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Digital Entrepreneurial Governance for Cooking Oil Supply Chains and Food Security in Indonesia

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ABSTRACT

Food security remains a critical challenge in Indonesia despite its position as the world's largest Crude Palm Oil (CPO) producer. Although various policies have been implemented to regulate the cooking oil trade, limited research has examined how governance mechanisms and digital systems can improve supply chain transparency, accountability, and resilience. **This study** evaluates the governance of Indonesia's cooking oil distribution system and assesses the role of digital governance in strengthening food security. **A qualitative** approach was employed using purposive sampling of twelve experts representing government institutions, industry associations, practitioners, academics, food task forces, and law enforcement agencies. Data were analyzed using descriptive and thematic techniques. The effectiveness of the proposed digital governance system was assessed across four dimensions: distribution transparency and traceability, monitoring effectiveness, data integration and accessibility, and contribution to supply availability and price stability. **The findings** reveal persistent governance challenges, including distribution inefficiencies, limited transparency in Domestic Market Obligation (DMO) implementation, weak inter-institutional coordination, and market concentration. Expert assessments highlighted the importance of integrated digital monitoring systems in improving accountability, reducing information asymmetry, and enhancing policy responsiveness. The study proposes a digital governance framework integrating CPO traceability, distribution monitoring, transparent DMO quota management, regulatory reforms, and stronger farmer and cooperative participation. **The proposed** framework can improve distribution efficiency, support price stability, reduce regional disparities, and strengthen food security. The study demonstrates how digital governance can enhance transparency, resilience, and equitable distribution within Indonesia's strategic food commodity supply chains.

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1. INTRODUCTION

Cooking oil is a strategic staple commodity in Indonesia and one of the nine basic necessities consumed by both urban and rural households. Dominated by palm oil, household consumption increased by an average of 2.32% annually between 2015 and 2020 [1]. Despite being the world's largest producer of CPO, Indonesia faces significant challenges in its cooking oil supply chain and trade system. The supply chain involves multiple actors, from palm oil farmers to consumers, and consists of upstream CPO production from

Fresh Fruit Bunches (FFB), refining into Refined, Bleached, and Deodorized Palm Oil (RBDPO) and RBD Olein, and downstream distribution through large and medium-scale distributors to retailers. To ensure availability and affordability, the government has implemented policies such as the Highest Retail Price (HET), DMO, Domestic Price Obligation (DPO), and the Minyakita program. However, long distribution chains, high logistics costs, and an oligopolistic market structure often cause retail prices to exceed the HET, particularly outside Java, while reducing the bargaining power of small retailers and consumers. Distribution inequalities are especially evident in Eastern Indonesia due to inadequate transportation infrastructure and high logistics costs. In addition, fluctuations in global CPO prices can reduce domestic supply when producers prioritize exports, leading to higher consumer prices [2]. Competition for CPO is further intensified by the B30 biodiesel program, where the Corruption Eradication Commission (KPK) evaluations identified inefficiencies in subsidy mechanisms and potential conflicts between food and energy priorities [3]. The implementation of SIMIRAH highlights the importance of digital monitoring in improving transparency and accountability within the cooking oil distribution system [4]. However, its effectiveness depends on institutional capacity, cross-agency data integration, and regulatory enforcement [5]. Therefore, strengthening digital governance should be accompanied by improved oversight mechanisms and transparent stakeholder coordination to minimize corruption risks and enhance food security outcomes. This system is expected to prevent hoarding and detect supply shortages more quickly and transparently [6].

