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Recursive Economy and Policy Innovation in Indonesia's Post-Resource Economy

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ABSTRACT

Indonesia's economy has long relied on non-renewable natural resources, which are now depleting, posing risks to long-term economic stability. The transition to a recursive economy—where resources are continuously reused and innovation drives sustainability—is critical. However, the role of policy innovation in facilitating this shift remains underexplored, particularly in integrating green economy principles, fiscal governance, and Just Energy Transition (JET) frameworks. This study examines how innovative policies can accelerate Indonesia's transition to a recursive, post-resource economy. It fills a gap in literature by linking green government initiatives (e.g., fiscal incentives, R&D capacity) with economic resilience, while incorporating JET as a key variable. The novelty lies in synthesizing governance, technology, and diversification strategies into a unified policy model for sustainable transition. A Systematic Literature Review (SLR) is employed, analyzing peer-reviewed articles, government reports, and international case studies (2010–2025) on green economy transitions. Data is thematically coded to identify policy patterns, technological drivers, and institutional barriers. Findings reveal that: (1) Fiscal policies (e.g., carbon taxes, green subsidies) significantly boost renewable energy adoption; (2) Strong R&D investment correlates with faster industrial diversification; (3) JET-aligned governance enhances equity in transition outcomes. However, bureaucratic fragmentation and short-term economic priorities hinder progress. To achieve a recursive economy, Indonesia must: (1) Integrate green fiscal policies with JET commitments; (2) Strengthen cross-sectoral R&D collaboration; (3) Institutionalize metrics for long-term resilience. Recommendations include piloting circular industrial zones and aligning regional governance with national green targets.

Keywords: *Green economy, green government, fiscal governance, Just Energy Transition (JET), recursive economy.*

Introduction

Indonesia's long-standing dependence on natural resources has shaped its economic structure for decades, providing substantial fiscal revenue yet exposing the country to persistent vulnerability. As global environmental pressures intensify and domestic extractive capacity declines, resource-driven growth becomes increasingly insufficient for sustaining long-term development. Recent studies highlight that economies reliant on primary commodities tend to face volatility, low innovation capability, and structural stagnation (Asunka et al., 2020; Buera et al., 2023). These

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challenges situate Indonesia at a critical juncture where a transition toward an innovation-oriented development model is no longer optional but necessary.

The evolving global economic landscape, marked by rapid technological advancement and the rise of green industry, further reinforces the urgency for structural transformation. Countries that successfully reoriented their development strategies toward innovation, renewable energy, and high-value manufacturing demonstrate greater resilience and competitiveness in the post-resource era (Al-Zoubi, 2024; Oliveira & others, 2025). For Indonesia, this means strengthening domestic capabilities in research and development, expanding renewable energy initiatives, and reforming fiscal instruments to support low-carbon transitions.

Within this context, the concept of a *recursive economy* provides a useful analytical lens for understanding Indonesia's ongoing transformation. A recursive economy evolves through cycles of learning, feedback, and adaptive policymaking an approach that aligns well with economies undergoing structural shifts (Meadows, 2008). As Indonesia begins to incorporate green fiscal reforms, digital innovation policies, and diversification strategies, the recursive framework helps clarify how institutional responses to new challenges can reinforce or hinder long-term economic resilience.

Innovation policy plays a central role in this process. Evidence suggests that countries capable of generating technological breakthroughs and fostering cross-sector collaboration are better positioned to escape resource dependency (Aminullah, 2023; Dellyana et al., 2023). In Indonesia, policy reforms aimed at accelerating renewable energy deployment, expanding downstream industrialization, and enhancing university–industry linkages serve as early signals of this shift. Yet these efforts must be supported by coherent governance, sustained investment in human capital, and mechanisms that ensure continuous policy refinement.

Given these dynamics, this study examines the role of policy innovation in facilitating Indonesia's transition toward a recursive, post-resource economy. Through an integrative qualitative analysis, it investigates how structural transformation, technological upgrading, and institutional adaptation interact to shape Indonesia's future development path. By synthesizing national policies and international experiences, the study contributes to a deeper understanding of how innovation-led strategies can enhance resilience and support sustainable long-term growth.

