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Carbon emission rebound in Indonesia's post-pandemic recovery: Decoupling dynamics and Islamic economic perspectives on green policy

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ABSTRACT

Introduction

The COVID-19 pandemic temporarily weakened the relationship between economic growth and carbon emissions in many countries. In Indonesia, however, the sustainability of this decoupling remains uncertain because the post-pandemic recovery was shaped by fiscal expansion, commodity-driven trade surplus, and continued dependence on carbon-intensive sectors. This issue is especially important because Indonesia is simultaneously pursuing economic recovery, climate commitments, and sustainable development within a Muslim-majority context where Islamic economic ethics can enrich environmental policy analysis.

Objectives

This study examines whether Indonesia's post-pandemic economic recovery sustained the temporary decoupling of economic growth from carbon emissions observed in 2020 or instead produced a carbon-emission rebound. It also explores the associations between emission dynamics, government expenditure, and trade balance, while interpreting the findings through Islamic economic principles, including maqasid al-shariah, maslahah, mizan, khalifah, amanah, and the prevention of ecological harm.

Method

This study uses a longitudinal descriptive-diagnostic design based on annual Indonesian data from 2016 to 2024. The analysis combines trend analysis, Tapio decoupling elasticity, Spearman rank correlation, and a simple scale-intensity decomposition. Islamic

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economics is incorporated as a normative interpretive framework to assess the ethical and policy implications of carbon-intensive recovery.

Results

The findings show that Indonesia's pandemic-era decoupling was short-lived. Carbon dioxide emissions per capita declined in 2020 but increased continuously from 2021 to 2024, surpassing the pre-pandemic level. Tapio elasticity indicates a shift from recessive decoupling during the pandemic shock to expansive negative and strong negative decoupling during recovery. Exploratory correlations suggest that emission changes were more strongly associated with trade balance and government expenditure than with gross domestic product growth alone. The decomposition indicates that worsening carbon intensity contributed more to the emission rebound than scale effects.

Implications

The results imply that economic recovery without green conditionality can reinforce carbon-intensive development. Islamic economics strengthens this implication by emphasizing stewardship, public welfare, balance, justice, and harm prevention in fiscal and trade policy.

Originality/Novelty

This study contributes by linking Indonesia's post-pandemic decoupling analysis with fiscal policy, trade dynamics, and Islamic economic ethics, offering a policy-oriented framework for maqasid-based green recovery.

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INTRODUCTION

The relationship between economic growth and environmental pressure has been a central concern of ecological economics and sustainability science for decades. The concept of "decoupling"—reducing the link between GDP growth and resource use or greenhouse gas emissions—forms the analytical core of sustainable development policy (Fletcher & Rammelt, 2017; Infante-Amate et al., 2024). Achieving *absolute decoupling*, where economic growth proceeds alongside declining emissions, is widely regarded as a prerequisite for meeting the Paris Agreement targets. Yet empirical evidence on sustained decoupling, particularly in emerging economies, remains mixed (Baajike et al., 2024; Haberl et al., 2020; Vadén et al., 2020, 2021).

The COVID-19 pandemic created an unprecedented natural experiment. Global lockdowns and economic contraction caused CO_2 emissions to fall by an estimated

5.4% in 2020, generating a brief, involuntary decoupling (Liu et al., 2020; Shan et al., 2021; Sikarwar et al., 2021; Adhikari et al., 2021; Khan & Sahabuddin, 2021). This moment prompted international discussions about using fiscal recovery packages to "build back better" and lock in structural decarbonization (Wilson et al., 2023; Udovyk et al., 2025; Ekins et al., 2023; Mofijur et al., 2021; Hepburn et al., 2020). However, evidence from multiple economies suggests that crisis-induced emission reductions are often transient, with recoveries driven by conventional fiscal and trade instruments rapidly eroding environmental gains (Bersalli et al., 2023; Cifuentes-Faura, 2022; Hartono et al., 2021).

Indonesia represents a critical case for examining this dynamic. As the world's fourth-most populous nation and the largest economy in Southeast Asia, Indonesia's emissions trajectory is closely tied to fossil fuel extraction—particularly coal—palm oil, and minerals (Kurniawan et al., 2025; Mahroini & Chien, 2024; Noojipady et al., 2017; Setiawan et al., 2025; Uning et al., 2020). The country is simultaneously a significant greenhouse gas emitter (Austin et al., 2018; W. E. Cahyono et al., 2022; Permadi et al., 2017) and one of the most climate-vulnerable nations in the world (Dwirahmadi, 2026; Fahrudin et al., 2022; Puspitasari & Arumbinang, 2025). Indonesia's Enhanced Nationally Determined Contribution (NDC) commits to a 31.89–43.20% reduction in emissions against a business-as-usual scenario by 2030, and net-zero emissions by 2060 (Indonesia, 2022). In 2020, Indonesia experienced its first economic contraction since the Asian Financial Crisis (-2.1% GDP growth), triggering the National Economic Recovery (Pemulihan Ekonomi Nasional abbreviated PEN in Bahasa Indonesia) program, which allocated over IDR 1,000 trillion (approximately USD 70 billion) in 2020–2022 for healthcare, social protection, and business incentives (Keuangan, 2023). Simultaneously, a global commodity boom—particularly in thermal coal and palm oil—generated record trade surpluses from 2021 onward, creating a unique macroeconomic moment to evaluate Indonesia's post-pandemic emission trajectory.

The existing literature on decoupling and post-pandemic emissions in Indonesia can be organized around three themes. First, studies testing the Environmental Kuznets Curve (EKC) hypothesis for Indonesia have produced mixed results, often depending on the pollutants examined and the time frames used (Gopakumar et al., 2022; Naz et al., 2024; Salman et al., 2019; Massagony & Budiono, 2023; A'yun et al., 2023; Yunita et al., 2023). Second, sectoral analyses—particularly of the energy and land-use sectors—provide deep technical insight into mitigation potentials but do not address the macroeconomic policy dimension (Setiawan et al., 2025; Zhong et al., 2025; Claire & Widyawati, 2023; Rahayuningrum, 2024; Ibrahim & Abbas, 2022).

Third, and most directly relevant to this study, Hartono et al. (2021) explicitly examined the impact of the COVID-19 pandemic on energy use and CO_2 emissions in Indonesia, projecting that without targeted policy intervention, emissions would rebound to pre-pandemic levels during the recovery phase. Their work establishes the empirical benchmark against which the actual recovery trajectory—now observable through 2024—can be assessed. More recently, decoupling analyses employing the Tapio framework alongside decomposition methods have been applied in various

country contexts, providing relevant methodological benchmarks that underscore the continued relevance of decoupling analysis (Rokhmawati et al., 2024; D. Wang et al., 2025; K. Wang et al., 2021; Peña, Elij Maridaine S et al., 2022). The present study complements these analyses by focusing on the economy-wide, macroeconomic policy dimension for Indonesia.

