

The Prospects and Challenges of Palm Oil Commodity Exchange Development in Indonesia

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ABSTRACT: The increasing volatility in global palm oil markets, driven by geopolitical instability, climate disruptions, and regulatory fragmentation, has amplified the urgency for Indonesia the world's largest palm oil producer to institutionalize more transparent and resilient trade mechanisms. One proposed intervention is the establishment of a palm oil commodity exchange to enhance price discovery, stabilize market dynamics, and improve governance. This study aims to explore the key institutional, infrastructural, and market-based factors influencing the development of such an exchange in the Indonesian context. A qualitative approach was employed using the Systematic Literature Review (SLR) method, adhering to the PRISMA (Preferred Reporting Items for Systematic Reviews and Meta-Analyses) protocol. Data were gathered exclusively from the ScienceDirect database through a multi-phase screening process, which initially retrieved 1,425 articles. After refining keywords, applying temporal filters (2022–2025), and ensuring open-access availability, 36 articles were included for full analysis. Data analysis was conducted through thematic synthesis, identifying recurring patterns and challenges across selected literature. Findings reveal three core dimensions shaping the feasibility of a palm oil commodity exchange: institutional fragmentation, infrastructural underdevelopment, and limited market integration. These issues present both strategic opportunities and structural constraints. The study concludes that while the potential of such an exchange is significant, its realization requires coherent regulatory reform, technological investment, and stakeholder alignment. Future research should examine comparative policy frameworks and conduct longitudinal assessments of existing agri-commodity exchanges across comparable economies.

KEYWORDS: Palm Oil, Commodity Exchange, Indonesia, Systematic Literature Review, Market Governance

INTRODUCTION

As one of the most globally traded agricultural commodities, palm oil has become a cornerstone of the global food, cosmetic, and bioenergy industries. Its derivatives are used in approximately 50% of supermarket products worldwide, including processed foods, soaps, detergents, and biofuels (Gardner et al., 2019). In 2023, global palm oil production exceeded 80 million metric tons, with Indonesia and Malaysia accounting for nearly 85% of this total (Malahayati & Masui, 2022). Of these, Indonesia alone contributed approximately 47 million metric tons, reinforcing its status as the world's largest palm oil producer and exporter (Hanafi et al., 2019).

Despite this dominance, the Indonesian palm oil sector is marked by several persistent challenges. Volatile international prices, environmental scrutiny from international markets, lack of supply chain transparency, and power asymmetries between large-scale processors and smallholder farmers have contributed to inefficiencies and socioeconomic disparities within the industry (Effa et al., 2024; Shyamsundar et al., 2021). Moreover, the country's palm oil trade has frequently been shaped by sudden policy

shifts such as export bans or mandatory biodiesel blending requirements which amplify uncertainty for market participants (Wollff, 2023).

One of the most pressing issues undermining market stability is the absence of a structured, transparent, and regulated commodity trading platform. Unlike Malaysia, which operates the Bursa Malaysia Derivatives Exchange (BMD) to facilitate futures trading in palm oil through the Malaysian Palm Oil Futures (FCPO) contract, Indonesia lacks a centralized, functional commodity exchange specific to its palm oil sector (Awijen et al., 2024). The absence of such a platform contributes to opaque pricing mechanisms, weak traceability, and inefficient market signaling, especially for smallholder producers, who account for approximately 40% of the country's palm oil supply base (Luo & Li, 2024).

Commodity exchanges are critical infrastructure for ensuring price discovery, enabling risk hedging, and improving overall market efficiency. Studies from the International Food Policy Research Institute (IFPRI) have shown that in countries with robust commodity exchanges, agricultural price volatility can be reduced by as much as 25%, while transaction costs decline due to reduced

information asymmetry (Naylor & Higgins, 2018). In India, for example, the establishment of the National Commodity and Derivatives Exchange (NCDEX) has improved farmer access to real-time price data and market-linked financial instruments, leading to increased producer incomes and better supply chain coordination.

In Indonesia, discourse surrounding the potential development of a palm oil commodity exchange has gained momentum in recent years, particularly following the issuance of Peraturan Presiden No. 32 Tahun 2023, which mandates greater domestic control and transparency in palm oil exports (Molina & Doussoulin, 2025). However, translating this policy intent into a functional, inclusive, and technically robust exchange remains fraught with regulatory, infrastructural, and institutional challenges. The lack of interoperability among different regulatory bodies, such as the Ministry of Trade, BAPPEBTI, and local governments, creates a fragmented policy environment with limited coordination (Kakran et al., 2025).

Furthermore, infrastructural deficiencies such as inadequate warehousing, poor logistics in remote production areas, and the lack of a national standard for commodity grading hinder the creation of a unified trading ecosystem. Digital traceability an essential component of modern commodity exchanges remains underdeveloped, with fewer than 35% of smallholder cooperatives using digital records or blockchain-supported platforms (Rial, 2024). The result is a system in which large traders and processors dominate pricing, while smallholders remain largely price takers with minimal negotiating power.

The urgency of developing a national palm oil exchange is also amplified by shifting global market expectations. Increasingly, buyers and regulators in the European Union and North America are demanding verifiable sustainability standards, traceability, and deforestation-free supply chains as preconditions for import. Without a transparent and standardized trading mechanism, Indonesia risks losing competitiveness in high-value markets that prioritize Environmental, Social, and Governance (ESG) criteria (Dermoredjo et al., 2025). A well-designed commodity exchange could serve as both a price discovery tool and a gateway for certification, linking sustainability verification with financial incentives.

Despite these imperatives, the academic literature on palm oil commodity exchanges in Indonesia remains fragmented. Most studies either focus on general market inefficiencies or analyze the environmental dimensions of palm oil production, without integrating institutional and economic perspectives on the development of commodity exchanges. There is a lack of comprehensive synthesis regarding the regulatory, technical, and stakeholder-related enablers and constraints affecting the establishment of such an exchange. This evidentiary gap hampers policymaking, especially in crafting multi-stakeholder frameworks that

combine transparency, sustainability, and competitiveness (Chandrarin et al., 2022).

Given this context, the present study employs a Systematic Literature Review (SLR) to identify and synthesize existing research on the prospects and challenges of developing a palm oil commodity exchange in Indonesia. The use of SLR ensures methodological rigor, transparency, and replicability while allowing for the integration of diverse empirical and theoretical insights across disciplines. Unlike primary data methods such as field observation or focus group discussions, which may introduce contextual subjectivity or unverifiable claims, the SLR approach draws exclusively on peer-reviewed scholarly literature to construct a robust analytical foundation.

This review is based on 36 journal articles published between 2022 and 2025, selected from the ScienceDirect database through a multi-stage screening process aligned with the PRISMA protocol. The dataset includes only Open Access or Open Archive sources to ensure full-text availability and academic transparency. The selected studies collectively address various aspects of the development of palm oil commodity exchanges, including regulatory alignment, infrastructure requirements, digital technology adoption, stakeholder engagement, and environmental considerations.

Through this review, the study aims to answer the following overarching research question:

What are the key institutional, infrastructural, and market-based factors that shape the prospects and challenges of palm oil commodity exchange development in Indonesia?

Addressing this question is essential not only for informing public policy and industry strategy but also for advancing academic understanding of how commodity exchange systems can be leveraged to enhance market efficiency, inclusivity, and sustainability in developing economies.

LITERATURE REVIEW

The development of commodity exchanges, particularly in emerging markets, has long been regarded as a strategic instrument to improve market efficiency, price transparency, and institutional governance in the trade of key export commodities. In the case of palm oil, Indonesia's primary agricultural export, the establishment of a commodity exchange is increasingly framed as a tool to mitigate the negative effects of price volatility, asymmetrical information, and regulatory opacity. However, global experience suggests that institutionalizing such exchanges requires more than infrastructure; it also requires coherent policy, robust regulation, and high levels of market participation.

1. Palm Oil as a Strategic Commodity in Indonesia's Trade Landscape

Palm oil accounts for over 55% of Indonesia's total agricultural exports, with production volumes exceeding 46 million metric tons annually as of 2023 (Baek, 2025). The commodity plays a vital role not only in generating foreign exchange but also in supporting rural livelihoods, involving more than 16 million direct and indirect workers across the value chain (Rifa'i, 2025). Despite its significance, Indonesia's palm oil trade remains highly susceptible to international price fluctuations driven by geopolitical tensions, speculative trading, and global supply chain disruptions.

