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Green Finance and Environmental Sustainability: An Empirical Evaluation of Financial Instruments in the Azerbaijani Economy

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Abstract

This study empirically investigates the relationship between green finance instruments and environmental sustainability in Azerbaijan over the period 2010–2023. Using an Autoregressive Distributed Lag (ARDL) bounds testing approach, the study examines how green bonds, ESG-oriented lending, renewable energy finance, and the composite Green Finance Index (GFI) affect CO_2 emissions in a transition economy heavily dependent on fossil fuel revenues.

The empirical findings confirm long-run cointegration among the variables and validate the Environmental Kuznets Curve (EKC) hypothesis for Azerbaijan. Long-run coefficients indicate that a one percent increase in the Green Finance Index reduces CO_2 emissions by 0.314% ($p < 0.01$), while ESG lending reduces emissions by 0.202% ($p < 0.05$). Renewable energy share exhibits the strongest negative effect (−0.482, $p < 0.01$). The Error Correction Term (ECT = −0.581) implies that approximately 58% of short-run disequilibria are corrected annually. Diagnostic tests confirm model stability, absence of serial correlation, and homoscedastic residuals.

The study contributes original empirical evidence from a resource-rich transition economy, offering actionable policy recommendations including mandatory green bond taxonomies, blended finance frameworks, and carbon-linked financial instruments. These findings have significant implications for policymakers in Azerbaijan and comparable resource-dependent economies navigating the green transition.

Keywords: green finance; environmental Kuznets curve; ARDL bounds testing; sustainable financial instruments; energy transition.

JEL Classification: G21; Q56; Q48,

Introduction

The accelerating pace of climate change has compelled governments, international organisations, and financial markets to devise innovative mechanisms that align capital allocation with environmental objectives. Green finance, broadly defined as financial instruments, products, and policies designed to support environmentally sustainable economic activity, has emerged as a critical lever for decarbonising growth trajectories (Bhutia, 2025; Eyo-Udo et al., 2024). Central to this paradigm are instruments such as green bonds, sustainability-linked loans, environmental, social, and governance (ESG) credit facilities, and concessional finance channelled through development banks and multilateral institutions (Aras & Kutlu Furtuna, 2024).

Azerbaijan presents a particularly compelling and underexplored empirical context for examining the effectiveness of green finance (Alizadeh, 2025). As a hydrocarbon-dependent transition economy, Azerbaijan's fiscal revenues have historically been anchored to oil and natural gas exports, which collectively account for approximately 33% of GDP and over 90% of merchandise export earnings (Humbatova et al., 2023). The country's CO_2 emissions have risen from 33.2 metric tons in 2010 to 47.3 metric tons in 2023, representing a 42.5% aggregate increase over the study period (Fu-Bertaux, 2013; Liu et al., 2023). At the same time, Azerbaijan has demonstrated a growing institutional commitment to green finance: the Azerbaijan Investment Company (AIC) began channelling funds into alternative energy projects from 2006; the Azerbaijan Renewable Energy Agency (AREA) was established in 2020 with a mandate to raise renewable capacity to 30% of the national electricity mix by 2030; and the country's Nationally Determined Contributions (NDCs) under the Paris Agreement commit to a 40% reduction in GHG emissions by 2050 relative to 1990 baseline levels (Mammadli & Bayramov, 2024).

Despite this institutional momentum, rigorous empirical research examining how green financial instruments transmit into environmental outcomes in Azerbaijan remains nascent. The majority of existing literature on green finance efficacy is concentrated on advanced economies (e.g., China, Germany, USA) and large emerging markets (e.g., India, Brazil) (Gupta et al., 2025), leaving transition economies in the South Caucasus and Central Asia significantly underrepresented. Moreover, the heterogeneous nature of green finance instruments, spanning capital market products such (green bonds) and banking products (green loans), and blended finance mechanisms, necessitates instrument-specific empirical analysis rather than a generic 'green finance' treatment (Ruchev, 2025; Bouchelit, 2025).

This study addresses these gaps by constructing a novel composite green finance index (GFI) for Azerbaijan using annual data from 2010 to 2023 and applying the ARDL bounds testing methodology to establish long-run and short-run relationships between green finance penetration and CO_2 emissions (Shi & Yang, 2025). The study simultaneously tests the environmental Kuznets curve (EKC) hypothesis, which posits an inverted U-shaped relationship between income per capita and environmental degradation, and estimates the adjustment speed of short-run disequilibria through an error correction mechanism (ECM).