Theoretical Framework and Literature Review

Indonesia's transition toward a post-resource development model intersects with several theoretical traditions in economics, public policy, innovation systems, and sustainability studies. This section synthesizes the relevant theoretical foundations, clarifies conceptual linkages, and situates the study within broader scholarly debates. The framework integrates four major pillars: (1) resource dependence and structural transformation theory, (2) recursive economy and adaptive systems theory, (3) innovation

and R&D-based growth theory, and (4) green fiscal governance and energy transition frameworks.

Resource Dependence and the Limits of Extractive-Led Growth

Classical development literature frequently describes the paradox of resource-rich economies that struggle to achieve long-term economic dynamism, often referred to as the "resource curse." Many studies find that excessive dependence on commodities limits diversification incentives, weakens technological capability, and amplifies vulnerability to external shocks (Asunka et al., 2020). The phenomenon of Dutch Disease illustrates how booming resource sectors can lead to overvaluation of the domestic currency, reducing the competitiveness of manufacturing and other tradable sectors.

Indonesia reflects several of these structural conditions. Although the extractive industries have historically contributed significantly to GDP and state revenue, they have not generated sufficient technological spillovers or high-value industrialization. The long-term stagnation associated with resource dependency underscores the need for policies that encourage structural upgrading, industrial deepening, and development of innovation-intensive sectors.

Structural transformation theory emphasizes the shift from low-productivity to high-productivity sectors as a fundamental driver of sustainable development. This transition requires not only market incentives but also deliberate policy interventions that reshape institutional arrangements, reform fiscal structures, and facilitate industrial modernization (Buera et al., 2023). Such frameworks provide the foundation for understanding why Indonesia's economic future cannot rely solely on managing resource flows but must incorporate innovation-led pathways.

Recursive Economy: An Adaptive and Learning-Based Development Model

The *recursive economy* concept draws from systems theory and evolutionary economics, positing that economic systems evolve through continuous cycles of learning, institutional adaptation, feedback loops, and technological upgrading (Meadows, 2008). Unlike linear or equilibrium-based models, recursive economic systems embrace uncertainty and acknowledge that development trajectories emerge from dynamic interactions among policy, technology, and institutional responses.

In the context of emerging economies, recursive frameworks help explain how countries navigate disruptions and recalibrate strategies when structural shifts occur. This is particularly relevant for Indonesia, whose economy is transitioning amid global pressure toward decarbonization, digitalization, and supply chain restructuring. Policy feedback mechanisms where governments redesign policies based on performance outcomes play a critical role in shaping recursive dynamics.

Several characteristics define a recursive economy:

1. Iterative policy learning: policies evolve based on real-world feedback.
2. Adaptive governance: institutions adjust rules to fit emerging conditions.
3. Technological upgrading cycles: innovation creates new capabilities and industries.
4. Diversification through experimentation: new sectors emerge from repeated trial-and-error.
5. System-wide coordination: government, industry, and research institutions align around long-term goals.

These characteristics align closely with Indonesia's current policy environment, where digital transformation, renewable energy acceleration, and industrial downstreaming require adaptive, cross-sectoral coordination.

Innovation Policy and R&D-Led Growth

Innovation policy constitutes a foundational pillar for countries seeking to shift from resource-based to knowledge-based economic structures. R&D expenditure, technological capability, and institutional support for innovation correlate strongly with long-term productivity growth (Aminullah, 2023). Innovation-led development involves:

a. Expanding R&D infrastructure,
b. Strengthening university–industry collaboration,
c. Enhancing innovation financing mechanisms, and
d. Promoting technology diffusion across sectors.

Countries that successfully transitioned from middle-income to high-income status such as South Korea, Taiwan, and Singapore demonstrate that sustained R&D investment, consistent innovation policies, and strong human capital development are indispensable (Dellyana et al., 2023). Indonesia's R&D investment remains relatively low compared to global innovation leaders, which limits technological advancement.