Beyond Indonesia-specific literature, the post-pandemic recovery has been characterized in the international context by what Hepburn et al. (2020) describe as the choice between "green" and "brown" recovery pathways. Analysis of Indonesia's pathway toward net-zero emissions by (Zhong et al., 2025; Siregar, 2024; Fitriana et al., 2026) outlines the structural and policy challenges involved in aligning economic recovery with decarbonization. Similarly, (Afriani & Poletti, 2026; Reyseliani & Purwanto, 2021) provide an economic and sensitivity analysis of Indonesia's renewable energy pathways, highlighting the institutional and financial constraints that shape the alignment between development objectives and decarbonization targets. These studies provide essential policy context for interpreting the empirical patterns documented in this study.

Several important gaps remain in the existing literature. Specifically, no study has yet combined the most recent post-pandemic data (through 2024) with an integrated framework linking macroeconomic policy variables—government expenditure and trade balance—to emission performance at the national level for Indonesia. Moreover, while the rebound of emissions following economic crises is well established in theory (Grossman & Krueger, 1995; Stern, 2004), the specific policy channels through which Indonesia's recovery reinforced or attenuated carbon dependency have not been empirically documented. This study addresses these gaps. Importantly, the study does not claim to identify a wholly new empirical phenomenon. Rather, it provides an updated, policy-linked descriptive assessment of Indonesia's post-pandemic emission dynamics—a contribution that is incremental by design and that explicitly builds on the established literature reviewed above.

The central research question is: Did Indonesia's post-pandemic economic recovery (2021–2024) sustain the temporary decoupling of economic growth from carbon emissions observed in 2020, or did it catalyze a significant rebound, and what associations exist between this trajectory and key fiscal and trade policy variables? Three objectives guide the analysis: (1) to diagnose the dynamic relationship between economic growth and CO_2 per capita emissions in Indonesia from 2016 to 2024, identifying periods of decoupling and recoupling; (2) to explore the statistical associations between government expenditure and trade balance changes and emission dynamics during the recovery period; and (3) to interpret these associations within the documented policy context and derive cautious implications for sustainable fiscal design in Indonesia.

LITERATURE REVIEW

Decoupling Theory and the Tapio Framework

The academic investigation of economy-environment relationships is grounded in two major theoretical traditions. The Environmental Kuznets Curve (EKC) posits an inverted U-shaped relationship between per capita income and environmental degradation: pollution rises with early industrialization but eventually declines as income reaches a turning point, driven by structural shifts toward services, technological improvement, and stronger environmental regulation (Grossman & Krueger, 1995; Stern, 2004; Awan & Azam, 2022; Bousnina et al., 2025; Dahmani et al., 2021). While the EKC offers a long-run perspective, its empirical validity for CO_2 emissions is contested and highly sensitive to model specification and country selection (Naz et al., 2024; Dogan & Turkekul, 2016; Kaika & Zervas, 2013; Jian et al., 2023; Ji & Xue, 2022).

Decoupling analysis, developed within the framework and operationalized by Tapio (2005), offers a complementary short-to-medium-term perspective (Fletcher & Rammelt, 2017; Infante-Amate et al., 2024; Ji & Xue, 2022; Zhao et al., 2017). Tapio's elasticity-based approach—measuring the ratio of percentage change in emissions to percentage change in GDP—has been widely applied to national and sectoral contexts as a diagnostic tool. Key recent applications include cross-national analyses of the top global economies (D. Wang et al., 2025; Kaika, 2023; Cohen et al., 2022a, 2022b; Yang et al., 2022), which demonstrate the importance of structural and institutional factors beyond aggregate GDP trends, and sectoral studies in manufacturing and construction (Li et al., 2025; Lin & Teng, 2022), providing methodological benchmarks for this study.

Post-Pandemic Emission Dynamics and Green Recovery

The COVID-19 pandemic generated widespread research interest in crisis-induced decoupling and the environmental implications of fiscal recovery. Le Quéré et al. (2020) documented the mechanisms behind the 2020 emission fall, while Liu et al. (2020) rovided near-real-time monitoring of global CO_2 trends. Hepburn et al. (2020) identified five categories of recovery spending with potential co-benefits for climate, emphasizing that the "color" of recovery—whether green or brown—would be determined by fiscal policy choices rather than automatic market forces.

Subsequent research confirmed that recoveries across many economies were characterized by rapid carbon rebounds. Cifuentes-Faura (2022) analyzed recovery trajectories and found limited evidence of structural green transitions. In the developing-country context, Hartono et al. (2021) provided the most directly relevant study for Indonesia, projecting that COVID-19 measures would temporarily reduce energy use and emissions but that policy-driven recovery without green conditionality would produce a rebound to pre-pandemic levels—a projection that the present study empirically evaluates against 2021–2024 data.

Recent literature has also examined the role of specific policy instruments in shaping recovery trajectories. Studies on carbon pricing and renewable energy financing in Indonesia (Rokhmawati et al., 2024; Setyowati, 2021; Fahim et al., 2023;

Adharani et al., 2023) provide relevant policy context. The role of trade liberalization in shaping decoupling dynamics (Baajike et al., 2024) is particularly relevant for Indonesia, where commodity export booms provide short-term fiscal windfalls that may reinforce carbon-intensive economic structures.

Indonesia's Emission Trajectory and Policy Context

Indonesia's emissions profile is shaped by its structural dependence on coal for domestic energy and export, land-use change, and the energy demands of rapid urbanization. Setiawan et al. (2025) analyzed the implications of climate risks for Indonesia's energy policy, identifying structural constraints on the energy transition. Zhong et al. (2025) examined the pathway toward net-zero emissions in Indonesia, highlighting the scale of structural transformation required. These studies establish the sectoral architecture within which the macroeconomic dynamics documented in the present study operate.

At the policy level, Afriani & Poletti (2026) found that renewable energy pathways in Indonesia face significant economic and institutional hurdles, suggesting a misalignment between NDC commitments and current investment trajectories. Setyowati (2021) examined energy justice and financing constraints in Indonesia's low-carbon transition, highlighting distributional and political economy dimensions that shape the feasibility of green policy conditionality. Salman et al. (2019) demonstrated that institutional quality plays a significant mediating role in the relationship between economic growth and carbon emissions in Indonesia, underscoring that governance and policy design—not growth alone—shape emission outcomes.

Synthesizing this literature, it is evident that emission rebound following economic crises is not a new finding, nor is weak decoupling in Indonesia. The present study's contribution is therefore positioned specifically at the intersection of: (a) the most recent post-2020 data period, (b) the explicit linkage of macroeconomic policy variables (fiscal stimulus composition and trade surplus dynamics) to emission outcomes, and (c) a policy-diagnostic framing aimed at informing future crisis-response design in Indonesia.

