Industrial Chain Resilience Metrics and Enhancement Strategies: Systematic Review and Policy Advice for Indonesia's Nickel Industry

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Abstract. Indonesia's nickel industry has become central to global supply chains for stainless steel and electric vehicle batteries, yet its rapid expansion has exposed structural vulnerabilities in sustainability and resilience. This paper presents a systematic literature review (2014–2024) and policy analysis to examine how industrial chain resilience can be measured and enhanced in resource-based economies. Resilience is conceptualised as a multi-dimensional capacity encompassing resistance, recovery, re-organisation, and renewal, while sustainability is framed as long-term value creation that integrates environmental stewardship, economic diversification, and social inclusion.We applied the PRISMA approach and used CNKI and Scopus indexation database which eventually came up with 21 articles those were analysed. The review identifies four dominant perspectives—process, alliance, value, and correlation—used in resilience measurement. Methods such as entropy weighting, TOPSIS, grey relational analysis, DEMATEL-ISM, and spatial econometrics are widely employed to capture indicators including innovation capability, industrial diversification, digital infrastructure, and collaborative clustering. Comparative insights from China's rare-earths policy evolution illustrates how governance transitions from quota-based to market-oriented approaches can strengthen resilience while safeguarding sustainability. Meanwhile in Indonesia, our findings highlight risks related to export dependence, technological reliance on foreign partners, weak environmental enforcement, and limited circular economy practices. At the same time, opportunities exist in education and R&D investment, institutional upgrading, stricter labour and environmental standards, and greater international cooperation. This study contributes a benchmarked conceptual and methodological framework for assessing industrial chain resilience and provides policy recommendations to balance competitiveness with sustainable development in Indonesia's nickel sector.

Keywords: Industrial Chain Resilience, Sustainability, Nickel Industry.

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1 Introduction

Indonesia has become the world's largest nickel producer, supplying over 40% of global demand and positioning itself as a critical player in stainless steel and electric vehicle (EV) battery supply chains (International Energy Agency, 2021). Since the 2020 export ban on raw nickel ore, the Indonesian government has promoted downstream industrialisation, encouraging investment in smelters and EV battery production (Ministry of Energy and Mineral Resources, 2021). This strategy aims to capture greater value from domestic resources and reduce dependency on commodity exports (World Bank, 2020).

Yet the rapid growth of the nickel sector has highlighted two pressing challenges: sustainability and resilience. Environmentally, nickel mining is associated with deforestation, waste management problems, and high carbon emissions (Ali et al., 2021). Socially, concerns about labour standards and uneven benefits for local communities persist (Hasibuan, 2022). From a resilience perspective, the industry remains vulnerable to global price fluctuations, technological dependence on foreign partners, and weak governance capacity (Xia and Yuliatiningtyas, 2024). These risks undermine the long-term stability of Indonesia's industrial chain.

Resilience is defined here as a multi-dimensional capability, encompassing resistance, recovery, re-organisation, and renewal (Christopher and Peck, 2004; Ivanov, 2020). Literature highlights several approaches: process-based resilience focused on flexibility (Tang, 2006), alliance-based resilience emphasising collaboration (Luthra et al., 2018), value-based resilience linked to innovation and upgrading (Kumar and Lee, 2022), and correlation-based resilience examining systemic interdependencies (Dolgui et al., 2020). These perspectives provide useful lenses for evaluating the Indonesian nickel industry.

Comparative lessons are available from other resource-dependent economies. China's rare-earth industry, for example, shifted from export rebates to quotas and eventually toward stricter environmental and market-based governance. This transition strengthened resilience while promoting sustainability (Zhao and Chen, 2020). For Indonesia, such experiences underscore the importance of adaptive institutions and effective regulatory enforcement.

Despite growing attention to supply chains and sustainability transitions, research on Indonesia's nickel sector remains fragmented. Many studies examine competitiveness or environmental impacts in isolation, but few provide an integrated framework to measure and enhance industrial chain resilience. This limits both academic understanding and practical policymaking.

To address this gap, this paper undertakes a systematic literature review (2014–2024) using the PRISMA method, complemented by comparative policy analysis. The study has three objectives:

1. To map existing conceptual and methodological approaches to resilience in industrial chains.
2. To identify structural vulnerabilities and opportunities in Indonesia's nickel industry.

3. To propose policy recommendations that strengthen both sustainability and resilience.

This paper contributes conceptually by benchmarking resilience metrics and practically by offering strategies tailored to Indonesia's industrial and environmental priorities. The remainder of the paper is structured as follows: Section 2 reviews the literature on industrial chain resilience; Section 3 outlines the methodology; Section 4 presents key findings; Section 5 discusses implications for Indonesia; and Section 6 concludes with recommendations and future research directions.