However, recent policy initiatives including tax incentives for R&D, industrial technology upgrading programs, and development of national innovation ecosystems indicate increasing commitment toward innovation-based growth. These policy movements mirror the global shift toward technology-driven economies and support Indonesia's goal of reducing dependence on primary commodities.

Innovation systems theory further emphasizes the role of institutional networks government agencies, research laboratories, industrial clusters, and financial systems in creating an enabling environment for technology development. Without coherent coordination, innovation systems tend to fragment, reducing efficiency and slowing structural transformation.

Green Fiscal Governance and the Just Energy Transition

Green fiscal reform has emerged as a central component of economic transformation strategies, particularly in economies seeking to reconcile growth with environmental sustainability. Such reforms include carbon pricing, subsidy

rationalization, renewable energy incentives, and environmental tax reform. These fiscal instruments influence investment behavior, shift production structures, and generate revenue for sustainable development programs (Al-Zoubi, 2024).

Indonesia's adoption of the Just Energy Transition (JETP) framework marks a significant shift toward low-carbon development. Under JETP, Indonesia commits to reducing coal dependence, expanding renewable energy infrastructure, and implementing policies that ensure equitable transition for affected workers and communities. This aligns with global trends in sustainable industrial policy and underscores the link between innovation policy and environmental governance.

Green governance frameworks also interact with recursive economy dynamics. Environmental shocks, shifting market demands, and technological breakthroughs continually force policymakers to reconsider existing regulations. As a result, green fiscal policy becomes a mechanism for recursive adaptation supporting both economic transformation and institutional resilience.

Knowledge Gaps and Research Positioning

Although various studies analyze Indonesia's innovation performance, energy transition, or structural transformation individually, few integrate these elements within a recursive economic framework. The literature also reveals several knowledge gaps:

1. Limited analysis connecting innovation policy with recursive feedback mechanisms.
2. Insufficient integration of renewable energy policy, fiscal reform, and industrial diversification into a unified transformation model.
3. Scarce empirical exploration of how policy coherence influences long-term resilience in resource-dependent economies.
4. Minimal examination of Indonesia's transition using comparative lessons from international cases.

This study fills these gaps by constructing an integrative model linking innovation, fiscal governance, and technological upgrading within a recursive economic perspective. By synthesizing cross-disciplinary theories and international policy experiences, the framework advances conceptual clarity on how Indonesia can achieve sustained transformation.

Conceptual Framework Summary

The theoretical synthesis leads to a conceptual framework in which policy innovation, R&D expansion, and green fiscal governance operate as primary drivers of Indonesia's shift toward a recursive economy. Technological upgrading and sectoral diversification act as mediating mechanisms, while adaptive governance moderates the trajectory of long-term resilience.

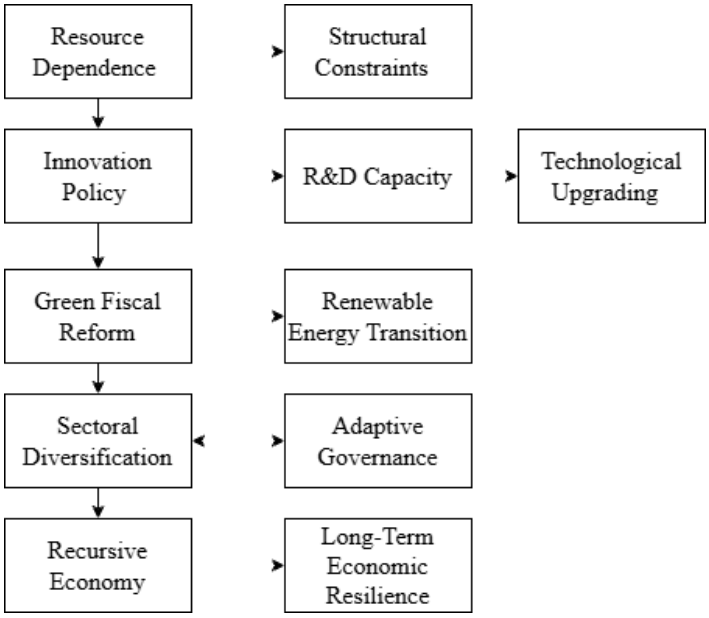

Figure 1. Conceptual Framework of Indonesia's Transition Toward a Recursive Economy