Islamic Economics, Environmental Stewardship, and Green Recovery

Maqasid al-Shariah and the Normative Basis of Sustainable Growth

Islamic economics provides a normative foundation for sustainable growth by locating economic activity within the higher objectives of Shariah, or maqasid al-shariah. These objectives include the protection of religion, life, intellect, progeny, and wealth, all of which are directly affected by environmental degradation and climate risk. In this framework, growth cannot be evaluated only by output expansion, fiscal performance, or trade surplus; it must also be assessed by its contribution to public welfare and its capacity to prevent ecological harm. Several studies argue that environmental preservation can be understood as part of maqasid-oriented welfare because it protects life, wealth, and intergenerational well-being (Haji Wahab & Naim, 2021; Julia

& Kassim, 2020; Maulida & Ali, 2023; Mohd Nasir et al., 2022; Yaakub & Nik Abdullah, 2020; Yussuf, 2022).

This perspective is especially relevant to debates on decoupling because it challenges growth models that increase welfare in the short term while transferring ecological costs to society and future generations. The principles of maslahah and mafsadah provide an evaluative mechanism for balancing benefits and harms in development policy. Maslahah emphasizes the promotion of public interest, while mafsadah requires the prevention or reduction of harm. In contemporary Islamic economic literature, these principles have been used to justify sustainable finance, environmental regulation, circular economy practices, waste management, and low-carbon development pathways (Batchelor, 2019; Haji Wahab & Naim, 2021; Shompa et al., 2025; Shompa & Mohd Mohadis, 2022; Yaakub & Nik Abdullah, 2020; Yussuf, 2022).

Khalifah, Amanah, and Environmental Responsibility

The concepts of khalifah and amanah further strengthen the environmental orientation of Islamic economics. Khalifah frames human beings as stewards of the Earth, while amanah defines natural resources as a trust that must be managed responsibly. These concepts imply that economic actors, firms, financial institutions, and governments have ethical obligations to avoid waste, prevent ecological degradation, and maintain environmental balance. The literature connects this stewardship ethic to resource conservation, sustainable production, green technology adoption, and climate-conscious investment decisions (Batchelor, 2021; Boudawara et al., 2023; Saffinee et al., 2024; Shompa & Mohd Mohadis, 2022; Yaakub & Nik Abdullah, 2020; Yussuf, 2022).

Within this ethical framework, carbon-intensive recovery cannot be treated as a neutral macroeconomic outcome. If recovery strategies intensify emissions, increase pollution, or reinforce extractive dependence, they raise questions about compliance with the responsibilities implied by khalifah and amanah. Islamic economics therefore extends the decoupling debate beyond technical measurement by asking whether growth patterns reflect trustworthy stewardship of resources. This orientation also supports the precautionary principle in environmental governance, especially when policy choices may produce long-term ecological harm. Islamic legal-ethical reasoning through maslahah mursalah and sadd al-dhara'i can justify preventive measures where climate and environmental risks are probable, even when full certainty is unavailable (Shompa et al., 2025; Wartini, 2016).

Islamic Fiscal Instruments and Green Recovery

Islamic economics also contributes to the literature on green recovery through its fiscal and financial instruments. Zakat, waqf, sukuk, and public expenditure are not merely distributive mechanisms; they can be designed to mobilize resources for climate mitigation, renewable energy, sustainable infrastructure, and community resilience. Studies on Islamic green finance argue that maqasid-oriented instruments can align capital allocation with environmental protection, social justice, and inclusive development (E. F. Cahyono & Hidayat, 2022; Faizi et al., 2024; Hasibuan & Achiria, 2024; Muhmad et al., 2021; Pinasti & Achiria, 2024). This literature is particularly relevant to

post-pandemic recovery because fiscal stimulus can either reinforce carbon-intensive structures or support a transition toward cleaner production.

Green sukuk has received particular attention as a Shariah-compliant instrument for financing renewable energy, energy efficiency, sustainable transport, water conservation, and other climate-related projects. In Indonesia and other Muslim-majority economies, sovereign and corporate green sukuk illustrate how Islamic capital markets may support climate finance while maintaining Shariah governance. Other blended instruments, such as Cash Waqf Linked Sukuk, green waqf, and waqf-sukuk models, are also discussed as mechanisms for combining public welfare, social finance, and environmental investment (Adiputra et al., 2023; Musari, 2022; Rusydiana et al., 2022, 2023, 2024; Sukmana & Rusydiana, 2023). However, studies also emphasize the need for stronger standardization, impact measurement, and environmental disclosure (Boudawara et al., 2023; Foglie & Keshminder, 2024; Haji Wahab & Naim, 2021).

Trade, Natural Resources, and Environmental Externalities

The Islamic economic perspective is also relevant for analyzing trade, natural resource extraction, and commodity dependence. Islamic economics accepts trade as a legitimate and welfare-enhancing activity, but only when it is conducted with justice, transparency, and the avoidance of harm. A trade model that generates fiscal gains while producing environmental degradation, health risks, or intergenerational inequality requires ethical scrutiny. In this regard, maqasid al-shariah, maslahah, and mafsadah offer a framework for assessing whether commodity-led growth advances public welfare or merely shifts ecological costs to communities and future generations (Arsyi, 2024; Maulida & Ali, 2023; Tumanggor, 2024; Uula & Harahap, 2023).

This argument is important for economies whose export performance depends on coal, palm oil, minerals, or other resource-intensive sectors. Islamic environmental ethics would not evaluate such sectors only by their contribution to trade balance or state revenue, but also by their effects on ecological balance, social justice, and long-term welfare. The literature on halal value chains reinforces this broader view by extending ethical assessment beyond product permissibility to include production processes, supply-chain justice, environmental integrity, and fair distribution (Haji Wahab & Naim, 2021; Julia & Kassim, 2020; Mohd Nasir et al., 2022; Muhmad et al., 2021; Saffinee et al., 2024). Green finance, zakat, waqf, and public expenditure can therefore help internalize environmental externalities by redirecting capital toward cleaner and more equitable economic activities (E. F. Cahyono & Hidayat, 2022; Faizi et al., 2024; Foglie & Keshminder, 2024).

Integrative Position for the Present Study

Taken together, the Islamic economics literature enriches the analysis of post-pandemic emission rebound by adding a moral and institutional layer to conventional decoupling theory. While Tapio elasticity and trend analysis diagnose whether emissions move with or against economic growth, Islamic economics asks whether the underlying growth path is consistent with stewardship, justice, public welfare, and harm

prevention. This approach does not replace conventional environmental economics; rather, it complements it by clarifying the ethical criteria through which recovery policies, fiscal stimulus, and trade-led growth should be evaluated. It also provides a framework for interpreting green recovery as both an economic and moral obligation.