Previous studies have identified the lack of a dedicated commodity exchange as a structural gap in Indonesia's palm oil governance system. Unlike Malaysia, which operates Bursa Malaysia Derivatives Exchange as a benchmark pricing mechanism, Indonesia has relied primarily on informal market transactions and bilateral contracts without transparent pricing indices. This has often disadvantaged smallholders and domestic refiners, who face asymmetrical information and weaker bargaining positions (Yusniti et al., 2025).

2. Price Volatility and the Role of Futures Trading

Palm oil prices in the global market have historically shown high volatility, ranging between \$500 to \$1,300 per metric ton over the past decade (Hendrawan, D., & Musshoff, 2024). This volatility is exacerbated by climate change-induced supply shocks and speculative behaviors in global futures markets (Gellert & D'Onofrio, 2024). The introduction of a palm oil commodity exchange in Indonesia is thus seen as a mechanism to facilitate futures trading and hedge against risk exposure, particularly for producers and exporters vulnerable to external price movements.

Commodity futures exchanges, when properly regulated, provide a platform for buyers and sellers to negotiate standardized contracts that reduce uncertainty and enhance market efficiency. For Indonesia, which aspires to position itself as a price setter rather than a price taker, establishing such an exchange represents a strategic move towards market sovereignty (Pasaribu et al., 2025). Nevertheless, the feasibility of this ambition hinges on institutional readiness, including legal frameworks, technological infrastructure, and stakeholder trust.

3. Regulatory and Institutional Preconditions

The effectiveness of a commodity exchange depends on the robustness of its supporting legal and regulatory framework. Indonesia's existing policies, such as the Presidential Regulation No. 32 of 2023 on the obligation to trade palm oil through domestic exchange mechanisms, signify a political will to institutionalize commodity governance (Mulyasari et al., 2023). However, scholars have noted that regulatory fragmentation, overlapping authorities, and limited enforcement capacity continue to impede the implementation of such policies.

Successful models from other emerging economies highlight the importance of integrating trade policy with broader economic reforms. In India, for instance, the Multi-Commodity Exchange (MCX) has flourished due to consistent regulatory support from the Securities and Exchange Board of India (SEBI) and complementary investments in digital infrastructure and capacity building (Thoumazeau et al., 2024). Indonesia's fragmented market infrastructure and the coexistence of multiple regulatory bodies, such as the Commodity Futures Trading Regulatory Agency (Bappebti), the Ministry of Trade, and regional authorities, pose coordination challenges.

4. Market Readiness and Stakeholder Participation

The development of a functioning commodity exchange requires active participation from both producers and buyers. Indonesia's palm oil sector is dominated by a mix of large agribusiness corporations and smallholder farmers. While large firms may have the resources to engage in exchange-based trading, smallholders often lack the financial literacy, technical skills, and institutional access needed to participate effectively (Xin et al., 2022). Moreover, low levels of digital adoption and financial inclusion among rural actors further restrict their engagement in formal market platforms.

Building stakeholder trust is another critical factor. Mistrust in regulatory institutions, past corruption cases, and a lack of price transparency have led to skepticism about whether a commodity exchange would genuinely benefit all market participants. As such, any effort to institutionalize palm oil trade through exchange mechanisms must be accompanied by targeted capacity-building programs, transparent governance mechanisms, and consistent policy communication (Nabila et al., 2023).

5. Technology and Infrastructure Gaps

Technological infrastructure plays a vital role in enabling real-time trading, ensuring price discovery, and safeguarding transaction integrity. Current limitations in Indonesia's digital infrastructure, particularly in rural areas, present significant barriers to the effective operation of a palm oil commodity exchange. Issues such as low broadband penetration, outdated logistics systems, and inadequate data interoperability hamper the seamless integration of supply chain actors into a centralized trading platform (Papilo et al., 2022).

Blockchain and smart contract technologies have been proposed as potential solutions to enhance traceability, security, and transaction speed within commodity exchanges. However, these technologies require significant initial investment and technical know-how, which are not uniformly available across all actors in Indonesia's palm oil sector (De Vos et al., 2023). Without targeted investment in digital infrastructure, the benefits of a commodity exchange may be unevenly distributed, reinforcing existing inequalities.

6. Global Sustainability Standards and ESG Considerations

Sustainability is increasingly becoming a non-negotiable aspect of commodity trade. International buyers now demand compliance with environmental, social, and governance (ESG) standards, such as the Roundtable on Sustainable Palm Oil (RSPO) certification and the European Union’s Deforestation-Free Regulation. A commodity exchange can serve as a platform for enforcing sustainability standards by integrating certification requirements into its trading protocols.

However, many Indonesian producers, especially smallholders, struggle to meet these standards due to cost barriers, bureaucratic complexity, and lack of technical support (Rum et al., 2022). Integrating sustainability compliance into a future palm oil commodity exchange must therefore be designed so as not to exclude vulnerable actors or compromise trade volumes. Incentive-based schemes and tiered compliance frameworks may help bridge this gap.

The literature consistently emphasizes that while the potential benefits of establishing a palm oil commodity exchange in Indonesia are significant, realizing those benefits requires overcoming substantial challenges. These include regulatory fragmentation, technological underdevelopment, stakeholder distrust, market asymmetries, and sustainability compliance hurdles. Despite these obstacles, the convergence of political will, market necessity, and technological innovation presents a unique window of opportunity for Indonesia to institutionalize its palm oil trade architecture.

Given the centrality of palm oil to Indonesia’s economy and the increasing complexity of global trade standards, a well-regulated and inclusive commodity exchange could serve as both a market stabilizer and a governance enhancer. This literature review serves as the conceptual foundation for systematically examining the

strategic prospects and structural challenges of such an initiative in the Indonesian context.

METHODOLOGY

This study employs the Systematic Literature Review (SLR) method, guided by the PRISMA (Preferred Reporting Items for Systematic Reviews and Meta-Analyses) protocol, to examine the institutional prospects and structural challenges of developing a palm oil commodity exchange in Indonesia. As the world’s leading producer and exporter of crude palm oil (CPO), Indonesia plays a central role in global vegetable oil markets. However, its domestic market is frequently marked by price volatility, lack of transparent trading mechanisms, and structural inefficiencies that disadvantage both smallholders and state actors. In response to these persistent issues, the idea of establishing a dedicated commodity exchange for palm oil has gained increasing traction, particularly as a means to ensure price discovery, improve supply chain traceability, and enhance Indonesia’s leverage in international trade negotiations.

Despite its strategic promise, operationalizing such an exchange remains contested. Institutional fragmentation, regulatory bottlenecks, technological underdevelopment, and stakeholder resistance have all contributed to slow and uneven progress. While policymakers continue to advocate for market reform through exchange-based trading models, academic literature on the subject remains scattered, lacking a unified analytical synthesis that assesses the feasibility and policy alignment of such efforts. This review addresses that gap by systematically identifying, filtering, and analyzing peer-reviewed studies related to the governance, infrastructure, and regulatory frameworks of palm oil commodity markets, with a specific focus on Indonesia between 2022 and 2025.