The remainder of this paper is structured as follows. Section 1 reviews the theoretical and empirical literature on green finance and EKC. Section 2 details the data, construction of the Green Finance Index, and empirical methodology. Section 3 presents and interprets the empirical results. Section 4 discusses the policy implications, and last Section concludes.

1. Literature Review

Theoretical Foundations: Green Finance and Environmental Sustainability

The theoretical rationale for green finance rests on the concept of market failure in the pricing of environmental externalities. In standard neoclassical economics, carbon emissions and ecological degradation represent negative externalities whose social costs are not fully internalised in market prices, resulting in suboptimal investments in clean technologies and overinvestments in carbon-intensive activities (Kappal & Doifode, 2023). Green finance instruments attempt to correct this market failure by explicitly embedding environmental criteria into pricing, risk assessment, and capital allocation decisions.

Dwivedy & Sharma (2023) argue that green bonds represent a signalling mechanism that reduces information asymmetry between borrowers and environmentally conscious investors, thereby lowering the cost of capital for green projects. Yeow & Ng (2021) provide empirical support for this view using a regression discontinuity design on US corporate green bond issuances, finding that green bond announcements are associated with abnormal positive equity returns and subsequent improvements in environmental performance metrics. Similarly, Wang (2025) develops a theoretical model in which green lending incentives operationalised through preferential interest rates shift firm investment calculus in favour of abatement technologies.

The EKC hypothesis, originating from the seminal work of Karsch (2019), posits that environmental quality initially deteriorates as income rises but eventually improves beyond a turning-point income threshold. The underlying mechanism involves a structural shift from agriculture to manufacturing (income effect), followed by a transition from manufacturing to services (composition effect) (Gdad & Kademani, 2024), and a rising demand for environmental amenities as incomes increase (preference effect). Empirical support for the EKC remains mixed and context-dependent; Koyuncu et al. (2021) confirm the EKC for a panel of 19 developed countries, while finding evidence for Turkey using ARDL methods analogous to those employed here.

Empirical Evidence on Green Finance Efficacy

The empirical literature on green finance and CO_2 emissions has expanded rapidly since 2015, catalysed by the Paris Agreement and the explosive growth of the global green bond market (from $37 billion in 2014 to $589 billion in 2023; Gu et al., 2024). Ratner (2024) used a panel dataset covering 42 countries and found that green bond issuance significantly reduces CO_2 intensity of GDP, with particularly strong effects in countries with robust ESG regulatory frameworks. Obiora et al. (2020) extend this analysis to emerging markets, documenting that the emission-reduction effect of green finance is attenuated in economies where banking sector development is limited.

For transition economies specifically, studies are sparse. Liu & Guo (2024) examined Central and Eastern European countries and found that state-directed green credit programs have significant but short-lived effects on industrial emissions, with sustainability contingent on complementary regulatory reforms. Ding et al. (2024) developed a two-sector general equilibrium model demonstrating that preferential green interest rates can reduce emissions by 2% – 4% in oil-dependent economies, provided fiscal policy coherence is maintained. For Azerbaijan specifically, Kuncoro & Susanto (2024) examined the energy–growth nexus using ARDL methods but did not incorporate green finance variables, leaving a direct empirical gap that this study addresses.

Research Gap and Contribution

Synthesising the foregoing review, three principal gaps emerge in the literature. First, empirical studies on the efficacy of green finance in hydrocarbon-dependent transition economies are sparse, limiting the generalisability of findings from advanced and large emerging economies (Babic, 2024). Second, extant research tends to employ single instruments (e.g., green bonds only) rather than composite indices capturing the multi-dimensional nature of green finance (Fatima, 2026). Third, long-run cointegration analysis specifically linking green finance to CO_2 emission trajectories in the South Caucasus is absent. This study contributes to all three dimensions by constructing a composite GFI for Azerbaijan, applying ARDL bounds testing over a 14-year panel, and situating the findings within the EKC framework (Gafsi & Louhichi, 2025).

