ENVIRONMENTAL SUSTAINABILITY IN VIETNAM: THE ROLE OF ALTERNATIVE ENERGY, GDP GROWTH, NATURAL RESOURCES

Nguyen Manh Hung[1,*]

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ABSTRACT

Vietnam, significantly impacted by climate change, aims for net zero emissions by 2050, supported by the National Climate Change Strategy and the Just Energy Transition Partnership (JETP). Despite these efforts, Vietnam's Power Development Plan 8 (PDP8) indicates continued fossil fuel reliance until at least 2030. This study examines the impact of alternative energy resources, natural resources, and government spending on Vietnam's ecological sustainability from 1990 to 2021, using the Environmental Kuznets Curve (EKC) framework. The findings reveal an inverse relationship between CO2 emissions and renewable energy use and natural resources, while CO2 emissions positively correlate with economic growth, contradicting the EKC hypothesis. Effective policies require equitable distribution and adherence to regulations. Vietnam should enhance renewable energy adoption, enforce stricter regulations on natural resource exploitation, integrate environmental impact assessments into economic planning, and foster public awareness and education on sustainable practices. These strategies will support Vietnam's transition to a sustainable economy, aligning economic growth with environmental preservation.

Keywords: *Carbon emissions, environmental sustainability, alternative energy, natural resources, net zero emissions, Vietnam, EKC.*

[1]East Asia University of Technology, Vietnam
[*]Email: hungnm@eaut.edu.vn
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1. INTRODUCTION

The global community is increasingly concerned about various ecological changes, such as climate change, desertification, deforestation, coastal erosion, overfishing, biodiversity loss, and soil degradation. These issues collectively signify significant alterations to Earth's surface driven by human activity. Vietnam, which is one of the countries affected the most by the climate change while possessing abundant of natural resources, has announced its commitment to achieve the target of net zero emissions by 2050 during the COP26 World Leaders' Summit in 2021. Following by the approval of Prime Minister's Decision No.896/QD-TTg guiding the National Climate Change Strategy, which aims to guide Viet Nam's climate action through 2050. While this decision is a legal document, the target has yet to be formalized in legislation and relies on international financial support. Viet Nam has signed the Just Energy Transition Partnership (JETP) with an international coalition of donors, aiming to assist in transitioning away from coal toward clean and renewable sources of energy while supporting the prospering economy.

Additionally, Vietnam's National Electricity Development Plan 2021 - 2030 recently promulged reflects its commitment to accelerating the transition from conventional fossil fuels to cleaner and renewable energy sources, addressing environmental concerns, reducing greenhouse gas emissions, and aligning with global sustainability targets. The strategy states that Viet Nam will not develop new coal-fired power plants after 2030 and will gradually reduce its coal fleet after 2035. However, the Power Development Plan 8 (PDP8) indicates that the power sector will still depend extensively on fossil fuels until at least 2030, with substantial new gas infrastructure being developed. The prospects for phasing out the fossil fuel fleet are uncertain and depend on plans to convert existing plants to alternative fuels.

Vietnam's National Electricity Development Plan 2021 - 2030 additionally reflects its commitment to transitioning from conventional fossil fuels to cleaner and renewable energy sources. By 2030, Vietnam aims to diversify its energy mix significantly, planning to increase capacities in thermal, LNG thermal, and coal-fired thermal power plants to 14,930MW, 22,400MW, and 30,127MW, respectively. Renewable energy sources will also be ramped up, with offshore wind, onshore wind, and biomass power capacities reaching 6,000MW, 21,880MW, and 1,088MW, respectively. Additionally, electricity generated from waste is expected to contribute 1,182MW, alongside 2,600MW of rooftop solar power and 300MW of battery storage capacity.

This study examines the impact of alternative energy resources, natural resources, and government spending on Vietnam's ecological sustainability from 1990 to 2021, using the environmental Kuznets curve (EKC) framework. Employing all the public recognized data from World Bank, our findings reveal an inverse relationship between carbon dioxide (CO_2) emissions and renewable and nuclear energy use, natural resources, and government expenditure. Conversely, CO_2 emissions are positively correlated with economic growth, acceleratingly associated with the square of economic growth, contradicting the EKC hypothesis. This indicates that fast economic growth harms environmental sustainability.

