International Journal of Sustainable Development and Planning
Vol. 20, No. 11, November, 2025, pp. 4819-4827
Journal homepage: http://iieta.org/journals/ijsdp

The Resource Paradox: Coal Export Dependency, Environmental Degradation, and Growth Constraints in Jambi Province, Indonesia

Siti Hodijah[1*], Junaidi Junaidi[1], Syahmardi Yacob[2], Hardiani Hardiani[1], Fadwa Rhogib Asfahani[1]

[1] Department of Economics, Faculty of Economics and Business, Universitas Jambi, Kota Jambi 36361, Indonesia
[2] Department of Management, Faculty of Economics and Business, Universitas Jambi, Kota Jambi 36361, Indonesia

Corresponding Author Email: sitihodijah@unja.ac.id

https://doi.org/10.18280/ijsdp.201122

Received: 11 September 2025
Revised: 22 November 2025
Accepted: 27 November 2025
Available online: 30 November 2025

Keywords:
resource curse, extractive dependency, regional sustainability, structural break analysis, ARDL model, post-coal transition, ecological-economic trade-offs

ABSTRACT

This study investigates the long-term relationship among coal export concentration, economic growth, and environmental quality in Jambi Province, Indonesia—a region characterized by structural dependence on extractive industries and rising environmental pressures. Using annual data from 2009 to 2023, the analysis employs the Autoregressive Distributed Lag (ARDL) model and Bai–Perron (BP) structural break tests to capture both long-run dynamics and regime shifts. The findings show that coal export concentration has no significant long-term impact on economic growth, whereas environmental degradation exerts a strong, persistent negative effect on regional economic performance. In contrast, the short-run effects of changes in coal export concentration and environmental quality are statistically insignificant, indicating that annual fluctuations in growth are driven more by structural factors than by temporary shocks. Structural breaks identified in 2015, 2018, and 2022 align with major regulatory reforms and global energy market disruptions, highlighting the vulnerability of resource-dependent regions. Overall, the results underscore the importance of reducing reliance on coal-based development and strengthening environmental management. The study provides evidence-based recommendations for economic diversification, improved environmental governance, and investments in cleaner energy pathways to support sustainable and resilient regional development.

1. INTRODUCTION

The global reliance on coal as a primary energy source raises urgent concerns regarding long-term economic sustainability and environmental integrity. By 2024, global coal demand is projected to reach 8.7 billion tons and remain elevated through 2027 [1]. While this surge brings short-term economic benefits for exporting countries through revenues and sectoral growth, it also entails long-term structural risks. Coal price volatility illustrates this vulnerability, as fluctuations in coal market prices have been shown to impact broader economic and financial conditions in energy markets [2].

In resource-rich developing economies, prolonged dependence on fossil fuel exports often leads to structural stagnation, institutional fragility, and environmental degradation—commonly referred to as the resource curse. Many countries fail to transform resource wealth into broad-based growth due to rent-seeking, weak institutions, and limited diversification [3-7]. This vulnerability is reinforced by global trade dynamics: the Prebisch–Singer hypothesis posits a long-term decline in terms of trade for primary commodities, which increases risks for economies reliant on raw material exports [8, 9]. In Indonesia, mining-based provinces have been particularly vulnerable, with limited diversification, as illustrated by evidence from East Kalimantan, where mining dominance has not translated into broad-based income gains [10].

Coal exploitation also generates ecological and social pressures. The Environmental Kuznets Curve (EKC) hypothesis posits a non-linear relationship between economic growth and environmental quality: degradation worsens during early growth stages but may improve after reaching a certain income threshold, supported by stronger regulation and cleaner technologies [11, 12]. Yet, evidence from China, India, and South Asia shows that the turning point is often absent or delayed, particularly in coal-dependent regions with weak governance [13, 14]. In Indonesia, Prasetyanto and Sari [15] found that growth and primary energy consumption drive environmental degradation, although an EKC pattern may emerge if regulatory enforcement strengthens. Beyond environmental concerns, coal mining leads to land degradation, pollution, and increased health risks from particulate matter and heavy metals [16, 17]. Moreover, its economic benefits are unevenly distributed, with profits concentrated among elites while local communities experience widening socio-economic disparities [18, 19].

Several countries have addressed the structural challenges of resource dependence through institutional innovation. Norway, for example, redirected rents into a sovereign wealth

fund to finance green transitions [20]. By contrast, most Indonesian provinces remain in the early stages of transition, and coal-producing regions, such as Jambi, have yet to reach the EKC turning point [21].

In Jambi Province, coal has increasingly dominated the export structure [22]. As shown in Figure 1, this growing dependence heightens vulnerability to global shocks and ecological stress while constraining economic diversification. At the same time, national policies—such as the government's downstreaming agenda. At the same time, national policy directions related to energy transition and development priorities [23], the 2025 amendment of the mining law to broaden access for small enterprises and religious groups [24], and Indonesia's pledge to achieve carbon neutrality before 2050 with a 15-year fossil fuel phase-out plan [25]—underscore the urgency of reducing coal dependence.

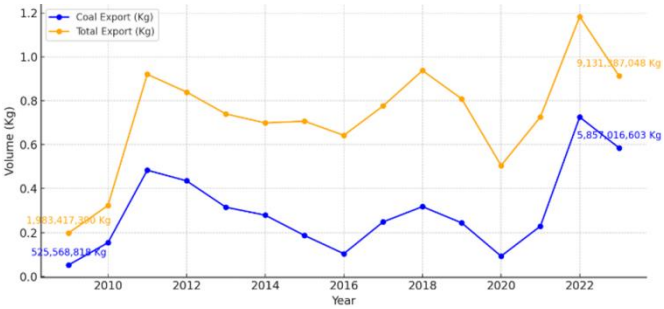

Figure 1. Volume of coal exports and total exports of Jambi province, 2009–2023
Source: BPS (Central Statistics Agency) of Jambi province, 2024

Despite extensive research on the resource curse and EKC, several gaps remain. First, most studies focus on national or macroeconomic effects, with limited attention to regional coal dependency. Second, prior work often uses aggregate production or exports, overlooking how concentration in a single commodity destabilizes economic resilience and ecological sustainability [26-29]. Third, many empirical studies employ linear models that fail to capture structural breaks triggered by policy reforms or global shocks [7, 28].

