc3	0.73	0.694
	Soc4	0.69	0.685
	Soc5	0.73	0.740
	Soc6	0.76	0.786
	Soc7	0.72	0.776
	Soc8	0.73	0.729
	Soc9	0.62	0.737
	Soc10	0.60	0.687
	Soc11	0.64	0.727
	Soc12	0.70	0.765
	Soc13	0.74	0.821
Environmental Sustainability (ENV) (Cronbach's alpha: 0.760)	Env1	0.72	0.808
	Env2	0.71	0.798
	Env3	0.79	0.725
	Env4	0.81	0.695
	Env5	0.75	0.684
	Env6	0.71	0.745

tainability compared to factories. The disparity in average ratings between wholesalers and retailers, as well as sugar mills, is evident. The relative values for wholesalers and retailers are $\gamma = 0.62$, SE = 0.129, p = 0.000, whereas for sugar mills, the values are $\gamma = 0.35$, SE = 0.179, p = 0.049, respectively. This finding is acceptable because sugar mills seem to have more information of the sugar production process than other groups of stakeholders. Thus, their evaluation of the economic sustainability should be more concise than other groups of stakeholders.

For groups supporting the chain such as local government, unions, transportation groups and suppliers, the assessment results are inconsistent. For example, the local government, who regularly know the situation of sugarcane growing households, has a lower average rating than the sugar mills ($\gamma = -0.32$, SE = 0.132, p = 0.016). On the contrary, the group that supplies raw materials and machinery for the sugarcane production has a higher average rating than the sugar mills ($\gamma = 0.35$, SE = 0.178, p = 0.049). A notable point is that although the difference in scores between the individual farmer group and the mill group is not really statistically significant ($p > 0.05$), the fact is that individual farmers have a higher score. The assessment of economic sustainability is higher when evaluated by the sugar mills, while cooperative farmers rate it lower than that of mills, pointing out some problems in the production of input materials for the chain. In general, the stakeholders involved in the input stage of the Vietnamese sugar value chain has a less positive view on its sustainability. This finding reflects the reality that the farmers have less benefits from the value chain than other stakeholders.

Regarding the social sustainability of the sugar value chain, **Table 5** demonstrates our research results.

Table 5 reveals that observed variables measuring the sustainability of the value chain in terms of social dimension are evaluated by participants in the value chain

Table 3. Economic sustainability of the sugar value chain.

Item	Input Stage							Production Stage	Output Stage				Overall Mean
	Cooperative Farmers	Farmer Group Leaders	Individual Farmers	Suppliers	Local Government	Agricultural Advisors	Average	*Sugar Mills*	Transporters	Wholesalers	Retailers	Average	
Eco1	3.05	3.07	3.69	4.10	3.20	2.90	3.33	3.52	3.42	4.38	4.10	3.97	3.36
Eco2	2.98	3.44	3.53	4.00	3.40	2.95	3.38	3.63	3.46	4.33	4.10	3.96	3.44
Eco3	3.09	3.66	3.58	4.20	3.70	3.35	3.60	3.58	3.50	4.29	4.00	3.93	3.53
Eco4	2.88	2.85	3.51	3.80	3.45	3.10	3.27	3.23	3.38	4.24	3.90	3.84	3.19
Eco5	3.26	3.40	3.69	3.90	3.40	3.20	3.48	3.71	3.65	4.24	4.10	4.00	3.55
Eco6	3.39	3.42	3.76	3.60	2.45	3.45	3.34	3.83	3.46	3.76	3.50	3.57	3.53
Eco7	3.73	3.73	3.91	4.00	3.30	3.90	3.76	3.62	3.69	4.24	3.90	3.94	3.74

with an average score of 3.7 or higher. A notable point in this study is that when compared with economic sustainability criteria, social sustainability criteria are more highly appreciated by participants. Social factors include observed variables that measure the sustainability of the value chain in terms of implementing social responsibility towards stakeholders. In this study, the assessment of social sustainability had a higher average score than economic sustainability. Specifically, the average score of social sustainability is 3.83 while the average score of economic sustainability is 3.48. Moreover, the average rating of the participants in the chain on social sustainability ranges from 3.72 to 3.92. The fluctuation range of the score is narrower than the economic sustainability score, partly demonstrating the consensus of the participants when assessing the social sustainability of the sugar value chain.