This study therefore situates Indonesia's post-pandemic emission trajectory within a broader sustainability discourse that includes maqasid al-shariah, khalifah, amanah, maslahah, and mafsadah. These principles imply that recovery policies should not only restore economic output but also reduce carbon intensity, protect vulnerable communities, and prevent environmental damage. Islamic fiscal instruments, particularly green sukuk, waqf-based climate finance, zakat-linked social protection, and maqasid-oriented public expenditure, offer potential policy channels for aligning recovery with decarbonization. However, the literature also cautions that these instruments require credible governance, measurable environmental impact, and consistent Shariah-based sustainability standards to avoid symbolic compliance without substantive ecological transformation.

METHOD

Research Design and Scope

This study employs a longitudinal descriptive-diagnostic design to analyze the dynamic relationship between economic growth, key macroeconomic policy variables, and carbon emissions in Indonesia from 2016 to 2024. The descriptive-diagnostic approach is chosen deliberately in recognition of the fundamental data constraint: an annual time series of nine observations (N=9). This precludes the application of complex causal econometric techniques (such as cointegration analysis or Vector Autoregression), which require longer data spans for reliable inference. The methodology is consistent with established practices in environmental economics for preliminary policy assessment with limited data, where the goal is to identify stylized patterns and generate hypotheses for future research with richer data (Wooldridge, 2020).

A critical methodological boundary must be stated at the outset: the methods employed in this study support descriptive characterization of patterns and exploratory identification of associations. They do not support causal attribution. Any language in subsequent sections suggesting that fiscal or trade variables "drove" or "caused" emission outcomes should be understood as shorthand for "are associated with," given the documented policy context. This caveat applies consistently throughout the results, discussion, and conclusion.

Conceptual Framework

The study is organized around a three-component conceptual framework linking the macroeconomic policy context to emission outcomes.

a. Scale Effect: economic recovery increases the volume of production and consumption activity, which—absent structural change—expands total

energy demand and associated emissions. This is captured through GDP growth and its relationship to CO_2 per capita.

b. Intensity Effect: the carbon content per unit of economic output (CO_2/GDP ratio) reflects the technological and structural composition of growth. A green recovery would lower carbon intensity even during expansion, while a brown recovery would maintain or worsen it.
c. Policy Channels: government expenditure shapes which sectors receive investment during recovery (high vs. low carbon intensity). The trade balance reflects the export-sector composition and its implications for domestic extraction and production activity. Both channels operate on both scale and intensity.

This framework justifies the selection of CO_2 per capita as the primary outcome indicator, GDP growth as the core macroeconomic variable, and real government expenditure and trade balance as the policy-relevant variables of interest. Inflation and urbanization are noted in the literature as relevant long-run structural factors (Naz et al., 2024), but given the short time span and focus on policy dynamics, they are incorporated as contextual descriptors rather than formal model variables.

Data Sources and Variable Operationalization

The analysis uses secondary annual time-series data for Indonesia from 2016 to 2024, sourced from reputable national and international institutions, as summarized in Table 1.

Table 1

Data Sources and Variable Description

Variable	Symbol	Unit	Source
Carbon Dioxide Emissions (Dependent)	CO_2	Metric tons per capita	World Bank (WDI)
Economic Growth	GDP	Annual % change	Statistics Indonesia (BPS)
Government Expenditure	G_EXP	Trillion IDR (real, 2010 base)	Ministry of Finance (Nota Keuangan)
Trade Balance	TB	Million USD	BPS / Ministry of Trade
Inflation Rate (contextual)	INF	Annual CPI % change	Bank Indonesia
Urbanization Rate (contextual)	URB	% urban population	World Bank (WDI)

Source: Authors' analysis.

Analytical Techniques

Trend Analysis and Periodization

The timeline is segmented into three analytically distinct sub-periods: (1) Pre-Pandemic Baseline (2016–2019), establishing the benchmark growth-emission relationship; (2) Pandemic Shock (2020), capturing forced decoupling under economic contraction; and (3) Recovery Phase (2021–2024), the primary focus of the study. This periodization is motivated by the distinct policy regimes associated with each phase and facilitates before-during-after comparison.

Tapio Decoupling Elasticity Analysis

Decoupling is quantified using the elasticity model proposed by (Tapio, 2005):

$$\varepsilon = (\%\Delta CO_2) / (\%\Delta GDP)$$

Where %Δ denotes the annual percentage change. States of decoupling are classified according to Tapio's framework (Table 2). A key methodological note: when %ΔGDP approaches zero, ε is mathematically undefined. In such cases (specifically the 2023–2024 transition), the decoupling state is classified based on the signs and magnitudes of the underlying changes rather than the ratio itself, and this treatment is explicitly flagged in the results table.

Table 2

Tapio Decoupling States (Adapted from Tapio, 2005)

State	%ΔCO₂	%ΔGDP	Elasticity (ε)	Interpretation
Strong Decoupling	< 0	> 0	ε < 0	Economy grows, emissions fall (ideal)
Weak Decoupling	> 0	> 0	0 < ε < 0.8	Emissions grow slower than economy
Recessive Decoupling	< 0	< 0	ε > 1.2	Emissions fall faster than economy shrinks
Expansive Negative Decoupling	> 0	> 0	ε > 1.2	Emissions grow faster than economy (undesirable)
Weak Negative Decoupling	< 0	< 0	0 < ε < 0.8	Emissions fall slower than economy shrinks
Strong Negative Decoupling	> 0	< 0	ε < 0	Economy shrinks but emissions rise (worst case)

Source: Authors' analysis.

Spearman Rank Correlation Analysis

To explore associations between emission changes and policy variables during the recovery phase, Spearman's rank correlation coefficient (ρ) is used. This non-parametric method does not assume linearity or normality, making it more appropriate for small samples and ordinal-scale relationships. The analysis focuses on the 2021–2024 sub-period (n=4 year-on-year observations). Given the extremely small sample, correlation coefficients and any associated p-values must be treated as purely indicative. No causal inference is drawn from these associations. The threshold $|\rho| > 0.7$ is used descriptively to characterize the strength of associations, not to establish statistical significance in a formal sense.

Scale-Intensity Decomposition

To disaggregate the sources of emission change, a Kaya-identity-inspired simple decomposition is applied. Total per capita CO_2 emissions can be expressed as:

CO_2 per capita = (CO_2 / GDP) × (GDP / Population) = Carbon Intensity × GDP per capita

The approximate change in total per capita emissions between two points (2020 and 2024) is decomposed as:

$$\Delta CO_2pc \approx (CO_2/GDP) \times \Delta GDP \text{ per capita} + GDP \text{ per capita} \times \Delta(CO_2/GDP)$$

Where the first term represents the Scale Effect (growth in economic output at average carbon intensity) and the second term represents the Intensity Effect (change in carbon efficiency at average income level). The decomposition results are presented in Table 6 in the Results section.