This study differs from previous provincial research in Indonesia in two key ways. First, it introduces the Coal Export Concentration Ratio (CECR) to quantify coal's dominance in Jambi's export profile. Earlier studies in East Kalimantan used coal activity as a proxy for emissions but ignored export dependence as a structural vulnerability [30]. Research in South Kalimantan analyzed the economic and environmental effects of coal mining but did not measure how export concentration amplifies external shocks [31]. Other Indonesia-focused and Sumatra-relevant analyses examined economic–environmental linkages without incorporating export concentration as a determinant [32].

Second, this study extends the export concentration literature [33-35], which typically uses concentration ratios (CR) and the Herfindahl–Hirschman index (HHI) at the national level, to a subnational context. Export concentration increases vulnerability to external shocks and growth volatility [36-38]; yet, no prior research has systematically linked provincial coal export concentration with both growth and environmental quality in Indonesia. By combining ARDL estimation with Bai–Perron (BP) multiple structural break tests, this study also addresses methodological gaps by capturing policy- and market-driven regime shifts often overlooked in linear models. This framing aligns with global evidence that energy series—coal in particular—exhibit structural breaks that affect their long-run properties [39] and with findings on the dynamic relationships between international energy price trends and coal prices in China [40].

Unlike previous provincial studies in Indonesia that rely on export values or export shares, this study introduces the CECR as a structural indicator of commodity dependence. CECR captures the degree of export concentration and long-run vulnerability more accurately than conventional export metrics, thereby offering a more precise framework for understanding the structural exposure of resource-dependent regions such as Jambi.

Against this backdrop, the study investigates the long-term relationship between coal export concentration, environmental quality, and economic growth in Jambi Province. Using a non-linear empirical approach with ARDL and BP structural break tests, this study aims to provide new insights into the interplay among export dynamics, ecological stress, and sustainable regional growth. In doing so, it contributes to theoretical debates on resource dependence and the EKC, while offering empirical evidence to inform Indonesia's policy reforms and its broader post-coal transition.

2. MATERIALS AND METHODS

This study uses annual time-series data from 2009 to 2023 to examine the dynamic relationships among coal export concentration, environmental quality, and regional economic growth in Jambi Province, Indonesia. The selected time frame encompasses key policy reforms and environmental shifts, particularly those related to coal governance and post-Paris Agreement energy transition commitments.

The data were meticulously collected from the Central Statistics Agency (BPS) of Jambi Province and the Indonesian Ministry of Environment and Forestry. The analysis focuses on three core variables: economic growth (measured by Gross Regional Domestic Product (GRDP) growth at constant prices), CECR, and the Environmental Quality Index (EQI). The definitions and data sources of the variables are presented in Table 1.

The CECR variable was constructed using the concentration ratio (CR) method to quantify the extent to which coal exports dominate the province's overall export structure. It is essential to note that the dataset used in this study has not been employed in any previously published research by the authors, thereby providing a unique empirical contribution.

Table 1. Variable definitions and data sources

Variable	Definition	Measurement	Data Source
Economic Growth (EG)	Regional GRDP growth at constant prices	Percentage	BPS Jambi Province
Coal Export Concentration Ratio (CECR)	The ratio of coal exports to total provincial exports	Ratio	BPS Jambi Province
Environmental Quality Index (EQI)	Composite score of air, water, and land quality	Index	Ministry of Environment and Forestry RI

To ensure analytical rigor, the BP structural break test is employed to detect potential structural changes in the time series, particularly those induced by regulatory reforms or fluctuations in global coal markets. The identified breakpoints are subsequently incorporated into the estimation framework to account for regime shifts.

The core econometric analysis is conducted using the Autoregressive Distributed Lag (ARDL) model, which allows for the estimation of both short-run dynamics and long-run equilibrium relationships. The general form of the ARDL model is specified as follows:

$$EG_t = \alpha + \beta_1 CECR_t + \beta_2 EQ_{It} + \mu_t \quad (1)$$

where,

EG_t = Economic growth at time t,

$CECR_t$ = Coal export concentration ratio,

EQ_{It} = Environmental quality index,

α = Constant term,

β_1 and β_2 = Estimated coefficients,

μ_t = Error term.

To reflect short-run dynamics, the model is expanded into its error correction form:

$$\Delta EG_t = \alpha_i + \sum_{i=1}^{p} \alpha_i \Delta EG_{t-i} + \sum_{j=0}^{q} \beta_j \Delta CECR_{t-j} - \sum_{k=0}^{r} \gamma_k \Delta EQI_{t-k} + \delta_1 \Delta EG_{t-1} + \delta_2 \Delta CECR_{t-i} + \delta_3 \Delta EQI_{t-i} + \varepsilon_t \quad (2)$$

where,

Δ = the first difference operator,

α_i, β_j, γ_k = short-run coefficients,

δ_1, δ_2, δ_3 = long-run equilibrium coefficients,

ε_t = the disturbance term.

Bounds testing is employed to evaluate the presence of cointegration among the variables. If cointegration is established, the long-run coefficients are interpreted as stable equilibrium relationships, while the short-run coefficients capture the dynamic adjustment processes that lead to that equilibrium.

