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ORIGINAL RESEARCH PAPER

International Trade, Income Inequality, and Ecological Efficiency: HPI Evidence from OPEC-Plus Countries

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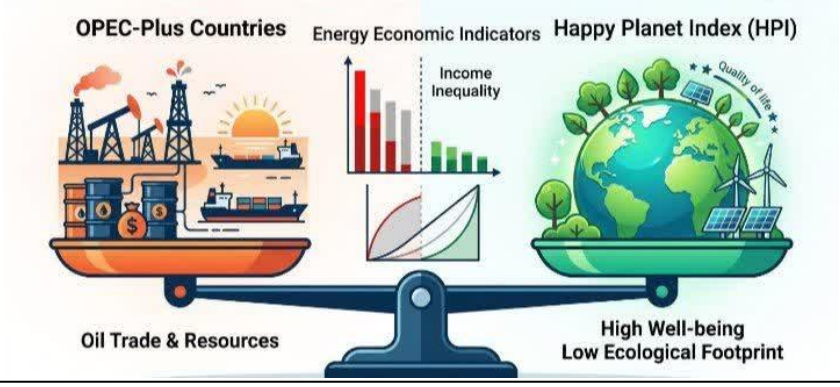
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A B S T R A C T

Environmental sustainability and ecological efficiency remain critical challenges for resource-dependent economies characterized by carbon-intensive trade and significant oil rents. This study investigates the impact of international trade openness and income inequality on the Happy Planet Index (HPI), a key environmental economics indicator that measures the efficiency of transforming natural resources (Ecological Footprint) into human well-being. Focusing on selected OPEC-Plus (OPEC+) countries from 2006 to 2020, we employ a dynamic panel data framework using the two-step System Generalized Method of Moments (GMM) to address endogeneity. The model evaluates how trade and social disparities affect the balance between experienced well-being and ecological limits. Results indicate that both trade openness and income inequality exert a statistically significant negative effect on HPI, suggesting that the current trade structures in these nations prioritize volume over environmental quality. Furthermore, oil resource rents and unemployment are found to exacerbate the ecological-social deficit, reinforcing the resource curse in a sustainability context. However, a positive interaction effect between trade and inequality suggests that trade may provide compensatory economic channels under high-inequality conditions. These findings underscore the urgent need for green trade reforms, inclusive redistribution, and policies aimed at decoupling economic growth from ecological degradation to foster long-term sustainable well-being in oil-producing regions



1. Introduction

In recent years, environmental concerns and sustainable development have attracted growing attention from economists and policymakers worldwide. The Happy Planet Index (HPI) has emerged as a comprehensive indicator for assessing human well-being by integrating environmental sustainability with social welfare [1]. Specifically, the HPI captures three core dimensions, subjective well-being, life expectancy, and ecological footprint, all of which are directly or indirectly influenced by socio-economic factors [2, 3]. Among these, international trade volume plays a critical role. While trade expansion can enhance economic opportunities, facilitate access to global markets, and promote the diffusion of cleaner technologies, it may simultaneously intensify environmental pressures through excessive resource extraction and increased greenhouse gas emissions [3]. Alongside trade, income inequality constitutes a key determinant of sustainable welfare, as unequal income distribution limits access to social services and environmental amenities for lower-income groups, thereby reducing overall well-being [4-6].

For OPEC-Plus Countries, which are highly dependent on oil revenues, the interaction between international trade, income inequality, and environmental sustainability poses particularly complex challenges. Although oil and energy exports have historically supported economic growth and infrastructure development, they have often been accompanied by structural income disparities and environmental degradation [7]. This paradox highlights the limitations of conventional development indicators in capturing sustainable welfare outcomes in resource-dependent economies.

