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Adaptive Governance and Sustainable Supply Chain Strategies to Address Market Distortion in the Seaweed Industry

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ABSTRACT

The Indonesian seaweed industry holds significant economic potential; however, it faces structural challenges, particularly related to market distortion within the supply chain. These issues often affect price formation, quality standards, and distribution efficiency, ultimately influencing market behavior. This study aims to analyze market preference structures and identify the dominant factors shaping market distortion in the seaweed sector, with a specific focus on price mechanisms across regions. The study employs a mixed-method approach by integrating the Analytic Hierarchy Process (AHP) and Bayesian analysis. Data were collected from 120 respondents, including farmers, collectors, and industry actors across West and South Sulawesi, with 98 valid responses meeting AHP consistency criteria. AHP was used to determine the relative importance of decision criteria, while Bayesian analysis refined the estimation of their influence. The results reveal that price is the most dominant factor influencing aggregated market preferences, with local price emerging as the most critical sub-criterion. Consistency Ratio (CR) values ranging from 2.9% to 7.4% confirm the reliability of the AHP results. The study concludes that market distortion in the seaweed industry is primarily driven by price mechanisms at the local level. Policy efforts should therefore prioritize price stabilization and improved market coordination to enhance sustainability.

1. INTRODUCTION

Indonesia is a tropical archipelagic nation with biological conditions that support seaweed growth. Seaweed itself is a multicellular plant with a complexly differentiated thallus, is macrobenthic, and lacks true roots and leaves [1]. As a cultivated fishery commodity, seaweed plays a strategic role in national economic development. With its long coastline and favorable geographic conditions, Indonesia has great potential to become a major global seaweed producer [2, 3].

According to 2023 One Data from the Ministry of Maritime Affairs and Fisheries (KKP), total national production in 2022 reached 9,282,391 tons with a value of IDR 40.85 trillion [4]. In West Sulawesi Province, production in 2022 was 16,353 tons, a sharp decrease compared to 2021's 77,271 tons [5]. However, research with the Conservation Strategy Fund (CSF) in 2023 found potential new cultivation locations in Majene Regency, so increasing production is still very possible [6].

Based on Figure 1, the distribution of seaweed production highlights Indonesia's significant contribution to the global market, accounting for approximately 16.2%. In 2023, Indonesia recorded export volumes of 251,071.5 tons, representing the highest level in the past decade [7]. These figures indicate the strong production capacity of Indonesia's seaweed sector and underscore West Sulawesi's potential as a key regional supplier, provided that effective management and appropriate policy support are implemented.

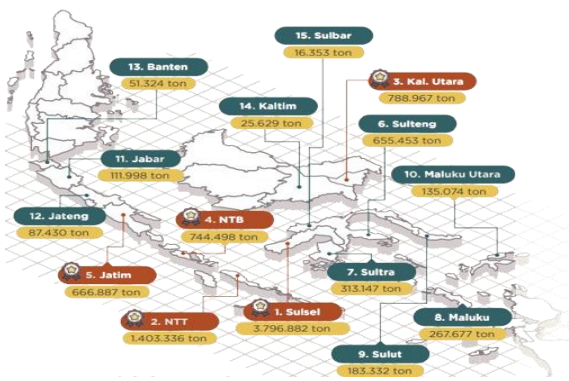

Figure 1. Seaweed production in 2022

However, the seaweed industry is not without challenges, particularly the issue of market distortion. This industry forms a complex network of business-to-business (B2B) and business-to-consumer (B2C) relationships [8, 9]. Previous research has emphasized the importance of sustainable communication and distribution strategies for a competitive, integrated MSME-based seaweed industry [10]. However, practices of market distortion appear at various stages of the process.

In this study, market distortion is conceptualized not merely as price suppression, but as a broader structural condition involving asymmetric power relations, quality manipulation, and market dependency across the supply chain. This includes practices such as underpricing by collectors, quality distortion at the production level, and unequal bargaining positions between actors. Thus, market distortion is understood as a systemic market distortion rather than an isolated pricing issue.