However, the effectiveness of SIMIRAH's implementation in the field still depends heavily on the capacity of implementers and cross-agency data integration, which is currently not fully optimized. Based on expert assessments, the success of the proposed digital governance model should be measured through improvements in distribution transparency, traceability of CPO and cooking oil flows, responsiveness to supply disruptions, and the availability of integrated data for policy decision-making. Nevertheless, several limitations remain. The system requires consistent participation from supply chain actors, reliable data reporting mechanisms, adequate digital infrastructure in remote regions, and strong inter-institutional coordination. These factors may influence the effectiveness and scalability of implementation across different regions of Indonesia. From a trade oversight perspective, the KPK identified significant corruption risks in cooking oil distribution regulations, including preferential treatment, conflicts of interest in export licensing, and misuse of DMO allocations. The KPK therefore recommended clearer separation of roles among producers, distributors, and incentive recipients, along with stronger regulatory controls to prevent cartel practices and market manipulation. Government intervention is particularly important because the cooking oil industry remains oligopolistic, creating opportunities for collusion and price fixing that can harm consumers and weaken competition [7]. Although Law No. 18 of 2012 mandates the government to ensure food availability, affordability, and accessibility, policy implementation remains suboptimal due to the continued dominance of large private actors in both production and distribution [8]. Major business groups, including Wilmar, Musim Mas, Sinar Mas, Salim Group, and Royal Golden International, continue to exert substantial influence across the supply chain, and private sector involvement remains significant even after BULOG's participation in MinyaKita distribution. While Indonesia's cooking oil distribution system has been designed to maintain stock availability, geographical constraints, unpredictable weather, and limited government control continue to hinder its effectiveness. These challenges are particularly evident in Eastern Indonesia, where longer distribution chains and higher logistics costs cause prices to exceed the HET. According to the Minister of Trade, cooking oil prices in Eastern Indonesia were 8.8% higher than the national average in 2024, while East Nusa Tenggara recorded the highest price nationwide at IDR 28,000 per kilogram in April 2025 [9].

Efforts to ensure affordability and price balance can be achieved through the development of distribution systems that incorporate technology, transparency, and streamlined supply chains [10]. Unlike previous studies that primarily emphasized digital monitoring of cooking oil distribution through systems such as SIMIRAH, this study proposes an integrated digital governance framework that combines end-to-end CPO traceability, transparent DMO quota management, enhanced digital monitoring (SIMIRAH+), strengthened farmer and cooperative market access, and multi-stakeholder governance mechanisms. This approach extends the role of digital systems beyond distribution monitoring by improving transparency, accountability, coordination among supply chain actors, and food security outcomes [11]. These efforts are particularly targeted at remote areas far from capital cities, such as Eastern Indonesia, where supply chain inefficiencies and price disparities remain significant challenges [12]. The government's bargaining position in regulating the cooking oil market remains weak because distribution is still dominated by large private companies. As a result, policies often struggle to counter oligopolistic market forces, despite evidence that government interventions such as taxes, price con-

trols, and purchasing contracts can improve welfare in uncompetitive markets [13, 14]. This limitation has contributed to difficulties in addressing shortages and price instability, leading some observers to argue that the government has been unable to effectively control prices amid strong oligopolistic interests [15]. Strengthening local producers, including smallholder farmers, regional CPO mills, and state-owned enterprises, is therefore essential to creating a more balanced market structure [16, 17]. Another challenge is the uneven distribution of cooking oil factories. Most production facilities are concentrated in East Java, North Sumatra, DKI Jakarta, and West Java, while many provinces have fewer than four factories [18]. Consequently, cooking oil supplies in Central and Eastern Indonesia depend heavily on production centers in Western Indonesia, increasing transportation costs, reducing efficiency, and heightening vulnerability to supply disruptions [19]. To address these challenges and strengthen food security, the government has implemented policies across the supply chain [20]. At the production level, policies include plantation partnerships, FFB pricing, DMO requirements, and CPO export duties to secure raw material availability and support plantation sustainability [21]. At the distribution level, policies focus on monitoring distribution channels and ensuring nationwide access to packaged and bulk cooking oil. At the consumption level, the HET and DPO policies aim to maintain affordability and price stability [22]. Collectively, these measures seek to ensure cooking oil availability, affordability, equitable distribution, and market stability [23]. Therefore, this study examines Indonesia's cooking oil supply chain and trade system and evaluates how distribution policies influence national food security [24].