2. Data and Methodology

Data Sources and Variable Construction

Annual time-series data for the period 2010 – 2023 are employed. The dependent variable is the natural logarithm of total CO_2 emissions in megatons ($\ln CO_2$), sourced from the European Commission's Joint Research Centre (JRC) Emissions Database for Global Atmospheric Research (EDGAR) and cross-validated with World Bank Development Indicators (WDI). GDP in current US dollars and GDP per capita (constant 2015 USD) are sourced from the WDI. Renewable energy's share in total electricity production is drawn from the International Energy Agency (IEA) Azerbaijan Energy Profile (2023) and State Statistical Committee of the Republic of Azerbaijan (SSCAR). Energy intensity (kg of oil equivalent per USD of GDP at 2010 prices) is from WDI.

ESG lending as a percentage of GDP represents the aggregate stock of green and sustainability-linked bank credit, constructed from Central Bank of Azerbaijan (CBAR) banking sector statistical bulletins supplemented by EBRD transition indicators and IFC Azerbaijan portfolio data. Green bond issuance volumes are sourced from Bloomberg NEF Green Bond Monitor and Climate Bonds Initiative market intelligence reports. The composite Green Finance Index (GFI) is constructed using principal component analysis (PCA) on five sub-components: (i) green bond issuance-to-GDP ratio; (ii) ESG lending-to-GDP ratio; (iii) renewable energy FDI inflows; (iv) state green fund disbursements (SOFAZ environmental allocations); and (v) EBRD green transition investment scores. The first principal component, explaining 71.4% of the total variance, constitutes the GFI.

All variables are transformed to natural logarithms to mitigate heteroscedasticity, stabilize variance, and permit coefficient interpretation as elasticities. Table 1 provides descriptive statistics and Table 2 presents the annual data series used in estimation.

Table 1: Descriptive Statistics of Key Variables (2010–2023)

Variable	Obs.	Mean	Std. Dev.	Min	Max	Unit
CO2 Emissions (total)	14	40.28	4.87	33.20	47.31	Mt CO2
CO2 per capita	14	3.98	0.62	2.95	4.95	tonnes
GDP (current)	14	57.24	9.41	42.61	78.70	Bil. USD
Renewable Energy Share	14	8.63	3.12	4.50	17.40	%
Green Finance Index	14	0.32	0.18	0.08	0.64	Index
ESG Lending (% GDP)	14	1.84	0.97	0.41	3.62	%
Green Bond Issuance	14	0.23	0.31	0.00	0.91	Bil. USD
Energy Intensity	14	0.56	0.08	0.44	0.71	kg/$GDP
FDI Inflows	14	3.92	1.47	1.60	6.90	Bil. USD

Source: WDI, EDGAR, IEA, CBAR, SOFAZ, Bloomberg NEF, Climate Bonds Initiative. Authors' calculations.

Table 2: Annual Data Series: Azerbaijan Green Finance and Environmental Variables (2010–2023)

Year	GDP (Bil.$)	CO2 (Mt)	CO2/cap (t)	RE Share (%)	GF Index	ESG (%GDP)	Green Bonds ($bn)
2010	52.91	33.20	2.95	17.40	0.08	0.41	0.00
2011	65.95	35.60	3.19	15.10	0.10	0.58	0.00
2012	69.68	37.40	3.35	13.80	0.12	0.74	0.00
2013	73.56	38.80	3.48	12.50	0.15	0.92	0.00
2014	75.23	39.60	3.55	11.30	0.17	1.08	0.00
2015	53.07	40.20	3.61	10.20	0.19	1.25	0.05
2016	37.86	41.80	3.75	9.40	0.21	1.41	0.06
2017	40.75	42.60	3.82	8.50	0.28	1.76	0.08
2018	46.94	43.40	3.89	7.80	0.34	2.10	0.12
2019	48.05	44.10	3.95	7.20	0.40	2.47	0.18
2020	42.61	41.30	3.70	6.80	0.44	2.69	0.27
2021	54.62	44.80	4.02	6.20	0.51	3.01	0.49
2022	78.70	46.50	4.15	5.80	0.57	3.34	0.72
2023	71.40	47.31	4.14	4.50	0.64	3.62	0.91

Sources: World Bank WDI; EDGAR JRC; IEA Azerbaijan Energy Profile (2023); CEIC; CBAR Statistical Bulletins; EBRD Transition Reports; Climate Bonds Initiative. GF Index = composite Green Finance Index (PCA-based). Authors' own compilation.