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From a theoretical perspective, the Theory of Sustainable Growth emphasizes that economic development should be achieved through efficient resource use while safeguarding the welfare of future generations. In OPEC-Plus Countries, heavy reliance on natural resource exports places increasing pressure on ecological systems, underscoring the need to align international trade policies with environmental conservation objectives [8]. Moreover, Robinson's [9] theory of income inequality and social welfare suggests that rising inequality erodes collective well-being—a framework particularly relevant for oil-rich economies characterized by uneven income distribution. Complementarily, Becker's [10] Rational Choice Theory assumes that governments and economic agents make decisions aimed at maximizing welfare, implying that OPEC-Plus policymakers must carefully balance economic growth objectives with environmental protection in trade and fiscal policy design.

Empirical evidence on these relationships remains mixed. Studies by Doğan et al. [11] and Manta et al. [12] document the dual effects of international trade on sustainable development. Some scholars report that trade expansion positively influences the HPI by increasing income, reducing poverty, and improving access to technology [13, 14]. In contrast, other studies argue that trade can reduce sustainable welfare by intensifying resource depletion and environmental degradation [3, 15, 16].

Similarly, a growing body of research identifies income inequality as a significant factor undermining sustainable well-being. Empirical findings by Tausch [2] and Ozar & Eyuboglu [17] demonstrate that higher inequality levels are associated with lower HPI values due to unequal access to essential services and increased social and environmental stress. Furthermore, Zhou et al. [18], employing the Common Correlated Effects Mean Group (CCEMG) estimator, show that exports, imports, and foreign direct investment are positively correlated with ecological footprints, lending empirical support to the Pollution Haven Hypothesis and highlighting the importance of environmental regulation quality.

Overall, theoretical and empirical insights indicate that the relationship between international trade, income inequality, and the HPI in OPEC-Plus Countries is complex, multidimensional, and non-linear. Despite relatively strong performance in traditional economic indicators such as GDP and per capita income, many OPEC-Plus Countries rank poorly in terms of sustainable welfare due to excessive resource consumption, high energy intensity, and persistent social challenges. Income inequality further exacerbates these outcomes by reducing life satisfaction and encouraging unsustainable consumption patterns. In this context, oil rents and unemployment rates emerge as critical complementary variables: while well-managed resource rents can enhance public services, poor governance often leads to corruption, environmental degradation, and declining welfare.

Despite the expanding literature on the trade–environment nexus and income inequality, empirical evidence on their joint and simultaneous effects on environmentally adjusted welfare indicators—such as the HPI—remains limited, particularly for OPEC and non-OPEC oil-exporting countries. Addressing this gap, the present study investigates the combined impact of international trade volume and income inequality on sustainable well-being, as measured by the HPI, using annual data from selected oil-producing countries over the period 2010–2020. Given the dynamic nature of sustainable welfare, the analysis employs a two-step dynamic panel Generalized Method of Moments (System GMM) estimator to control for endogeneity and capture persistence effects. By focusing on the interaction between trade and income inequality within a sustainability framework, this research contributes to the environmental economics literature and offers policy-relevant insights for designing integrated trade, redistribution, and environmental strategies aimed at improving long-term sustainable well-being in resource-dependent economies. The rest of this paper is structured as follows: Section 2 presents the research methodology, including the study area, the data used, and the econometric methods. The third section is devoted to model estimation and experimental results of the study. Finally, the conclusion is presented in section 4.

2. Materials and methods

2.1. Data Used and Study Area

The study uses annual panel data for selected OPEC-Plus Countries over the period 2010–2020, determined by data availability. The sample includes: Algeria, Republic of Congo, Iran, Iraq, Azerbaijan, Ecuador, Saudi Arabia, Qatar, United Arab Emirates, Kuwait, Mexico, Malaysia, Kazakhstan, Russia, and Bahrain. This group represents a diverse set of oil-exporting economies with varying levels of economic openness, inequality, and institutional quality, making it suitable for analyzing sustainable welfare outcomes. Table 1 presents a brief description of references for the data used in this study. Here, Stata/MP17 and Eviews13 software has been applied to estimate the model.