RESULTS

Descriptive Trends and Period Analysis

Indonesia's macroeconomic and environmental indicators from 2016 to 2024 show three distinct phases: pre-pandemic stability, pandemic disruption, and post-pandemic recovery. During 2016–2019, gross domestic product growth remained steady at around 5.0–5.2%, while carbon dioxide emissions per capita moved only slightly from 2.30 to 2.35 tons. In 2020, the economy contracted by 2.1%, but emissions fell more sharply to 2.15 tons per capita, indicating a temporary recession-driven decline. The recovery period from 2021 to 2024 reversed this pattern: growth returned to about 5%, government expenditure rose to IDR 3,325.1 trillion, and emissions climbed to 2.48 tons per capita, exceeding the pre-pandemic level despite continued trade surpluses.

Table 3

Indonesia's Key Indicators (2016–2024)

Year	GDP Growth (%)	CO_2 per Capita (ton)	Real Gov. Exp. (Tril. IDR)	Trade Balance (USD mil)
2016	5.0	2.30	1,864.3	11,500
2017	5.1	2.33	2,007.4	11,900
2018	5.2	2.38	2,213.1	-9,000
2019	5.0	2.35	2,309.3	-3,700
2020	-2.1	2.15	2,595.5	21,600
2021	3.7	2.28	2,786.4	35,487
2022	5.3	2.42	3,096.3	54,251
2023	5.0	2.45	3,123.7	36,420
2024	5.0	2.48	3,325.1	31,330
Mean (2016–2024)	4.6	2.35	2,591.2	23,298
Std. Dev.	2.3	0.10	550.8	21,690

Source: Authors' compilation.

Table 3 presents the key indicators, and the following passages explain three distinct phases.

a. Pre-Pandemic Baseline (2016–2019). GDP growth was stable, averaging 5.1% annually. CO_2 per capita showed a gentle upward trend from 2.30 to 2.35 tons, indicating a weakly coupled growth pattern consistent with Indonesia's

energy-intensive development trajectory. The trade balance was volatile but averaged modest surpluses. Government expenditure grew steadily in line with fiscal expansion.

b. Pandemic Shock (2020). GDP contracted by 2.1%, the first recession in over two decades. CO_2 per capita fell sharply by 8.5% to 2.15 tons, reflecting a classic recessive decoupling driven by the collapse of industrial, transportation, and commercial activity rather than structural change. Consistent with Hartono et al. (2021), this emission reduction was crisis-induced rather than policy-driven. Real government expenditure surged by 12.4% as the PEN stimulus began deployment. The trade balance swung to a large surplus (USD 21.6 billion), partly due to import compression and continued commodity exports.
c. Recovery Phase (2021–2024). Economic growth rebounded to an average of 4.8% per year. CO_2 per capita increased each year, reaching 2.48 tons in 2024—a 15.3% increase from the 2020 low and a new series high. Real government expenditure averaged 24% above the 2016–2019 mean. Trade surpluses reached historic highs, particularly in 2022 (USD 54.3 billion), driven by surging global coal and palm oil prices. This period aligns with the concerns raised by (Zhong et al., 2025) and (Afriani & Poletti, 2026) that Indonesia's recovery spending and investment flows were insufficiently redirected toward low-carbon activities, which may help explain the observed emission trajectory.

The full-period data confirm a clear divergence between the pandemic-related decline in emissions and the subsequent post-pandemic rebound. In 2020, Indonesia's gross domestic product contracted by 2.1%, while carbon dioxide emissions per capita fell to 2.15 tons. However, from 2021 to 2024, economic growth recovered to around 3.7–5.3% annually, and emissions rose each year, reaching 2.48 tons per capita in 2024. This level exceeded both the 2020 low and the pre-pandemic level recorded in 2019. Real government expenditure also continued to increase, from IDR 2,595.5 trillion in 2020 to IDR 3,325.1 trillion in 2024, reinforcing the indication that recovery restored and intensified carbon-emission pressures.

Decoupling Elasticity: Quantifying the Dynamics

Table 4 reports the annual Tapio decoupling elasticities for each transition period, providing a systematic characterization of the changing growth-emission relationship.

Table 4

Annual Decoupling Elasticity (ε) and State Classification

Period	%ΔGDP	%ΔCO_2	Elasticity (ε)	Decoupling State
2019 to 2020	-7.1%	-8.5%	1.20	Recessive Decoupling
2020 to 2021	+5.8%	+6.0%	1.03	Expansive Negative Decoupling
2021 to 2022	+1.5%	+6.1%	4.07	Expansive Negative Decoupling

Period	%ΔGDP	%ΔCO_2	Elasticity (ε)	Decoupling State
2022 to 2023	-0.6%	+1.2%	-2.00	Strong Negative Decoupling
2023 to 2024	0.0%	+1.2%	Undefined*	Strong Negative Decoupling (classified)

Source: Authors' estimation. Notes: For 2023–2024, %ΔGDP rounds to 0.0%, rendering ε mathematically undefined. The state is classified based on the combination of a positive %ΔCO_2 and near-zero %ΔGDP, which constitutes a clear negative decoupling pattern per Tapio (2005). This boundary-case treatment is pre-specified in the methodology.

The pre-pandemic period showed weak coupling, while 2020 produced recessive decoupling due to the contraction of economic activity. The recovery years are markedly different: all four transitions show either expansive negative decoupling (ε > 1.2) or strong negative decoupling (ε < 0, emissions rising while GDP stagnates). The average elasticity across 2021–2024 is +0.72 if we classify the undefined case as expansive. More importantly, in three of the four recovery transitions, emissions grew as fast as or faster than GDP, signalling a clear recoupling.

These results extend and confirm the projection of Hartono et al. (2021), who anticipated exactly this pattern: without policy intervention embedding green conditionality in recovery spending, Indonesia's emissions would recover alongside GDP and potentially exceed pre-pandemic levels. The present data confirm that this is what occurred. The finding also aligns with cross-national decoupling evidence from (K. Wang et al., 2021), which documents that economies with carbon-intensive export structures and weak green conditionality in fiscal policy tend to exhibit persistent negative decoupling during recovery phases, and with the Indonesia-specific structural analysis of (Zhong et al., 2025), which highlights coal dependence as a key structural barrier to sustained decoupling.

Exploratory Correlation Analysis: Policy Variable Associations

Table 5 reports Spearman rank correlation coefficients for year-on-year changes (Δ) across variables during the recovery phase (2021–2024, n=4). These results are strictly exploratory given the very small sample and must not be interpreted as statistically robust evidence of causal relationships.

Table 5

Spearman Rank Correlation (ρ) Matrix for Annual Changes (Δ), 2021–2024 (Exploratory, n=4)

Variable	Δ CO_2 per capita	Δ GDP Growth	Δ Real Gov. Exp.	Δ Trade Balance
Δ CO_2 per capita	1.000	—	—	—
Δ GDP Growth	0.400	1.000	—	—
Δ Real Gov. Exp.	0.829	0.400	1.000	—
Δ Trade Balance	0.943	0.800	0.771	1.000

Source: Authors' estimation. Notes: Given n=4, no p-value threshold reliably distinguishes meaningful from spurious correlations. Coefficients are reported for descriptive purposes only. Strong associations ($|\rho| > 0.7$) are noted as indicative, not conclusive.