This distortion is evident in the practice of farmers drying their products without racks, resulting in contamination with stones and sand to increase weight. This is detrimental to the processing industry due to increased sorting costs. Meanwhile, collectors often purchase at inflated prices or make incomplete payments, exploiting capital ties with farmers. This mutual pressure creates serious problems that impact market perceptions and preferences. Perceptions are formed through the process of selecting and interpreting product stimuli [11], while preferences are influenced by social factors and benefits [12].

Previous research confirms that market distortion can influence market behavior. For example, in China, distortion on the distribution of goods resulted in inefficiencies, but market recovery through redistribution revitalized the rural sector [13]. Meanwhile, in Slovakia, suppressed agricultural land prices significantly influenced market dynamics [14]. Therefore, understanding the perceptions and preferences of both B2B and B2C markets is crucial for formulating sustainable commercial strategies for seaweed cultivation centers in West Sulawesi.

Based on the above background, this study aims to: (1) identify the dominant factors shaping market preferences in the seaweed supply chain, and (2) determine governance priorities to address market distortion through an integrated market perspective. This study does not aim to compare B2B and B2C actors independently, but rather to analyze their interconnected roles within a unified market system.

2. LITERATURE REVIEW

2.1 Market distortion and supply chain structure in seaweed industry

Seaweed is a strategic aquaculture commodity with significant economic, nutritional, and industrial value. It is widely utilized in food, pharmaceuticals, and processing industries [1]. Supported by favorable geographic conditions, Indonesia has strong potential as a leading global producer [2, 3]. However, the development of the seaweed industry is constrained by structural challenges, particularly in the form of market distortion.

Market distortion refers to inefficiencies that prevent prices and production outcomes from reflecting true market conditions, often driven by asymmetric information, unequal bargaining power, and policy or market interventions [15]. In the seaweed sector, such distortions are evident in price suppression, inconsistent quality standards, and imbalanced relationships between farmers, collectors, and processors [13, 14]. Empirical evidence shows that post-harvest practices, including improper drying and contamination, reduce product quality and weaken farmers' bargaining positions [16, 17].

Price dynamics further reinforce these structural issues. Studies indicate that the Indonesian carrageenan seaweed industry is highly sensitive to both global and domestic price fluctuations, which directly affect income stability [18]. In addition, risks across the supply chain, including production uncertainty and limited market access, exacerbate inefficiencies [19]. These challenges are compounded by asymmetric information, where farmers often lack access to reliable market data [20].

From a broader value chain perspective, weak coordination and limited trust among actors reduce efficiency and create unequal benefit distribution [21, 22]. While seaweed farming offers sustainable livelihood opportunities for coastal communities [23], structural inefficiencies continue to limit its potential. Therefore, understanding market distortion within the supply chain context is essential for improving both economic performance and equity in the industry.

2.2 Market preferences and governance in seaweed value chains

Market preferences play a crucial role in shaping value creation and distribution within the seaweed industry. Perceptions are formed through the evaluation of product quality and value [11], while preferences are influenced by socio-economic factors and expected benefits [12]. These dynamics operate within complex value chains that involve both B2B and B2C interactions, requiring effective coordination and communication among actors [8-10].

Price remains the most influential factor in determining market behavior. Global price volatility significantly impacts farmer income and production decisions [24], while local price stabilization mechanisms can mitigate risks and enhance competitiveness [3]. In coastal economies, strengthening value chains is essential for improving income security and ensuring sustainable livelihoods [25, 26]. However, without effective governance, these benefits may not be equitably distributed.

Recent studies emphasize the importance of innovation and institutional support in addressing these challenges. Digital technologies can enhance market access and increase value-added opportunities in fisheries and aquaculture sectors [27]. Similarly, traceability systems and supply chain digitalization can improve transparency and reduce opportunistic behavior [28-30]. Cooperative-based institutional models have also been shown to strengthen farmers' bargaining positions [31], while inclusive financing mechanisms support access to capital [32]. In addition, sustainability is increasingly linked to regulatory and environmental considerations. Issues such as pollution, environmental governance, and compliance with sustainability targets affect long-term industry viability [33-37].