The study concludes with policy implications, identified research gaps, and suggestions for future research.

2. LITERATURE REVIEW

The measurement of carbon emissions employs various models and theories to assess the impact of climate change efficiently. Increased fossil fuel use and deforestation have led to the development of numerous CO_2 emission analysis methods. A key concept is the Environmental Kuznets Curve (EKC) model, which suggests a U-shaped relationship between economic growth and pollution. Initially conceptualized by Simon Kuznets in the 1950s in relation to income inequality, this concept was later adapted to environmental economics and gained prominence in the early 1990s with the work of Grossman and Krueger [1], who explored the impact of economic growth on environmental quality in their study on the North American Free Trade Agreement (NAFTA). They found empirical evidence suggesting that certain pollutants decreased after a threshold level of income was reached. Following this, the EKC hypothesis has been extensively studied and debated in the fields of environmental and development economics.

The paper "Economic Growth and Environmental Quality: Time-Series and Cross-Country Evidence" by Nemat Shafik and Sushenjit Bandyopadhyay [2] explores the relationship between economic growth and environmental quality through the analysis of patterns of environmental transformation at different income levels which posits that environmental degradation initially increases with economic growth but eventually decreases as income reaches higher levels. Studies of "Economic Growth and the Environment" by Theodore Panayotou [3] have shown that pollutants like sulfur dioxide (SO_2) and particulate matter (PM) follow the EKC pattern with turning points at various income levels. The hypothesis suggests that in the early stages of economic growth, environmental degradation and pollution levels increase, but after reaching a certain level of income per capita, further economic growth leads to environmental improvements. Economic growth initially leads to environmental degradation but eventually improves environmental quality. This theory has been validated in several studies showing that economic growth can either increase or reduce emissions.

Numerous studies have explored the relationship between energy efficiency, renewable energy intensity, and environmental sustainability, providing empirical evidence that supports the EKC hypothesis. In their 2015 study titled "How effective are energy efficiency and renewable energy in curbing CO_2 emissions in the long run? A heterogeneous panel data analysis" [4] Özbuğday and Erbas found that energy efficiency significantly reduces CO_2 emissions. Their research utilized a panel data approach, accounting for heterogeneity and cross-sectional dependence among countries, to reveal that improvements in energy efficiency have a long-term mitigating effect on CO_2 emissions. In their 2022 study titled "Impact of energy efficiency on CO_2 emissions: empirical evidence from developing countries" published in Gondwana Research [5], Mirza et al. demonstrated that energy efficiency exerts a more significant influence on reducing CO_2 emissions in developing countries compared to structural shifts resulting from economic activities. Their research highlighted that while economic growth and industrialization contribute to carbon emissions, improvements in energy efficiency play a more crucial role in mitigating these emissions across the examined developing nations. Mirza et al. provided robust empirical evidence that enhancing energy efficiency can lead to substantial reductions in CO_2

emissions, thereby underscoring its importance in achieving sustainable environmental outcomes. Similarly, in the paper titled "Toward a sustainable mitigation approach of energy efficiency to greenhouse gas emissions in the European countries" published in Heliyon in 2020 [6], Akdag and Yildirim demonstrated that energy efficiency decreases greenhouse gas (GHG) emissions in the European Union and Turkey. By employing a combination of Granger causality and long-run estimators like fully modified and dynamic ordinary least squares (FMOLS and DOLS), they provided robust evidence that enhanced energy efficiency leads to significant reductions in GHG emissions. Additionally, Özkan, Alola, and Adebayo, in their paper "Environmental benefits of non-renewable energy efficiency and renewable energy intensity in the USA and EU: Examining the role of clean technologies," published in Sustainable Energy Technologies and Assessments [7], analyzed the environmental performances of the USA and the EU in response to non-renewable energy efficiency, renewable energy intensity, and environmental-related technologies from 1990 to 2019. Using Kernel-Based Regularized Least Squares and robustness measures, the study found that non-renewable energy efficiency, renewable energy intensity, and environmental technologies significantly mitigate greenhouse gas (GHG) emissions in both economies emphasizing that increasing efficiency in non-renewable energy use and enhancing renewable energy intensity are crucial strategies for reducing GHG emissions and achieving environmental sustainability.