To ensure the model's reliability and stability, diagnostics are conducted using the CUSUM and CUSUM of Squares tests. These tests assess the consistency of model parameters over time. Model robustness is confirmed when the test statistics remain within the 5% confidence bounds. This rigorous validation process provides a solid foundation for the credibility of the study's empirical findings.

3. RESULTS

3.1 Bai-Perron (BP) test

To account for potential regime shifts in the time-series data, the BP multiple structural break test was applied to the two independent variables, CECR and EQI. Structural breaks indicate statistically significant changes in the underlying data-generating process—typically caused by regulatory reforms, market volatility, or environmental shocks—and may affect model stability and the validity of long-run relationships in the ARDL framework.

The BP test identified two significant structural breaks in the CECR series, occurring in 2015 and 2022, with F-statistics of 12.18 and 13.85, respectively. Both values exceed the 5% critical thresholds (8.58 and 10.13), providing robust evidence of structural change. For EQI, one significant breakpoint was detected in 2018 (F = 68.65), indicating a substantial shift in environmental quality conditions, whereas the second-break test was not significant (F = 5.00 < 10.13) (refer to Table 2).

These breakpoints closely correspond to major policy and market developments. The 2015 breakpoint in CECR aligns with Indonesia's large-scale revocation of mining permits and the tightening of district-level coal export regulations. The 2022 breakpoint reflects a surge in global coal demand triggered by geopolitical tensions—particularly the Russia–Ukraine conflict—and the sharp rise in global coal prices. Meanwhile, the 2018 structural shift in EQI is consistent with the environmental impacts of large-scale forest fires and the introduction of stricter environmental controls that altered the province's ecological conditions.

By identifying these breakpoints, the analysis incorporates key non-linear dynamics into the subsequent ARDL modelling. This step enhances the robustness and reliability of the estimation by ensuring that long-run relationships are evaluated within an empirically stable structural environment.

3.2 Unit root test

Before estimating the ARDL model, unit root tests were conducted to determine the integration order of each variable. The Augmented Dickey–Fuller (ADF) test was applied in EViews using a specification with an intercept and no deterministic trend. Lag length was selected automatically using the Schwarz Information Criterion (SIC), with a maximum of 1 lag, given the characteristics of the small annual dataset. If the null hypothesis of a unit root could not be rejected at the level form, the test was repeated at the first-difference form.

As a confirmatory step, the Phillips–Perron (PP) test was also employed because it is more robust to heteroskedasticity and residual autocorrelation. The PP test results were used to ensure consistency with the ADF findings.

Based on the ADF and PP test results presented in Table 3, all variables in the study—economic growth (EG), coal export concentration (CECR), and the EQI—become stationary after first differencing. Accordingly, the three variables are classified as I(1) processes, and none are integrated of order two. This condition is essential, as it ensures that the ARDL model can be validly applied and allows for the examination of potential long-run relationships through the bounds testing approach.

Table 2. BP structural break test results

Variables	Break Test	F-Statistic	Critical Value	Break Dates	Sequential	Repartition
CECR	0 vs. 1*	12.17665	8.58	1	2022	2015
	1 vs. 2*	13.84832	10.13	2	2015	2022
	2 vs. 3	2.132503	11.14			
EQI	0 vs. 1*	68.64587	8.58	1	2018	2018
	1 vs. 2	5.004109	10.13			

Note: Asterisks indicate statistical significance at the 5% level

Table 3. Augmented Dickey–Fuller and PP unit root test results

Variables	Augmented Dickey–Fuller			Phillps-Perron		
	t-Statistic	Prob	Stationary at	Adj. t-Statistic	Prob	Stationary at
EG	-4.477798	0.0049	1st Difference	-7.053972	0.0001	1st Difference
CECR	-3.178465	0.0473	1st Difference	-3.011456	0.0600	1st Difference
EQI	-4.999629	0.0021	1st Difference	-4.996090	0.0021	1st Difference

3.3 Bound cointegration test

In estimating the ARDL model, the maximum lag length for both the dependent and independent variables was restricted to two lags to maintain model parsimony, given the relatively small annual sample size. The optimal lag combination was selected automatically using the Akaike Information Criterion (AIC), yielding ARDL(1, 0, 2) as the best-fitting specification. Based on this model, the Bounds Cointegration Test was conducted to assess the existence of long-run relationships among the variables.

Table 4. Bound cointegration test results

Test Statistic	Value	Signif.	I(0)	I(1)
F-statistic	13.58040	10%	2.63	3.35
k	2	5%	3.1	3.87
		2.5%	3.55	4.38
		1%	4.13	5

Table 4 presents the Bounds test results. The F-statistic of 13.580 is far above the upper bound critical values (I(1)) at the 10%, 5%, and 1% significance levels. Considering that the number of explanatory variables is two (k = 2) and the sample size is relatively small, the interpretation relies on finite-sample critical values (n ≈ 30), which similarly indicate that the F-statistic lies well above the upper bound for cointegration.

Based on these results, the null hypothesis of no long-run relationship can be rejected at all significance levels. Thus, there is strong evidence of cointegration among coal export concentration, environmental quality, and economic growth in Jambi Province.

Overall, the Bounds test findings indicate that the ARDL model used is sufficiently capable of capturing the long-run linkages among the variables. This supports the model's validity for further analysis of short-run dynamics and long-run equilibrium relationships in the province.

3.4 Autoregressive distributed lag model estimation

Given the limited number of observations for the 2009–2023 period, the ARDL model was estimated using a maximum of two lags. Model selection was performed automatically using the AIC, which identified the ARDL (1, 0, 2) as the optimal specification. The complete estimation results are presented in Table 5.