Table 1. ntroduction of variables and data sources

Variable	Definition	Data Source
Happy Planet Index (HPI)	Composite indicator of sustainable well-being, calculated as the product of life expectancy and experienced well-being divided by the ecological footprint	Happy Planet Index Global Database
Life Expectancy	Average number of years a newborn is expected to live under current mortality conditions	Happy Planet Index / World Bank (WDI)
Experienced Well-being	Overall life satisfaction measured using the Ladder of Life scale (0–10)	Happy Planet Index Global Database
Ecological Footprint	Per capita consumption of natural resources, including land, energy, water use, and waste generation (global hectares)	Happy Planet Index Global Database
International Trade (TRADE)	Degree of trade openness measured as the ratio of total exports and imports to GDP	World Bank – World Development Indicators (WDI)
Income Inequality (INEQ)	Palma Ratio, defined as the income share of the richest 10% divided by that of the poorest 40% of the population	World Income Inequality Database (WIID)
Oil Resource Rents (RENT)	Oil rents expressed as a percentage of GDP, indicating dependence on oil resource extraction	World Bank – WDI
Unemployment Rate (UNEMP)	Annual unemployment rate as a percentage of the total labor force	World Bank – WDI
Interaction Term (TRADE × INEQ)	Interaction between trade openness and income inequality to capture their joint effect on sustainable well-being	Author's own calculation

Notes: All the data are annual over the period 2010-2020.

2.2. Model Specification

To analyze the impact of international trade volume and income inequality on the Happy Planet Index (HPI) across selected OPEC Plus economies, a dynamic panel data approach estimated through the Generalized Method of Moments (GMM) is employed. Given the complex nature of the dependent variable and the interrelated nature of economic and social factors in the model, this estimator provides consistent and efficient results by addressing potential endogeneity and the dynamic structure inherent in the data [19-21].

The Happy Planet Index, defined by the integration of subjective well-being, life expectancy, and ecological footprint, inherently reflects persistent and gradual dynamics. These underlying components respond to cumulative policy effects that materialize only over time—investments in education and health generate improvements in life expectancy slowly, and environmental regulations aimed at reducing ecological footprint produce long-term outcomes. Consequently, current levels of HPI depend heavily on past realizations, which justifies the inclusion of a lagged dependent variable in the empirical specification (22, 23).

This dynamic character aligns with the sustainable development framework emphasizing that improvements in welfare and environmental quality evolve through gradual processes. Endogenous growth theory similarly indicates that welfare-enhancing and sustainability-oriented investments have persistent effects extending into future periods [24]. The strong autocorrelation of HPI thus requires a model capable of capturing these structural intertemporal relationships, for which dynamic panel GMM is well-suited [25].

From the econometric standpoint, when the lagged dependent variable appears among the regressors, the model becomes dynamic, and estimates obtained through Ordinary Least Squares or Fixed Effects estimators turn biased due to correlation between the lagged dependent variable and the error term. The GMM estimator overcomes this issue by utilizing internal instruments derived from the lagged values of explanatory variables, satisfying orthogonality conditions among moment restrictions [26, 27]. The method minimizes a quadratic form of the sample moments, expressed as

$$\min_{\theta} g(\theta)' W g(\theta) \tag{1}$$

where $g(\theta)$ represents the vector of moment conditions, W is the optimal weighting matrix, and heteroscedasticity-consistent weighting ensures efficiency.

The model is represented in dynamic panel form as

$$y_{it} = \alpha y_{it-1} + X_{it}\beta + \mu_{it} + \varepsilon_{it} \tag{2}$$

where y_{it} is the dependent variable, X_{it} denotes the set of explanatory variables, μ_{it}captures the unobserved individual heterogeneity, and ε_{it} denotes the idiosyncratic disturbance term. Because y_{it-1} and $\varepsilon_{it}$are correlated, traditional estimators are inconsistent, and GMM becomes appropriate for unbiased estimation [28].