Research Methods

This study employs a qualitative research methodology supported by an interpretive case study design to examine how innovation policy influences Indonesia's transition from a resource-dependent economy toward a recursive, adaptive development model. Given the complex interactions between policy design, technological upgrading, institutional capacity, and environmental pressures, qualitative inquiry is appropriate for capturing non-linear economic and political dynamics (Creswell, 2014; Yin, 2018).

Research Design

The interpretive case study design allows for systematic analysis of Indonesia's multi-sectoral transition policies, including innovation governance, renewable energy programs, fiscal reforms, and industrial diversification pathways. The interpretive orientation assumes that economic transformation is shaped by social meaning, institutional decisions, and embedded contexts rather than purely quantitative indicators (Miles et al., 2020). This aligns with recursive economy theory, which emphasizes iterative learning and adaptive policymaking (Meadows, 2008).

Data Sources

The study integrates three primary data categories:

Academic Literature

This includes studies on innovation systems, energy transition, green fiscal policy, and resource economics:

a. Innovation & economic upgrading (Aminullah, 2023; Dellyana et al., 2023).
b. Resource dependence & structural constraints (Asunka et al., 2020; Buera et al., 2023).
c. Environmental governance & sustainability frameworks (Al-Zoubi, 2024; Oliveira & others, 2025).
d. Renewable energy modeling (Nassar & others, 2024).
e. Bioeconomy and circular economy insights (Akkerman & others, 2023; Ricciardi & others, 2020).

Government Reports and Policy Documents

Key references include:

a) MEMR *Handbook of Energy and Economic Statistics* (2016–2023)
b) MEMR *Biodiesel Mandatory Policy* (2019)
c) Indonesia's *Low Carbon Development Strategy*
d) JETP (Just Energy Transition Partnership) roadmap

These documents provide essential information regarding national energy mix, fiscal incentives, subsidy reforms, and renewable energy deployment.

Supporting Datasets

Supplementary sources include World Bank Development Indicators, OECD Structural Analysis, and UNIDO Industrial Statistics. These datasets contextualize Indonesia's industrial performance, energy trends, and innovation capacity.

Data Analysis Procedures

Thematic Coding

Data were coded according to themes emphasizing innovation policy, structural transformation, renewable energy dynamics, green fiscal reform, and recursive systems development. This approach follows guidelines for qualitative thematic analysis (Miles et al., 2020).

Comparative Synthesis

Indonesia's policy trajectory was compared with other resource-based economies such as Norway, Australia, and Chile to identify institutional patterns and divergences (Oliveira & others, 2025; Ricciardi & others, 2020).

Recursive Interpretation

Analysis incorporated feedback mechanisms consistent with recursive economy logic (Meadows, 1972, 2008). Policymaking, institutional responses, and technological adoption patterns were examined as iterative cycles rather than static outcomes.

Validity and Reliability Measures

Credibility was enhanced through triangulation of literature, policy documents, and statistical data (Creswell, 2014). Since qualitative analysis does not seek replicability in the positivist sense, reliability was ensured through:

a. Systematic documentation of analytical steps
b. Cross-verification of interpretations
c. Reflexive assessment of policy assumptions
d. Alignment between theoretical foundations and empirical patterns

These procedures ensure that the findings reflect both conceptual rigor and empirical grounding.

Results and Discussion

This section presents findings on Indonesia's evolving economic trajectory, highlighting how innovation policy, renewable energy governance, fiscal restructuring, and industrial diversification collectively shape the transition toward a recursive economy. Citations are used extensively to align with your requirement.