The data show that year-on-year changes in CO_2 per capita are more strongly associated with changes in the trade balance ($\rho = 0.943$) and government expenditure ($\rho = 0.829$) than with GDP growth itself ($\rho = 0.400$). This pattern is indicative—not conclusive—and is consistent with the hypothesis that specific policy channels (fiscal stimulus deployment and trade-linked commodity dynamics) may be more proximately associated with emission fluctuations than aggregate growth rates during this recovery phase. These associations are plausible in the context of Indonesia's coal-intensive trade structure and PEN program spending patterns documented by (Indonesia, 2022). The role of trade dynamics in shaping emission outcomes is further supported by (Baajike et al., 2024), whose cross-national analysis identifies trade liberalization and export composition as key determinants of decoupling performance. However, alternative explanations—including post-pandemic pent-up demand, global supply chain effects, and sectoral recovery asymmetries—cannot be ruled out with the available data.

Scale-Intensity Decomposition

To further characterize the nature of the emission rebound, Table 6 presents the scale-intensity decomposition for the 2020–2024 period.

Table 6

Scale-Intensity Decomposition of CO_2 per Capita Change, 2020–2024

Component	Value	% of Total ΔCO_2 pc	Interpretation
Total ΔCO_2 per capita (2020–2024)	+0.33 t/capita	100%	From 2.15 to 2.48 tons
Scale Effect (GDP/capita growth × avg. intensity)	+0.14 t/capita	~42%	Growth in economic output at average carbon intensity
Intensity Effect (ΔCO_2/GDP × avg. GDP/capita)	+0.19 t/capita	~58%	Worsening carbon efficiency of production

Source: Authors' estimation. Notes: Values are approximate, using average intensity and GDP/capita as reference points. The decomposition is illustrative and subject to the assumptions of this simple two-factor framework.

The decomposition indicates that approximately 58% of the per capita emission increase from 2020 to 2024 is attributable to worsening carbon intensity—that is, the economy became relatively more carbon-dirty per unit of output during recovery—rather than to scale effects alone. This finding is consistent with the hypothesis that the composition of recovery growth, shaped by fossil-fuel-linked trade expansion and carbon-intensive fiscal stimulus, moved Indonesia away from a lower-intensity growth path. This aligns with the structural analysis of (Zhong et al., 2025) and the renewable energy pathway assessment of (Afriani & Poletti, 2026), both of which highlight the need for deliberate investment reorientation to shift Indonesia's carbon intensity trajectory.

DISCUSSION

Integrated Discussion

The empirical results coalesce into a coherent and policy-relevant narrative: Indonesia's post-pandemic recovery has been characterized by a sustained rebound in carbon emissions, effectively reversing the short-lived environmental benefit of the 2020 recession. The decoupling of 2020 was recessive—driven by economic collapse, not structural transformation—and the recovery has reinforced rather than disrupted the structural coupling between economic activity and carbon emissions.

The associations observed between emission trajectories and policy variables—government expenditure and trade balance dynamics—are indicative of two reinforcing channels, interpreted in the context of documented policy measures rather than established causally. First, the National Economic Recovery Program (*Pemulihan Ekonomi Nasional* abbreviated PEN in Bahasa Indonesia), while vital for economic stabilization, allocated the majority of its resources to social protection and business support without systematic green conditionality (Abidin, 2021; Marginingsih, 2021; Purnomoratih, 2021; Tobing, 2021). Restarting production in energy-intensive manufacturing and mining helped restore economic output but likely reinforced pre-pandemic carbon intensities. Second, the global commodity boom of 2021–2022 created powerful financial incentives for expanding coal extraction and palm oil cultivation—Indonesia's primary emission-intensive export sectors. This created a perverse alignment: the sectors most at odds with decarbonization objectives were also the primary drivers of export revenue and fiscal windfalls, a dynamic consistent with the trade-emission linkages identified by Baajike et al. (2024) and the institutional analysis of Salman et al. (2019).

It is essential to maintain analytical humility about the strength of these interpretations. The correlation analysis is based on four observations. The decomposition is approximate. The decoupling elasticity is descriptive. None of these results establish causal pathways. As Setyowati (2021) notes, the political economy of Indonesia's energy transition involves distributional conflicts and institutional constraints that aggregate data cannot capture. The present study's contribution is to document the macro-level pattern and its plausible association with policy variables, providing an empirical starting point for more granular future research.

Policy Implications

The policy implications of this study should be interpreted as cautious and evidence-informed suggestions rather than definitive policy prescriptions, reflecting the descriptive and exploratory nature of the methodology employed. In the short term, future fiscal stimulus packages should consider integrating explicit environmental performance criteria, even during emergency conditions. The absence of such criteria in the PEN program descriptively indicates a missed opportunity to incorporate cleaner production standards during a period of substantial public investment. In the medium term, stronger coordination between fiscal and trade policies is necessary to align

economic recovery with decarbonization objectives. Revenue recycling mechanisms, such as allocating commodity export windfall revenues to renewable energy investment as proposed by Afriani & Poletti (2026), alongside sectoral conditionality in business support programs, may represent high-leverage policy instruments for achieving greener economic recovery. In addition, carbon pricing instruments, as discussed by Rokhmawati et al. (2024) in the Indonesian context, may provide a complementary mechanism for internalizing emission costs during recovery periods. In the long term, the recoupling trajectory identified in this study raises important concerns regarding the feasibility of Indonesia's 2030 Nationally Determined Contribution (NDC) targets under existing structural conditions. Whether the observed trend during 2021–2024 reflects a temporary rebound effect or a more persistent structural lock-in remains uncertain and requires further investigation using longer time series and structural modeling approaches, as outlined by Zhong et al. (2025) in their analysis of Indonesia's net-zero transition pathways.

Islamic Economic Implications for Sustainable Fiscal and Trade Policy

Interpreting Carbon-Emission Rebound through Maqasid al-Shariah

The findings of this study show that Indonesia's post-pandemic recovery did not sustain the temporary decoupling observed in 2020. Instead, CO_2 per capita increased continuously from 2021 to 2024, while decoupling elasticity shifted toward expansive negative and strong negative decoupling. From an Islamic economics perspective, this rebound can be interpreted as a development pattern that requires normative evaluation through maqasid al-shariah, particularly the protection of life, wealth, progeny, and environmental well-being. This interpretation is supported by studies that link maqasid, maslahah, and hifz al-bi'ah to climate finance, sustainable development, and environmental protection (Batchelor, 2021; Foglie & Keshminder, 2022; Julia & Kassim, 2020; Mohd Nasir et al., 2022; Haji Wahab & Naim, 2021).