Accordingly, the empirical specification follows the structure proposed by Albulescu et al. [29]:

$$HPI = f\,(HPI_{it-1}, Trade_{it}, Inequality_{it}, TIV_{it}, Natural\ resources_{it}, Unemployment_{it}) \quad (3)$$

where i refers to countries and refers to time periods. In the model, HPI is the dependent variable; Trade indicates international trade volume; Inequality is proxied by the Palma ratio; Natural resources captures oil and natural resource rents; Unemployment denotes the unemployment rate; and TIV is the interaction term between trade volume and income inequality.

The dynamic panel GMM estimator is most effective when the number of cross-sections exceeds the time dimension (N> T), which is the case here, as the model covers multiple countries over a finite sample of years. The estimator accounts for heteroscedasticity, autocorrelation, and potential simultaneity among repressors through an appropriate instrument matrix constructed from valid lag structures.

Finally, the reliability of the estimation procedure is confirmed through diagnostic tests for serial correlation and instrument validity. The Arellano-Bond test for autocorrelation [19], the Arellano-Bover correction [30], and the Blundell-Bond system GMM validation [20] ensure the absence of second-order serial correlation and verify the appropriateness of the chosen instruments. Collectively, these tests substantiate the consistency of the GMM estimator and affirm its suitability for analyzing the dynamic relationships among trade, inequality, and environmental well-being across the selected countries.

3. Results and Discussion

This section presents the empirical findings of the study and discusses the econometric results obtained from the panel data analysis. Given the multidimensional nature of the Happy Planet Index (HPI), which integrates human well-being and environmental sustainability, identifying its key economic determinants requires robust econometric techniques. Accordingly, the analysis proceeds by first reporting descriptive statistics of the variables, followed by panel unit root and cointegration tests to ensure the validity of the estimations. Subsequently, model selection tests and dynamic panel GMM estimation results are presented and evaluated.

3.1. Descriptive Statistics

Table 2 summarizes the descriptive statistics of the study variables for selected OPEC-Plus Countries over 2010–2020. The results reveal substantial cross-country heterogeneity in all variables. The average Happy Planet Index (HPI) indicates a moderate level of sustainable well-being, with notable dispersion across countries. Trade volume and income inequality exhibit considerable variability, reflecting heterogeneous economic structures and income distribution patterns. Oil resource rents and unemployment rates also vary markedly, underscoring differences in resource dependence and labor market conditions. Overall, these patterns justify the use of panel data techniques.

Table 2. Statistical description of all the variables.

Variable	Mean	Median	Maximum	Minimum	Std. Deviation
HPI (Happy Planet Index)	41.448	40.127	61.225	24.655	8.164
Trade (Trade Volume)	86.405	74.585	185.805	39.426	37.763
Palma (Income Inequality Index)	6.155	5.412	22.124	1.996	4.151
OR (Oil Resource Rents)	19.332	15.942	58.369	0.686	14.022
Unemployment (Unemployment Rate)	6.258	4.930	22.198	1.360	5.152

Source: Authors' computation

3.2. Panel Unit Root Tests

As reported in Table **3**, the LLC test rejects the null hypothesis of a unit root for all variables at the 1% significance level, indicating that HPI, trade volume, income inequality (Palma index), oil resource rents, unemployment rate, and the interaction term are stationary in levels. This confirms the stability of the variables over the 2010–2020 period and supports the suitability of the dataset for panel data estimation. The stationarity of all variables further justifies the use of a dynamic panel GMM framework and ensures the reliability of the estimated results.

Table 3. Results of the Panel Unit Root (LLC) Test.

Variable	Test Used	Test Statistic	Probability
HPI (Happy Planet Index)	Levin–Lin–Chu	−4.8946	0.0001***
Trade (Trade Volume)	Levin–Lin–Chu	−3.0293	0.0012***
Palma (Income Inequality Index)	Levin–Lin–Chu	−7.4789	0.0000***
OR (Oil Resource Rents)	Levin–Lin–Chu	−5.7391	0.0000***
Unemployment (Unemployment Rate)	Levin–Lin–Chu	−3.4937	0.0002***
Trade × Palma	Levin–Lin–Chu	−3.9562	0.0000***

Notes; *** indicates 1% significant level. Source: Authors' computation

3.3. Panel Cointegration Test (Kao Test)

As the p-value is below 0.05, the null hypothesis of no cointegration is rejected, confirming a long-run equilibrium relationship between the Happy Planet Index (HPI) and the explanatory variables. This indicates that the model is not spurious. Despite the existence of cointegration, a dynamic System GMM approach is employed to capture short-run dynamics and to address potential endogeneity arising from the persistence of environmental sustainability indicators.