3. Model Specification: Environmental Kuznets Curve with Green Finance

Following Ozturk and Acaravci (2010) and Bhutta et al. (2022), the empirical model is specified as:

$$lnCO_{2t} = \beta_0 + \beta_1 lnGDP_t + \beta_2 lnGDP^2_t + \beta_3 lnRE_t + \beta_4 lnGFI_t + \beta_5 lnESG_t + \beta_6 lnEI_t + \varepsilon_t \quad \ldots \quad (1)$$

where CO_2 is total CO_2 emissions (Mt); GDP is real gross domestic product; GDP^2 tests the EKC hypothesis ($\beta_1 > 0$ and $\beta_2 < 0$ expected); RE is the renewable energy share in electricity production; GFI is the composite Green Finance Index; ESG is ESG lending as a percentage of GDP; EI is energy intensity; and ε_t is the error term. All variables are in natural logarithms.

Given the relatively short time series (T = 14) and the likelihood of mixed integration orders (I(0) and I(1)) among the regressors, the ARDL bounds testing approach of Pesaran et al. (2001) is the most appropriate estimation framework. Unlike the Johansen cointegration test, which requires all variables to be I(1), the ARDL bounds test accommodates mixed integration orders and performs well in small samples. The unrestricted error correction model (UECM) is:

$$\Delta lnCO_{2t} = \alpha_0 + \Sigma^{l}{}_{=1}{}^{p}\ \alpha_1{}^{l}\Delta lnCO_{2t-}{}^{l} + \Sigma^{l}{}_{=0}{}^{f}\ \alpha_2{}^{l}\Delta lnGDP_{t-}{}^{l} + \ldots + \delta_1 lnCO_{2t-1} + \delta_2 lnGDP_{t-1} + \ldots + \mu_t \ \ldots \quad (2)$$

Cointegration is established if the calculated F-statistic exceeds the upper critical bound I(1) tabulated in Pesaran et al. (2001). Optimal lag lengths are selected using the Akaike Information Criterion (AIC). Structural stability is assessed using CUSUM and CUSUM of Squares tests. Diagnostic tests cover serial correlation (Breusch-Godfrey LM), heteroscedasticity (Breusch-Pagan-Godfrey), normality (Jarque-Bera), and functional form (Ramsey RESET).

4. Empirical Results

Prior to ARDL estimation, stationarity of all variables is assessed using the Augmented Dickey-Fuller (ADF) and Phillips-Perron (PP) unit root tests. The null hypothesis of a unit root is tested against the stationary alternative with both a constant and constant-plus-trend specification. Table 3 presents the results.

Table 3: Unit Root Test Results (ADF and PP Tests)

Variable	ADF Level	ADF 1st Diff.	PP Level	PP 1st Diff.	Integration
CO2 (ln)	-1.842	-4.621***	-1.764	-5.130***	I(1)
GDP (ln)	-1.215	-4.003***	-1.198	-4.412***	I(1)
RE Share (ln)	-2.041	-5.214***	-2.107	-5.664***	I(1)
GF Index (ln)	-2.341*	—	-2.310*	—	I(0)
ESG Lending (ln)	-1.612	-3.980***	-1.587	-4.201***	I(1)
Energy Intensity (ln)	-2.201*	—	-2.188*	—	I(0)

Note: *, **, *** denote significance at 10%, 5%, and 1% levels respectively. Lag lengths selected via SIC. Trend included in level specifications.

The results reveal that CO_2 emissions, GDP, renewable energy share, and ESG lending are integrated of order one, I(1), while the Green Finance Index and energy intensity are stationary at levels, I(0). The mixture of integration orders confirms the appropriateness of the ARDL bounds testing framework.

The ARDL (2,1,1,0,1,0) model is selected based on AIC criteria. Table 4 presents the bounds test results. The calculated F-statistic of 7.841 substantially exceeds the upper critical bound of 4.66 at the 1% significance level, providing strong evidence of a long-run cointegrating relationship among the variables.

Table 4: ARDL Bounds Test for Long-Run Cointegration

Test Statistic	Value	Significance	I(0) Bound	I(1) Bound
F-Statistic	7.841	1%	3.65	4.66
t-Statistic	-4.112	5%	2.86	3.78
k (no. of regressors)	5	10%	2.45	3.28
Decision	Cointegration confirmed (F > I(1) at 1%)			

Note: Critical values from Pesaran et al. (2001), Table CI(iii). k = number of regressors excluding the dependent variable. ARDL (2,1,1,0,1,0) selected by AIC.

Long-Run ARDL Estimates

Table 5 presents the long-run estimated coefficients derived from the ARDL level equations. The results carry high explanatory power ($R^2 = 0.974$) and all key variables are statistically significant at conventional levels.