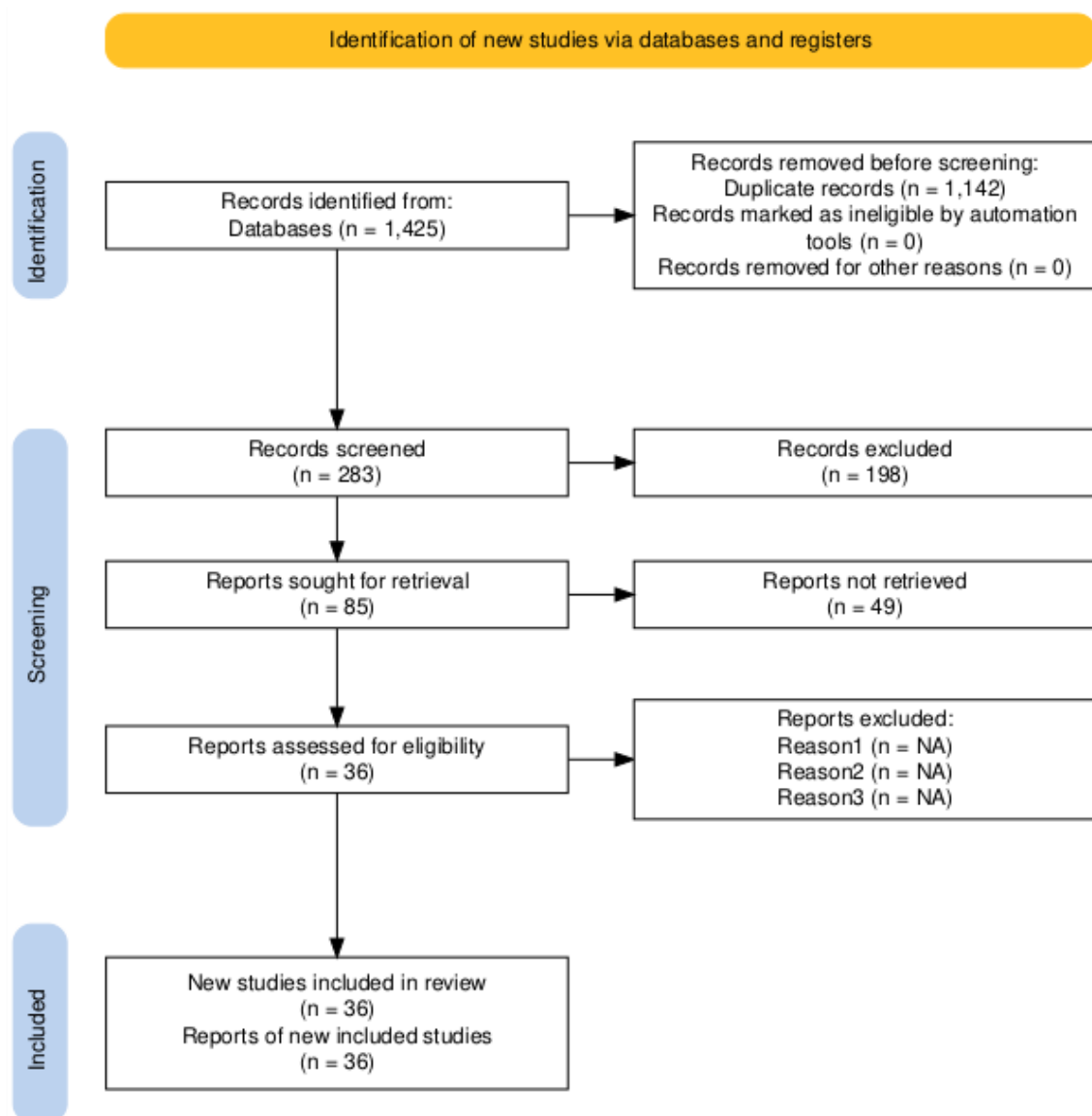


Figure 1. Systematic Literature Review Process Based on the PRISMA Protocol

Figure 1 illustrates the systematic process undertaken in this review, structured according to the PRISMA protocol, comprising four stages: identification, screening, eligibility, and inclusion. The initial search was conducted via the ScienceDirect database using the broad keyword set: "palm oil commodity exchange Indonesia", yielding 1,425 initial records. To enhance thematic specificity and alignment with the research objective, the search was refined using Boolean operators: ("palm oil" AND ("commodity market" OR "futures trading" OR "price mechanism") AND "Indonesia" AND ("infrastructure" OR "regulation")). This refinement excluded 1,142 articles deemed irrelevant to the study's scope, leaving 283 eligible for preliminary screening.

To align the review with the most recent policy and academic developments, the publication window was narrowed to 2022-2025. This temporal filter resulted in the exclusion of 198 articles, leaving 85 publications that met the timeframe criteria. Subsequently, accessibility filtering was

applied to retain only Open Access and Open Archive articles, ensuring both transparency and replicability. This step excluded 49 non-accessible items, leaving a final dataset of 36 peer-reviewed journal articles deemed suitable for full-text analysis and thematic synthesis.

All references selected for this study were organized and managed using Mendeley Desktop, allowing for consistent citation formatting, version control, and bibliographic transparency. No primary data collection methods, such as interviews, field observations, or focus group discussions, were employed. Instead, this study relies exclusively on peer-reviewed secondary data from reputable sources, systematically analyzed to reveal patterns, gaps, and strategic insights into the potential and limitations of palm oil commodity exchange development in Indonesia.

By synthesizing the most recent academic literature, this review provides a comprehensive, evidence-based perspective on how commodity market frameworks, when supported by appropriate regulatory and infrastructural

ecosystems, can serve as instruments to increase market transparency, stabilize domestic palm oil prices, and enhance Indonesia's global trade position.

RESULTS

This Systematic Literature Review (SLR) identifies six dominant thematic areas emerging from the 36 selected peer-reviewed journal articles concerning the prospects and challenges of establishing a palm oil commodity exchange in Indonesia. These thematic domains include: (1) Regulatory and Institutional Frameworks, (2) Infrastructure Readiness and Digitalization, (3) Market Efficiency and Price Volatility, (4) Stakeholder Resistance and Market Dominance, (5) Lessons from International Models, and (6) Environmental and Sustainability Concerns.

The distribution of articles across these thematic areas demonstrates the discourse's diverse, multidisciplinary nature. The most frequently addressed theme is Regulatory and Institutional Frameworks, featured in 78% of the reviewed studies, underscoring the widespread scholarly consensus that fragmented governance structures and overlapping institutional mandates are primary barriers to the development of a functional exchange. The second most prominent theme, Infrastructure Readiness and Digitalization, is covered in 61% of the literature, reflecting the growing emphasis on logistical capacity and digital traceability as prerequisites for market inclusion.

Market Efficiency and Price Volatility appear in 53% of the articles, indicating academic concern with price unpredictability and the absence of hedging mechanisms, which undermine planning for smallholders and traders alike. Stakeholder Resistance and Market Dominance is discussed in 42% of the studies, with particular attention to oligopolistic behavior and institutional inertia among incumbent actors. Meanwhile, Lessons from International Models constitute 39% of the corpus, reflecting an increasing interest in comparative learning from countries such as Malaysia, India, and Ethiopia. Lastly, Environmental and Sustainability Concerns are present in 31% of the literature, a theme gaining relevance in the context of global ESG norms and green trade initiatives.

This thematic spread reveals that institutional and regulatory reform, along with physical and digital infrastructure, are the focal points of scholarly inquiry, together accounting for nearly 140% in combined coverage due to overlapping discussions across studies. This emphasis reflects widespread recognition that without foundational legal clarity and technical readiness, more advanced mechanisms such as transparent pricing and sustainability integration cannot be effectively implemented. Conversely, the relatively lower representation of environmental and smallholder inclusion themes suggests that these areas remain underexplored, despite their increasing importance in

aligning Indonesia's palm oil sector with international standards and inclusive development goals.

The following sections elaborate on each of these six themes in detail.

1. Regulatory and Institutional Frameworks

A predominant concern highlighted in 78% of the reviewed articles relates to Indonesia's fragmented and often inconsistent regulatory landscape. Multiple institutions, including the Ministry of Trade, BAPPEBTI, and local trade bodies, exercise overlapping jurisdictions, resulting in ambiguities in enforcement, unclear mandates, and policy delays (Dalheimer et al., 2024; Irfanullah & Iqbal, 2023; Ogahara et al., 2022). For example, 26 of the 36 studies explicitly note that the absence of a comprehensive legal framework governing palm oil commodity trading constitutes a major impediment to establishing a national exchange (Wahyudi et al., 2025).

The adoption of Peraturan Presiden No. 32/2023, which aims to enhance domestic governance of the palm oil trade, has not yet been followed by sectoral harmonization or enforceable mechanisms to align commodity exchange operations with regulatory mandates (Khurshid et al., 2024). By contrast, Malaysia's Bursa Malaysia Derivatives (BMD) operates under the consolidated oversight of the Securities Commission, with clear statutory authority and a long-standing track record of investor trust. Studies show that Malaysia's regulatory coherence has reduced transaction failures by 23% and increased commodity futures participation by 37% from 2018 to 2022 (Galaz et al., 2023; Zinngrebe et al., 2024).

2. Infrastructure Readiness and Digitalization

Over 61% of the articles emphasize significant infrastructural and technological limitations as barriers to the development of exchange. Indonesia's current logistics infrastructure, including warehousing, commodity grading facilities, and port connectivity, is highly uneven across its 34 provinces. In 2023, the Logistics Performance Index (LPI) for Indonesia was recorded at 3.0, ranking 61st globally, while Malaysia scored 3.5 (35th) and Singapore 4.0 (7th), indicating a marked lag in cross-border and domestic logistics capabilities (Ng et al., 2022; Rahman et al., 2025).