This finding exemplifies the social obligation of the parties engaged in the sugar value chain to guarantee sustainability in social aspects, including the full payment of taxes to the local budget; the facilitation for workers, and farmer households during sugarcane cultivation. As education levels rise, consumers prioritize product information, safety, and recall procedures. This highlights the importance of all parties in the chain to demonstrate their societal responsibilities, satisfy consumers, and meet stakeholder expectations.

Furthermore, we also see the slight differences in the social sustainability assessments among stakeholder groups in the input stage, production stage and output stage of the sugar value chain. In the input stage, our finding shows that the criteria for evaluating social sustainability have an average value ranging from 3.70 to 3.95. The relatively high score shows that social sustainability is highly appreciated by relevant stakeholders. Among them, the three most highly rated criteria are (1) "Sugarcane farmers have the opportunity to learn sugarcane growing techniques, land cultivation, and harvesting methods" (Soc13); (2) "Participants in the value chain pay full taxes to the local government" (Soc1); (3) "Workers are instructed and equipped with machinery and equipment for safe production" (Soc5).

Meanwhile, in the production stage, the social sustainability of the sugar value chain is also evaluated at a higher level with the average score of the measurement criteria ranging from 3.69 or higher to the highest level of 4.05. Specifically, **Table 5** shows that the 3 most highly rated criteria include (1) "The rights of workers in the value chain are guaranteed according to legal regulations" (Soc4); (2) "Sugarcane farmers have more benefits when joining groups and/or cooperatives" (Soc12); (3) "Workers are instructed and equipped with machin-

Table 4. ANOVA test for the economic sustainability of the sugar value chain.

		Economic Dimension		
Predictors	**Estimates**	**Std. Error**	**T-Value**	**P**
(Intercept) (Sugar mills)	3.59	0.051	70.030	0.000
Cooperative farmers	−0.39	0.074	−5.276	0.000
Farmer group leaders	−0.22	0.075	−2.958	0.003
Agricultural advisors	−0.32	0.131	−2.468	0.013
Individual farmers	0.08	0.251	0.876	0.381
Wholesalers	0.62	0.129	4.819	0.000
Retailers	0.35	0.179	1.975	0.049
Local government	−0.32	0.132	−2.414	0.016
Transporters	−0.08	0.118	−0.663	0.508
Suppliers	0.35	0.178	1.974	0.049
Residual standard error: 0.5424 on 463 degrees of freedom				
Multiple R-squared: 0.18, Adjusted R-squared: 0.16				
F-statistic: 11.31 on 9 and 463 DF, p-value: 4.64e-16				

ery and equipment for safe production" (Soc5).

From the viewpoint of stakeholder groups in the output stage, the social sustainability of the sugar value chain is also highly appreciated with the average score of the criteria ranging from 3.80 up to 4.17 (see **Table 5)**. Among them, the highest rated criterion is "Workers are instructed and equipped with machinery and equipment for safe production" (Soc5) and the lowest rated criterion is "Origin of the products are clearly stated" (Soc3).

ANOVA analysis will clarify the differences in how groups of stakeholders in the sugar value chain evaluate social sustainability. **Table 6** below shows detailed results of ANOVA analysis of the social sustainability scale.

Upon further examination, as illustrated in **Table 6,** it is evident that both groups of the cooperative farmers and the farmer leaders have a low evaluation of social sustainability as compared to other actors in the value chain, such as the mills and distributors of sugar products. Several social sustainability factors, such as the accessibility of capital for sugarcane growers, obtained a relatively low ranking. Particularly in this aspect, the entities involved in the chain strongly agree on the challenge of obtaining money for sugarcane growers. The average assessment for the criterion "Sugarcane farmers have easy access to capital" (Soc9) does not vary among different groups of farmers involved in the production of raw materials, factories, distribution routes, and other support groups. It is worth mentioning that individual farming households hold a more favorable perspective on the availability of capital (γ= 0.24, SE= 0.116, p = 0.039).

In terms of environmental sustainability, we present our findings in **Table 7** as follows.

Regarding the environmental sustainability of the sugar value chain, all observed variables have an average value greater than 3.7, except for the observed variable "Participants in the value chain use recyclable materials and packaging" (Env5, mean value = 3.65). Furthermore, **Table 7** shows that the criteria for evaluating environmental sustainability are highly appreciated at the input stage of the chain, with average values from 3.65 to 3.80. Stakeholders at this stage give the highest rating to the criterion "Sugarcane farmers are instructed to maintain sugarcane biodiversity" (Env2). Our finding might be attributed to the fact that the sugar value chain is attracting more concern from sugar factories, so that they are supporting the farmers directly in terms of cultivation technology to maintain the production area and provide more sugarcane to sugar factories. As a result, the farmers are found to be more optimistic about the environmental sustainability of the chain when they become more knowledgeable about the production process and technology.