In the context of France, Ridwan et al. in their paper titled "Environmental Sustainability in France: The Role of Alternative and Nuclear Energy, Natural Resources, and Government Spending" [8] examined the impacts of alternative and nuclear energy, natural resources, and government spending on France's ecological sustainability from 1990 to 2021. The study employed the EKC framework, using fully modified least squares (FMOLS) and dynamic ordinary least squares (DOLS) for long-run estimates. Their findings indicate an inverse relationship between CO_2 emissions and the use of renewable and nuclear energies, natural resources, and government spending, while a positive relationship is observed between CO_2 emissions and economic development. The results support the EKC hypothesis, suggesting that as the economy grows, environmental sustainability initially declines but improves in the long run underscoring the importance of promoting alternative and nuclear energy, implementing sustainable resource management policies, and directing government spending towards environmental protection and sustainable practices to achieve substantial environmental benefits and support sustainable development goals.

These studies collectively emphasize the importance of energy efficiency as a key factor in reducing environmental degradation and align with the principles of the EKC hypothesis. They highlight the potential for energy efficiency measures to achieve substantial environmental benefits, supporting sustainable development goals. Factors such as foreign direct investment, financial development, and energy research influence emissions. There is though a research gap in understanding the environmental impacts of alternative and nuclear energy shares on energy consumption and supply, natural resources, and government spending in Vietnam. This study aims to fill this gap by analysing these factors' impact on CO_2 emissions within the EKC context. The study concludes with policy implications, identified research gaps, and future research suggestions.

3. METHODOLOGY

3.1. Theoretical framework

Numerous studies have investigated the relationship between environmental sustainability, renewable energy usage, and economic development. Several linear and nonlinear impacts of economic growth are examined, along with their effects on environmental sustainability, natural resources depletion, and more. Renewable energy sources such as sunlight, wind, and water are primary contributors to green energy. In contrast to carbon-emitting fossil fuels, these renewable sources represent a sustainable alternative.

The rising demand for already scarce natural resources has been exacerbated by various factors, including population growth and changing weather patterns. The quality of water supply and watersheds is deteriorating due to increasing household, industrial, and agricultural demands. Consequently, watersheds and irrigated fields are losing their integrity and functionality. Furthermore, deforestation, overgrazing, salinization, and erosion are increasing, severely impacting people living in poverty who rely on natural resources for their livelihoods. Governments play a crucial role in regulating polluters, maintaining water quality through taxation, and controlling the environmental impact of certain industries.

Economic growth influences the country's actual output by increasing economic activities. However, increased production and consumption can harm ecosystems. Ecological impacts of economic development include global temperature rise, depletion of non-renewable resources, increased pollution, and

Table 1. Data on Vietnam CO_2 Emissions, Renewable Energy Consumption. Natural Resources Rent, Population, GDP, Consumption Expenditure and Trade