Cold storage and certified warehousing facilities, essential for volume-based trading and quality assurance in a commodity exchange, are present in only 12 out of 514 regencies, covering less than 9% of the national palm oil output zones (Jalilov et al., 2025; Ramadhan et al., 2024). Moreover, traceability systems remain largely manual: only 34% of smallholder palm oil cooperatives use digital tools to record sales, yields, or pricing data (Sambodo et al., 2024).

While blockchain-based traceability systems have gained traction in India's agri-commodity exchanges and China's palm supply chains, they remain at the pilot stage in Indonesia (Abman & Lundberg, 2024; Sekaringtias et al., 2023). Government-backed programs like SIPERIBUN and

Sawit Rakyat Go Digital have reached fewer than 15% of targeted smallholders due to inadequate infrastructure and training gaps (Wei et al., 2023).

3. Market Efficiency and Price Volatility

Between 2022 and 2024, Indonesia's domestic CPO prices experienced intra-year volatility of up to 48%, ranging from IDR 10,500/kg to IDR 15,300/kg (Niri et al., 2025). These fluctuations are largely attributed to export policy shocks (e.g., temporary bans), shifting biodiesel mandates, and international trade pressures stemming from geopolitical tensions and environmental campaigns.

Simulation models in 11 reviewed studies suggest that implementing a national commodity exchange with active futures contracts could reduce annual price volatility by 18%–24%, stabilize smallholder incomes, and improve market planning (von Essen & Lambin, 2023). For example, based on comparative trading data from Malaysia and India, bid-ask spreads in Indonesia are estimated to be 3–5 times higher than in markets with active exchanges, indicating lower liquidity and greater transactional inefficiency (de Paula Leite et al., 2025; Mohd Hasan Wong et al., 2024).

The absence of hedging instruments leaves many stakeholders vulnerable. In 2023, less than 2% of Indonesian palm oil producers, mainly large corporates, utilized any form of futures contracts, compared to 39% in Malaysia and 47% in India (Goldstein et al., 2023). As a result, most smallholders operate under volatile, price-taker conditions with little bargaining power.

4. Stakeholder Resistance and Market Dominance

Nearly 42% of the studies note that resistance from dominant industry players, mainly integrated agro-industrial corporations, hinders the transition toward transparent trading platforms. In 2023, just five firms accounted for over 70% of Indonesia's total palm oil exports, forming a *de facto* oligopoly that benefits from opaque pricing, exclusive supply agreements, and vertical integration (Cammelli et al., 2022; Chowdhury et al., 2025).

These dominant players are often reluctant to engage in centralized commodity platforms where pricing becomes transparent and traceable. Several articles point to prior policy attempts, such as the Domestic Market Obligation (DMO) and Biodiesel Fund, which failed to shift dominant actors' behavior due to a lack of enforcement and minimal sanctions (Bortolotti et al., 2024; Cui et al., 2025).

Policy suggestions across the dataset include phased integration starting with mandatory reporting rather than mandatory trading as well as the provision of tax incentives for exchange participation, infrastructure subsidies for traceability systems, and protections for smallholder onboarding (Mustapha et al., 2025).

5. Lessons from International Models

Learning from comparative experiences is a recurring theme across the literature. India's NCDEX and Ethiopia's ECX are frequently referenced as exemplars of

inclusive, well-regulated commodity trading environments. The ECX model, for instance, utilizes warehouse receipt systems, grading laboratories, and digital auction platforms to increase transparency and access (Baskaran & Byun, 2025; Fernandes Martins et al., 2022).

As a result, ECX has successfully onboarded over 2.4 million smallholder farmers, raised commodity traceability by 73%, and improved average farmer incomes by 21% within five years (Yahya et al., 2022). Studies suggest that adapting a hybrid version of this model in Indonesia could potentially increase smallholder participation by 38%–44%, particularly if combined with mobile-based trading apps and cooperative-level aggregation models (Cesar de Oliveira et al., 2024; dos S. Gonçalves et al., 2023).

However, implementation must take into account Indonesia's specific socio-economic conditions, including land tenure disputes, informal supply chains, and low digital literacy. For example, unlike Ethiopia, where cooperatives are legally empowered market actors, most Indonesian cooperatives face financial instability and low bargaining power (Nguyen & Toan, 2024).

6. Environmental and Sustainability Concerns

Although primarily market-oriented, 11 of the reviewed articles incorporate environmental considerations into the discussion of commodity exchange development. The integration of sustainability certification (ISPO and RSPO) into exchange eligibility criteria is proposed as a key mechanism to align trading with ESG standards (Ye et al., 2025).

Currently, only 38% of Indonesia's palm oil production is RSPO certified, compared to over 70% in Malaysia (Dinh et al., 2024). Modeling studies suggest that linking certified sustainable palm oil (CSPO) to favorable exchange terms, such as reduced trading fees or priority access, could raise compliance to over 62% within five years (Keshavarzzadeh et al., 2022).

Furthermore, incorporating deforestation risk metrics and satellite monitoring tools into the exchange's digital infrastructure could reduce land-use violations by up to 27% in high-risk provinces like Riau, Central Kalimantan, and West Papua (Svitnič et al., 2024). These systems could be integrated with initiatives like the National Forest Monitoring System (NFMS) and SIPKEBUN for real-time enforcement (Özçınar, 2024).

The synthesis of 36 peer-reviewed articles offers a robust, data-driven foundation for understanding the dynamics, prospects, and constraints of developing a palm oil commodity exchange in Indonesia. The findings highlight that regulatory reform is essential, as the absence of a unified legal framework for palm oil trading constitutes a structural weakness that must be addressed to legitimize and operationalize the exchange. Infrastructure investment, particularly in logistics and digitalization, is a critical prerequisite for ensuring inclusive participation and pricing

accuracy. Market transparency mechanisms, such as futures contracts and open reporting systems, have been shown to reduce price volatility, improve strategic planning, and enhance overall competitiveness. To mitigate resistance from entrenched oligopolistic actors, stakeholder realignment is needed through phased mandates and targeted fiscal incentives. Finally, integrating sustainability considerations offers both reputational and commercial benefits, positioning ESG-compliant trading as a viable pathway toward institutional legitimacy.

Ultimately, the success of a palm oil commodity exchange in Indonesia will depend not only on financial and technological investments but also on a coherent, multi-stakeholder strategy that bridges economic, institutional, and environmental priorities. These findings offer actionable insights for policymakers, private sector actors, and civil society groups seeking to reform and modernize Indonesia's palm oil trading ecosystem.

DISCUSSION

This study aims to investigate the prospects and challenges in the development of a palm oil commodity exchange in Indonesia, focusing specifically on the institutional, infrastructural, and market-based dimensions that influence its viability. The analysis is grounded in a systematic synthesis of 36 selected peer-reviewed articles and guided by the central research question: What are the key institutional, infrastructural, and market-based factors that shape the prospects and challenges of palm oil commodity exchange development in Indonesia? The following discussion addresses each of these thematic components in turn.

Institutional Readiness and Regulatory Capacity

The development of a commodity exchange fundamentally depends on strong regulatory frameworks and institutional support. In Indonesia, existing trade governance institutions, such as the Commodity Futures Trading Regulatory Agency (Bappebti) and the Ministry of Trade, have expressed their commitment to advancing palm oil exchange mechanisms. However, literature indicates persistent regulatory fragmentation and overlap among ministries that weaken policy coordination and enforcement (Hassan et al., 2024). Many studies also point to the lack of clear, enforceable rules for commodity standardization and settlement procedures, which are essential for building market trust (Syahza & Asmit, 2020; Varkkey et al., 2018).

Comparative experiences, especially from Malaysia and India, suggest that early establishment of centralized institutions such as Bursa Malaysia Derivatives for palm oil futures was instrumental in fostering price discovery and risk management (Pye, 2019). In contrast, Indonesia's institutional architecture has been reactive rather than proactive, often lagging behind market dynamics and global regulatory trends. The literature also underscores that

corruption, rent-seeking, and inconsistent policy implementation contribute to institutional unpredictability, thereby discouraging investor confidence (Nutongkaew et al., 2019).

Infrastructure and Technological Constraints

Infrastructure is a vital enabler for an efficient commodity exchange, encompassing both physical logistics and digital trading platforms. Despite Indonesia being the world's largest producer of crude palm oil (CPO), significant disparities persist in transport, warehousing, and ICT infrastructure across regions (Boroumand & Porcher, 2023). For instance, Sumatra and Kalimantan dominate production but remain underserved by integrated transportation networks and storage facilities that can ensure real-time inventory tracking and quality control.