Table 4. Results of the Kao Panel Cointegration Test.

Test	Test Statistic (ADF t)	Probability (p-value)
Kao Cointegration Test	−2.1522	0.0157**

Notes; ** denotes rejection of the null hypothesis at 5% significance level.
Source: Authors' computation

3.4. Chow Test

The p-value of the Chow test is below 0.05, leading to the rejection of the null hypothesis of pooled data. This result confirms the presence of significant cross-sectional heterogeneity, indicating that panel-based estimation methods are more appropriate. Such heterogeneity reflects structural differences in environmental and economic conditions across countries.

Table 5. Results of the Chow Test.

Test	F-Statistic	Probability (p-value)
Chow Test	79.24	0.0000***

Notes; ** indicates 1% significant level. Source: Authors' computation

3.5. Hausman Specification Test

The Hausman specification test is used to select between fixed and random effects models. As shown in Table **6**, the p-value (0.0369) is below the 5% significance level, leading to the rejection of the null hypothesis. Accordingly, the fixed effects model is identified as the appropriate estimation method for this study.

Table 6. Results of the Hausman Specification Test.

Test	Chi-square Statistic	Probability (p-value)
Hausman Test	8.78	0.0369**

Notes; ** indicates 5% significant level. Source: Authors' computation

3.6. Classical Assumption Tests

Given the panel nature of the data, violations of classical assumptions such as heteroskedasticity and autocorrelation may arise. These issues can affect the efficiency of estimators and the validity of statistical inference. Therefore, prior to model estimation, the presence of heteroskedasticity and serial correlation is formally examined.

3.6.1. Heteroskedasticity Test

Given the panel structure of the data, the modified Wald test is employed to examine heteroskedasticity. As reported in Table **7**, the p-value is below the 5% significance level, leading to the rejection of the null hypothesis of homoskedasticity and confirming the presence of heteroskedasticity in the model.

Table 7. Results of the Heteroskedasticity Test (Modified Wald Test).

Test	Z-Statistic	Probability (p-value)
Modified Wald Test	786.09	0.0000***

Notes; *** indicates 1% significant level. Source: Authors' computation

3.6.2. Autocorrelation Test

Serial correlation is examined using the Arellano–Bond test. As reported in Table **8**, both AR(1) (p = 0.2332) and AR(2) (p = 0.4033) tests are insignificant at the 5% level. Since the absence of second-order autocorrelation is the key requirement for GMM validity, these results confirm that the model is structurally sound.

Table 8. Results of the Autocorrelation Test (Arellano–Bond).

Order of Autocorrelation	Z-Statistic	Probability (p-value)
AR(1)	−1.192	0.2332
AR(2)	−0.836	0.4033

Source: Authors' computation

3.7. Empirical Results and Discussion of the Dynamic GMM Model

Table **9** reports the estimation results obtained from the two-step dynamic panel GMM estimator proposed by Arellano and Bond [19], applied to annual data for selected OPEC-Plus countries over the period 2006–2020. This approach is well suited for dynamic panel settings, as it effectively controls for endogeneity, unobserved country-specific effects, and potential autocorrelation in the error terms.

The model incorporates a lagged dependent variable to capture the dynamic persistence of sustainable well-being. The explanatory variables include international trade volume, income inequality (measured by the Palma ratio), oil resource rents, the unemployment rate, and an interaction term between trade and income inequality (Trade × Palma). The joint significance of the regressors and the robustness of the estimated coefficients confirm the adequacy of the specified model.