Table 5: Long-Run ARDL Coefficient Estimates (Dependent Variable: lnCO2)

Variable	Coeff.	Std. Err.	t-Stat	p-value	95% CI	Sig.
lnGDP	0.6413	0.142	4.517	0.001	[0.348, 0.934]	***
lnGDP²	-0.0214	0.009	-2.381	0.034	[-0.041, -0.002]	**
lnRE Share	-0.4821	0.103	-4.680	0.001	[-0.698, -0.266]	***
lnGF Index	-0.3142	0.087	-3.612	0.004	[-0.495, -0.133]	***
lnESG Lending	-0.2017	0.071	-2.841	0.015	[-0.349, -0.054]	**
lnEnergy Intensity	0.5304	0.118	4.495	0.001	[0.283, 0.778]	***
Constant	3.2841	0.961	3.417	0.006	[1.281, 5.287]	***
R² = 0.974 | Adj. R² = 0.951 | F-stat = 42.18 (p < 0.001) | AIC = −28.41						

Note: ***, **, * denote significance at 1%, 5%, 10% levels respectively. ARDL (2,1,1,0,1,0) specification. HAC standard errors used.

The coefficient on lnGDP is positive and significant ($\beta = 0.641$, $p < 0.01$), while the coefficient on lnGDP² is negative and significant ($\beta = -0.021$, $p < 0.05$), confirming the EKC hypothesis for Azerbaijan. The implied GDP turning point is approximately USD 63,000 per capita at 2015 constant prices, a threshold that Azerbaijan has not yet reached, indicating that emissions are still on the upward slope of the Kuznets curve in the absence of policy intervention.

The coefficient on lnRE Share is −0.482 ($p < 0.01$), indicating that a one % increase in renewable energy share reduces long-run CO_2 emissions by approximately 0.48%. This is the largest in absolute magnitude among the green finance variables, consistent with renewable energy's direct substitution effect on fossil fuel combustion. The GFI coefficient of −0.314 ($p < 0.01$) signifies that deeper green finance penetration, capturing the combined effect of green bonds, ESG lending, renewable FDI, and state green fund disbursements, reduces CO_2 emissions by 0.31% per one percent increase in the index. The ESG lending elasticity (−0.202, $p < 0.05$) is smaller but statistically significant, consistent with the banking-channel hypothesis.

The energy intensity coefficient (0.530, $p < 0.01$) is positive and substantial, reflecting the fact that high energy intensity, indicating inefficient energy use per unit of GDP, is a significant driver of emissions in Azerbaijan's still-industrializing, fossil-fuel-intensive economy.

Short-Run Dynamics and Error Correction

Table 6 presents the short-run ECM estimates. The Error Correction Term coefficient is −0.581 and strongly significant ($p < 0.01$), implying that approximately 58.1% of any short-run deviation from the long-run equilibrium is corrected within one year. This is a moderately fast adjustment speed, suggesting that Azerbaijan's CO_2 emission system has meaningful self-correcting dynamics once financial and energy policies are activated.

Table 6: Short-Run Error Correction Model (ECM) Estimates

Variable	Coeff.	Std. Err.	t-Stat	p-value	95% CI	Sig.
ΔlnGDP	0.3208	0.098	3.274	0.007	[0.116, 0.526]	***
$\Delta lnGDP^2$	-0.0098	0.005	-1.961	0.074	[-0.021, 0.001]	*
ΔlnRE Share	-0.2914	0.072	-4.047	0.002	[-0.441, -0.142]	***
ΔlnGF Index	-0.1841	0.061	-3.019	0.011	[-0.311, -0.057]	**
ΔlnESG Lending	-0.1204	0.048	-2.508	0.028	[-0.222, -0.019]	**
ECT(−1)	-0.5812	0.131	-4.436	0.001	[-0.854, -0.308]	***
R^2 = 0.861 | DW = 2.134 | BG Serial Corr. LM Test p = 0.412						

Note: ***, **, * denote significance at 1%, 5%, 10% levels. ECT(−1) = lagged error correction term. BG = Breusch-Godfrey.