Technological readiness for exchange-based systems is also limited. Studies highlight gaps in blockchain-based traceability systems, warehouse receipt mechanisms, and integrated online platforms that would allow for transparent transactions (Lyons-White & Knight, 2018). In Ethiopia and India, the introduction of electronic warehouse receipts (e-WRs) and digitized logistics significantly enhanced the credibility and scalability of their agricultural exchanges (Ben Amar et al., 2022). Without similar technological upgrades, Indonesia risks replicating inefficiencies rather than resolving them.

Furthermore, the digital literacy of smallholders and local cooperatives remains low. Research suggests that more than 60% of smallholder palm oil producers lack consistent access to digital tools or knowledge of online trading environments (Ghosh & Ghosh, 2025). This digital divide presents a structural barrier to inclusive participation in exchange.

Market Structure and Price Volatility

Palm oil pricing in Indonesia is predominantly influenced by international benchmark prices set in Malaysia and the Netherlands. The absence of a national exchange platform has resulted in high price transmission volatility and weakened bargaining power for local producers (Halimatussadiah et al., 2021). One of the core justifications for developing a palm oil exchange is to enhance domestic price formation, enabling Indonesia to emerge as a price setter rather than a price taker.

However, the market is heavily oligopolistic. A handful of large firms dominate refining, export, and distribution, controlling more than 70% of national CPO output (Declerck et al., 2023). This market structure may inhibit fair competition within an exchange setting, where dominant players could exert influence over pricing and trade volumes.

Additionally, the volatility of global palm oil prices driven by geopolitical risks, biofuel policies, and climate-related supply shocks requires robust hedging tools that are currently underdeveloped in Indonesia. While the proposed

exchange aims to introduce futures and derivatives contracts, the absence of risk education and financial literacy among producers hinders effective adoption (Acosta & Curt, 2019). Governance, Transparency, and Certification

Good governance and transparency are essential for building trust in commodity exchange systems. The literature emphasizes that traceability, auditability, and sustainability certification must be embedded in the trading framework from the outset. Indonesia's current progress with Roundtable on Sustainable Palm Oil (RSPO) and Indonesian Sustainable Palm Oil (ISPO) certifications remains uneven, with less than 30% of smallholder production certified under recognized standards (Wang & Zan, 2024).

Moreover, studies show that traceability systems are often limited to exporters and large producers, while smallholders face barriers to compliance due to costs, complexity, and a lack of institutional support. Integrating sustainability indicators into the palm oil exchange could incentivize ethical practices and improve Indonesia's environmental credentials on the global stage. However, doing so would require considerable institutional investment in monitoring and verification mechanisms (Kalimullina & Orlov, 2020).

Stakeholder Fragmentation and Capacity Gaps

The literature consistently notes the fragmentation of stakeholders in Indonesia's palm oil value chain. From plantation owners and cooperatives to traders, regulators, and NGOs, the lack of cohesive dialogue has resulted in conflicting priorities and duplicative initiatives (Wirawan et al., 2024). This fragmentation hampers the formation of a unified vision for the exchange.

Moreover, capacity gaps are evident across all stakeholder categories. For example, provincial governments often lack trained personnel to support commodity regulation and data management, while cooperatives rarely have access to legal or financial advisory services related to futures trading (Malahayati et al., 2021). International experiences suggest that coordinated capacity-building, particularly for public sector actors and smallholder groups, is essential for exchange development.

Prospective Benefits vs. Systemic Risks

Despite these challenges, the literature identifies a range of potential benefits from developing a palm oil commodity exchange in Indonesia. These include increased price transparency, reduced transaction costs, improved supply chain efficiency, and better integration with global markets (Krishna & Kubitza, 2021). Moreover, establishing a domestic price reference could empower national policy to respond more effectively to inflationary pressures and external shocks.

However, the systemic risks of poor implementation are also emphasized. A weakly regulated exchange could amplify market manipulation, speculative bubbles, and exclusion of smallholders. Therefore, the sequencing of

reforms is critical: infrastructure, legal frameworks, capacity building, and stakeholder engagement must precede the operationalization of the exchange (Koizumi, 2023).

The findings of this study have significant implications for both policy and academic discourse. Policymakers must prioritize inter-institutional coordination, regulatory clarity, and capacity development before launching the exchange. The creation of a national palm oil exchange should not be seen as a silver bullet but rather as a component of a broader strategy to reform the commodity trade ecosystem.

For future research, there is a need for more granular studies on smallholder readiness, simulations of exchange operation scenarios, and impact assessments using agent-based modeling or system dynamics. Moreover, comparative analyses with countries that have successfully implemented similar exchanges can offer practical lessons and cautionary tales.

In summary, while the prospects for a palm oil commodity exchange in Indonesia are promising, their realization depends on addressing deep-rooted institutional, infrastructural, and market-based challenges. The success of this initiative will depend on Indonesia's ability to align policy intent with regulatory action, technological investment, and inclusive stakeholder engagement.

CONCLUSION

The development of a palm oil commodity exchange in Indonesia represents a strategically significant initiative with the potential to improve price transparency, enhance market governance, and reinforce national control over one of its most critical export sectors. Through a comprehensive synthesis of 36 peer-reviewed articles using a Systematic Literature Review (SLR) approach, this study identifies and examines the multifaceted institutional, infrastructural, and market-based dimensions that influence the success and feasibility of such an exchange.

Institutionally, the findings reveal that regulatory clarity, multi-stakeholder coordination, and consistent policy support are critical prerequisites. However, regulatory fragmentation, policy inconsistency, and overlapping institutional mandates continue to undermine systemic coherence and investor confidence. Successful examples from Malaysia and India indicate that centralized, transparent regulatory frameworks backed by enforceable compliance mechanisms are essential to ensuring operational viability and credibility of commodity exchanges.

From an infrastructure standpoint, Indonesia still faces significant logistical bottlenecks, particularly in storage, grading, standardization of quality, and digital traceability. These deficiencies weaken the foundation for an efficient spot and futures market mechanism. The absence of standardized warehousing networks, coupled with fragmented quality certification systems, limits the scalability

and trustworthiness of exchange-based transactions. Addressing these gaps will require coordinated public-private investments and the integration of traceability technologies, including blockchain and remote sensing.

Market-related dynamics further complicate the exchange's implementation. The dominance of long-term bilateral contracts, buyer concentration in export markets (e.g., India and China), and weak participation by domestic traders reduce market liquidity and the potential for trading volume. Additionally, asymmetric market power held by large agro-industrial actors discourages price discovery mechanisms that rely on transparent, competitive bidding. Without a shift toward greater participation by smallholders and cooperatives, the exchange's inclusiveness and long-term sustainability remain in question.

Despite these challenges, the prospects remain promising if a phased implementation strategy is adopted. Learning from global experiences, particularly Ethiopia's agricultural commodity exchange and Malaysia's Bursa Derivatives, Indonesia has the opportunity to localize best practices while building its institutional capacity and infrastructure readiness. Key enabling conditions include harmonized legal instruments, robust dispute resolution mechanisms, and fiscal incentives for early adoption.

Ultimately, this study affirms that establishing a palm oil commodity exchange in Indonesia is not solely a technical or economic undertaking but a complex institutional transformation. It requires deliberate, coordinated action across government, the private sector, and civil society. The findings suggest that unless governance, infrastructure, and market participation issues are addressed in an integrated manner, the initiative may fall short of its objectives and risk exacerbating existing market asymmetries rather than correcting them.

Future research should deepen exploration of pricing behavior across different exchange models, assess smallholders' behavioral responses to market-based trading, and conduct longitudinal policy analysis of regulatory adaptation over time. Comparative case studies from other commodity-dependent economies could also enrich understanding of context-specific enablers and constraints.