To examine the impact of international trade volume and income distribution inequality on the Happy Planet Index (HPI) in selected OPEC-Plus member countries, the following model is specified:

$$HPI_{it} = \beta_0 + \beta_1 HPI_{it-1} + \beta_2\, Trade_{it} + \beta_3 Palma_{it} + \beta_3 OaR_{it} + Unemployment_{it} + \beta_3 Trade * Palma_{it} + \varepsilon_{it}) \quad (4)$$

In equation (4), HPI is the dependent variable representing the Happy Planet Index. Trade denotes the volume of international trade, while Palma refers to the Palma ratio, which is used as an indicator of income distribution inequality. OR represents oil resource rents, Unemployment denotes the unemployment rate, and Trade × Palma is an interaction term constructed as the product of international trade volume and income inequality. These variables are included as independent variables in the model. The parameters associated with the explanatory variables are to be estimated.

Table 9. GMM Estimation Results of the Research Model.

Variables	Symbol	Coefficient	z-Statistic	p-Value
Lagged Happy Planet Index	HPI(−1)	−0.1505	−4.37	0.000
International Trade Volume	Trade	−0.0589	−2.86	0.004
Income Inequality (Palma Ratio)	Palma	−0.9565	−5.27	0.000
Oil Resource Rents	OR	−0.0881	−3.14	0.002
Unemployment Rate	Unemployment	−1.0314	−5.81	0.000
Trade × Income Inequality	Trade × Palma	0.0076	2.53	0.011
Constant Term	Constant	46.4201	14.95	0.000
Wald χ^2		**735.07**		
Prob (Wald χ^2)				0.0000

Source: Authors' computation

The coefficient of the lagged Happy Planet Index (HPI(−1)) is negative and statistically significant at the 1% level, indicating the presence of short-run adjustment dynamics. Specifically, an increase in the previous period's HPI leads to a decline in its current value, suggesting short-term instability in sustainable well-being. This result is consistent with the volatile nature of welfare and environmental indicators in resource-dependent and oil-exporting economies, where external shocks and structural rigidities may weaken persistence in well-being outcomes.

International trade volume exhibits a negative and statistically significant effect on the Happy Planet Index. This finding suggests that trade expansion in OPEC-Plus countries—largely driven by oil and primary commodity exports—tends to reduce sustainable well-being. Trade growth is often accompanied by higher energy consumption, increased international transportation, and intensified pollutant emissions, which expand the ecological footprint and adversely affect environmental quality. Moreover, when the gains from trade are unevenly distributed, trade expansion may exacerbate social dissatisfaction and reduce subjective well-being, thereby weakening the HPI.

Income inequality, measured by the Palma ratio, also shows a negative and highly significant relationship with the Happy Planet Index. This result indicates that widening income disparities undermine both social welfare and environmental sustainability, reinforcing the view that unequal societies face greater challenges in achieving sustainable well-being.

Similarly, oil resource rents have a negative and statistically significant impact on the HPI, supporting the resource curse hypothesis. Greater dependence on oil revenues may intensify income concentration, weaken institutional quality, and generate adverse environmental externalities, all of which reduce sustainable welfare in the long run.

The unemployment rate exerts a strong and negative effect on the Happy Planet Index, highlighting the critical role of labor market conditions in shaping sustainable well-being. Rising unemployment not only reduces income security but also undermines social cohesion and quality of life, leading to lower levels of happiness and environmental satisfaction.

Notably, the interaction term between international trade and income inequality (Trade × Palma) is positive and statistically significant. This result suggests that the negative effect of trade on sustainable well-being is partially moderated in contexts of higher inequality. Under such conditions, trade expansion may create employment opportunities or income channels for lower-income groups, thereby mitigating its standalone adverse impact on the Happy Planet Index.

Finally, the Wald chi-square statistic ($\chi^2 = 735.07$, $p < 0.01$) confirms the overall statistical significance of the model and indicates strong joint explanatory power of the included variables. Overall, the results provide robust empirical evidence that trade dynamics, inequality, resource dependence, and labor market conditions play a crucial role in shaping sustainable well-being in OPEC-Plus economies.