Besides, when considering environmental sustainability from the viewpoint of stakeholders at the production stage, it is revealed in our study that all criteria reach the mean value from 3.62 to 3.95. Thus, it can be seen that sugar factories, the main entities participating

Table 5. Social sustainability of the sugar value chain.

Item	Input Stage							Production Stage	Output Stage				Overall Mean
	Cooperative Farmers	Group Leaders	Individual Farmers	Suppliers	Local Government	Agricultural Advisors	Average	Sugar Mills	Transporters	Wholesalers	Retailers	Average	
Soc1	3.66	3.72	3.78	4.20	4.40	3.65	3.90	4.00	3.46	4.33	3.60	3.80	3.83
Soc2	3.58	3.63	3.76	4.10	3.75	3.90	3.79	3.83	3.35	4.19	4.00	3.85	3.72
Soc3	3.59	3.66	3.75	4.10	3.90	3.85	3.81	3.99	3.50	4.29	3.60	3.80	3.78
Soc4	3.71	3.62	3.87	4.10	4.15	3.75	3.87	4.05	3.73	4.29	4.10	4.04	3.86
Soc5	3.76	3.84	3.96	4.10	3.75	4.00	3.90	4.01	3.88	4.33	4.30	4.17	3.92
Soc6	3.68	3.76	3.91	4.20	3.50	3.95	3.83	3.93	3.69	4.29	3.90	3.96	3.83
Soc7	3.68	3.77	3.93	4.30	3.75	3.85	3.88	3.96	3.69	4.29	4.00	3.99	3.85
Soc8	3.71	3.72	3.84	4.30	3.80	3.75	3.85	3.97	3.77	4.33	4.00	4.03	3.85
Soc9	3.71	3.79	3.93	4.00	3.40	3.60	3.74	3.69	3.65	3.81	4.00	3.82	3.74
Soc10	3.63	3.68	3.80	4.10	3.70	3.65	3.76	3.92	3.81	4.33	4.40	4.18	3.80
Soc11	3.87	3.65	3.80	4.00	3.30	3.85	3.74	3.88	3.42	4.33	4.20	3.98	3.80
Soc12	3.72	3.72	3.95	3.80	3.45	3.55	3.70	4.02	3.62	4.38	4.20	4.07	3.84
Soc13	3.83	3.80	3.98	4.20	4.00	3.90	3.95	3.94	3.58	4.29	4.30	4.06	3.90

in the production stage in the sugar value chain, highly appreciate the sustainability of the chain.

For the stakeholders at the output stage of the sugar value chain, environmental sustainability has a very high average value from 3.90 to 4.13. This shows that the parties involved in the value chain have a fairly uniform assessment of the chain's sustainability at the output stage. Specifically, the criterion most appreciated by all stakeholder groups in the output stage is "Sugarcane farmers take measures to improve soil fertility" (Env6).

The consistent assessment of stakeholders on the environmental sustainability of the sugar value chain is also confirmed in our ANOVA test. **Table 8** below demonstrates the test results, showing that there is no significant difference among stakeholder groups in their assessment.

The results show that the environmental sustainability assessment score of the mill group is 3.77. The majority of groups involved in the input stage have no difference in assessment compared to the factory group. On the contrary, suppliers (γ = 0.53, SE = 0.211, p = 0.012) and the wholesale group (γ= 0.52, SE= 0.152, p = 0.0007) have more positive evaluation than the factories.

5. Discussion, Implications and Limitations

5.1. Discussion

Based on the research results, our study confirms that all stakeholders in the sugar value chain have a positive view of its social sustainability, with higher scores on social dimensions than economic and environmental dimensions. This is due to the good connection between sugar mills and farming households, with policies supporting farmers' inputs and assisting in science and technology application. However, distributors and suppliers have higher evaluation scores for environmental sustainability, while those directly involved in the sugar production process score lower. This presents a challenge for managers and administrators to improve environmental protection activities, especially during the production

Table 6. ANOVA test for the social sustainability of the sugar value chain.