2 Literature Review

2.1 Industrial Chain and Its Evolution

The concept of the industrial chain, while a cornerstone of economic thought, lacks a single, universally accepted definition (Deng et al., 2015). Its theoretical roots can be traced to Adam Smith's principle of the division of labor, initially an intra-firm concept that was later expanded by Alfred Marshall to encompass inter-firm cooperation. The term "industrial chain" was first introduced by Hirschman in 1958. While Western academic discourse has largely shifted its focus from the industrial chain to the more prevalent concepts of the supply chain and value chain, the industrial chain has regained scholarly attention, particularly in the context of increasing geopolitical risks and trade competition (Song & Yang, 2022).

Current scholarship identifies four primary perspectives on the industrial chain:

- **Process Perspective:** Views the industrial chain as a linear production sequence, from raw materials to final consumption (Yu, 2005).
- **Alliance Perspective:** Defines it as a strategic network of interconnected enterprises with spatial-temporal and value-adding functions (Liu, 2006).
- **Value Perspective:** Considers the industrial chain an extension of the value chain, focusing on value distribution and inter-firm relationships (Huang, 2020).
- **Correlation Perspective:** Characterizes it by the technological and economic linkages between upstream, midstream, and downstream industries (Zheng, 2011).

Despite these distinct definitions, there is a growing consensus that the industrial chain, supply chain, and value chain are converging into an integrated system (Hu & Zhang, 2023). The networked structure of the industrial chain, while facilitating technology diffusion and industrial clustering, also amplifies the risk of "chain breaks" when a shock to one node rapidly propagates to others (Dong, 2023).

2.2 The Concept of Resilience

The concept of resilience originated in engineering and has since been adopted by a wide range of disciplines. It was initially defined as the ability of an object to absorb and rebound from external shocks (Holling, 1973). This definition has since been broadened by scholars across different fields. For instance, resilience has been defined as the capacity of systems to withstand disturbances (Cutter et al., 2003) or as a result of the interaction between individuals and their environment in the face of adversity (Kari, 1995).

In an economic context, resilience is often described as the capacity of an economic system to transform its structure and functions in response to disruptions, absorbing crises and achieving renewed growth (Martin, 2014). This perspective aligns with Briguglio et al.'s (2008) definition of economic resilience as a policy-driven capacity that allows an economy to recover from negative shocks and capitalize on positive ones. This includes the ability to both absorb shocks and recover quickly, which can be achieved through a diversified industrial structure and flexible labor allocation.

3 Methodology

This study adopts a systematic literature review (SLR) approach to comprehensively analyze and synthesize existing research on industrial chain resilience. The SLR methodology is chosen for its systematic and transparent nature, which minimizes bias and allows for a replicable and rigorous synthesis of findings (Snyder, 2019). The review process follows the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) framework, which guides the identification, screening, eligibility, and inclusion phases of the literature selection process (Moher et al., 2009).

3.1 Literature Search Strategy

The literature search was conducted in two primary academic databases: the China National Knowledge Infrastructure (CNKI) and Scopus. These databases were selected to ensure a broad coverage of both Chinese and international scholarly work. The search was performed using a combination of keywords, including "industrial chain resilience," "supply chain resilience," and "strategies for improving resilience." To ensure the currency and relevance of the findings, the search was limited to peer-reviewed journal articles published between 2014 and 2024. The search was conducted in the title, abstract, and keyword fields to maximize the retrieval of relevant documents.

3.2 Inclusion and Exclusion Criteria

A set of predefined criteria was applied to filter the retrieved literature and select a relevant sample for analysis. Articles were included if they met the following criteria: (1) published in a peer-reviewed journal; (2) available in full text; (3) relevant to the

topic of industrial chain resilience, specifically focusing on its measurement or enhancement strategies; and (4) based on empirical research methods. Studies were excluded if they were duplicate publications, not a full-text article, or lacked direct relevance to the research questions. A preliminary screening of titles and abstracts was followed by a thorough review of the full text for final inclusion.

3.3 Data Extraction and Synthesis

From the final sample of included studies, relevant data were systematically extracted and coded. The extracted information included the research question, theoretical framework, methodology, key findings, and proposed strategies for enhancing industrial chain resilience. A thematic analysis was then performed to synthesize the findings from the coded data. This involved identifying recurring themes and patterns related to the measurement of resilience, the key indicators influencing it, and the most effective strategies for improvement. The synthesis aimed to provide a comprehensive overview of the current state of research and highlight key research gaps.

4 Finding and Discussion

This section synthesizes the key findings from the systematic literature review on industrial chain resilience and applies them critically to the case of Indonesia's nickel industry. It provides a sharp, analytical discussion that connects theoretical concepts, empirical observations, and public policy implications to offer strategic policy advice for the country's nickel sector.