	C	RE	N	P	U	T	C	GDP	GDP²
Year	Vietnam CO_2 Emission in Mega Tons (Mt)	Renewable energy consumption (% of total final energy consumption)	Total natural resources rents (% of GDP)	Vietnam Total Population	Urban population (% of total population)	Trade (% of GDP)	Final consumption expenditure (% of GDP)	Vietnam GDP in billion USD	Vietnam GDP squared
1990	19.33	75.91	12.33	66.91	20.3	81.3		6.47	41.88
1991	19.80	75.46	8.02	68.36	20.6	66.9		9.61	92.42
1992	20.81	74.52	10.26	69.79	21.0	73.6		9.87	97.36
1993	24.24	70.62	7.69	71.18	21.4	66.2		13.18	173.74
1994	26.68	67.77	6.74	72.50	21.8	77.5		16.29	265.25
1995	31.40	64.88	7.28	73.76	22.2	74.7	81.80	20.74	429.99
1996	35.03	62.61	7.00	74.95	22.6	92.7	82.79	24.66	607.99
1997	40.84	60.53	5.75	76.06	23.0	94.3	79.90	26.84	720.58
1998	45.47	59.23	4.56	77.13	23.4	97.0	78.51	27.21	740.36
1999	46.41	59.32	5.64	78.12	23.8	102.8	75.43	28.68	822.75
2000	51.21	57.73	9.69	79.00	24.4	111.4	72.88	31.17	971.73
2001	56.72	56.14	7.98	79.82	24.9	112.0	71.18	32.69	1068.32
2002	66.50	52.2	7.43	80.64	25.5	116.7	71.33	35.06	1229.49
2003	70.90	50.83	7.95	81.48	26.1	124.3	72.58	39.55	1564.40
2004	85.05	45.77	11.76	82.31	26.7	133.0	71.47	45.43	2063.69
2005	92.37	44.15	12.13	83.14	27.3	130.7	70.95	57.63	3321.59
2006	94.87	44.25	12.23	83.95	27.9	138.3	70.62	66.37	4405.20
2007	105.14	41.9	11.41	84.76	28.5	154.6	73.66	77.41	5992.99
2008	117.59	39.26	13.92	85.60	29.1	154.3	76.50	99.13	9826.82
2009	132.29	36.97	7.40	86.48	29.8	134.7	74.27	106.01	11239.11
2010	151.41	34.58	7.48	87.41	30.4	114.0	68.82	147.20	21668.19
2011	155.97	36.33	9.07	88.35	31.1	125.3	66.47	172.60	29789.05
2012	155.52	37.91	7.30	89.30	31.8	123.2	66.15	195.59	38255.71
2013	164.30	37.37	5.91	90.27	32.4	130.8	67.80	213.71	45671.46
2014	180.70	36.69	5.66	91.24	33.1	135.4	67.33	233.45	54499.59
2015	201.51	26.54	3.38	92.19	33.8	144.9	69.99	239.26	57244.55
2016	222.03	26.97	2.68	93.13	34.5	145.4	69.14	257.10	66098.35
2017	229.88	28.52	3.21	94.03	35.2	161.0	68.13	281.35	79159.85
2018	286.14	24.59	3.26	94.91	35.9	164.7	66.82	310.11	96166.03
2019	341.72	20.65	2.50	95.78	36.6	164.7	66.41	334.37	111800.13
2020	355.32	19.11	1.81	96.65	37.3	163.2	65.45	346.62	120142.47
2021	0.00		2.55	97.47	38.1	186.4	65.05	366.14	134056.72
2022	0.00			98.19	38.8	185.7	63.92	408.80	167119.38

Source: World Bank Open Data

habitat loss. While no method of economic growth is inherently detrimental to the environment, increased disposable income can lead to more investment in environmental causes. Technological advancements can also help mitigate environmental damage, indicating that a thriving economy can support environmental sustainability.

The Environmental Kuznets Curve (EKC) model provides a theoretical framework for understanding the relationship between economic development and environmental degradation. According to the EKC hypothesis, environmental degradation initially worsens as an economy grows, but improves after reaching a certain level of economic maturity. This inverted U-shaped curve suggests that while industrial growth leads to environmental damage, post-industrial economies tend to adopt cleaner technologies and more efficient resource management practices, ultimately enhancing environmental quality. However, not all pollutants follow this pattern, and the increased prosperity does not necessarily slow the consumption of finite resources. For instance, reducing pollution in one country by importing coal from poorer nations can lead to environmental degradation elsewhere. Often, long-term environmental concerns are overlooked in favor of addressing immediate challenges.

3.2. Data description

From 1990 through 2022, this research uses the EKC model to examine how the Vietnam Trade, Urbanization rate, population, GDP, and the usage of alternative energy sources will affect Vietnam's environmental sustainability. Emissions of CO_2 are reported in Mt. The percentage of ultimate energy consumption that came from renewable sources was calculated. GDP was used because it is a consistent indicator of economic growth in US dollars. All the information for the yearly series comes from the World Bank Open Data Sources.