3. RESEARCH METHODS

This study was conducted in West Sulawesi and South Sulawesi Provinces, focusing on seaweed farmers and firms

engaged in seaweed cultivation and processing activities. A non-probability purposive sampling technique was employed to select participants with relevant experience in the seaweed value chain [27]. The sample consisted of distribution channel actors operating under both B2B and B2C schemes across two regencies in West Sulawesi and three regencies in South Sulawesi, including firms involved in export–import activities.

The total sample consisted of 120 respondents, comprising 70 seaweed farmers, 30 collectors/intermediaries, and 20 representatives from processing companies and export-oriented business units. The respondents were categorized into B2B (business actors such as processors and exporters) and B2C (farmers and local traders) segments to reflect the structure of the seaweed supply chain. Data collection was conducted over a three-month period from May to July 2024 across two regencies in West Sulawesi and three regencies in South Sulawesi.

The sample consisted of distribution channel actors operating under both B2B and B2C schemes across two regencies in West Sulawesi and three regencies in South Sulawesi, including firms involved in export–import activities. Although respondents were categorized into B2B and B2C segments, the analysis was conducted at the aggregate level to capture the integrated structure of the seaweed market. This approach reflects the interdependent nature of actors within the supply chain, rather than treating them as isolated analytical groups.

The analytical approach integrates the Analytic Hierarchy Process (AHP) and Bayesian methods to enhance robustness in decision modeling. AHP was first applied to structure the decision hierarchy and derive the relative importance (weights) of criteria through pairwise comparisons. Respondents evaluated each criterion using a standardized Saaty scale (1–9), and consistency ratios (CR) were calculated to ensure the reliability of judgments [38, 39].

Although the total number of respondents was 120, only responses meeting the AHP consistency threshold (CR < 0.1) were included in the final analysis to ensure reliability. Out of the total sample, 98 responses satisfied this criterion and were retained for further analysis. This approach is consistent with AHP methodological standards, which emphasize the importance of judgment consistency rather than large sample size. Furthermore, the use of purposive sampling ensures that respondents possess relevant knowledge and experience in the seaweed supply chain, thereby improving the validity of the pairwise comparison assessments.

In addition to the CR, several complementary consistency indicators were used, including the Geometric Consistency Index (GCI), Psi index (Ψ), Mean Relative Error (MRE), and Estimated Mean Relative Error (MRE est). GCI evaluates the geometric consistency of pairwise comparison matrices, while Psi reflects the degree of deviation from ideal judgment consistency. MRE and MRE est measure the relative inconsistency between observed and estimated pairwise comparison values. Lower values of these indicators indicate better internal consistency and reliability of respondent judgments.

To complement the AHP results, Bayesian updating was applied to refine the priority weights obtained from pairwise comparisons. This integration allows for improved estimation accuracy, particularly in conditions of limited or uncertain data [40]. The normalized AHP weights were treated as prior probabilities, while observed respondent preference frequencies were incorporated as likelihood evidence. Posterior probabilities were then calculated using Bayes' theorem:

$$P(C_i \mid D) = \frac{P(D \mid C_i)P(C_i)}{P(D)}$$

where, $P(C_i)$ represents the prior weight derived from AHP, $P(D \mid C_i)$ denotes the likelihood of observed market preference data, and $P(C_i \mid D)$ represents the posterior probability of each criterion after updating.

Thus, this study adopts a mixed-methods analytical approach, combining multi-criteria decision-making (AHP) with probabilistic modeling (Bayesian inference) to capture both subjective expert judgment and statistical uncertainty in analyzing real-world phenomena [41].

4. RESULT

Market distortion is defined in this study as a structural inefficiency in the seaweed supply chain, including price suppression, quality manipulation, and asymmetric bargaining power among actors. Such distortion reflects conditions where prices do not fully represent actual market value due to coercive or imbalanced practices [15]. In general, seaweed prices and production are affected by price fluctuations and quality issues related to sand and stone contamination and high-water content from conventional drying processes [16, 17, 24]. To support the achievement of research results that are consistent in answering the problem, researchers compiled supporting factors and criteria as outlined in Table 1.