2. LITERATURE REVIEW

Food security is closely related to the availability, accessibility, affordability, and stability of strategic food commodities [25]. In Indonesia, cooking oil is an essential household commodity, however, despite being the world's largest CPO producer, Indonesia still faces price volatility and distribution disparities due to long supply chains, logistics inefficiencies, and market concentration among large producers [26]. These challenges indicate that production capacity alone is insufficient to ensure food security without effective governance and transparent distribution systems [27]. To maintain market stability, the Indonesian government has implemented policies such as the HET, DMO, DPO, and the Minyakita program. Government intervention is particularly important in the oligopolistic palm oil industry because dominant firms may influence prices and market access [28]. Weak supervision and overlapping interests may also create corruption risks and unfair competition within the distribution system. Digital governance has emerged as an important approach for improving transparency, accountability, and efficiency in food supply chains [29]. Systems such as SIMIRAH support distribution monitoring, traceability, and inter-agency coordination while reducing information asymmetry and improving policy responsiveness [30]. Nevertheless, the effectiveness of digital governance depends on infrastructure readiness, regulatory enforcement, and stakeholder participation.

Table 1. Key Concepts in Literature Review

Concept	Brief Explanation
Food Security	Refers to the availability, accessibility, affordability, and stability of cooking oil supply for communities.
Trade Governance	Government policies such as HET, DMO, DPO, and Minyakita are implemented to stabilize prices and maintain domestic supply.
Digital Governance	Digital systems such as SIMIRAH improve transparency, traceability, monitoring, and accountability in cooking oil distribution.
Stakeholder Mapping	Identifies the roles, interests, and influence of stakeholders involved in the cooking oil supply chain.
AHP and FAHP	Decision-support methods used to evaluate strategic policy priorities under uncertainty and subjective expert judgments.

Table 1 summarizes the main concepts discussed in the literature review, including food security, trade governance, digital governance, stakeholder mapping, and the application of AHP and FAHP methods. The table highlights that cooking oil governance in Indonesia is influenced not only by supply availability and price stability, but also by regulatory effectiveness, digital monitoring systems, and stakeholder coordination [31]. In addition, the table emphasizes the importance of decision-support methods such as FAHP in addressing uncertainty and subjective expert judgments when formulating strategic policy recommendations for strengthening cooking oil distribution and national food security [32].

Stakeholder theory further highlights the complexity of cooking oil governance, involving government institutions, producers, distributors, farmers, cooperatives, consumers, and regulatory agencies with different

interests and levels of influence [33]. Therefore, Multi-Stakeholder Mapping Analysis (MSMA) is required to identify stakeholder relationships, conflicts of interest, and collaborative governance opportunities. To determine strategic policy priorities under uncertainty, this study applies the Analytic Hierarchy Process (AHP) and Fuzzy Analytic Hierarchy Process (FAHP) [34]. While AHP supports hierarchical decision-making through pairwise comparisons, FAHP enhances the method by integrating fuzzy logic and Triangular Fuzzy Numbers (TFN) to better represent uncertainty and subjective expert judgments. This approach provides a more comprehensive framework for evaluating governance strategies to strengthen cooking oil distribution and food security in Indonesia [35].

3. METHOD

AHP is a decision-support method that evaluates complex problems through hierarchical structures and pairwise comparisons. However, traditional AHP uses crisp values, making it less effective in handling uncertainty and subjective judgments. Therefore, this study applies the FAHP, which integrates fuzzy logic and TFN to better represent ambiguity in decision-making. The process begins by identifying the problem and arranging criteria, sub-criteria, and alternatives into a hierarchical structure. Each element is evaluated using pairwise comparisons with a scale from 1 to 9, while consistency is considered acceptable when the Consistency Ratio (CR) is less than or equal to 10%. The FAHP method then generates priority vectors for each criterion and alternative strategy to determine the most appropriate policy recommendations.