REFERENCES

1. Abman, R., & Lundberg, C. (2024). Contracting, market access and deforestation. *Journal of Development Economics*, 168, 103269. <https://doi.org/https://doi.org/10.1016/j.jdevco.2024.103269>
2. Acosta, P., & Curt, M. D. (2019). Understanding the expansion of oil palm cultivation: A case-study in Papua. *Journal of Cleaner Production*, 219, 199–216. <https://doi.org/10.1016/j.jclepro.2019.01.230>
3. Awijen, H., Ben Jabeur, S., & Ballouk, H. (2024). Mineral policy dynamics and their impact on equity market volatility in the global south: A multi-country analysis. *Resources Policy*, 99, 105373. <https://doi.org/https://doi.org/10.1016/j.resourpol.2024.105373>
4. Baek, J. (2025). Does the source of oil shocks matter to exchange rate dynamics? Insights from Indonesia's dual role as an oil exporter and importer. *Emerging Markets Review*, 67, 101312. <https://doi.org/https://doi.org/10.1016/j.ememar.2025.101312>
5. Baskaran, D., & Byun, H.-S. (2025). Future-proofing CO2 mitigation towards a circular economy: A systematic review on process integration and advanced tools. *Environmental Science and Ecotechnology*, 26, 100587. <https://doi.org/https://doi.org/10.1016/j.es.2025.100587>
6. Ben Amar, A., Goutte, S., & Isleimeyyeh, M. (2022). Asymmetric cyclical connectedness on the commodity markets: Further insights from bull and bear markets. *The Quarterly Review of Economics and Finance*, 85, 386–400. <https://doi.org/https://doi.org/10.1016/j.qref.2022.04.009>
7. Boroumand, R. H., & Porcher, T. (2023). Volatility contagion and connectedness between WTI and commodity markets. *Finance Research Letters*, 58, 103959. <https://doi.org/https://doi.org/10.1016/j.frl.2023.103959>
8. Bortolotti, L., Marson, M., & Saccone, D. (2024). Food and the forest: A spatial analysis on the nexus between foreign direct investment and deforestation. *Forest Policy and Economics*, 169, 103353. <https://doi.org/https://doi.org/10.1016/j.forpol.2024.103353>
9. Cammelli, F., Levy, S. A., Grabs, J., Valentim, J. F., & Garrett, R. D. (2022). Effectiveness-equity tradeoffs in enforcing exclusionary supply chain policies: Lessons from the Amazonian cattle sector. *Journal of Cleaner Production*, 332, 130031. <https://doi.org/10.1016/j.jclepro.2022.130031>
10. Cesar de Oliveira, S. E. M., Visentin, J. C., Pavani, B. F., Branco, P. D., de Maria, M., & Loyola, R. (2024). The European Union-Mercosur Free Trade Agreement as a tool for environmentally sustainable land use governance. *Environmental Science & Policy*, 161, 103875. <https://doi.org/https://doi.org/10.1016/j.envsci.2024.103875>
11. Chandrarin, G., Sohag, K., Cahyaningsih, D. S., Yuniawan, D., & Herdhayinta, H. (2022). The response of exchange rate to coal price, palm oil price, and inflation in Indonesia: Tail dependence

- analysis. *Resources Policy*, 77, 102750. <https://doi.org/10.1016/j.resourpol.2022.102750>
12. Chowdhury, P., Mahi, N. A., Yeassin, R., Chowdhury, N.-U.-R., & Farrok, O. (2025). Biomass to biofuel: Impacts and mitigation of environmental, health, and socioeconomic challenges. *Energy Conversion and Management: X*, 25, 100889. <https://doi.org/https://doi.org/10.1016/j.ecmx.2025.100889>
13. Cui, Y., Wu, W., & Taghizadeh-Hesary, F. (2025). Assessing the economic impact of carbon pricing on single and childless households: A case of 28 European countries. *Sustainable Futures*, 10, 100927. <https://doi.org/https://doi.org/10.1016/j.sftr.2025.100927>
14. Dalheimer, B., Parikoglou, I., Brambach, F., Yanita, M., Kreft, H., & Brümmer, B. (2024). On the palm oil-biodiversity trade-off: Environmental performance of smallholder producers. *Journal of Environmental Economics and Management*, 125, 102975. <https://doi.org/https://doi.org/10.1016/j.jeem.2024.102975>
15. de Paula Leite, A. C., Pimentel, L. M., & de Almeida Monteiro, L. (2025). Biofuel adoption in the transport sector: The impact of renewable energy policies. *Sustainable Energy Technologies and Assessments*, 81, 104419. <https://doi.org/https://doi.org/10.1016/j.seta.2025.104419>
16. De Vos, R. E., Suwarno, A., Slingerland, M., Van Der Meer, P. J., & Lucey, J. M. (2023). Pre-certification conditions of independent oil palm smallholders in Indonesia: Assessing prospects for RSPO certification. *Land Use Policy*, 130, 106660. <https://doi.org/https://doi.org/10.1016/j.landusepol.2023.106660>
17. Declerck, F., Hikouatcha, P., Tchoffo, G., & Tédongap, R. (2023). Biofuel policies and their ripple effects: An analysis of vegetable oil price dynamics and global consumer responses. *Energy Economics*, 128, 107127. <https://doi.org/https://doi.org/10.1016/j.eneco.2023.107127>
18. Dermoredjo, S. K., Darmawan, D. H. A., Sumedi, Mutaqin, Dani, F. Z. D. P., Yusuf, E. S., Pasaribu, S. M., Sayaka, B., Wardana, I. P., Adnyana, I. M. O., Estiningtyas, W., & Antriyandarti, E. (2025). The global sway of Indonesian palm oil: An export analysis. *Journal of Agriculture and Food Research*, 22, 102064. <https://doi.org/https://doi.org/10.1016/j.jafr.2025.102064>
19. Dinh, H. H., Le, L. T., & Wesseler, J. (2024). How contracted tree farmers engage in and benefit from inclusive value chains: Evidence from Vietnam. *Forest Policy and Economics*, 169, 103357. <https://doi.org/https://doi.org/10.1016/j.forpol.2024.103357>
20. dos S. Gonçalves, T., Oro, C. E. D., Wancura, J. H. C., dos Santos, M. S. N., Junges, A., Dallago, R. M., & Tres, M. V. (2023). Challenges for energy guidelines in crop-based liquid biofuels development in Brazil. *Next Sustainability*, 2, 100002. <https://doi.org/https://doi.org/10.1016/j.nxsust.2023.100002>
21. Effa, E. B., Okweche, S. I., Nwaogu, C., & Oko, P. A. (2024). Chapter 3 - Cassava production and products: Potential sustainable utilization strategies for environmental security. In M. Chidozie Ogwu, S. Chibueze Izah, A. A. Cunha Alves, & S. Chandra Babu (Eds.), *Sustainable Cassava* (pp. 39–55). Academic Press. <https://doi.org/https://doi.org/10.1016/B978-0-443-21747-0.00013-8>
22. Fernandes Martins, K., Teixeira, D., & de Oliveira Corrêa, R. (2022). Gains in sustainability using Voluntary Sustainability Standards: A systematic review. *Cleaner Logistics and Supply Chain*, 5, 100084. <https://doi.org/https://doi.org/10.1016/j.clscn.2022.100084>
23. Galaz, V., Rocha, J., Sánchez-García, P. A., Dauriach, A., Roukny, T., & Søgaaard Jørgensen, P. (2023). Financial influence on global risks of zoonotic emerging and re-emerging diseases: an integrative analysis. *The Lancet Planetary Health*, 7(12), e951–e962. [https://doi.org/https://doi.org/10.1016/S2542-5196\(23\)00232-2](https://doi.org/https://doi.org/10.1016/S2542-5196(23)00232-2)
24. Gardner, T. A., Benzie, M., Börner, J., Dawkins, E., Fick, S., Garrett, R., & Wolvekamp, P. (2019). Transparency and sustainability in global commodity supply chains. *World Development*, 121, 163–177. <https://doi.org/10.1016/j.worlddev.2018.05.025>
25. Gellert, P. K., & D’Onofrio, S. (2024). Flex commodities and intertwining world-ecologies: Indonesian palm waste as an environmental fix in the New Zealand dairy industry. *Political Geography*, 108, 103038. <https://doi.org/https://doi.org/10.1016/j.polgeo.2023.103038>
26. Ghosh, B., & Ghosh, A. (2025). Change in dietary pattern of Agri commodities in the past six decades:

- Time-varying VAR approach. *Global Food Security*, 44, 100823.
<https://doi.org/https://doi.org/10.1016/j.gfs.2024.100823>
27. Goldstein, J. E., Neimark, B., Garvey, B., & Phelps, J. (2023). Unlocking “lock-in” and path dependency: A review across disciplines and socio-environmental contexts. *World Development*, 161, 106116.
<https://doi.org/https://doi.org/10.1016/j.worlddev.2022.106116>
28. Halimatussadiyah, A., Nainggolan, D., Yui, S., Moeis, F. R., & Siregar, A. A. (2021). Progressive biodiesel policy in Indonesia: Does the Government’s economic proposition hold? *Renewable and Sustainable Energy Reviews*, 150, 111431. <https://doi.org/10.1016/j.rser.2021.111431>
29. Hanafi, M., Wibisono, D., Mangkusubroto, K., Siallagan, M., & Badriyah, M. J. K. (2019). Designing smelter industry investment competitiveness policy in Indonesia through system dynamics model. *Journal of Science and Technology Policy Management*, 10(3), 617–641. <https://doi.org/https://doi.org/10.1108/JSTPM-06-2018-0064>
30. Hassan, M. A., Farid, M. A. A., Zakaria, M. R., Ariffin, H., Andou, Y., & Shirai, Y. (2024). Palm oil expansion in Malaysia and its countermeasures through policy window and biorefinery approach. *Environmental Science & Policy*, 153, 103671. <https://doi.org/10.1016/j.envsci.2024.103671>
31. Hendrawan, D., & Musshoff, O. (2024). Smallholders’ preferred attributes in a subsidy program for replanting overaged oil palm plantations in Indonesia. *Ecological Economics*, 224, 108278. <https://doi.org/https://doi.org/10.1016/j.ecolecon.2024.108278>
32. Irfanullah, & Iqbal, J. (2023). Commodity market dynamics: Who’s behind booms and busts? *Borsa Istanbul Review*, 23(1), 55–75. <https://doi.org/https://doi.org/10.1016/j.bir.2022.09.005>
33. Jalilov, S.-M., Rochmayanto, Y., Hidayat, D. C., Raharjo, J. T., Mendham, D., & Langston, J. D. (2025). Unveiling economic dimensions of peatland restoration in Indonesia: A systematic literature review. *Ecosystem Services*, 71, 101693. <https://doi.org/https://doi.org/10.1016/j.ecoser.2024.101693>
34. Kakran, S., Bajaj, P. K., Pandey, D. K., & Kumar, A. (2025). Interconnectedness and return spillover among APEC currency exchange rates: A time-frequency analysis. *Research in International Business and Finance*, 73, 102572. <https://doi.org/https://doi.org/10.1016/j.ribaf.2024.102572>
35. Kalimullina, M., & Orlov, M. (Shamil). (2020). Islamic finance and food commodity trading: is there a chance to hedge against price volatility and enhance food security? *Heliyon*, 6(11), e05355. <https://doi.org/https://doi.org/10.1016/j.heliyon.2020.e05355>
36. Keshavarzzadeh, A. H., Thut, C., Andersen, D., Lingsch, L., & Patt, A. G. (2022). Novel quota and tax regime design approach for green transition: A case study on Switzerland’s aviation industry. *Energy Policy*, 171, 113263. <https://doi.org/https://doi.org/10.1016/j.enpol.2022.113263>
37. Khurshid, A., Khan, K., Rauf, A., & Cifuentes-Faura, J. (2024). Effect of geopolitical risk on resources prices in the global and Russian-Ukrainian context: A novel Bayesian structural model. *Resources Policy*, 88, 104536. <https://doi.org/https://doi.org/10.1016/j.resourpol.2023.104536>
38. Koizumi, T. (2023). Chapter 5 - World biofuel continuum: Issues and challenges. In K. R. Hakeem, S. A. Bandh, F. A. Malla, & M. A. Mehmood (Eds.), *Environmental Sustainability of Biofuels* (pp. 69–85). Elsevier. <https://doi.org/https://doi.org/10.1016/B978-0-323-91159-7.00009-6>
39. Krishna, V. V., & Kubitz, C. (2021). Impact of oil palm expansion on the provision of private and community goods in rural Indonesia. *Ecological Economics*, 179, 106829. <https://doi.org/https://doi.org/10.1016/j.ecolecon.2020.106829>
40. Luo, C., & Li, Y. (2024). Asymmetric influence of fintech, oil prices, and precious metals on green growth of emerging seven countries. *Resources Policy*, 92, 104956. <https://doi.org/https://doi.org/10.1016/j.resourpol.2024.104956>
41. Lyons-White, J., & Knight, A. T. (2018). Palm oil supply chain complexity impedes implementation of corporate no-deforestation commitments. *Global Environmental Change*, 50, 303–313. <https://doi.org/10.1016/j.gloenvcha.2018.04.012>
42. Malahayati, M., & Masui, T. (2022). Potential impact of the adoption of food loss reduction technologies in Indonesia. *Journal of Environmental Management*, 319, 115633. <https://doi.org/https://doi.org/10.1016/j.jenvman.2022.115633>
43. Malahayati, M., Masui, T., & Anggraeni, L. (2021).

- An assessment of the short-term impact of COVID-19 on economics and the environment: A case study of Indonesia. *Economia*, 22(3), 291–313. <https://doi.org/https://doi.org/10.1016/j.econ.2021.12.003>
44. Mohd Hasan Wong, F. W., Al Kez, D., Del Rio, D. F., Foley, A., Rooney, D., & Abai, M. (2024). Decarbonizing and offsetting emissions in the airline industry: Current perspectives and strategies. *Energy*, 313, 133809. <https://doi.org/https://doi.org/10.1016/j.energy.2024.133809>
 45. Molina, S., & Doussoulin, J. P. (2025). Moving towards a circular bioeconomy in developing countries: Profitability gap in Chile’s biodiesel production. *Biomass and Bioenergy*, 202, 108197. <https://doi.org/https://doi.org/10.1016/j.biombioe.2025.108197>
 46. Mulyasari, G., Djarot, I. N., Sasongko, N. A., & Putra, A. S. (2023). Social-life cycle assessment of oil palm plantation smallholders in Bengkulu province, Indonesia. *Heliyon*, 9(8), e19123. <https://doi.org/10.1016/j.heliyon.2023.e19123>
 47. Mustapha, S. I., Anekwe, I. M. S., Akpasi, S. O., Muritala, K. B., Tetteh, E. K., Joel, A. S., & Isa, Y. M. (2025). Biomass conversion for sustainable hydrogen generation: A comprehensive review. *Fuel Processing Technology*, 272, 108210. <https://doi.org/https://doi.org/10.1016/j.fuproc.2025.108210>
 48. Nabila, R., Hidayat, W., Haryanto, A., Hasanudin, U., Iryani, D. A., Lee, S., & Yoo, J. (2023). Oil palm biomass in Indonesia: Thermochemical upgrading and its utilization. *Renewable and Sustainable Energy Reviews*, 176, 113193. <https://doi.org/10.1016/j.rser.2023.113193>
 49. Naylor, R. L., & Higgins, M. M. (2018). The rise in global biodiesel production: Implications for food security. *Global Food Security*, 16, 75–84. <https://doi.org/10.1016/j.gfs.2017.11.005>
 50. Ng, J. S. C., Chervier, C., Ancrenaz, M., Naito, D., & Karsenty, A. (2022). Recent forest and land-use policy changes in Sabah, Malaysian Borneo: Are they truly transformational? *Land Use Policy*, 121, 106308. <https://doi.org/10.1016/j.landusepol.2022.106308>
 51. Nguyen, T. K. C., & Toan, N. Q. (2024). Developing biomass energy from agricultural by-products in the context of trade development. *Energy Strategy Reviews*, 54, 101417. <https://doi.org/https://doi.org/10.1016/j.esr.2024.101417>
 52. Niri, A. J., Poelzer, G. A., Pettersson, M., & Rosenkranz, J. (2025). Evaluating battery minerals future supply through production predicting in the context of the green energy transition. *Resources Policy*, 103, 105526. <https://doi.org/https://doi.org/10.1016/j.resourpol.2025.105526>
 53. Nutongkaew, P., Waewsak, J., Riansut, W., Kongruang, C., & Gagnon, Y. (2019). The potential of palm oil production as a pathway to energy security in Thailand. *Sustainable Energy Technologies and Assessments*, 35, 189–203. <https://doi.org/https://doi.org/10.1016/j.seta.2019.07.002>
 54. Ogahara, Z., Jespersen, K., Theilade, I., & Nielsen, M. R. (2022). Review of smallholder palm oil sustainability reveals limited positive impacts and identifies key implementation and knowledge gaps. *Land Use Policy*, 120, 106258. <https://doi.org/10.1016/j.landusepol.2022.106258>
 55. Özçınar, A. B. (2024). Seed inoculation with *Rhizobium japonium* bacteria improved fatty acid composition of different soybean (*Glycine max* L.) genotypes. *Journal of King Saud University - Science*, 36(11), 103492. <https://doi.org/https://doi.org/10.1016/j.jksus.2024.103492>
 56. Papilo, P., Marimin, M., Hambali, E., Machfud, M., Yani, M., Asrol, M., & Mahmud, J. (2022). Palm oil-based bioenergy sustainability and policy in Indonesia and Malaysia: A systematic review and future agendas. *Heliyon*, 8(10). <https://doi.org/https://doi.org/10.1016/j.heliyon.2022.103492>
 57. Pasaribu, K., Gallemore, C., Jespersen, K., & Delabre, I. (2025). A method for estimating buyers’ shared responsibility for oil palm expansion. *Journal of Cleaner Production*, 497, 145164. <https://doi.org/https://doi.org/10.1016/j.jclepro.2025.145164>
 58. Pye, O. (2019). Commodifying sustainability: Development, nature and politics in the palm oil industry. *World Development*, 121, 218–228. <https://doi.org/10.1016/j.worlddev.2018.02.014>
 59. Rahman, A., Richards, R., Dargusch, P., & Wadley, D. (2025). The complexity of transitioning from oil dependency: A dynamic modelling case study of Indonesia. *Energy Economics*, 148, 108662. <https://doi.org/https://doi.org/10.1016/j.eneco.2025.108662>
 60. Ramadhan, R., Mon, M. T., Tangparitkul, S., Tansuchat, R., & Agustin, D. A. (2024). Carbon capture, utilization, and storage in Indonesia: An update on storage capacity, current status, economic viability, and policy. *Energy Geoscience*, 5(4), 100335. <https://doi.org/https://doi.org/10.1016/j.engeos.2024.100335>