Table 5 shows that the CECR variable has a positive and significant effect at p = 0.0010. This indicates that increases in coal export concentration provide a direct short-run stimulus to economic growth. Meanwhile, the second lag of EQI has a negative, significant coefficient (p = 0.0217), suggesting that declines in environmental quality exert a detrimental impact that materializes with a two-year lag. The negative coefficient on EG(-1) reflects an adjustment mechanism toward long-run equilibrium, although it is not statistically significant at conventional levels.

The existence of long-run relationships among the variables was examined using the Bounds Cointegration Test, presented earlier in Table 4. The F-statistic of 13.580 exceeds all upper-bound critical values (I(1)) at the 10%, 5%, and 1% significance levels, including the finite-sample category. This allows rejection of the null hypothesis of no cointegration, indicating that a stable long-run relationship binds economic growth, coal export concentration, and environmental quality. Accordingly, the use of the ARDL model to investigate both short-run dynamics and long-run equilibrium relationships is fully justified.

Table 5. ARDL estimation results

Variable		Coefficient	Std. Error	t-Statistic	Prob.*
EG (-1)		-0.263992	0.187638	-1.406924	0.2023
CECR		0.108760	0.020223	5.378163	0.0010
EQI		-0.132628	0.119808	-1.107007	0.3049
EQI (-1)		-0.095171	0.129341	-0.735813	0.4858
EQI (-2)		-0.345571	0.117534	-2.940183	0.0217
C		39.43254	8.076968	4.882097	0.0018
R-squared	0.892794	Mean dependent var	4.944615		
Adjusted R-squared	0.816218	S.D. dependent var	2.143286		
S.E. of regression	0.918822	Akaike info criterion	2.972590		
Sum squared resid	5.909642	Schwarz criterion	3.233336		
Log likelihood	-13.32183	Hannan-Quinn criter	2.918995		
F-statistic	11.65896	Durbin-Watson stat	2.152232		
Prob (F-statistic)	0.002748				

Long-run estimates obtained through the level equation are shown in Table 6. The results indicate that environmental quality, represented by the coefficient on EQI(-1), has a negative and significant long-run effect on economic growth (p = 0.0017). This implies that deteriorating environmental conditions are associated with slower long-run economic growth. Conversely, there is no empirical evidence supporting a long-run effect of CECR. In the EViews output, CECR appears in the long-run form as Z = Z(-1) + D(Z), so its coefficient cannot be interpreted as a long-run parameter.

Therefore, environmental quality stands as the only significant long-run determinant of economic growth, while coal export dominance exerts influence only in the short run.

Table 6. Long-term ARDL estimation results

Variable	Coefficient	Std. Error	t-Statistic	Prob.
C	39.43254	8.076968	4.882097	0.0018
EG(-1)*	-1.263992	0.187638	-6.736345	0.0003
CECR**	0.108760	0.020223	5.378163	0.0010
EQI (-1)	-0.573370	0.116732	-4.911859	0.0017
D(EQI)	-0.132628	0.119808	-1.107007	0.3049
D(EQI(-1))	0.345571	0.117534	2.940183	0.0217

Note: CECR appears in the long-run table as the transformation "Z = Z(-1) + D(Z)," and thus cannot be interpreted as a long-run coefficient.

3.5 Error-correction model estimation

The short-run dynamics are presented in Table 7. The ECM estimation results indicate that none of the differenced variables—whether changes in CECR, changes in EQI, or their respective lags—are statistically significant at conventional levels. This condition is common in annual data with small sample sizes, where short-run variation is relatively limited and typically influenced more by random fluctuations than by substantial structural changes.

Table 7 shows that the ECT(-1) coefficient is negative, as predicted by cointegration theory. Its sign indicates the presence of an adjustment mechanism toward the long-run equilibrium when deviations occur in the previous period. However, the p-value of 0.2126 shows that this adjustment process is not statistically significant. In other words, although the correction toward long-run equilibrium moves in the theoretically expected direction, its speed is not strong enough to be confirmed econometrically.

The two structural dummy variables—DUM_CECR15 and DUM_CECR22—are also not significant. This suggests that the regime shifts identified by the BP test in 2015 and 2022 did not generate measurable short-run effects on economic growth. The regulatory changes or coal market shocks in those years appear to have had a stronger influence on long-run dynamics, as indicated by the ARDL results, rather than on short-run fluctuations.

Overall, the ECM results indicate that the effects of coal export dependence and environmental quality on Jambi's economic growth operate primarily through long-run mechanisms. Short-run effects are not statistically significant, suggesting that annual growth dynamics are shaped more by structural factors reflected in the long-run relationship than by year-to-year volatility.

3.6 Parameter stability testing

To ensure that the parameters in the estimated ARDL model remain stable throughout the observation period, two key diagnostic tests were conducted: the Cumulative Sum (CUSUM) and the Cumulative Sum of Squares (CUSUMSQ) tests. These tests are part of the Recursive Estimates procedure and are widely recommended in the econometric literature for detecting potential parameter instability [41]. The results are illustrated in Figure 2.