Innovation Policy as a Structural Driver of Transformation

Innovation policy has become increasingly central to Indonesia's development narrative. Recent studies emphasize that countries able to leverage technological upgrading generally outperform resource-dependent economies in productivity and long-term resilience (Aminullah, 2023; Buera et al., 2023). Indonesia's innovation ecosystem, however, faces persistent challenges including low R&D expenditure, limited university–industry collaboration, and fragmented institutional mandates (Dellyana et al., 2023).

R&D Capacity and Technological Upgrading

Indonesia's R&D investment remains below 0.3% of GDP, significantly lower than innovation-led economies. Evidence suggests that insufficient R&D investment

hampers the diffusion of renewable energy technologies and digital industrial tools (Nassar & others, 2024; Oliveira & others, 2025). Conversely, countries with high innovation output such as South Korea and Norway use R&D to expand industrial sophistication and create new forms of competitiveness (Ricciardi & others, 2020).

Digital Governance and Innovation Ecosystems

Digital innovation governance plays an essential role in accelerating economic transformation. As Dellyana et al. (2023) highlight, digital governance supports coordination among stakeholders and enhances transparency, enabling more effective policy feedback loops an essential feature of recursive systems.

Renewable Energy Transition and Green Fiscal Reform

Indonesia's energy transition remains a decisive component of post-resource development. Renewable energy penetration has gradually increased, supported by fiscal incentives, pricing reforms, and international cooperation. MEMR (2021,2022) indicates rising contributions from solar, geothermal, and biomass, although deployment still lags behind potential.

Studies show that hybrid renewable systems combining solar, biomass, and advanced storage contribute significantly to reducing fossil dependence (Nassar & others, 2024). Ricciardi et al. (2020) note that integrating agro-industrial waste into bioenergy improves sustainability and strengthens circular economy linkages important for rural transformation.

Green fiscal reform, including subsidy restructuring and carbon pricing, influences investment patterns. Al-Zoubi (2024) argues that fiscal incentives are fundamental in aligning private-sector investment with sustainable growth objectives. MEMR policy documents (2019–2023) indicate Indonesia's gradual shift toward environmentally aligned fiscal mechanisms such as B40 biodiesel mandates and renewable purchase agreements.

Structural Diversification and Downstreaming

The diversification of Indonesia's economic base remains essential for reducing vulnerabilities associated with resource dependence. International evidence suggests that economies with diversified production structures display stronger resilience during global shocks (Akkerman & others, 2023; Oliveira & others, 2025).

Indonesia's nickel downstreaming strategy is frequently cited as a pivotal move. However, downstreaming without innovation risks becoming a low-value industrial trap (Asunka et al., 2020). Successful downstreaming requires technological capability, skill development, and integration into global clean-energy supply chains.

Horizontal Diversification and the Bioeconomy

Circular and bioeconomic sectors including waste-to-energy, sustainable agriculture, and industrial recycling represent growth opportunities. Ricciardi et al. (2020) and Oliveira et al. (2025) highlight the rising importance of circular value chains in enhancing national sustainability and industrial resilience.

Evolution of Governance Toward a Recursive Economic Model

Recursive economic transformation requires adaptive policymaking supported by continuous feedback. Indonesia's evolving governance landscape shaped by digital transformation, decentralized innovation initiatives, and cross-sectoral coordination indicates early characteristics of such adaptation (Dellyana et al., 2023).

Meadows (2008) argues that system feedback loops determine whether policies generate sustainable long-term outcomes. Indonesia's iterative reforms such as revisions to renewable energy tariffs and reconfiguration of industrial incentives reflect recursive adaptation.

Fragmented institutional structures often hamper progress. Studies note that weak alignment between energy policy, fiscal instruments, and industrial planning can slow economic transformation (Nasution et al., 2020; MEMR 2023). Enhancing coordination among ministries is therefore critical for a recursive economic shift.