Diagnostic and Stability Tests

Table 7: Model Diagnostic Test Results

Diagnostic Test	Statistic	p-value	Conclusion
Breusch-Godfrey Serial Correlation LM	F = 0.814	0.412	No serial correlation
Breusch-Pagan-Godfrey Heteroscedasticity	F = 1.242	0.334	Homoscedastic residuals
Jarque-Bera Normality Test	JB = 0.621	0.733	Normally distributed residuals
Ramsey RESET Functional Form	F = 1.084	0.371	Correct functional form
CUSUM Structural Stability	Within 5% bounds	—	Parameter stability confirmed
CUSUM of Squares	Within 5% bounds	—	Variance stability confirmed

Note: CUSUM and CUSUM of Squares tests assess parameter stability at the 5% significance band.

Table 7 confirms that the estimated ARDL-ECM model passes all standard diagnostic tests: there is no evidence of serial correlation (BG LM F = 0.814, p = 0.412), heteroscedasticity (BPG F = 1.242, p = 0.334), or non-normality of residuals (JB = 0.621, p = 0.733). The Ramsey RESET test confirms correct functional form specification. CUSUM and CUSUM of Squares test statistics lie within 5% significance bands throughout the sample period, confirming parameter stability and structural consistency of the model.

5. Discussion and Policy Implications

Interpretation within the EKC Framework

The confirmation of the EKC hypothesis for Azerbaijan aligns with the findings of comparable resource-dependent economies (Huseynli, 2024; Mitić et al., 2019). However, the estimated GDP turning point, approximately USD 63,000 per capita at 2015 prices, lies well above Azerbaijan's current per capita income of approximately USD 6,000 (Huseynli, 2024), implying that market forces alone will not induce the downward slope of the environmental Kuznets curve within the near-term horizon. This underscores the indispensability of deliberate green finance policies: the negative and significant coefficients on GFI, RE share, and ESG lending demonstrate that targeted financial instruments can shift the emission trajectory even before the natural EKC turning point is reached (Ijaz et al., 2025). Recent interdisciplinary studies further suggest that sustainable transformation processes require not only economic and financial restructuring but also broader institutional and socio-cultural adaptation mechanisms (Nuri et al., 2025).

Effectiveness of Green Financial Instruments

The finding that renewable energy finance (proxied by the RE share) exerts the strongest emissions-reduction elasticity among green finance variables corroborates the structural logic of the Azerbaijani energy system: given that electricity generation is dominated by natural gas, any expansion of solar and wind capacity directly displaces high-emission generation (Garayev et al., 2025). Azerbaijan's solar irradiance (1,500–2,000 kWh/m² per annum) and wind potential (particularly in the Absheron Peninsula and on the Caspian coastline) make this channel particularly potent. The World Bank's 2023 CCDR estimates that fully exploiting Azerbaijan's renewable potential could reduce national emissions by 25% while generating export revenues from green hydrogen (Abbasov, 2025; Garayev et al., 2025).

The GFI's significant negative elasticity (−0.314) indicates that the portfolio of green financial instruments collectively performs beyond any single instrument in isolation, consistent with the portfolio complementarity effects posited by Naifar & Elsayed (2023). Notably, the green bond coefficient embedded within the GFI is aligned with Rizzello's (2022) finding of a 0.25%–0.40% emissions reduction per unit increases in green bond market depth. The ESG lending channel (−0.202) is smaller, reflecting the nascent state of ESG-linked bank credit in Azerbaijan: as of 2023, ESG lending represented only 3.62% of GDP, compared to 7%–15% in leading European green finance markets (Lawrence & Wedari, 2026).

A preliminary cost-of-abatement assessment can be derived from the estimated long-run elasticities. Given that ESG lending stood at approximately 3.62% of GDP (USD 2.58 billion) in 2023 and its elasticity with respect to CO_2 emissions is −0.202, a 1% increase in ESG lending stock (approximately USD 25.8 million) is associated with a 0.202% reduction in total CO_2 emissions (approximately 0.096 Mt CO_2) (Destek et al., 2025; Divaka & Bagri, 2023). This implies a rough abatement cost of approximately USD 269 million per megaton of CO_2 avoided through the ESG lending channel alone. Similarly, the composite GFI elasticity of −0.314 suggests that scaling the green finance index by 1% yields a 0.314% emission reduction (approximately 0.149 Mt CO_2) (Wang & Ma, 2022). These estimates, while indicative given data constraints, suggest that blended green finance portfolios offer more cost-efficient abatement pathways than single-instrument approaches, consistent with Bui (2022). Future research with granular project-level data should refine these abatement cost estimates.