Table 7. Short-term ARDL-ECM estimation

Variable		Coefficient	Std. Error	t-Statistic	Prob.
C		0.136563	0.717967	0.190208	0.8584
D(CECR)		0.129288	0.083915	1.540708	0.1982
D(EQI)		-0.171337	0.367001	-0.466856	0.6649
D(EQI (-1))		-0.032413	0.331599	-0.097748	0.9268
ECT(-1)		-1.531878	1.033880	-1.481679	0.2126
DUM_CECR15		-0.746826	2.408031	-0.310140	0.7719
DUM_CECR22		-2.676176	3.890996	-0.687787	0.5294
R-squared	0.717812	Mean dependent var	-0.266667		
Adjusted R-squared	0.223982	S.D. dependent var	2.211969		
S.E. of regression	1.948565	Akaike info criterion	4.406784		
Sum squared resid	15.18762	Schwarz criterion	4.730055		
Log likelihood	-18.44071	Hannan-Quinn criter	4.287098		
F-statistic	1.453562	Durbin-Watson stat	2.107743		
Prob(F-statistic)	0.377157				

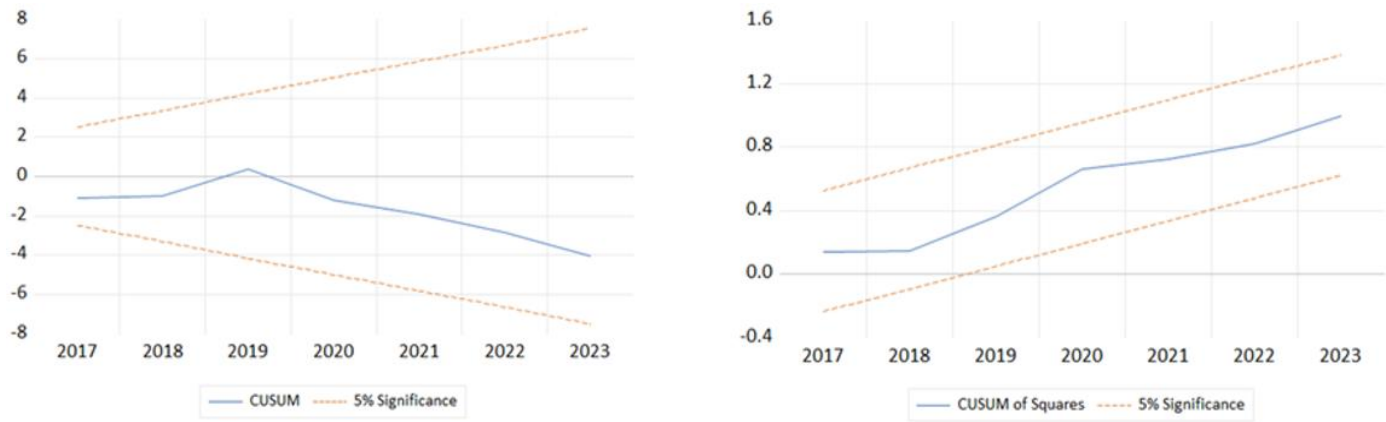

Figure 2. The plot of cumulative sum (CUSUM) and cumulative sum of squares (CUSUMSQ)

The first panel (CUSUM) displays the dynamics of the accumulated recursive residuals. The CUSUM line trends downward from 2019 and remains within the 5 percent significance bounds across the entire sample period. This pattern indicates the absence of major structural shocks or abrupt shifts in model parameters. In other words, the estimated ARDL coefficients are stable over time.

The second panel (CUSUMSQ) reflects the stability of the residual variance. Although an upward trend appears after 2020, the CUSUMSQ line stays within the 5 percent critical bounds, suggesting that the increase is not large enough to signal variance instability. Thus, the observed fluctuations in variance remain within an acceptable range.

Overall, both tests show that the CUSUM and CUSUMSQ lines remain within the 5 percent critical bounds throughout the estimation period. No patterns emerge suggesting parameter instability, and the ARDL model is confirmed to be stable with respect to both coefficient behavior and residual variance.

Given this evidence, the ARDL model used in the analysis is reliable for examining both the short-run dynamics and the long-run relationships among coal export dependence (CECR), environmental quality (EQI), and economic growth (EG) in Jambi Province. These findings are also consistent with the econometric literature, which emphasizes parameter stability as a fundamental requirement for valid time-series inference.

4. DISCUSSION

The empirical findings can be interpreted in the context of recent policy changes, environmental events, and global energy transitions affecting Jambi Province. The BP structural break test identified three significant breakpoints: CECR in 2015 and 2022, and EQI in 2018. These correspond to major developments, including strengthened environmental governance and stricter enforcement of coal mining regulations in Jambi Province following escalating environmental and social pressures [19], the 2018 haze crisis that prompted stricter environmental regulation [42], and the global surge in coal demand in 2022 driven by geopolitical disruptions such as the Russia–Ukraine conflict [43, 44].

The ARDL long-run estimation indicates that coal export concentration has no significant impact on economic growth. This result reinforces the value of CECR as a structural indicator that captures deeper vulnerabilities associated with commodity dependence. While coal exports generate short-term revenue, they do not provide a stable or sustainable foundation for long-run development. These findings align with the neutrality hypothesis observed in Turkey, where coal consumption was found to have no causal effect on GDP [44], as well as broader international evidence showing that resource-dependent economies often struggle to achieve stable long-term growth despite temporary revenue gains [29]. The uneven growth trajectory in Jambi, despite rising export dependence, reflects the structural fragility commonly associated with natural resource specialization in volatile markets [45].

In contrast, environmental quality emerges as a more important structural determinant of long-run economic performance. The significant negative long-run coefficient of EQI(–1) indicates that environmental degradation imposes persistent constraints on growth. This finding is consistent with research demonstrating that environmental deterioration—driven by pollution, land degradation, and ecological stress—erodes long-term productivity and public welfare. Although the short-run ECM results do not show statistically significant effects of changes in environmental quality, the long-run evidence emphasizes that ecological conditions remain fundamental to sustained economic development.

It is important to note that none of the short-run coefficients in the ECM—including changes in CECR or EQI—are statistically significant. This suggests that short-term changes in export concentration or environmental conditions do not meaningfully drive annual fluctuations in economic growth. Instead, the primary channels through which both variables affect growth are long-run and structural in nature. This pattern is typical in small-sample annual data, where year-to-year variation is limited, and structural forces shape broader development trajectories more than short-term shocks.