Table 1. Arrangement of supporting factors and criteria

Objective	Factor	Sub-Factor
Adaptive approach to seaweed market distortion	A. National Policy	A.1 Down Streaming Policy
		A.2 Export Policy
	B. Product	B.1 Dried Seaweed
		B.2 Seaweed Flour (Carrageenan)
		B.3 Seaweed Agar
		B.4 Seaweed Chips
	C. Quality	C.1 Indonesian National Standard (SNI)
		C.2 non-SNI
	D. Price	D.1 Global
		D.2 National
		D.3 Regional
		D.4 Local
	E. Distribution	E.1 Downstream Industry (Processed Products)
		E.2 Primary Processing Industry (Raw Materials)
		E.3 Cooperative-Based Collaboration
		E.4 Integrated Village
		E.5 Conventional Middlemen

The results of the AHP calculations indicate significant variations in aggregated market preferences across regions for seaweed commodities in two main provinces, South Sulawesi and West Sulawesi. This difference is reflected in the weight

distribution of the criteria prioritized by respondents from each region. The CR values obtained across all AHP models range from 2.9% to 7.4%, which are below the acceptable threshold of 10% (0.1), indicating that the pairwise comparisons are consistent and reliable [28, 29, 42].

Respondents in South Sulawesi Province, including Pangkep Regency, Takalar Regency, Bantaeng Regency, and Makassar City, ranked the "Price" criterion highest, with a weighting of 53.2%. This indicates that market players in South Sulawesi, including farmers, collectors, and primary processors, are highly price-sensitive. Their reliance on raw material exports makes global prices a dominant factor affecting the sustainability of their businesses. This high weighting also indicates market pressure on narrow profit margins due to global price fluctuations.

The results of the AHP of respondents in West Sulawesi Province point to "Price" as the most dominant criterion. This indicates that market players in West Sulawesi are highly dependent on global price fluctuations, as most production is still exported in raw form. This high weighting also indicates that price stability is a primary concern, directly impacting the income and sustainability of seaweed cultivation businesses.

AHP testing results in both provinces revealed price as the most dominant criterion in understanding the perceptions and preferences of seaweed commodity market players. This reflects those various entities, from cultivators, collectors, to processors, are significantly influenced by price in seaweed cultivation and distribution activities. However, price categories in the context of commodity markets are not single-dimensional. Prices are divided into several market levels, such as global, national, regional, and local. Therefore, testing these sub-criteria is crucial to determine which level is perceived as most dominant and relevant in influencing market decisions in West Sulawesi. These results will provide a clearer direction for pricing policy interventions and exchange rate protection schemes for seaweed farmers.

It is important to distinguish between two analytical levels in this study: (1) province-level criteria analysis (Tables 2 and 3; Figures 2 and 3), and (2) price sub-criteria analysis (Table 4; Figure 4).

Local prices (55.5%) were the most dominant sub-criterion. This indicates that market players, particularly local farmers and collectors, are heavily influenced by local price fluctuations and pricing. Local prices reflect real-world conditions, including direct trade relationships between farmers and collectors, as well as local supply chain conditions.

The Bayesian updating results as shown in Table 5 further confirm the robustness of the AHP findings. After incorporating observed preference evidence, the price criterion remained the most dominant factor, with its posterior probability increasing slightly compared to the prior AHP weight. This indicates strong empirical consistency between expert judgment and observed market behavior.

Table 2. Seaweed assessment criteria

No.	Criterion	Comment	Main Problem	Weights	+/-
1	Policy	Policies related to down streaming and export of seaweed	Export ban, in support of down streaming	5.5%	1.5%
2	Product	Seaweed cultivation products	Dependence on raw material exports	25.0%	8.4%
3	Quality	Quality of seaweed	Contamination, moisture content, drying process	9.3%	2.7%
4	Price	Global and national prices	Global price fluctuations	53.2%	17.8%
5	Distribution	Distribution of seaweed cultivation results	Limited distribution and tracking of cultivation results	7.0%	1.0%
Eigenvalue (λmax): 5.159					
Consistency Index (CI): 0.040					
Consistency Ratio (CR): 3.5%					
Geometric Consistency Index (GCI): 0.13					
Psi: 3.3%					
Mean Relative Error (MRE): 28.3%					
MRE est: 28.2%					