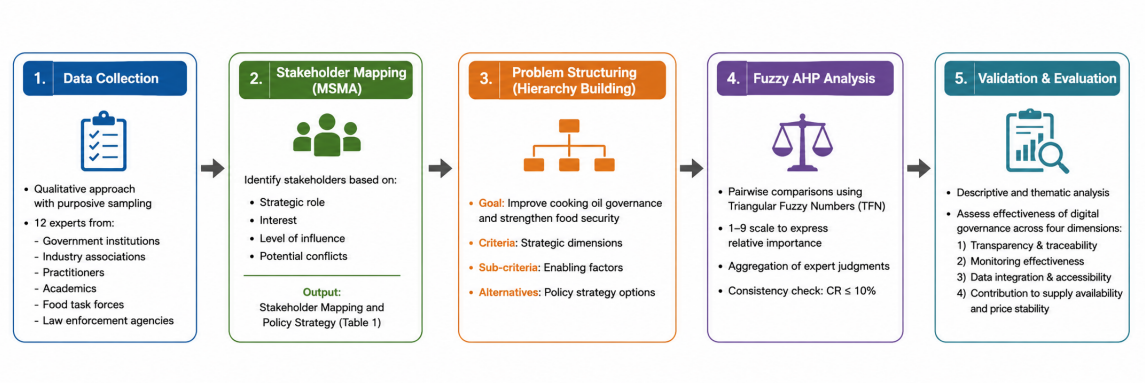


Figure 1. Research Workflow

Figure 1 illustrates the overall research workflow applied in this study. The process begins with qualitative data collection through purposive sampling involving experts from government institutions, academics, industry practitioners, and law enforcement agencies. The study then applies MSMA to identify stakeholder roles, interests, and potential conflicts in the cooking oil distribution system. Furthermore, the problem is structured hierarchically and evaluated using the FAHP to determine policy priorities under uncertainty. The final stage involves validation and descriptive evaluation to formulate strategic recommendations for strengthening cooking oil governance and national food security.

There are just two potential memberships for a crisp set, membership and non-membership. On the other hand, fuzzy set members have an unclear fuzzy value that ranges from false to true. A fuzzy set can distinguish between black, gray, and white, unlike a firm set, which can only distinguish between black and white. A membership function, or curve, that displays the data input points into a fuzzy set membership with an interval between 0 and 1, can be used to define any fuzzy set. The membership value can be obtained using a function technique. Numerous functions are available for use, such as triangular, trapezoidal, and linear representation. For future research, it would be important to examine the long-term effects of Internet of Things (IoT) adoption on Edupreneurship outcomes and explore how such technologies can be adapted in different cultural and geographic contexts [36]. Another area of future research could include evaluating the effectiveness of training programs for teachers and staff, as well as investigating the scalability of IoT solutions in more rural or economically disadvantaged regions [37]. Challenges in the implementation of IoT could include overcoming resistance from traditional Edupreneurship stakeholders, addressing privacy

and security concerns associated with IoT devices, and ensuring equitable access to the required technology. These considerations are crucial for the successful integration of IoT in Islamic boarding schools and similar Edupreneurship contexts [38].