3.3. Econometric model

The assumption is formulated that the Vietnam GDP will follow the EKC model hypothesizing relationship between environmental quality improvement and economic development growth in Vietnam and its economic growth will eventually lead to environmental sustainability. However, relying solely on economic growth without active environmental policies may not lead to the desired outcomes. We need to consider other factors that may affect the Vietnam’s Path toward sustainability represented by the CO_2 Emissions.

Based on the EKC, this research paper investigates the impacts of renewable energies and natural resources, population growth, urbanization rate alongside government spending on Vietnam's ecological sustainability throughout 1990 - 2022. But due to the lack of data on government, the suggested empirical model is denoted by the subsequent equation:

Ct = b0 + b1REt+ b2Nt + b3Pt + b4Ut + b5Tt + b6Ct + b7GDPt + b8GDP2t

Where RE is alternative energy, N is natural resources rent, P is the population in million, U is the urbanization rate, T is the total trade in % of GDP, C is final consumption in % of GDP, GDP is the economic growth (GDP) and GDP2 is the square of GDP. Additionally, the dependent variable C is CO_2 emissions. Besides, b0 is the intercept and t reflect the time series (1990 to 2021). In addition, b1 to b8 denote the coefficients.

3.4. Estimation strategies

Testing all the regression models ought to be introduced to determine the most influencing factors. Sometimes, in economic and financial theory, it is assumed that non-stationary time series variables have some sort of long-term equilibrium relationship. By testing the model, we can find the most suitable model for explaining the correct sustainability factors in Vietnam.

4. RESULTS AND DISCUSSION

4.1. Result 1. CO_2 influenced by factors of RE, N, P, U, T, C, GDP, GDP2

The statistical results of many normality tests are also shown in Table 2. CO_2 emissions, renewable energies, natural resources, government spending, and economic progression are all summarized. All these variables have a normal distribution, as seen by the high degree of concordance between their means, medians, maximums, and minimums.

The regression model provided is highly significant, explaining 99.6% of the variance in CO_2 emissions based on multiple predictors: GDP, GDP squared (GDP2), Renewable Energy (RE), Natural Resources (N), Population (P), Urbanization Rate (U), Trade (T), and an additional variable (C). The exceptionally high R^2 value (0.996) and Adjusted R^2 (0.994) indicate a near-perfect fit, suggesting that the included predictors are very effective in capturing the variations in CO_2 emissions. This high explanatory power is crucial for making accurate predictions and understanding the main drivers of CO_2

Table 2. Model 1 Regression Result CO2 and RE, N, P, U, T, C, GDP, GDP2

Model Summary 1

Model	R	R Square	Adjusted R Square	Std. Error of the Estimate	Change Statistics				
					R Square Change	F Change	df1	df2	Sig. F Change
1	0.998[a]	0.996	0.994	7.07025	0.996	532.303	8	17	0.000

ANOVA 1[a]

Model		Sum of Squares	df	Mean Square	F	Sig.
1	Regression	212871.767	8	26608.971	532.303	0.000[b]
	Residual	849.802	17	49.988		
	Total	213721.569	25			

Coefficients 1[a]

Model		Unstandardized Coefficients		Standardized Coefficients	t	Sig.	Correlations			Collinearity Statistics	
		B	Std. Error	Beta			Zero-order	Partial	Part	Tolerance	VIF
1	(Constant)	-271.350	629.772		-0.431	0.672					
	RE	-3.497	0.926	-.516	-3.776	0.002	-0.941	-0.675	-0.058	0.013	79.784
	N	2.952	1.354	0.106	2.181	0.044	-0.589	0.468	0.033	0.098	10.162
	P	**7.657**	**9.498**	**0.567**	**0.806**	**0.431**	**0.946**	**0.192**	**0.012**	**0.000**	**2116.190**
	U	**-4.132**	**12.814**	**-0.212**	**-0.322**	**0.751**	**0.960**	**-0.078**	**-0.005**	**0.001**	**1845.774**
	T	-0.752	0.405	-0.199	-1.856	0.081	0.805	-0.410	-0.028	0.020	49.118
	C	**1.301**	**1.460**	**0.069**	**0.891**	**0.385**	**-0.747**	**0.211**	**0.014**	**0.039**	**25.771**
	GDP	-0.634	0.318	-0.761	-1.995	0.062	0.973	-0.436	-0.031	0.002	622.310
	GDP2	0.003	0.001	1.224	5.800	0.000	0.974	0.815	0.089	0.005	190.468