Table 3. Analytic Hierarchy Process (AHP) of West Sulawesi Province

No.	Criterion	Comment	Main Problem	Weights	+/-
1	Policy	Policies related to seaweed down streaming and export	Export ban to support down streaming	4.3%	1.9%
2	Product	Seaweed aquaculture products	Dependence on raw material exports	22.1%	8.5%
3	Quality	Quality of seaweed	Contamination, moisture content, drying process	11.1%	4.8%
4	Price	Global and national prices	Global price fluctuations	56.1%	26.0%
5	Distribution	Distribution of seaweed aquaculture products	Limited distribution and traceability of aquaculture products	6.4%	1.7%
Eigenvalue (λmax): 5.334					
Consistency Index (CI): 0.084					
Consistency Ratio (CR): 7.4%					
Geometric Consistency Index (GCI): 0.27					
Psi: 3.3%					
Mean Relative Error (MRE): 40.3%					
MRE est: 40.8%					

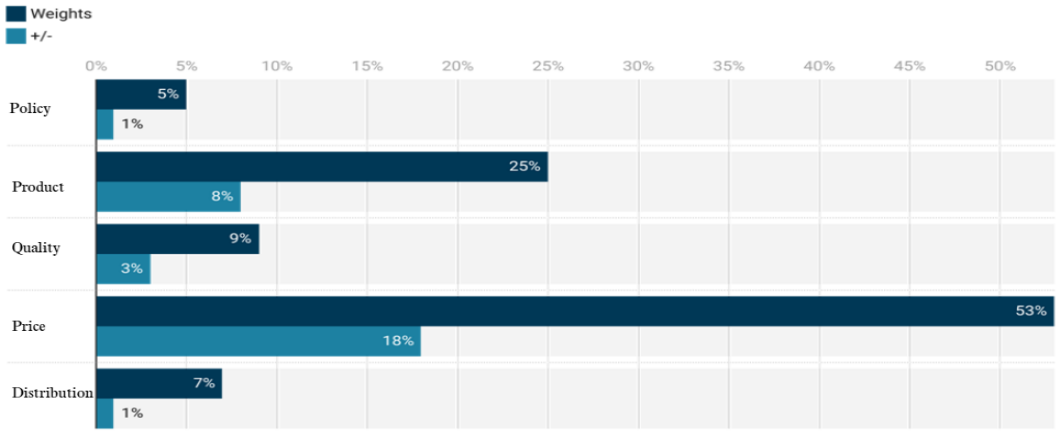

Figure 2. Analytic Hierarchy Process (AHP) of South Sulawesi Province

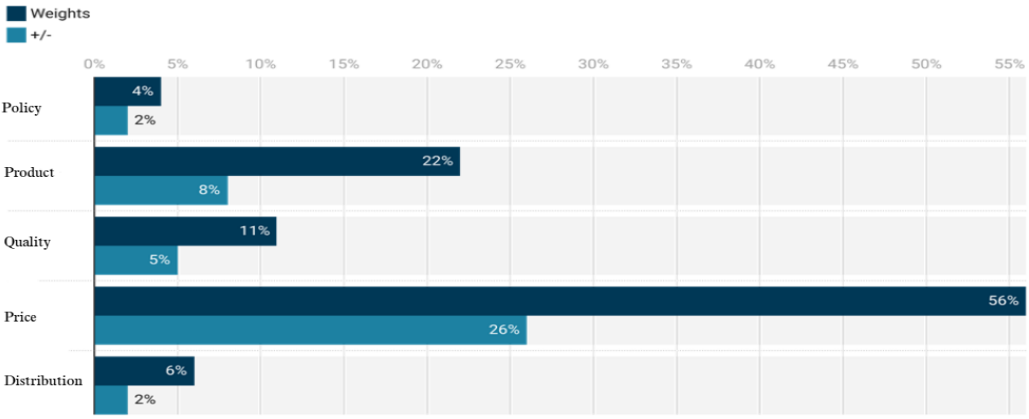

Figure 3. Analytic Hierarchy Process (AHP) of West Sulawesi Province

Table 4. Price sub-criteria test results

No.	Criterion	Comment	Weights	+/-
1	Global	Global Price	5.7%	1.6%
2	National	National Price	16.0%	3.4%
3	Regional	Regional Price	22.7%	3.0%
4	Local	Local Price	55.5%	15.2%
		Eigenvalue (λmax): 4.080		
		Consistency Index (CI): 0.027		
		Consistency Ratio (CR): 2.9%		
		Geometric Consistency Index (GCI): 0.11		
		Psi: 0.0%		
		Mean Relative Error (MRE): 23.1%		
		MRE est: 23.1%		

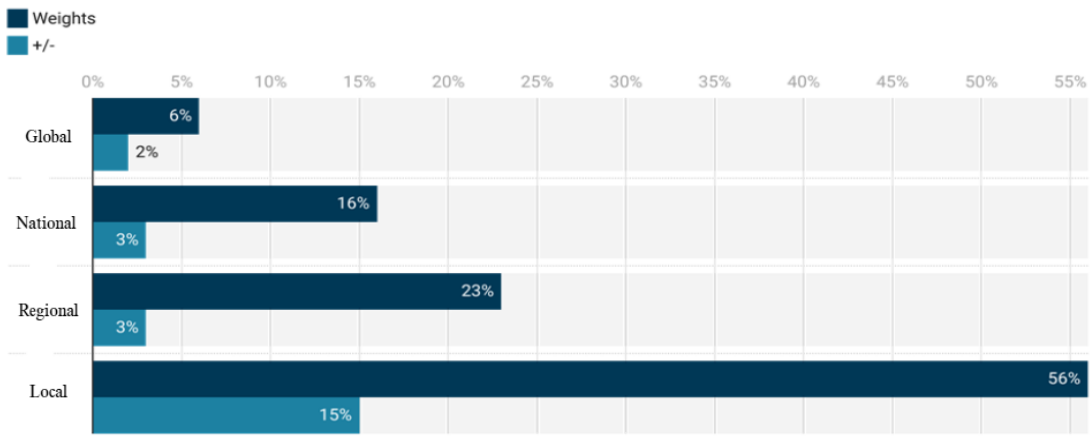

Figure 4. Analytic Hierarchy Process (AHP) price criteria for West Sulawesi Province