4. RESULT AND DISCUSSION

Cooking oil is a strategic staple commodity in Indonesia and one of the nine basic necessities consumed by almost all households [39]. Dominated by palm oil, household consumption increased by an average of 2.32% annually between 2015 and 2020. Although Indonesia is the world's largest producer of CPO, its cooking oil supply chain faces significant structural challenges. The supply chain involves multiple actors, ranging from palm oil farmers and CPO processors to distributors and retailers [40]. To ensure availability and affordability, the government has implemented several policies, including the HET, DMO, DPO, and the Minyakita program [41]. However, long distribution chains, high logistics costs, and an oligopolistic market structure often cause retail prices to exceed the HET, particularly outside Java, while reducing the bargaining power of small retailers and consumers. Distribution inequalities are especially evident in Eastern Indonesia due to inadequate transportation infrastructure and high logistics costs, resulting in supply delays and price fluctuations [42]. In addition, fluctuations in global CPO prices can reduce domestic supply when producers prioritize exports, while the B30 biodiesel program intensifies competition for domestic CPO resources. A KPK evaluation identified inefficiencies in biodiesel subsidy mechanisms and potential conflicts between food and energy priorities [43]. To improve transparency, the government introduced the SIMIRAH digital monitoring system to track distribution flows and prevent hoarding. Nevertheless, its effectiveness remains constrained by limited implementation capacity and weak inter-agency data integration [44]. Furthermore, the KPK's Corruption Risk Assessment (CRA) identified significant risks in cooking oil distribution governance, including preferential treatment, conflicts of interest, and misuse of DMO allocations, prompting recommendations for stronger oversight and clearer separation of stakeholder roles. The 2022 cooking oil crisis therefore highlighted the need for structural reforms, logistics improvements, and digital governance to ensure equitable distribution, price stability, and long-term food security in Indonesia [45].

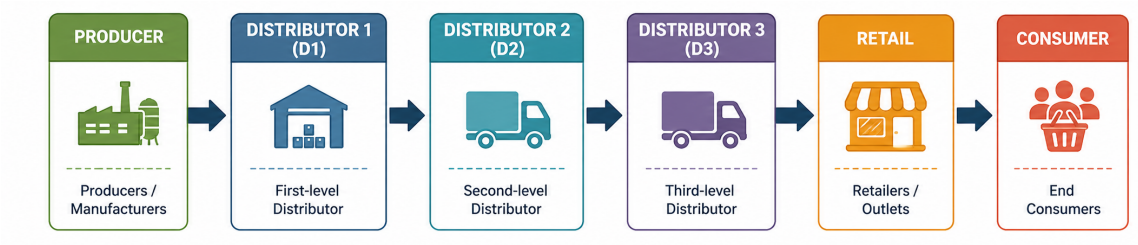


Figure 2. Distribution Structure of the Indonesian Cooking Oil Supply Chain

Figure 2 illustrates the cooking oil distribution workflow in Indonesia, beginning from producers and manufacturers, followed by first-level, second-level, and third-level distributors, before reaching retailers and final consumers. The figure highlights the complexity of the distribution chain and demonstrates how multiple intermediary stages may contribute to higher logistics costs, distribution inefficiencies, and regional price disparities. This workflow also emphasizes the importance of effective governance, transparent monitoring systems, and stakeholder coordination to ensure equitable distribution and price stability within the national cooking oil supply chain.

From the producer perspective, the HET provides domestic price stability, particularly for large integrated firms such as Wilmar, Musim Mas, and Permata Hijau. However, investigations revealed that these companies gained substantial illegal profits through manipulation of DMO compliance and export licensing processes. While large firms maintained market advantages, small producers and independent farmers faced lower margins, reduced bargaining power, low FFB prices, and production inefficiencies due to low factory utilization rates. Economic literature suggests that price ceilings can protect consumers but may also create shortages, market distortions, and supply pressures when monitoring systems are weak. Evidence from the Minyakita program and price volatility studies indicates that the HET alone has not eliminated market fluctu-

ations or distribution inefficiencies. These challenges are further compounded by the biodiesel subsidy (B30) program. KPK evaluations identified inefficiencies in subsidy calculations, transportation costs, and biodiesel pricing mechanisms, creating potential conflicts between food and energy objectives and indirectly benefiting business groups that dominate both industries.