Given the very limited sample size (n = 15), the statistical power of the estimation is low, increasing the risk of failing to detect true effects (Type II error). Therefore, coefficients with p-values approaching the 10 percent threshold are treated as preliminary indications (marginal evidence) that should be interpreted with caution.

The structural break dummies included in the ECM (2015 and 2022) also show no short-run significance, indicating that the identified breaks primarily influence long-run equilibrium relationships rather than producing sharp, immediate changes in economic performance. This is consistent with the theory that policy reforms and global energy shocks typically alter long-term structural conditions—such as investment patterns, environmental enforcement, or market expectations—rather than causing short-lived output fluctuations. Although more flexible time-varying parameter models (such as TVP-VAR or Kalman filter approaches) could capture such effects more precisely, these techniques require substantially larger samples than those available in this study.

At the global level, coal is becoming less viable as a development driver due to accelerating renewable energy adoption, declining clean energy costs, and strengthened climate commitments [46]. Developing countries are particularly exposed to the environmental and health burdens associated with coal extraction and consumption, reinforcing the urgency for resource-dependent regions like Jambi to adapt to shifting global and domestic conditions. These trends emphasize the need for long-term diversification strategies that reduce dependence on coal and strengthen regional resilience.

Lessons from South and Southeast Asia suggest that green investment, financial-sector development, and inclusive rural industries can help buffer economies from commodity price shocks [45]. Evidence from OECD countries further demonstrates that reducing fossil fuel dependence enhances economic stability and resilience [47]. In Jambi, agrotourism offers a tangible pathway for diversification by leveraging natural and cultural assets to promote sustainable livelihoods and environmental stewardship [48, 49]. Agriculture and horticulture-based industries also present opportunities for inclusive and sustainable growth [50].

Taken together, the results highlight the need for a forward-looking development strategy in Jambi that integrates regulatory reform, sustained green investment, and structural transformation toward low-carbon sectors. The province's long-term prosperity will depend on its ability to reduce

dependence on coal and transition toward diversified, environmentally sustainable economic activities. While this transition poses challenges, it offers substantial opportunities for more resilient growth and improved social and ecological outcomes.

This study has an important limitation related to data availability. The analysis draws on only 15 annual observations (2009–2023), which inevitably reduces statistical power and increases the sensitivity of the estimated relationships to model specification. Although the ARDL–Bounds approach is widely regarded as one of the most appropriate methods for small-sample time-series data, the limited number of observations warrants caution in interpreting the findings. Future research could benefit from using higher-frequency data (e.g., quarterly series) or from applying bootstrap-based ARDL and Bayesian estimation techniques to enhance the robustness of statistical inference.

5. CONCLUSIONS

This study examined the long- and short-run dynamics among coal export dependence, environmental quality, and economic growth in Jambi Province, Indonesia, using the ARDL framework supported by structural break and parameter stability tests. The results show that coal export concentration does not exert a significant long-term influence on regional economic growth, underscoring the structural limitations of development strategies that rely heavily on extractive industries. This finding reflects broader evidence that commodity-dependent economies often struggle to translate resource revenues into sustained, broad-based development.

Environmental quality, by contrast, emerges as a key structural determinant of long-run economic performance. The significant negative long-run coefficient for EQI indicates that environmental degradation imposes persistent constraints on growth, highlighting the central role of ecological conditions in shaping regional economic resilience. In the short run, however, neither changes in coal export concentration nor changes in environmental quality exhibit statistically significant effects, suggesting that annual growth fluctuations are not driven by temporary shocks but rather by deeper structural patterns.

These results emphasize the need for Jambi Province to reduce its reliance on coal-based development and strengthen environmental governance as part of a broader transition toward sustainable, resilient economic pathways. Policies that encourage diversification, promote environmental stewardship, and support low-carbon sectors can help buffer the region against volatility in global coal markets while fostering more inclusive long-term development.

Future research could advance these findings by incorporating higher-frequency or longer-term data, enabling more robust inference and deeper exploration of dynamic adjustment mechanisms. Comparative studies across Indonesian provinces, as well as analyses that integrate multidimensional indicators such as health, labor markets, and social equity, would also provide a more comprehensive understanding of how resource dependency interacts with environmental and socio-economic outcomes. The experience of Jambi offers valuable lessons for other resource-intensive regions facing similar development–environment trade-offs, and contributes to ongoing discussions surrounding Indonesia's Just Energy Transition Partnership (JETP) and the pursuit of equitable, sustainable regional transformation.

REFERENCES

[1] The Guardian. (2024). Coal use to reach new peak and remain at near record levels for years. https://www.theguardian.com/business/2024/dec/18/coal-use-to-reach-new-peak-and-remain-at-near-record-levels-for-years.