Table 5. Bayesian updating results of market preference criteria

Criterion	Prior (AHP)	Likelihood	Posterior
Policy	0.055	0.062	0.061
Product	0.250	0.210	0.231
Quality	0.093	0.108	0.101
Price	0.532	0.560	0.548
Distribution	0.070	0.060	0.059

Note: AHP = Analytic Hierarchy Process.

5. DISCUSSION

The findings should be interpreted as reflecting integrated market behavior rather than segmented B2B–B2C preferences. This confirms that market distortion operates systemically across the supply chain, rather than within isolated actor groups. The research results indicate that price is the most dominant criterion influencing perceptions and preferences in the seaweed market in South and West Sulawesi. This finding aligns with previous studies that emphasized that seaweed commodities in Indonesia are highly vulnerable to global price fluctuations, as the majority is still exported as raw materials [3, 24]. The dominance of local prices in the sub-criteria (55.5%) also emphasizes that price stability at the farmer and collector levels is the most pressing issue for ensuring business sustainability.

The phenomenon of market distortion found in this study reflects pressure practices within the distribution chain, both in terms of quality and price. Unstandardized drying practices by farmers result in product contamination [16, 17], while collectors often exploit capital dependence to purchase at low prices. This situation creates structural inequities in the supply chain, similar to similar phenomena in China [13] and Slovakia [14].