The CRA further highlighted vulnerabilities in HET and DMO implementation, including preferential treatment, weak oversight, and conflicts of interest. Consequently, although the HET helped mitigate price spikes during the crisis, it has not fully achieved equitable consumer welfare or sustainable producer development. Strengthening its effectiveness requires regulatory reforms, digital distribution monitoring through SIMIRAH, improved logistics, higher factory utilization, support for smallholders, and a clearer separation of functions among producers, distributors, and subsidy recipients. To formulate more effective policies, a MSMA approach is required to identify stakeholder interests, influence, and potential conflicts. Previous studies show that Indonesia's cooking oil trade system remains heavily influenced by oligopolistic market structures and the dominance of large integrated firms such as Wilmar, Musim Mas, and Permata Hijau, highlighting the need for stronger governance and distribution oversight.

Table 2. Stakeholder Mapping and Policy Strategy

Actor	Strategic Role	Interest	Level of Influence	Policy Strategy
Ministry of Trade & Ministry of Industry	HET, DMO, and distribution regulators	National price and supply stability	Tall	Reforming distribution regulations and strengthening digital-based monitoring systems (SIMIRAH+).
BPDPKS & Ministry of Energy and Mineral Resources	Distributor of biodiesel subsidies (B30)	Budget efficiency and energy sustainability	Tall	Revised HIP formula and subsidy delivery point based on KPK CRA evaluation (2021) to avoid overlapping interests with the cooking oil industry.
Integrated Producers (Wilmar, Musim Mas)	CPO production, distribution, and export	High profit margin	Very high	Separation of distribution functions, limitations on market dominance, and transparent data reporting obligations.
State-Owned Enterprises (Bulog)	Minyakita Distributor and Market Balancer	Reaching underdeveloped areas and stabilizing prices	Intermediate	Expansion of mandate and logistical support for Eastern Indonesia.
Palm Oil Farmers and Smallholder Producers	Supplier of FFB raw materials	Selling price and market access	Low	Empowerment through cooperatives, local distribution incentives, and partnerships with state-owned enterprises.
Consumer	Final beneficiary	Accessibility and affordability	Intermediate	Involvement in monitoring and education on fair consumption.
KPPU & KPK	Cartel oversight and policy corruption	Healthy business competition and accountability	Tall	Strengthening the regulatory oversight function of HET, DMO, and distribution through open audits and CRA.

Table 2 presents the stakeholder mapping and corresponding policy strategies for improving cooking oil governance in Indonesia. The analysis demonstrates that policy strategies cannot be formulated in a sectoral and fragmented manner. Instead, cross-institutional coordination and synergy between state and non-state actors are required, with collaborative and transparent governance serving as the guiding principles. As shown in Table 2, each stakeholder has distinct strategic roles, interests, and levels of influence, requiring tailored policy interventions to strengthen accountability and distribution efficiency.

This analysis reinforces the point that policy strategies cannot be formulated in a sectoral and fragmented manner. Instead, cross-institutional coordination and synergy between state and non-state actors are required, with collaborative and transparent schemes as key principles. Beyond improving governance effectiveness, the proposed reforms are expected to generate broader socio-economic benefits. Strengthening digital monitoring systems, enhancing supply chain transparency, and expanding market access for farmers and cooperatives can reduce transaction costs, improve bargaining power for smallholders, and create fairer value distribution across the cooking oil supply chain. Improved distribution efficiency may also reduce regional price disparities, particularly in remote and underserved areas such as Eastern Indonesia, thereby increasing consumer welfare and food accessibility. Furthermore, greater transparency in DMO allocation and subsidy management can support public trust, reduce market distortions, and encourage sustainable economic activities among local producers. Collectively, these outcomes contribute not only to food security objectives but also to inclusive economic growth, poverty reduction, and regional economic resilience.

5. MANAGERIAL IMPLICATIONS

Based on the above options review, the government needs to prioritize policies, taking into account effectiveness, sustainability, and socio-economic costs. Final decisions are made through a collaborative process between relevant ministries and the legislature. For example, the enactment of a new Presidential or Ministerial Regulation could revise the oil palm subsidy scheme with transparent parameters (referring to highest selling price or market prices) and clarify the limits of business participation in subsidy distribution. At this stage, a CRA analysis is also implemented, draft regulations are tested for corruption risks (potential irregularities in subsidy or licensing). Policy selection focuses on win-win solutions, maintaining affordable prices for consumers while not harming smallholder farmers/producers. For example, the decision to increase CPO export

levies was implemented while protecting smallholder palm oil productivity subsidies to maintain reasonable FFB prices, in accordance with the recommendations of Bappenas and the KPPU.