4.1 The State of Industrial Chain Resilience Research

The systematic review of 21 key articles reveals a research landscape that is highly dynamic and increasingly focused on industrial chain resilience, particularly since 2022. The overwhelming majority of these studies are China-centric, with authors and publications predominantly sourced from Chinese databases. This concentration highlights a significant research gap: while a deep understanding of resilience is developing within the Chinese context, a broader, cross-national comparative analysis remains limited. The findings from this body of literature are thus primarily a reflection of the challenges and policy responses within a single major economy, which may or may not be universally applicable to other countries.

The reviewed literature confirms a strong consensus on the multi-dimensional nature of resilience, typically conceptualized through four core dimensions: resistance, recovery, reorganization, and renewal. These dimensions provide a robust theoretical framework for both measurement and strategic planning. Measurement methods are predominantly quantitative, with the entropy method, TOPSIS, and grey relational analysis being the most frequently employed tools for constructing and evaluating indicator

systems. Common metrics, such as innovation capability (measured by patents) and industrial diversification (measured by the HHI), emerge as central to this evaluation.

From a factor-analysis perspective, the research consistently identifies a set of key drivers for enhancing industrial chain resilience. The digital economy and its related infrastructures, industrial collaboration, and industrial intelligence are prominent themes. These factors are shown to improve information flow, resource allocation, and overall chain efficiency, thereby strengthening resilience. Furthermore, the literature converges on a multi-stakeholder approach to enhancing resilience, emphasizing collaborative efforts among governments, enterprises, and research institutions. The primary strategies identified include innovation-driven development, digital transformation, and strategic international cooperation, alongside supportive public policies.

4.2 Analytical Discussion: The Indonesian Nickel Industry Case

Indonesia's public policy for its nickel industry provides a compelling real-world case study to critically examine the theories and findings from the systematic review. The government's strategy, centered on a raw material export ban and the promotion of domestic value-added processing, aligns directly with key concepts of economic resilience but also exposes critical vulnerabilities

From Resistance to Reorganization: A Theoretical Linkage: Indonesia's export ban, as a core policy, can be analyzed through the lens of economic resilience theory. The ban serves as a direct policy of resistance against the vulnerability of being a mere raw material supplier in the global market. By restricting exports, the government sought to insulate its domestic industry from volatile commodity price fluctuations and external demand shocks, thereby increasing its capacity for resistance. This action also represents a massive, government-driven effort at reorganization, aiming to transform Indonesia from a primary producer into a key player in the global battery and electric vehicle supply chain. The policy is a strategic attempt to shift the nation's position in the global industrial chain, moving up the value chain as defined by theorists like Huang (2020) and Zheng (2011). The rapid expansion of smelters and the tripling of nickel output between 2015 and 2023 clearly demonstrate a successful reorganization of the domestic industrial landscape (Michel, 2024).

The Incomplete Picture of Resilience Measurement: While Indonesia's strategy has yielded impressive metrics such as a significant increase in global market share and a surge in foreign investment, a critical analysis reveals that these measures represent an incomplete picture of true industrial chain resilience. As the literature review highlights, resilience should be measured across multiple dimensions—resistance, recovery, reorganization, and renewal—using a comprehensive set of indicators (Wang, 2022; Zhu et al., 2023). Indonesia's success, so far, has been measured primarily by quantitative output and financial inflows.

However, this approach fails to account for the negative externalities mentioned in the provided text. These include significant environmental degradation, marine pollution, and social tensions (Nasution, 2024; Sani, 2024). The rise in worker accidents and protests (Habchi, 2023) indicates a failure to manage the social dimension of resilience.

True resilience is not merely about production capacity; it's about the systemic ability to absorb shocks without generating new ones (Briguglio et al., 2008). In this case, the policy has traded one form of vulnerability (raw material export dependency) for new forms of vulnerability (environmental and social instability).

The Critical Gap in Innovation and Foreign Control: The systematic review consistently identifies innovation-driven development and technological autonomy as crucial strategies for long-term industrial chain resilience. However, this is arguably the most significant weakness in Indonesia's nickel strategy. The provided text notes that foreign companies, particularly from China, have established dominance and largely control the emerging value chain, while there is a lack of concrete policies to support domestic enterprises in adopting or co-developing licensed technologies (Lee & Kamiya, 2025).

This reliance on foreign technology creates a new point of vulnerability. While foreign capital is a powerful engine for initial growth and reorganization, it does not guarantee long-term renewal. The Indonesian government has successfully engineered a physical infrastructure for value-added processing but has not yet cultivated the intellectual and technological infrastructure necessary for self-sustaining growth. This dependency contradicts the literature's emphasis on local innovation capacity (Li, 2024) and poses a long-term risk to national control over this critical industry.