3.8. Sargan Test (Instrument Validity)

Following the estimation of the model using the two-step System Generalized Method of Moments (GMM), the validity of the instrumental variables is examined using the Sargan test of over-identifying restrictions. This test evaluates whether the imposed moment conditions—which assume that the instruments are orthogonal to the error term—are jointly satisfied.

The null hypothesis of the Sargan test states that the instruments are valid, meaning that they are not correlated with the disturbance term. Failure to reject the null hypothesis suggests that the selected instruments are appropriate within the specified GMM framework.

As reported in Table **10**, the p-value of the Sargan test is 0.2908, which exceeds the conventional 5% significance level. Accordingly, the null hypothesis cannot be rejected, providing evidence in support of the validity of the instrumental variables employed in the GMM estimation. These results indicate that the adopted moment conditions are consistent with the data and support the reliability of the estimated dynamic panel model.

Table 10. Results of the Sargan Test).

Test Type	Chi-square Statistic	Degrees of Freedom	Probability (p-value)
Sargan Test	13.39	11	0.2908

Source: Authors' computation

4. Conclusions

The empirical assessment of ecological efficiency within the OPEC-Plus bloc from 2006 to 2020 reveals a complex interplay between macroeconomic structures and sustainable well-being. By employing a two-step Dynamic Panel System GMM, validated through LLC, Chow, and Hausman tests, this analysis successfully navigated the inherent endogeneity and temporal dependencies typical of resource-dependent economies. The Sargan test (p-value = 0.2908) further confirmed the statistical integrity of the instrumental variables, providing a robust foundation for the observed correlations.

A defining characteristic of the investigated economies is the negative persistence of the Happy Planet Index (HPI). The statistically significant coefficient for the lagged HPI indicates that a unit increase in the prior year's performance leads to an approximate 15% decline in the current period. This dynamic highlights a structural instability in sustainable welfare gains within oil-exporting nations, echoing the volatility concerns raised by Wang et al. [31] and the foundational work of Arellano and Bond [19]. While Ricardo [32] and Heckscher-Ohlin [33] predicted that international trade would enhance welfare, in this context, trade and oil rents function as significant detractors from ecological efficiency. This misalignment lends empirical weight to the "pollution haven" and "resource curse" hypotheses, where trade structures dominated by raw material exports and carbon-intensive processes erode the foundations of long-term social and environmental health, as also noted in the regional findings of Behboodi [34]

The detrimental roles of income inequality, proxied by the Palma ratio, and unemployment further underscore that social fragmentation undermines ecological outcomes, aligning with the frameworks of Stiglitz [35]. However, the discovery of a positive interaction effect between trade and inequality introduces a critical nuance to the literature. This interaction suggests that while trade generally exerts a negative pressure on the HPI, it can serve as a corrective mechanism in highly unequal settings by facilitating localized economic participation for marginalized groups.

Addressing these systemic challenges requires a fundamental pivot in the economic architecture of OPEC-Plus nations. The evidence points toward a compelling need to transition away from a trade model centered on crude oil and toward a diversified structure focused on high-value, green sectors that can effectively decouple growth from environmental degradation. Moreover, the observed positive interaction between trade and inequality implies that trade liberalization must be strategically paired with inclusive social policies. By empowering lower-income strata to access global value chains, specifically through the promotion of export-oriented small and medium enterprises,

governments can transform trade into a vehicle for genuine, long-term ecological efficiency. Such a shift would not only stabilize the volatile welfare dynamics observed in this study but also ensure that economic engagement translates into resilient social prosperity and environmental stewardship.

Credit Authorship Contribution Statement

Somayeh Meyghani and Alihe Hamednia: Mahboobeh Khadem Nematollahy: Investigation and perform calculations, Mohammad Hossein Mahdavi Adeli: Supervision, Project administration, and Manuscript writing and editing results.

Conflicts of Interest

The authors declare that they do not have any personal or financial conflicts of interest.

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