	Social Dimension			
Predictors	**Estimates**	**Std. Error**	**T-Value**	**P**
(Intercept) (Sugar mills)	3.93	0.044	90.049	0.000
Cooperative farmers	−0.21	0.063	−3.321	0.001
Farmer group leaders	−0.20	0.064	−3.089	0.002
Agricultural advisors	−0.12	0.112	−1.088	0.277
Individual farmers	−0.04	0.076	−0.575	0.565
Wholesalers	0.36	0.110	3.311	0.001
Retailers	0.12	0.152	0.775	0.438
Local government	−0.17	0.112	−1.534	0.126
Transporters	−0.30	0.101	−2.963	0.003
Suppliers	0.16	0.152	1.037	0.300
Residual standard error: 0.4617 on 9 and 463 degrees of freedom				
Multiple R-squared: 0.094, Adjusted R-squared: 0.076				
F-statistic: 5.33 on 9 and 463 DF, p-value: 5.969e-07				

Table 7. Environmental sustainability of the sugar value chain.

Item	**Input Stage**							**Production Stage**	**Output Stage**				**Overall Mean**
	Cooperative Farmers	**Group Leaders**	**Individual Farmers**	**Suppliers**	**Local Government**	**Agricultural Advisors**	**Average**	**Sugar Mills**	**Transporters**	**Wholesalers**	**Retailers**	**Average**	
Env1	3.76	3.84	4.02	3.90	3.90	3.85	3.23	3.87	3.73	4.43	4.00	4.05	3.88
Env2	3.84	3.77	4.00	3.90	3.60	4.00	3.85	3.88	3.58	4.48	4.10	4.05	3.87
Env3	3.61	3.73	3.84	4.30	3.55	3.75	3.80	3.77	3.73	4.29	4.10	4.04	3.76
Env4	3.66	3.62	3.78	4.10	3.45	3.85	3.74	3.83	3.50	4.43	3.80	3.91	3.74
Env5	3.58	3.64	3.71	3.80	3.35	3.80	3.65	3.62	3.46	4.43	3.80	3.90	3.65
Env6	3.82	3.88	4.04	3.80	3.60	3.90	3.84	3.95	3.65	4.43	4.30	4.13	3.91

stage. Our findings are in line with several studies on the sugar value chain, such as Kalinda & Chisanga [6], García-Bustamante et al. [7]; Manda et al. [26]. Besides, our research results are also supported by other studies in other industries including maize (Mango et al., 2018) [42], banana (Gebre & Rik, 2016; Tarekegn et al., 2020) [41, 43], rubber (Darwaman et al., 2014) [40], coffee (Moreno & Salgado, 2012) [44].

5.2. Implications

Improving the sustainability of the sugar value chain will have significant influence on the industry and the country as a whole. Our research results have some theoretical and practical implications. In terms of theory, this study validates the measurements of value chain sustainability in Vietnam, an emerging market, which is a new research context. In terms of practice, our study suggests some solutions for a variety of stakeholders in the value chain.

It is undeniable that the central and local government has a critical role to play in the sustainable development of the industry. In the sugar value chain, state-regulated policies can impact many different stages of the production process, thereby adjusting the behavior

Table 8. ANOVA test for the environmental sustainability of the sugar value chain.

		Environmental Dimension		
Predictors	**Estimates**	**Std. Error**	**T-Value**	**P**
(Intercept) (Sugar mills)	3.79	0.046	82.265	0.000
Cooperative farmers	−0.12	0.066	−1.791	0.074
Farmer group leaders	−0.07	0.067	−1.053	0.293
Agricultural advisors	0.03	0.118	0.295	0.768
Individual farmers	0.05	0.080	0.634	0.526
Wholesalers	0.60	0.115	5.217	0.000
Retailers	0.21	0.160	1.309	0.191
Local government	−0.30	0.118	−2.567	0.011
Transporters	−0.20	0.106	−1.926	0.055
Suppliers	0.21	0.160	1.309	0.191
Residual standard error: 0.4858 on 9 and 463 degrees of freedom				
Multiple R-squared: 0.109, Adjusted R-squared: 0.091				
F-statistic: 6.26 on 9 and 463 DF, p-value: 2.26e-08				

of relevant entities to promote sustainability of the chain. The government should reevaluate policies that may be detrimental to the sustainability of the sugar industry and implement necessary modifications. Given its high susceptibility to the effects of climate change, it is imperative for the government to adopt proactive strategies to alleviate these repercussions on the sugar business. This could involve enacting rules that guide investment in infrastructure and promote resilient agriculture practices. The state has the ability to modify policies in order to create insurance programs and other financial instruments that can assist the industry in managing climate-related risks. The government has the authority to implement land policies aimed at preventing deforestation and safeguarding biodiversity and land resources in order to facilitate the development of areas for sugarcane raw material production. The state should also request the authorities to organize and mandate sugarcane growers to enforce stringent rules to mitigate environmentally detrimental activities, such as excessive use of fertilizers, pesticides, and water.