a. Dependent Variable: CO_2

emissions. The model is statistically significant overall, as indicated by the F-statistic (532.303) and its corresponding p-value ($p < 0.001$). This confirms that the model provides a better fit to the data than a model with no predictors. The most influencing individual Predictors are: GDP Squared (GDP2): Shows a strong positive relationship with CO_2 emissions (Beta = 1.224, $p < 0.001$), suggesting that as GDP grows, emissions initially increase at an accelerating rate; Renewable Energy (RE) displays a significant negative relationship (Beta = -0.516, p = 0.002), highlighting the importance of renewable energy in reducing CO_2 emissions. Natural Resources (N) is also positively associated with CO_2 emissions (Beta = 0.106, p = 0.044), indicating that higher exploitation of natural resources leads to higher emissions. However, the High Variance Inflation Factor (VIF) values for some predictors (e.g., Population, Urbanization Rate, GDP) indicate extreme multicollinearity that needs to be modified. This suggests that these predictors are highly correlated, potentially affecting the reliability of the coefficient estimates. Addressing multicollinearity through techniques like removing or combining variables, or using methods like Ridge regression, may improve the model's robustness.

The regression model demonstrates strong predictive power and statistical significance in explaining CO_2 emissions based on economic and environmental factors. However, addressing multicollinearity will be crucial to enhance the reliability of the findings. This model provides valuable insights for developing effective policies to reduce CO_2 emissions and promote sustainable development in Vietnam. It is recommended to remove the most no-reliable variables such as P, U, C.

Table 3. Model 2 Regression Result CO_2 RE, N, T, GDP, GDP2

Model Summary

Model	R	R Square	Adjusted R Square	Std. Error of the Estimate	Change Statistics				
					R Square Change	F Change	df1	df2	Sig. F Change
1	0.998[a]	0.996	0.995	6.72063	0.996	1178.945	5	25	0.000

a. Predictors: (Constant), GDP2, T, N, RE, GDP

ANOVA[a]

Model		Sum of Squares	df	Mean Square	F	Sig.
1	Regression	266245.837	5	53249.167	1178.945	0.000[b]
	Residual	1129.170	25	45.167		
	Total	267375.007	30			

a. Dependent Variable: CO2

b. Predictors: (Constant), GDP2, T, N, RE, GDP

Coefficients[a]

Model		Unstandardized Coefficients		Standardized Coefficients	t	Sig.	Correlations			Collinearity Statistics	
		B	Std. Error	Beta			Zero-order	Partial	Part	Tolerance	VIF
1	(Constant)	289.912	36.590		7.923	0.000					
	RE	-3.597	0.396	-0.644	-9.090	0.000	-0.921	-0.876	-0.118	0.034	29.685
	N	2.925	0.659	0.100	4.439	0.000	-0.597	0.664	0.058	0.332	3.010
	T	-0.419	0.146	-0.136	-2.876	0.008	0.829	-0.499	-0.037	0.076	13.163
	GDP	-0.339	0.084	-0.399	-4.019	0.000	0.977	-0.627	-0.052	0.017	58.401
	GDP2	0.003	0.000	0.999	12.808	0.000	0.966	0.932	0.166	0.028	36.040

a. Dependent Variable: CO_2

4.2. Result 2. CO_2 influenced by factors of RE, N, T, GDP, GDP2

The regression model is highly significant in explaining CO_2 emissions, with an exceptionally high R^2 value of 0.996, indicating that 99.6% of the variance in CO_2 emissions can be explained by the predictors. The model includes key variables such as GDP, GDP squared (GDP2), Renewable Energy (RE), Natural Resources (N), and Trade (T). The Adjusted R^2 of 0.995 confirms the model's robustness after accounting for the number of predictors.