Geopolitical and Collaborative Vulnerabilities: The literature review stresses the importance of industrial collaboration and international cooperation in building resilience (Pan & Zhou, 2024; Ren et al., 2024). The Indonesian case study reveals the complex, dual-sided nature of these strategies. While the establishment of industrial parks facilitates physical collaboration, the reported tensions between local and foreign workers (Pedroletti, 2022) highlight a failure to manage the social and human dimensions of this collaboration. Furthermore, while Indonesia has attracted significant foreign investment, its protectionist policies have resulted in a trade dispute with the EU (Reuters, 2022), leading to a World Trade Organization (WTO) ruling against it. This demonstrates that a singular focus on protectionism can undermine global cooperation and create new risks from trade disputes (Reinpal et al., 2023), proving that a more nuanced approach to international relations is necessary for sustainable resilience

4.3 Conclusion and Policy Advice

The analysis of Indonesia's nickel industry, guided by a systematic literature review, reveals a nuanced picture of resilience. The government's policies have been successful in achieving a short-term reorganization and a significant increase in production and value-added processing. However, this success is built on a foundation of long-term vulnerabilities that contradict key principles of sustainable industrial resilience identified in the academic literature. The reliance on foreign technology and capital, coupled with inadequate social and environmental safeguards, poses a significant risk to the industry's long-term autonomy and stability.

To address these challenges, the following policy advice is recommended:

Implement Multi-Dimensional Resilience Metrics: Indonesia must move beyond simple production and investment figures. Future policy decisions should be guided by

a holistic indicator system that measures resilience across all four dimensions: resistance, recovery, reorganization, and renewal. This system should incorporate key metrics such as technological autonomy (e.g., number of domestic patents), environmental impact, and social equity, providing a more accurate assessment of the industry's true health.

Prioritize Domestic Technological Innovation: To avoid a state of permanent foreign control, the government should implement concrete policies to foster domestic technological innovation. This includes providing incentives for domestic enterprises to co-develop or adopt licensed technologies, establishing dedicated R&D funds, and strengthening collaborations between industry, academia, and research institutions as suggested by Zhu et al. (2023).

Strengthen Social and Environmental Safeguards: A truly resilient industrial chain must be socially and environmentally sustainable. The government must establish and enforce more stringent environmental regulations, particularly regarding land clearing and waste management. Furthermore, public policies should address the social tensions arising from foreign investment by promoting inclusive labor practices and ensuring that local communities are meaningful beneficiaries of industrial development, not just hosts.

Navigate International Cooperation with Nuance: While protectionist policies can achieve short-term goals, they can also lead to long-term trade disputes that undermine economic stability. Indonesia should pursue a strategy of international cooperation that balances its national interest in value-added processing with adherence to global trade rules. This involves proactive diplomacy and potentially re-evaluating its export ban policies to find a more sustainable path for global integration.

5 Conclusion and Recommendations

This study has systematically reviewed and analyzed the multifaceted concept of industrial chain resilience, examining its measurement, influencing factors, and enhancement strategies. The review spanned key literature from 2014 to 2024, highlighting the strategic importance of resilience in an era of global transformation and geopolitical uncertainty. We found that the academic discourse, while growing, is heavily concentrated in China, with most research focusing on a multi-dimensional framework of resistance, recovery, reorganization, and renewal, evaluated using quantitative methods like the entropy method and TOPSIS.

By integrating these theoretical findings with a case study of Indonesia's nickel industry and drawing parallels with China's rare earth policy, this study offers critical insights. Indonesia's state-led strategy of resource nationalism, while successful in attracting investment and driving value-added production, has overlooked key components of true resilience. Specifically, the strategy has failed to fully address long-term challenges related to technological autonomy, social equity, environmental sustainability, and complex international relations.

Based on these findings, we recommend that Indonesia's policy approach evolves from a short-term, resource-extraction model to a long-term, knowledge-based one. The following key actions are crucial for ensuring the long-term sustainability and resilience of the nickel industrial chain:

Establish a comprehensive, multi-dimensional resilience framework: Policy should be guided by a holistic indicator system that measures not only economic output but also environmental, social, and technological factors.

Prioritize domestic technological innovation: The government must move beyond simply attracting foreign capital and actively invest in local R&D to cultivate its own technological capabilities and reduce dependency.

Implement stringent environmental and labor standards: Robust regulations and monitoring systems are necessary to mitigate the negative externalities of rapid industrialization.

Enhance governance and economic diversification: Strengthening legal frameworks and promoting alternative industries will prevent the "resource curse" and create a more diversified, resilient national economy.

Foster balanced international cooperation: Proactive diplomacy and adherence to global trade norms are essential to avoid sanctions and diversify export markets beyond a single country.

In conclusion, Indonesia has a unique opportunity to transform its resource wealth into sustainable national strength. However, this requires a strategic shift from a purely growth-oriented model to one that is balanced, inclusive, and forward-looking, ensuring that the development of its nickel industry contributes to a resilient and prosperous future.

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