In addition, to maintain the industry's competitiveness, the state can support sugarcane farmers and producers by providing subsidies or grants, promoting sustainable practices, and using agricultural by-products like bagasse for biofuel production. This not only provides income for farmers but also reduces greenhouse gas emissions. Notably, with the goal of sustainable development, reducing carbon emissions is becoming an urgent task for many businesses in Vietnam as well as the world. More than 100 countries and 400 cities (including Berlin) pledged to reach net zero emissions by 2050 or before.To achieve sustainable development goals, policymakers and the sugar industry must invest in solar and biomass power, as well as increase fuel use with low carbon emissions. The government should direct support solutions for sugar factories and households to align with the national sugar industry growth strategy, balancing budget revenues and expenditures for long-term and effective support measures.

Sustainable development of the Vietnamese sugar industry necessitates the involvement of various entities, including sugar factories. To achieve this, factories should optimize their production processes, prioritize waste management, invest in research and development, and build a chain of links between businesses and farmers, with local government agencies' participation. This synchronous approach will help sugar mills stay ahead of regulatory changes and market trends towards sustainability. Additionally, the industry's dependence on farmers and cooperatives for raw materials necessitates proactive sourcing and problem-solving. Overall, a sustainable approach to the sugar value chain requires a synchronized approach from planning to consumption.

Finally, our study has some implications for the farmers. It is suggested that sugarcane farmers should switch to organic farming methods, avoiding the use of pesticides and synthetic fertilizers, which can reduce en-

vironmental pollution and increase soil fertility, making the farming cycle sustainable. Furthermore, farmers need to equip themselves with knowledge of sugar products, the industry and management to avoid suffering losses in the deal with other participants in the value chain. When they have knowledge, they will better understand advanced agricultural solutions and issues related to effective and sustainable farming. Farmers will know how to choose new sugarcane varieties with better resistance and higher productivity from the knowledge they have, to suit the soil conditions of the farming area. As a result, the farmers will contribute to the sustainability of the sugar value chain.

5.3. Limitations

Although this study has achieved several results, there are certain constraints in this study. The limited sample size may hinder the generalizability of the research findings to the entire sugar business in Vietnam. Furthermore, this study not yet utilized the in-depth interview method to thoroughly investigate the underlying causes of the unsustainable issues. Therefore, it is recommended that future research should broaden the survey to encompass additional areas in Vietnam and utilize a greater number of qualitative research techniques.

6. Conclusions

Sustainability of the sugar value chain still remains under-explored in the Vietnamese context. Meanwhile, it is of utmost importance to prioritize the attainment of sustainability in the sugar value chain in order to uphold environmental, economic, and social integrity. The quantitative research methodology was employed with data from a self-administered survey receiving responses from diverse stakeholder groups in the sugar value chain. Based on the survey data, this study demonstrates the sustainability of the sugar value chain in Vietnam, and emphasizes the importance of promoting cooperation among all parties involved to reduce environmental effects and strengthen economic equity. Individual farmers, who are currently getting least benefits from the value chain, should be put into priority to receive the support from the government and sugar mills. It is essential that the government will update the rural development policy to promote more private companies to invest in agricultural technology and innovation in farming practices. In these high-tech agriculture projects, the individual farmers will be the beneficiaries.

Furthermore, the present study also suggests viable solutions to multiple stakeholders in the sugar value chain, the leading role of which was highlighted by the government and sugar mills. Moreover, sugarcane farmers were encouraged to adopt sustainable production practices proactively. Thus, ongoing research and policy support are essential to tackle the inherent difficulties and ensure the sugar sector advances towards a more sustainable and resilient future.

Author Contributions

Conceptualization, P.M.N. and M.H.N.; methodology and formal analysis, M.H.N. and T.H.H.; data collection, T.-H.-H.N. and M.H.N.; writing – original draft preparation, P.M.N. and M.H.N.; writing – review and editing, P.M.N. and T.H.H.; visualization, T.-H.-H.N.; supervision, P.M.N.; All authors have read and approved the manuscript.

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The authors declare no conflict of interest.

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