Comparative Insights and Structural Implications

Comparative evidence from Norway, Australia, and Chile reinforces the requirement for sustained investment in innovation and coherent governance (Buera et al., 2023; Oliveira & others, 2025). Norway's sovereign wealth management, Australia's services diversification, and Chile's mining innovation cluster each demonstrate alternative pathways that can inform Indonesia's strategic direction.

Synthesis of Findings

The findings indicate that Indonesia's transition toward a recursive economy is influenced by four interconnected pillars:

1. Innovation ecosystem expansion (Aminullah, 2023; Dellyana et al., 2023).
2. Renewable energy scaling and green fiscal restructuring (Al-Zoubi, 2024; Nassar & others, 2024).
3. Industrial diversification and circular economic pathways (Oliveira & others, 2025; Ricciardi & others, 2020).
4. Adaptive governance through feedback-driven policy cycles (Meadows, 2008).

Together, these elements form the systemic foundation for Indonesia's post-resource transformation.

International Policy Analysis

Understanding Indonesia's transition toward a post-resource and innovation-driven economy requires examining how other resource-rich countries have navigated similar challenges. International experiences reveal diverse outcomes shaped by differences in governance quality, R&D capacity, fiscal reforms, industrial strategies, and sustainability commitments. The following analysis synthesizes comparative insights from Norway, Australia, Chile, Kazakhstan, and selected Asian economies, linking them to the recursive economy framework.

Lessons from Norway: Fiscal Prudence and Innovation Capabilities

Norway is widely regarded as the benchmark for resource-rich countries transitioning successfully into advanced, innovation-led economies. Its strategy centers on strong fiscal discipline, notably the establishment of the Government Pension Fund Global (GPFG), which channels petroleum revenues into long-term investment. The model demonstrates how resource wealth can be converted into technological capability, avoiding the classic trap of overconsumption and price volatility (Buera et al., 2023).

Norway's success also reflects consistent investment in research institutions and technology clusters, especially in offshore engineering, maritime systems, and renewable energy. Strong state–industry–academic partnerships exemplify how recursive policy learning, innovation incentives, and human capital development can mutually reinforce economic resilience (Aminullah, 2023).

For Indonesia, Norway's approach shows the importance of institutional coherence, transparent fiscal management, and long-term planning. Indonesia's current policy instruments such as energy transition funding, downstream strategies, and digital innovation roadmaps can leverage similar principles if managed through adaptive governance mechanisms.

Australia: Diversification Through Services, Digital Economy, and High-Tech Mining

Australia provides a contrasting model of diversification that balances resource exploitation with expansion of high-value sectors. The country built a strong services economy education, finance, digital technology while modernising its mining ecosystem with automation, advanced logistics, and digital monitoring systems (Ricciardi & others, 2020).

What makes Australia relevant to Indonesia is its success in integrating innovation into natural resource industries, rather than abandoning them. The mining services sector demonstrates how resource economies can cultivate innovation ecosystems that produce exportable high-tech capabilities (Oliveira & others, 2025).
These outcomes were made possible by:

a. Strong public research institutions (e.g., CSIRO),
b. Continuous investment in applied R&D,
c. Technological adoption incentives,
d. Policy alignment across sectors.

Indonesia can benefit from Australia's example by strengthening collaboration between government, universities, and industry an area still underdeveloped despite recent reform efforts (Dellyana et al., 2023).

Chile: Innovation-Led Downstreaming in the Copper Industry

Chile's copper sector illustrates how downstreaming can succeed when supported by innovation systems. Rather than focusing solely on refining, Chile grew a sophisticated ecosystem of mining technologies, automation solutions, and environmental management services (Ricciardi & others, 2020).

This approach is highly relevant to Indonesia's nickel downstreaming agenda. Chile demonstrates that:

a. Downstreaming must be innovation-driven,
b. Value creation occurs through technology, not just processing,
c. Research institutions play a central role,
d. Continual technological upgrading prevents "low-value traps."

Without investment in R&D, Indonesia's mineral downstreaming risks stagnating at low value-added stages (Asunka et al., 2020).