Furthermore, differences in preferences between market players in South Sulawesi and West Sulawesi indicate differing market orientations. In South Sulawesi, dependence on raw material exports makes global prices a greater influence on decision-making, while in West Sulawesi, local prices are more decisive due to the direct trade linkages between farmers and collectors. This indicates the need for differentiated policy approaches that consider regional market structures, rather than uniform national price interventions.

Importantly, the empirical findings of this study primarily demonstrate the centrality of price as the dominant factor and highlight structural inefficiencies within the distribution chain. The data do not directly test the effectiveness of specific technological or institutional interventions. Therefore, the following discussion distinguishes between evidence-based findings and broader policy implications derived from the literature.

From an evidence-based perspective, the results suggest that improving price stability and addressing asymmetric bargaining power are critical priorities for reducing market distortion. Strengthening local price mechanisms and improving transparency in transactions emerge as key areas directly supported by the findings. The empirical findings of this study indicate that price dominance and asymmetric relationships between actors are the core mechanisms underlying market distortion. In this context, previous studies provide supporting evidence that institutional and technological interventions can address similar structural inefficiencies. For example, cooperative-based institutional arrangements have been empirically shown to strengthen farmers' bargaining positions and reduce dependency on intermediaries [31], which is consistent with the observed dominance of local price dynamics in this study. Likewise, supply chain transparency mechanisms, such as traceability systems, have been found to reduce information asymmetry and improve trust among actors [30], aligning with the identified distribution inefficiencies. In terms of quality-related distortion, prior evidence demonstrates that improved processing technologies, including controlled drying systems, can significantly reduce contamination and quality manipulation practices [24].

Furthermore, international literature shows that the successful development of the seaweed industry depends on the synergy of downstream policies, technological innovation, and inclusive supply chain governance [28, 29].

Overall, this study confirms that market distortion in the seaweed industry is not solely a technical cultivation issue but also a structural problem related to market governance and distribution systems. While the empirical findings emphasize price as the dominant factor, broader strategies involving institutional strengthening and technological adoption should be explored in future research to validate their effectiveness in addressing market distortion.

6. CONCLUSIONS

This study demonstrates that price is the most dominant factor influencing aggregated market preferences across the seaweed supply chain, rather than reflecting distinct B2B–B2C differences. The AHP results consistently show that the price criterion holds the highest weight in both provinces, with the local price sub-criterion emerging as the most influential, indicating that price formation at the farmer and collector level is the most critical determinant of market behavior.

These findings provide empirical evidence that market distortion in the seaweed sector is primarily manifested through price mechanisms, particularly at the local level, where direct transactions and bargaining asymmetries occur. This suggests that instability in local pricing structures has a direct impact on business sustainability, especially for small-scale farmers and intermediaries.

Based on the empirical results, policy implications should prioritize price stabilization mechanisms at the local level, including improving price transparency, strengthening reference pricing systems, and enhancing market information accessibility. Such interventions are directly aligned with the study's findings, which highlight the centrality of price in shaping market preferences.

In addition, the results indicate that distribution and institutional arrangements, although less dominant than price, remain relevant supporting factors within the market structure. This implies that improvements in supply chain coordination and institutional capacity may complement pricing interventions in addressing structural inefficiencies. Therefore, policy responses should focus on correcting pricing imbalances and strengthening market coordination, rather than relying on generalized or technology-driven solutions that are not directly examined in this study.

However, this study has several limitations. First, the analysis is based on aggregated AHP results, which do not explicitly differentiate between B2B and B2C respondent groups, thereby limiting the ability to capture segment-specific

preference structures. Second, the use of purposive sampling and a geographically limited scope (West and South Sulawesi) may affect the generalizability of the findings to other regions. Third, the study focuses primarily on preference weighting rather than empirically testing causal intervention mechanisms or policy impacts. Accordingly, future research should develop more disaggregated analytical models that explicitly compare B2B and B2C market segments to identify potential differences in decision-making behavior. In addition, expanding the geographic scope and employing probabilistic sampling techniques would enhance external validity. Further studies are also encouraged to empirically test specific policy interventions, such as pricing mechanisms, institutional arrangements, or supply chain governance models, to evaluate their effectiveness in reducing market distortion within the seaweed industry.

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