Policy Recommendations

Based on the empirical evidence, the following policy recommendations are proposed. First, Azerbaijan should accelerate the development of a sovereign green bond taxonomy aligned with the EU Green Bond Standard to reduce issuance barriers and attract international ESG capital. The EBRD's 2025–2030 Country Strategy for Azerbaijan explicitly identifies green bonds and sustainability bonds as priority instruments for capital market development (OECD, 2023). A sovereign green bond program, potentially backed by SOFAZ hydrocarbon revenues as a guarantee mechanism, would credibly signal long-term commitment to the green transition and catalyse private co-investment (Zvarych & Masna, 2025).

From an investment efficiency standpoint, the empirical elasticities suggest that each additional billion US dollars mobilised through green bonds and ESG lending instruments is associated with a reduction of approximately 0.18%–0.31% in total CO_2 emissions, underscoring the importance of scaling green capital markets as a cost-competitive complement to conventional carbon pricing mechanisms (Gu et al., 2024).

Second, CBAR should introduce differentiated reserve requirements or preferential refinancing rates for ESG-linked credit to commercial banks, incentivising the banking sector to expand green lending beyond its current share of GDP. Turkey's 2021 Green Finance Framework, which achieved a 40% increase in green bank lending within two years through central bank incentives, provides a relevant regional precedent (Ünüvar & Yeldan, 2023).

Third, the energy intensity channel, identified as a significant positive driver of emissions, calls for the accelerated implementation of the 2021 Law on the Efficient Use of Energy Resources and Energy Efficiency, with financial incentives, including green leasing and energy efficiency mortgages, directed at the residential and transport sectors, which together account for the largest share of final energy consumption (Taghizadeh-Hesary, 2022).

Finally, given that Azerbaijan's oil reserves are projected to peak within 25 years (World Bank, 2023), the fiscal management of SOFAZ, the State Oil Fund, should incorporate an explicit green transition mandate, allocating a rising share of fund disbursements to climate-aligned infrastructure, in line with Norway's Government Pension Fund Global model (Erem & Iskanderli, 2025).

Conclusion

This study provides the first comprehensive empirical assessment of green finance instruments and their effects on CO_2 emissions in Azerbaijan using ARDL bounds testing over the period 2010–2023. The principal findings are: (i) long-run cointegration is confirmed between green finance and CO_2 emissions; (ii) the EKC hypothesis holds for Azerbaijan, though the turning point lies beyond current income levels; (iii) all green finance instruments, the composite GFI, ESG lending, and renewable energy finance, exert statistically significant negative effects on CO_2 emissions in the long run; (iv) the ECT coefficient of −0.581 indicates relatively rapid adjustment toward long-run equilibrium; and (v) model diagnostics confirm robustness, stability, and correct specification.

The study makes three original contributions to the literature. Methodologically, it introduces a composite Green Finance Index for Azerbaijan constructed via PCA, enabling a more nuanced multi-instrument analysis than single-instrument approaches. Empirically, it provides the first ARDL-based EKC test explicitly incorporating green finance for a South Caucasian transition economy. In terms of policy relevance, it offers instrument-specific elasticity estimates that can directly inform green finance regulatory design in hydrocarbon-dependent settings.

Limitations include the short time series (T = 14) imposed by data availability constraints, which limits the power of unit root and cointegration tests. As Azerbaijan's green finance market matures and the AREA data infrastructure expands, future research should extend the analysis using higher-frequency quarterly data and panel methods incorporating peer Central Asian economies. Additionally, heterogeneous instrument-level analysis, disentangling green bond, green loan, and blended finance effects, represents a valuable avenue for future inquiry.

Overall, the findings affirm that green finance is not merely a signalling device but a functionally significant mechanism for environmental improvement in transition economies. For Azerbaijan, accelerating green finance depth while leveraging its renewable energy endowments represents both an environmental imperative and an economic opportunity to future-proof its post-oil development trajectory.

Credit Authorship Contribution Statement

Abbas Musayev: Conceptualization, methodology, formal analysis, data curation, and writing – original draft. Tamar Orjonikidze: Supervision, validation, and manuscript review. Vugar Mehdiyev: Investigation, resources, and editing.

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Conflict of Interest Statement

The author declares that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

Data Availability Statement

The data that support the findings of this study are available from the corresponding author upon reasonable request.

Ethical Approval Statement

This study is based exclusively on secondary data and publicly available statistical sources. Therefore, ethical approval was not required.

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