[2] Lin, B., Lan, T. (2025). The influence of coal price uncertainty on investment and consumption dynamics: Evidence from China. Energy Policy, 198: 114517. https://doi.org/10.1016/j.enpol.2025.114517

[3] Murtezaj, I.M., Rexhepi, B.R., Dauti, B., Xhafa, H. (2024). Mitigating economic losses and prospects for the development of the energy sector in the Republic of Kosovo. Economics of Development, 23(3): 82-92. https://doi.org/10.57111/econ/3.2024.82

[4] Rani, R., Kumar, N. (2019). On the causal dynamics between economic growth, trade openness and gross capital formation: Evidence from BRICS countries. Global Business Review, 20(3): 795-812. https://doi.org/10.1177/0972150919837079

[5] Adekunle, I.A., Maku, O., Williams, T., Gbagidi, J., Ajike, E.O. (2023). Natural resource endowments and growth dynamics in Africa: Evidence from panel cointegrating regression. Management of Environmental Quality: An International Journal, 34(5): 1295-1313. https://doi.org/10.1108/MEQ-10-2020-0241

[6] Chakraborty, S., Sarkar, P. (2020). From the classical economists to empiricists: A review of the terms of trade controversy. Journal of Economic Surveys, 34(5): 1111-1133. https://doi.org/10.1111/joes.12390

[7] Kelly, A.M., Ketu, I., Tchapchet Tchouto, J.E., Nembot Ndeffo, L. (2024). Investigating the link between exhaustion of natural resources and economic complexity in sub-Saharan Africa. African Development Review, 36(3): 486-502. https://doi.org/10.1111/1467-8268.12767

[8] Albrieu, R., Palazzo, G. (2020). Mapping social conflicts in natural resources: A text mining study of extractive activities. CEPAL Review, 2020(131): 27-54. https://doi.org/10.18356/16840348-2020-131-2

[9] Sadik-Zada, E.R., Loewenstein, W., Hasanli, Y. (2019). Commodity revenues, agricultural sector and the magnitude of deindustrialization: A novel multisector perspective. Economies, 7(4): 113. https://doi.org/10.3390/economies7040113

[10] Sutriadi, R., Muhammad Ihsan Yudanto, Ridho Ansori Romdan, Bintang Atha Araminta, Alifa, I. (2024). The multiple effects of mining activities on the ecology and economic development in East Kalimantan Province, Indonesia. Evergreen, 11(2): 1016-1027. https://doi.org/10.5109/7183384

[11] Mahmood, H. (2025). An empirical assessment of oil, natural gas, mineral, and forest rents on CO_2 emissions in Saudi Arabia. Challenges in Sustainability, 13(3): 366-376. https://doi.org/10.56578/cis130304

[12] Jaeger, W.K., Kolpin, V., Siegel, R. (2023). The environmental Kuznets curve reconsidered. Energy Economics, 120: 106561. https://doi.org/10.1016/j.eneco.2023.106561

[13] Ozturk, I., Majeed, M.T., Khan, S. (2021). Decoupling and decomposition analysis of environmental impact from economic growth: A comparative analysis of Pakistan, India, and China. Environmental and Ecological Statistics, 28(4): 793-820. https://doi.org/10.1007/s10651-021-00495-3
[14] Pata, U.K., Kumar, A. (2021). The influence of hydropower and coal consumption on greenhouse gas emissions: A comparison between China and India. Water, 13(10): 1387. https://doi.org/10.3390/w13101387
[15] Prasetyanto, K., Sari, F. (2021). Environmental Kuznets curve: Economic growth with environmental degradation in Indonesia. International Journal of Energy Economics and Policy, 11(5): 622-628. https://doi.org/10.32479/ijeep.11609
[16] Finkelman, R.B., Wolfe, A., Hendryx, M.S. (2021). The future environmental and health impacts of coal. Energy Geoscience, 2(2): 99-112. https://doi.org/10.1016/j.engeos.2020.11.001
[17] Pudasainee, D., Kurian, V., Gupta, R. (2020). Coal. In Future Energy, pp. 21-48. https://doi.org/10.1016/B978-0-08-102886-5.00002-5
[18] Rochgiyanti, Susanto, H., Nurdianti, S. (2021). Impact of coal mining company expansion for transmigrants in Wonorejo Village, Juai District, Balangan Regency. In Proceedings of the 2nd International Conference on Social Sciences Education (ICSSE 2020), pp. 244-248. https://doi.org/10.2991/assehr.k.210222.039
[19] Ternando, A. (2023). Legal analysis in mitigating environmental impacts due to coal mining in Batanghari Regency, Jambi Province. International Journal of Multidisciplinary: Applied Business and Education Research, 4(12): 4258-4269. https://doi.org/10.11594/ijmaber.04.12.09
[20] Gasparini, A. (2022). Norway's opportunities via the Sovereign Wealth Fund and the European Green Deal. International Journal of Environmental Studies, 80(5): 1445-1455. https://doi.org/10.1080/00207233.2022.2037335
[21] Yossinomita, P., MG, U., FN, E., Suratno, E., Pasaribu, J.P.K., Sidik, A. (2022). Analysis of the effects of economic growth and development on inequality and the environment. Review of Economics and Finance, 20(1): 457-468.
[22] Nugroho, N., Priyanto, S., Triatmodjo, B. (2025). Mode choice and spatial distribution of coal transport in Jambi, Indonesia. INERSIA Lnformasi Dan Ekspose Hasil Riset Teknik Sipil Dan Arsitektur, 21(1): 116-124. https://doi.org/10.21831/inersia.v21i1.64336
[23] Sekaringtias, A., Verrier, B., Cronin, J. (2023). Untangling the socio-political knots: A systems view on Indonesia's inclusive energy transitions. Energy Research & Social Science, 95: 102911. https://doi.org/10.1016/j.erss.2022.102911
[24] Reuters. (2024). Indonesia can reach net zero emissions before 2050, president says. https://www.reuters.com/business/environment/indonesia-can-reach-net-zero-emissions-before-2050-president-says-2024-11-20/.
[25] The Associated Press. (2024). Indonesia's Prabowo plans to retire all fossil fuel plants in 15 years, but experts are skeptical. https://apnews.com/article/2d8fd110a855a37167d49211e65fc51d.
[26] Qian, X., Wang, D., Wang, J., Chen, S. (2021). Resource curse, environmental regulation and transformation of coal-mining cities in China. Resources Policy, 74: 101447. https://doi.org/10.1016/j.resourpol.2019.101447
[27] Avom, D., Ntsame Ovono, N., Ongo Nkoa, E. (2022). Revisiting the effects of natural resources on income inequality in Sub-Saharan Africa. International Journal of Development Issues, 21(3): 389-412. https://doi.org/10.1108/IJDI-02-2022-0036
[28] Egger, E.M., Keller, M., Mouco, J.B. (2024). The socio-economic impact of coal mining in Mozambique. Journal of African Economies, 34(2): 161-183. https://doi.org/10.1093/jae/ejae006
[29] Saeed, K.A. (2021). Revisiting the natural resource curse: A cross-country growth study. Cogent Economics & Finance, 9(1): 2000555. https://doi.org/10.1080/23322039.2021.2000555
[30] Priyagus, P. (2024). Coal-based economy Kuznet kurve's environmental approach in East Kalimantan Province. INOVASI: Jurnal Ekonomi, Keuangan, dan Manajemen, 20(4): 789-795. https://doi.org/10.30872/jinv.v20i4.2172
[31] Fatah, L. (2008). The impacts of coal mining on the economy and environment of South Kalimantan Province, Indonesia. ASEAN Economic Bulletin, 25(1): 85-98.
[32] Sugiawan, Y., Managi, S. (2016). The environmental Kuznets curve in Indonesia: Exploring the potential of renewable energy. Energy Policy, 98: 187-198. https://doi.org/10.1016/j.enpol.2016.08.029
[33] Erkan, B., Bozduman, E.T. (2021). Analysis of export concentrations of China and Japan on product basis. ASSAM Uluslararası Hakemli Dergi, 8(19): 140-146.
[34] UNCTAD. (2019). Indicators explained #3: Export product concentration index. https://unctadstat.unctad.org/EN/IndicatorsExplained/statie2019d1_en.pdf.
[35] Orientation and Growth. https://wits.worldbank.org/WITS/WITS/TradeIndicatorsHelp/TradeOutcomes_Help.htm.
[36] Bednar-Friedl, B., Farmer, K. (2010). Nationally and internationally optimal climate policies: External balances versus environmental preferences. CESifo Economic Studies, 57(3): 432-457. https://doi.org/10.1093/cesifo/ifq020
[37] Mano, H., Combary, O.S. (2025). Effects of export diversification on economic vulnerability: The case of WAEMU countries. The Journal of International Trade & Economic Development, 34(7): 1872-1892. https://doi.org/10.1080/09638199.2025.2482542
[38] UNDP. (2012). Towards Human Resilience: Sustaining MDG Progress in an Age of Economic Uncertainty. United Nations Development Programme.
[39] Cansado-Bravo, P., Rodríguez-Monroy, C. (2020). The effects of structural breaks on energy resources in the long run: Evidence from the last two oil price crashes before COVID-19. Designs, 4(4): 49. https://doi.org/10.3390/designs4040049
[40] Tang, C. (2021). The linkages among Chinese coal and international fossil fuel markets. Journal of Environmental Information Science, 2021(1): 1-7. https://doi.org/10.11492/ceispapersen.2021.1_1
[41] Pesaran, M.H., Shin, Y., Smith, R.J. (2001). Bounds