In addition to stabilizing the cooking oil market, these policy measures are expected to create wider socio-economic benefits by improving income opportunities for smallholder farmers, strengthening local producer participation, reducing regional economic disparities, and enhancing household purchasing power through more stable food prices. By ensuring a more transparent and efficient supply chain, the proposed governance framework can support sustainable economic development while simultaneously improving food security and community welfare. This recommendation that interventions such as export taxes and price controls can influence output in oligopolistic markets if formulated appropriately. The decision-making process is fully documented to ensure accountability and participation (involving farmer associations, companies, NGOs, and food policy experts). These policy recommendations directly support SDG 2 (Zero Hunger) through improved food security, SDG 8 (Decent Work and Economic Growth) by strengthening smallholder participation, SDG 9 (Industry, Innovation and Infrastructure) through digital governance, and SDG 16 (Peace, Justice and Strong Institutions) by enhancing transparency and accountability in cooking oil distribution.

6. CONCLUSION

The forthcoming implementation of Indonesia's cooking oil governance reform represents a significant step toward addressing systemic inefficiencies, market distortions, and supply chain vulnerabilities that have historically affected price stability and food security. By embedding regulatory clarity, technological innovation, inclusive stakeholder participation, and robust supervision into the policy architecture, the government seeks not only to ensure the affordability and availability of cooking oil but also to strengthen institutional accountability and public trust. With the phased approach outlined in the 2025–2030 roadmap, the policy promises measurable improvements in subsidy administration, distribution equity, and market transparency. If executed effectively, this initiative can serve as a model for future reforms in agricultural commodities and contribute substantially to Indonesia's broader food security and anti-corruption agendas.

This study demonstrates that improving Indonesia's cooking oil distribution system requires a comprehensive governance approach that integrates regulatory reform, digital monitoring, stakeholder collaboration, and stronger institutional oversight. The findings reveal that persistent challenges such as distribution inefficiencies, regional price disparities, market concentration, and limited transparency can be addressed through a more accountable and technology-enabled governance framework. The proposed strategy emphasizes the integration of digital monitoring systems, transparent management of DMO allocations, strengthened support for farmers and cooperatives, and enhanced coordination among government agencies and market actors.

The study contributes to the literature on food supply chain governance by showing that digitalization should not be viewed merely as a monitoring tool but as an enabler of transparency, accountability, and equitable distribution. From a practical perspective, the proposed governance framework can improve supply chain resilience, reduce information asymmetries, support price stability, and expand access to affordable cooking oil, particularly in underserved regions. By aligning governance reforms with food security objectives, the study provides a policy-oriented roadmap for creating a more efficient, transparent, and sustainable cooking oil distribution system in Indonesia. These improvements are expected to contribute not only to market stability but also to broader socio-economic welfare and long-term national food security.

7. DECLARATIONS

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7.2. Author Contributions

Conceptualization: YW; Methodology: MS; Software: BY; Validation: ZA and BY; Formal Analysis: MS and YW; Investigation: MS; Resources: BY; Data Curation: MS; Writing Original Draft Preparation: YW

and ZA; Writing Review and Editing: BY and ZA; Visualization: YW; All authors, YW, MS, BY, and ZA, have read and agreed to the published version of the manuscript.

7.3. Data Availability Statement

The dataset supporting the findings of this study is publicly available in the Zenodo repository at https://doi.org/10.5281/zenodo.21257353. Additional information is available from the corresponding author upon reasonable request.

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7.5. Declaration of Conflicting Interest

The authors declare that they have no conflicts of interest, known competing financial interests, or personal relationships that could have influenced the work reported in this paper.

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