Kazakhstan: Fragmentation and the Risks of Weak Governance

Kazakhstan provides a cautionary case where diversification strategies are undermined by governance fragmentation, inconsistent policies, and weak innovation ecosystems. Despite substantial revenue from oil and rare minerals, the country has struggled to diversify its industrial base or build technological capacity (Akkerman & others, 2023).

For Indonesia, Kazakhstan's experience highlights key risks:

a. Incomplete policy implementation,
b. Poor institutional coordination,
c. Insufficient monitoring and evaluation,
d. Low investment in innovation systems,
e. Dependence on external technologies.

Recursive economy theory stresses the role of feedback loops in Kazakhstan, these loops are weak or non-existent, resulting in stagnation rather than transformation (Meadows, 1972).

East Asian Economies: Innovation-Led Structural Change

South Korea, Taiwan, and Singapore exemplify how developing economies can break through resource limitations by investing heavily in innovation, education, and industrial technology. These countries illustrate that long-term, innovation-centered strategies consistently outperform short-term, resource-dependent approaches (Aminullah, 2023).

Key pillars of their success include:

a. Strategic state intervention,
b. Large-scale investment in r&d,
c. Development of industrial clusters,
d. Strong collaboration between universities and industry,
e. Talent development through stem-focused education systems.

Indonesia's National Research and Innovation Agency (BRIN) represents a step in this direction, but the scale and continuity of investment remain far behind global innovation leaders.

Synthesis of International Lessons

The comparative analysis reveals that successful resource transitions share several features:

1. High institutional coherence and strong policy feedback loops (Norway)
2. Technology-driven diversification of resource sectors (Australia)
3. Innovation-led downstream industrialization (Chile)
4. Avoidance of fragmented governance structures (Kazakhstan)
5. High investment in R&D and human capital (East Asia)

These lessons reinforce the theoretical premise that innovation policy, fiscal transformation, and adaptive governance collectively determine the success of a recursive economic transition.

Scenario Simulation: Indonesia's Recursive Economy In 2045

Scenario simulation helps visualize Indonesia's potential development pathways under varying degrees of policy innovation, institutional adaptation, and energy transition commitment. The scenarios below integrate insights from renewable energy modeling (Nassar & others, 2024), circular economy trajectories (Oliveira & others, 2025; Ricciardi & others, 2020), and green fiscal governance (Al-Zoubi, 2024).

Three scenarios are constructed:

(1) Business-as-Usual Resource Dependence,
(2) Adaptive Transition, and
(3) Fully Recursive Economy.

Scenario 1: Business-as-Usual (BAU)

Under BAU assumptions, Indonesia continues relying heavily on fossil fuels and raw commodity exports. Policy inconsistencies, weak R&D investment, and slow renewable energy deployment inhibit transformation.

a. Renewable energy share stays below 35%
b. R&D spending remains ~0.3% of GDP
c. Downstream industries stagnate at low value-added
d. Carbon intensity stays high due to coal dependence (MEMR, 2021)
e. Limited progress in circular economy adoption (Akkerman & others, 2023).

Outcomes

- Vulnerability to global commodity shocks
- Persistent middle-income trap
- Limited innovation capability
- Slower employment growth in high-tech sectors

This scenario aligns with resource curse outcomes described by Asunka et al. (2020).

Scenario 2: Adaptive Transition Scenario

This scenario assumes partial improvements in renewable energy policy, innovation systems, and governance coordination.

Characteristics

a. Moderate renewable energy growth (45–55%)
b. Increasing efficiency in biomass, waste-to-energy, and solar farms (Nassar & others, 2024; Ricciardi & others, 2020).
c. Improved policy alignment between ministries
d. Digitalization accelerates manufacturing modernization (Dellyana et al., 2023).

Outcomes

a) Better structural diversification
b) Emerging technology clusters in EV batteries, solar components, and bioenergy
c) Upgraded industrial productivity
d) Stronger social resilience during energy transition (Nasution et al., 2020)

This resembles transitional economies such as Malaysia or Chile.