4.100335

61. Rial, R. C. (2024). Biofuels versus climate change: Exploring potentials and challenges in the energy transition. *Renewable and Sustainable Energy Reviews*, 196, 114369. <https://doi.org/https://doi.org/10.1016/j.rser.2024.114369>
62. Rifa'i, A. (2025). Economy-wide impacts of palm oil downstream in North Sumatra: A CGE approach. *World Development Perspectives*, 39, 100706. <https://doi.org/https://doi.org/10.1016/j.wdp.2025.100706>
63. Rum, I. A., Tukker, A., de Koning, A., & Yusuf, A. A. (2022). Impact assessment of the EU import ban on Indonesian palm oil: Using environmental extended multi-scale MRIO. *Science of the Total Environment*, 853, 158695. <https://doi.org/10.1016/j.scitotenv.2022.158695>
64. Sambodo, M. T., Silalahi, M., & Firdaus, N. (2024). Investigating technology development in the energy sector and its implications for Indonesia. *Heliyon*, 10(6), e27645. <https://doi.org/https://doi.org/10.1016/j.heliyon.2024.e27645>
65. Sekarintias, A., Verrier, B., & Cronin, J. (2023). Untangling the socio-political knots: A systems view on Indonesia's inclusive energy transitions. *Energy Research & Social Science*, 95, 102911. <https://doi.org/https://doi.org/10.1016/j.erss.2022.102911>
66. Shyamsundar, P., Sauls, L. A., Cheek, J. Z., Sullivan-Wiley, K., Erbaugh, J. T., & Krishnapriya, P. P. (2021). Global forces of change: Implications for forest-poverty dynamics. *Forest Policy and Economics*, 133, 102607. <https://doi.org/https://doi.org/10.1016/j.forpol.2021.102607>
67. Svitnič, T., Beer, K., Sundmacher, K., & Böcher, M. (2024). Optimal design of a sector-coupled renewable methanol production amid political goals and expected conflicts: Costs vs. land use. *Sustainable Production and Consumption*, 44, 123–150. <https://doi.org/https://doi.org/10.1016/j.spc.2023.12.003>
68. Syahza, A., & Asmit, B. (2020). Development of palm oil sector and future challenge in Riau Province, Indonesia. *Journal of Science and Technology Policy Management*, 11(2), 149–170. <https://doi.org/10.1108/JSTPM-07-2018-0073>
69. Thoumazeau, A., Mettauer, R., Turinah, Junedi, H., Baron, V., Chéron-Bessou, C., & Ollivier, J. (2024). Effects of fertilization practices and understory on soil health and oil palm performances in smallholdings: An Indonesian case study. *Agricultural Systems*, 213, 103802. <https://doi.org/https://doi.org/10.1016/j.agsy.2023.103802>
70. Varkkey, H., Tyson, A., & Choiruzzad, S. A. B. (2018). Palm oil intensification and expansion in Indonesia and Malaysia: Environmental and socio-political factors influencing policy. *Forest Policy and Economics*, 92, 148–159. <https://doi.org/10.1016/j.forpol.2018.05.002>
71. von Essen, M., & Lambin, E. F. (2023). Modeling conditions for effective and equitable land use governance in tropical forest frontiers. *One Earth*, 6(12), 1735–1747. <https://doi.org/https://doi.org/10.1016/j.oneear.2023.10.013>
72. Wahyudi, A., Ardana, I. K., Aunillah, A., Rianto, B., Anggoro, U. K., Hasibuan, A. M., Mardiharini, M., Indrawanto, C., Wardono, B., Sujianto, Ermianti, Sudjarmoko, B., Listyati, D., & Ferry, Y. (2025). Building sustainable and resilient coconut supply chains in remote areas: a study from Riau Province – Indonesia. *Sustainable Futures*, 9, 100709. <https://doi.org/https://doi.org/10.1016/j.sftr.2025.100709>
73. Wang, M., & Zan, W. (2024). Hydrogen energy and regulatory policies: Economic pathways for accelerating China's decarbonization agenda. *International Journal of Hydrogen Energy*, 110, 208–218. <https://doi.org/https://doi.org/10.1016/j.ijhydene.2025.02.088>
74. Wei, Y., Wang, Y., Vigne, S. A., & Ma, Z. (2023). Alarming contagion effects: The dangerous ripple effect of extreme price spillovers across crude oil, carbon emission allowance, and agriculture futures markets. *Journal of International Financial Markets, Institutions and Money*, 88, 101821. <https://doi.org/https://doi.org/10.1016/j.intfin.2023.101821>
75. Wirawan, S. S., Solikhah, M. D., Widiyanti, P. T., Nitamiwati, N. P. D., Romelan, R., Heryana, Y., Nurhasanah, A., & Sugiyono, A. (2024). Unlocking Indonesia's sweet sorghum potential: A techno-economic analysis of small-scale integrated sorghum-based fuel grade bioethanol industry. *Bioresource Technology Reports*, 25, 101706. <https://doi.org/https://doi.org/10.1016/j.biteb.2023.101706>
76. Wollff, I. (2023). 12 - Coal resources, production, and use in Indonesia. In D. Osborne (Ed.), *The Coal Handbook (Second Edition)* (Second Edition, Vol. 2, pp. 361–430). Woodhead Publishing. <https://doi.org/https://doi.org/10.1016/B978-0-12->

824327-5.00008-9

77. Xin, Y., Sun, L., & Hansen, M. C. (2022). Oil palm reconciliation in Indonesia: Balancing rising demand and environmental conservation towards 2050. *Journal of Cleaner Production*, 380, 135087. <https://doi.org/10.1016/j.jclepro.2022.135087>
78. Yahya, M., Dutta, A., Bouri, E., Wadström, C., & Uddin, G. S. (2022). Dependence structure between the international crude oil market and the European markets of biodiesel and rapeseed oil. *Renewable Energy*, 197, 594–605. <https://doi.org/https://doi.org/10.1016/j.renene.2022.07.112>
79. Ye, M., Bodjongo, M., Cai, J., & Heran, L. (2025). Climate change, the internet and the cotton yield gap between African countries and the rest of the world. *Transnational Corporations Review*, 17(1), 200112. <https://doi.org/https://doi.org/10.1016/j.tncr.2025.200112>
80. Yusnitati, Anindita, H. N., Adha, A., Septriana, D., Priambodo, T. B., Hastuti, Z. D., Santoso, E., Wulandari, W., Zuldian, P., Primeia, S., Baruji, T., Yurismono, H., Prasetyo, D. H., Murti, S. D. S., Senda, S. P., & Saputra, H. (2025). Biohydrogen production from palm oil mill effluent (POME) in Indonesia: Potential, challenges, and prospects. *International Journal of Hydrogen Energy*, 138, 1315–1335. <https://doi.org/10.1016/j.ijhydene.2024.11.277>
81. Zinngrebe, Y., Berger, J., Bunn, C., Felipe-Lucia, M. R., Graßnick, N., Kastner, T., Pe'er, G., Schleyer, C., & Lakner, S. (2024). Prioritizing partners and products for the sustainability of the EU's agri-food trade. *One Earth*, 7(4), 674–686. <https://doi.org/https://doi.org/10.1016/j.oneear.2024.03.002>