testing approaches to the analysis of level relationships. Journal of Applied Econometrics, 16(3): 289-326. https://doi.org/10.1002/jae.616
[42] Ministry of Environment and Forestry Republic of Indonesia. (2018). The state of Indonesia's forests 2018. https://wplibrary.co.id/sites/default/files/SoiFo.pdf.
[43] Apal'kova, T.G., Levchenko, K.G. (2022). Major trends in the global coal market in the short term. Ugol', (11): 32-37. https://doi.org/10.18796/0041-5790-2022-11-32-37
[44] Yanguas-Parra, P.A., Malz, N., Oei, P.Y., Furnaro, A., et al. (2023). Perspective: How a short-term relapse to coal could put exporting countries and just transition processes at risk. Energy Research & Social Science, 97: 102989. https://doi.org/10.1016/j.erss.2023.102989
[45] Alhassan, A., Ozturk, I., AL-Zyoud, M.F., Bekun, F.V. (2024). Coal consumption-environmental sustainability nexus in developed and developing major coal-consuming economies. Heliyon, 10(4): e25619. https://doi.org/10.1016/j.heliyon.2024.e25619
[46] Hauenstein, C., Holz, F. (2021). The U.S. coal sector between shale gas and renewables: Last resort coal exports? Energy Policy, 149: 112097. https://doi.org/10.1016/j.enpol.2020.112097
[47] Jin, T., Kim, J. (2018). Coal consumption and economic growth: Panel cointegration and causality evidence from OECD and non-OECD countries. Sustainability, 10(3): 660. https://doi.org/10.3390/su10030660
[48] Rustiadi, E., Pravitasari, A.E., Priatama, R.A., Singer, J., Junaidi, J., Zulgani, Z., Sholihah, R.I. (2023). Regional development, rural transformation, and land use/cover changes in a fast-growing oil palm region: The case of Jambi Province, Indonesia. Land, 12(5): 1059. https://doi.org/10.3390/land12051059
[49] Zulgani, Z., Junaidi, J., Hastuti, D., Rustiadi, E., Pravitasari, A.E., Asfahani, F.R. (2023). Understanding the emergence of rural agrotourism: A study of influential factors in Jambi Province, Indonesia. Economies, 11(7): 180. https://doi.org/10.3390/economies11070180
[50] Junaidi, J., Yulmardi, Y., Hardiani, H. (2020). Food crops-based and horticulture-based villages potential as growth center villages in Jambi Province, Indonesia. Journal of Critical Reviews, 7(9): 514-519. https://doi.org/10.31838/jcr.07.09.102