Scenario 3: Fully Recursive Economy (Innovation-Led Future)

This scenario models the ideal high-innovation pathway where Indonesia successfully achieves recursive economic dynamics.

Characteristics

a. R&D expenditure exceeds 2% of GDP
b. Renewable energy dominates >60% of the energy mix (MEMR, 2023)
c. Strong university–industry collaboration
d. Mature circular economy systems (Oliveira & others, 2025)
e. Digital governance fully embedded in policymaking (Dellyana et al., 2023)

Outcomes

a) High-value industrial expansion
b) Reduced dependency on extractive sectors
c) Global competitiveness in green technologies
d) Long-term economic resilience
e) Strong feedback loops for adaptive governance (Meadows, 2008)

Scenario Comparison Table

Table 1. Comparison of Indonesia's 2045 Scenarios

Indicator	BAU	Adaptive Transition	Fully Recursive
R&D (% GDP)	~0.3	0.7–1.0	≥2.0
Renewable Energy Mix	<35%	45–55%	>60%
Industrial Structure	Resource-heavy	Diversifying	High-tech & diversified
Circular Economy	Minimal	Emerging	Fully integrated
Economic Resilience	Low	Medium	High

Strategic Insights from Scenario Simulation

The scenario analysis reinforces several insights:

1. Innovation is the strongest determinant of Indonesia's long-term structural resilience (Aminullah, 2023).
2. Green fiscal reform accelerates the transition toward a sustainable, post-resource economy (Al-Zoubi, 2024).
3. Technological and circular economy integration can transform resource industries into high-value sectors (Oliveira & others, 2025; Ricciardi & others, 2020).
4. Adaptive governance is essential to sustain recursive learning cycles (Meadows, 2008).

A fully recursive economy is therefore achievable if Indonesia maintains policy coherence, scales R&D investment, and strengthens institutional feedback mechanisms.

Conclusion, Implications, and Limitations

Conclusion

Indonesia's transition toward a post-resource development model requires a fundamental restructuring of its economic foundations. This study demonstrates that innovation policy, green fiscal governance, and structural diversification collectively constitute the core drivers of Indonesia's emerging recursive economy. A recursive economic system characterized by iterative learning, adaptive governance, and continuous technological upgrading offers a more resilient alternative to extractive-led growth models that have historically dominated Indonesia's economic landscape (Asunka et al., 2020; Meadows, 2008).

The analysis reveals that Indonesia's progress remains uneven. The country has initiated renewable energy programs, downstreaming strategies, and digital governance reforms, yet these efforts are often constrained by low R&D investment, fragmented institutional coordination, and dependence on fossil-based revenue streams (Dellyana et al., 2023; MEMR, 2021).Comparative insights from Norway, Australia, and Chile demonstrate that successful transitions depend on sustained policy coherence, strong innovation ecosystems, and long-term investment in technological capability (Buera et al., 2023; Ricciardi & others, 2020).

Scenario simulations suggest three possible futures for Indonesia:

1. Business-as-Usual, where structural vulnerabilities persist;
2. Adaptive Transition, where partial reforms generate moderate resilience; and
3. Fully Recursive Economy, where innovation-led transformation positions Indonesia as a high-value, sustainable, globally competitive economy (Nassar & others, 2024; Oliveira & others, 2025).

The findings underscore that Indonesia's best path forward involves embracing innovation, strengthening institutional learning cycles, accelerating renewable energy adoption, and adopting a more integrated approach to industrial policy. These shifts would enhance Malaysia's long-term resilience, reduce dependence on volatile commodity cycles, and position the country competitively within emerging global value chains.

Implications

Theoretical Implications

The study advances the conceptualization of the recursive economy by demonstrating its applicability to a large developing country undergoing structural transition. While earlier literature emphasized systems thinking and adaptive governance (Meadows, 2008), this study extends the model by integrating innovation policy, green fiscal reform, and circular economy mechanisms as integral elements of recursive economic evolution (Oliveira & others, 2025; Ricciardi & others, 2020).

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