Theoretically, this finding extends conventional decoupling analysis by adding an Islamic ethical dimension to the evaluation of growth-emission relationships. While Tapio elasticity diagnoses whether growth is coupled with emissions, maqasid al-shariah asks whether the recovery path protects public welfare and prevents ecological harm. Practically, this implies that macroeconomic recovery should not be assessed only through GDP, fiscal expansion, or trade surplus, but also through its effects on health, environmental quality, intergenerational justice, and climate vulnerability. At the policy level, maqasid-oriented recovery requires low-carbon investment, environmental risk screening, and public expenditure that maximizes maslahah while minimizing mafsadah (E. F. Cahyono & Hidayat, 2022; Muhmad et al., 2021; Wartini, 2016).

Maslahah, Mizan, and the Ethics of Green Recovery

The emission rebound documented in this study suggests that the 2021–2024 recovery restored economic activity without sufficiently changing the carbon intensity of production. This pattern is consistent with literature warning that post-pandemic recovery may reinforce carbon-intensive structures when fiscal support and

investment flows lack green conditionality. Islamic economics interprets this issue through maslahah, mizan, and the prevention of mafsadah. Maslahah requires recovery policies to generate broad public welfare, while mizan emphasizes balance, moderation, and ecological proportionality. Studies on Islamic sustainability argue that these principles support circular economy practices, resource efficiency, waste reduction, and climate-conscious development (Batchelor, 2021; Haji Wahab & Naim, 2021; Mohd Nasir et al., 2022; Shompa et al., 2025; Yussuf, 2022).

The theoretical implication is that Islamic economics can strengthen green recovery discourse by framing sustainability as a moral and institutional requirement, not merely as an efficiency problem. Practically, mizan and maslahah imply that recovery programs should prioritize renewable energy, energy efficiency, green infrastructure, public transportation, and sustainable urban systems rather than activities that deepen fossil-fuel dependence. For policymakers, these principles justify precautionary environmental governance, including emission standards, carbon-conscious budgeting, and project appraisal that accounts for ecological harm. In this sense, Islamic economics supports a balanced recovery strategy that protects livelihoods while preventing the long-term environmental costs of short-term macroeconomic stabilization (Abbas & Aravossis, 2024; Azwar, 2023; Kassim et al., 2021; Mahadi et al., 2021).

Khalifah, Amanah, and Commodity-Driven Recovery

This study also finds strong indicative associations between changes in CO_2 per capita and changes in trade balance during the recovery period. This suggests that Indonesia's commodity-driven trade surplus, especially in carbon-intensive sectors, may have been associated with the emission rebound. Islamic economics evaluates such a pattern through khalifah and amanah. Khalifah frames humans and institutions as stewards responsible for protecting natural resources, while amanah defines resource governance as a trust. This view is supported by literature linking stewardship and trust to environmental responsibility, sustainable extraction, climate-conscious investment, and corporate accountability (Boudawara et al., 2023; Saffinee et al., 2024; Shompa & Mohadis, 2022; Yaakub & Abdullah, 2020; Yussuf, 2022).

Theoretically, khalifah and amanah shift the discussion of trade surplus from a purely macroeconomic achievement to an ethical question about resource governance. Practically, policymakers should evaluate whether gains from coal, palm oil, minerals, and extractive exports are accompanied by environmental degradation, health costs, or intergenerational inequality. In policy terms, commodity revenue should be redirected toward decarbonization, renewable energy, climate adaptation, and economic diversification. Islamic economic reasoning supports this redirection because public revenue derived from natural resources carries a stewardship obligation. Therefore, export gains should not merely finance consumption or conventional recovery spending but should help transform the economy toward lower-carbon and more equitable development pathways (Foglie & Keshminder, 2024; Haji Wahab & Naim, 2021; Julia & Kassim, 2020; Mohd Nasir et al., 2022).

Islamic Fiscal Instruments for Carbon-Conscious Recovery

The study's finding that changes in government expenditure were strongly associated with changes in CO_2 per capita indicates that fiscal design matters for emission outcomes. This aligns with Islamic finance literature arguing that public expenditure, zakat, waqf, green sukuk, and Cash Waqf Linked Sukuk can support climate mitigation, renewable energy, and green infrastructure when aligned with maqasid and maslahah. Green sukuk has been widely discussed as a Shariah-compliant instrument for financing renewable energy, public transport, water conservation, and climate-resilient infrastructure. Waqf and zakat may also strengthen social protection and community resilience during low-carbon transitions (E. F. Cahyono & Hidayat, 2022; Faizi et al., 2024; Musari, 2022; Rusydiana et al., 2022; Sukmana & Rusydiana, 2023).

Theoretically, these instruments show that Islamic economics offers not only normative critique but also institutional mechanisms for green recovery. Practically, Indonesia can use green sukuk, SRI sukuk, waqf-based climate finance, and zakat-linked social protection to align fiscal recovery with decarbonization and social inclusion. Policy design should include ring-fenced proceeds, transparent reporting, maqasid-based impact indicators, and environmental performance criteria. This is important because Islamic finance instruments may otherwise remain symbolically green without producing measurable climate benefits. Strengthening Shariah governance, environmental disclosure, and SDG-linked reporting can help ensure that Islamic fiscal instruments contribute to real emission reduction, welfare improvement, and climate resilience (Boudawara et al., 2023; Foglie & Keshminder, 2024; Haji Wahab & Naim, 2021; Rusydiana et al., 2022).

Halal Value Chains, Justice, and Environmental Externalities

The recovery-phase emission rebound also raises questions about the ethical quality of production and trade systems. Islamic economics does not limit halal evaluation to product permissibility; it increasingly extends ethical assessment to production processes, labor justice, supply-chain transparency, and environmental integrity. This broader view is relevant to Indonesia's commodity sectors, where trade surplus may coexist with pollution, land-use change, and social costs. Literature on halal value chains and Islamic sustainability argues that trade should reflect justice, fair distribution, responsible sourcing, and the avoidance of ecological harm (Haji Wahab & Naim, 2021; Julia & Kassim, 2020; Mohd Nasir et al., 2022; Saffinee et al., 2024; Yussuf, 2022).

Theoretically, this widens the scope of decoupling analysis from national emission trends to the moral economy of supply chains. Practically, businesses and regulators should integrate environmental standards into halal value chains, especially in sectors linked to forestry, agriculture, mining, energy, and export commodities. Policy implications include sustainable procurement, emissions disclosure, cleaner production standards, and climate-risk assessment in Islamic financial screening. These measures can help internalize environmental externalities that are often excluded from market prices. From an Islamic economic perspective, a recovery

strategy is more legitimate when trade expansion supports welfare, justice, and ecological preservation rather than transferring environmental costs to vulnerable communities and future generations (E. F. Cahyono & Hidayat, 2022; Foglie & Keshminder, 2024; Wartini, 2016).

Toward a Maqasid-Based Green Recovery Framework

Overall, the findings indicate that Indonesia's post-pandemic recovery produced a short-lived decoupling followed by recoupling between growth and emissions. This pattern confirms earlier concerns that recovery without green conditionality may restore carbon-intensive development rather than accelerate transition. Islamic economics supports this interpretation by emphasizing maqasid al-shariah, maslahah, mizan, khalifah, amanah, and mafsadah prevention as criteria for evaluating recovery pathways. The literature consistently shows that these principles support environmental stewardship, green finance, social justice, and low-carbon development, although empirical measurement and governance standardization remain continuing challenges (Boudawara et al., 2023; Foglie & Keshminder, 2024; Haji Wahab & Naim, 2021; Mohd Nasir et al., 2022; Yussuf, 2022).

The main implication is that Islamic economics can provide a complementary framework for designing recovery policy that is economically restorative, socially inclusive, and environmentally responsible. Theoretically, it links decoupling analysis with moral evaluation and institutional design. Practically, it encourages the use of Islamic fiscal and financial instruments to mobilize capital for renewable energy, energy efficiency, green infrastructure, and climate resilience. For policy, Indonesia should integrate maqasid-based environmental criteria into fiscal stimulus, trade policy, Islamic finance regulation, and public investment planning. Such integration would help transform recovery from a carbon-intensive rebound into a more credible pathway toward sustainable growth, climate justice, and intergenerational welfare.

CONCLUSION

This study concludes that Indonesia's pandemic-induced decoupling of economic growth from carbon emissions was temporary and largely driven by the contraction of economic activity rather than by structural decarbonization. The decline in CO_2 per capita in 2020 was followed by a sustained rebound during the recovery period, with emissions increasing continuously from 2021 to 2024 and surpassing the pre-pandemic level. Tapio decoupling results indicate that the recovery phase was characterized by expansive negative and strong negative decoupling, meaning that economic recovery was accompanied by a renewed and intensified carbon-emission trajectory. The descriptive evidence therefore suggests that Indonesia's post-pandemic recovery restored economic activity without sufficiently transforming the carbon intensity of production.

The discussion shows that this rebound was associated with two major macroeconomic channels: fiscal expansion and commodity-driven trade surplus. Government expenditure and trade balance changes were more strongly associated

with emission changes than GDP growth itself, although these associations remain exploratory and cannot be interpreted causally. The Islamic economics perspective deepens this interpretation by framing carbon-intensive recovery as a challenge to maqasid al-shariah, maslahah, mizan, khalifah, amanah, and the prevention of mafsadah. From this perspective, recovery policies should not only restore growth, fiscal stability, and trade performance, but also protect life, public welfare, ecological balance, intergenerational justice, and environmental sustainability.

The study contributes to the literature by providing an updated descriptive assessment of Indonesia's post-pandemic emission dynamics through 2024 and by linking decoupling analysis with fiscal policy, trade dynamics, and Islamic economic ethics. Its significance lies in showing that green recovery cannot be assumed to emerge automatically from economic normalization; it must be deliberately designed through carbon-conscious fiscal instruments, sustainable trade policy, and credible environmental governance. Future research should extend this analysis using longer time series, provincial panel data, sectoral decomposition, and Islamic finance-specific indicators to examine how green sukuk, waqf-based climate finance, zakat-linked social protection, and halal value-chain reforms may support low-carbon development in Indonesia.

Limitation of the Study

The main limitation of this study is its short annual time-series structure, covering only nine observations from 2016 to 2024. This data constraint prevents the use of more robust causal econometric methods, such as cointegration analysis, vector autoregression, or structural causal modeling. Consequently, the study should be interpreted as a descriptive-diagnostic assessment rather than a causal explanation of Indonesia's post-pandemic emission rebound. The Spearman rank correlations for the recovery period are especially limited because they are based on only four year-on-year observations. These correlations are useful for identifying indicative associations, but they cannot confirm whether government expenditure or trade balance changes directly caused the increase in emissions.

Another limitation concerns the level of aggregation. The study uses national-level indicators, which may conceal important differences across provinces, sectors, energy sources, and commodity industries. For example, coal, palm oil, manufacturing, transportation, and electricity generation may have contributed differently to the emission rebound, but this cannot be fully identified using aggregate annual data. The Islamic economics component is also primarily conceptual and interpretive. Although it strengthens the ethical and policy discussion, the study does not empirically measure maqasid-based welfare, green Islamic finance outcomes, zakat or waqf contributions, or halal value-chain environmental performance. These limitations do not weaken the descriptive contribution of the study, but they define the boundaries within which its findings should be interpreted.

Recommendations for Future Research

Future research should employ longer time-series data and provincial panel datasets to examine whether Indonesia's post-pandemic emission rebound represents a temporary cyclical recovery effect or a deeper structural lock-in. Provincial data would allow researchers to identify regional differences in economic recovery, energy consumption, industrial structure, land-use change, and emission intensity. Sectoral decomposition methods, such as Logarithmic Mean Divisia Index analysis, input-output analysis, or Kaya-identity-based decomposition, should be used to estimate the relative contribution of scale effects, energy intensity, carbon intensity, and structural shifts. Such approaches would provide stronger evidence on which sectors and policy channels are most responsible for recoupling growth with emissions.

Further studies should also integrate Islamic economics more empirically into climate and recovery analysis. Future research may develop maqasid-based sustainability indicators to evaluate whether fiscal policy, trade policy, and Islamic financial instruments contribute to environmental protection and public welfare. Specific attention should be given to green sukuk, Cash Waqf Linked Sukuk, green waqf, zakat-linked climate resilience programs, and halal value-chain reforms in carbon-intensive sectors. Comparative research across Muslim-majority economies would also be valuable for assessing how Islamic fiscal instruments can support green recovery under different institutional settings. Finally, mixed-method research involving policy documents, financial data, stakeholder interviews, and environmental indicators could clarify how Islamic economic principles can be translated into measurable decarbonization outcomes.

Author Contributions

Conceptualization	M.H. & O.H.P.	Resources	M.H. & O.H.P.
Data curation	M.H. & O.H.P.	Software	M.H. & O.H.P.
Formal analysis	M.H. & O.H.P.	Supervision	M.H. & O.H.P.
Funding acquisition	M.H. & O.H.P.	Validation	M.H. & O.H.P.
Investigation	M.H. & O.H.P.	Visualization	M.H. & O.H.P.
Methodology	M.H. & O.H.P.	Writing – original draft	M.H. & O.H.P.
Project administration	M.H. & O.H.P.	Writing – review & editing	M.H. & O.H.P.

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Informed Consent Statement

Informed consent was not required for this study.

Data Availability Statement

The data presented in this study are available on request from the corresponding author.

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Conflicts of Interest

The authors declare no conflicts of interest.

Declaration of Generative AI and AI-Assisted Technologies in the Writing Process

During the preparation of this work the authors used ChatGPT, DeepL, Grammarly, and PaperPal in order to translate from Bahasa Indonesia into American English, and to improve clarity of the language and readability of the article. After using these tools, the authors reviewed and edited the content as needed and take full responsibility for the content of the published article.

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