The model's F-statistic of 1178.945, with a p-value less than 0.001, demonstrates that the overall model is highly significant. Individually, all predictors have significant p-values, underscoring their importance in predicting CO_2 emissions. For instance, Renewable Energy (RE) shows a strong negative relationship with CO_2 emissions, suggesting that increased use of renewable energy significantly reduces emissions. Conversely, GDP squared (GDP2) has a very strong positive relationship, indicating that as the economy grows, emissions initially increase at an accelerating rate.

However, the model faces multicollinearity issues, as indicated by high Variance Inflation Factor (VIF) values for several predictors, particularly Renewable Energy (RE), Trade (T), GDP, and GDP squared (GDP2). This suggests that these variables are highly correlated with each other, which could affect the reliability of the coefficient estimates. Addressing multicollinearity through variable selection or combining methods would be essential for improving the model's reliability.

In conclusion, the model is highly significant effectively captures the main drivers of CO_2 emissions, providing valuable insights for policymakers and

Table 4. Model 3 Regression Result CO_2 and RE, N, T, GDP2

Model Summary									
Model	R	R Square	Adjusted R Square	Std. Error of the Estimate	Change Statistics				
					R Square Change	F Change	df1	df2	Sig. F Change
1	0.997[a]	0.993	0.992	8.45544	0.993	928.450	4	26	0.000

a. Predictors: (Constant), GDP2, T, N, RE

ANOVA[a]						
Model		Sum of Squares	df	Mean Square	F	Sig.
1	Regression	265516.151	4	66379.038	928.450	0.000[b]
	Residual	1858.856	26	71.494		
	Total	267375.007	30			

a. Dependent Variable: CO_2

b. Predictors: (Constant), GDP2, T, N, RE

Coefficients[a]											
Model		Unstandardized Coefficients		Standardized Coefficients	t	Sig.	Correlations			Collinearity Statistics	
		B	Std. Error	Beta			Zero-order	Partial	Part	Tolerance	VIF
1	(Constant)	183.421	31.751		5.777	0.000					
	RE	-2.379	0.320	-0.426	-7.432	0.000	-0.921	-0.825	-0.122	0.081	12.271
	N	2.306	0.806	0.079	2.860	0.008	-0.597	0.489	0.047	0.351	2.845
	T	-0.137	0.161	-0.044	-0.855	0.400	0.829	-0.165	-0.014	0.099	10.121
	GDP2	0.002	0.000	0.709	19.036	0.000	0.966	0.966	0.311	0.193	5.191

a. Dependent Variable: CO_2

researchers. However, high multicollinearity among some predictors suggests that the estimates might not be entirely reliable, necessitating further analysis or remedial measures like removing or combining variables. Yet, further refinement is necessary to address multicollinearity and enhance the robustness of the findings.

By removing the GDP out of the model, we have the following results:

4.3. Result 3. CO_2 influenced by factors of RE, N, T, GDP2

The regression model demonstrates a highly significant ability to predict CO_2 emissions, explaining 99.3% of the variance in the data. This is evidenced by an R^2 value of 0.993 and an Adjusted R^2 of 0.992, indicating that the model's predictors - GDP squared (GDP2), Trade as a percentage of GDP (T), Natural Resources Rent as a percentage of GDP (N), and Renewable Energy as a percentage of total energy consumption (RE) - are very effective in capturing the variations in CO_2 emissions. The model's F-statistic of 928.450, with a p-value less than 0.001, confirms the overall significance of the model.

The coefficients for Renewable Energy (RE) and GDP squared (GDP2) are particularly noteworthy. A unit increase in the share of Renewable Energy in total energy consumption leads to a significant decrease in CO_2 emissions by 2.379 units, highlighting the importance of renewable energy in mitigating emissions. Conversely, a unit increase in GDP squared results in a 0.002 unit increase in CO_2 emissions, reflecting the accelerating impact of economic growth on emissions. Natural Resources Rent as a percentage of GDP (N) also shows a positive relationship with CO_2 emissions, with a unit increase leading to a 2.306 unit increase in emissions, indicating that higher exploitation of natural resources correlates with higher emissions. Trade as a percentage of GDP (T) has a negative but not statistically significant effect on CO_2 emissions which lead to a rational removal of the Trade index out of the Model.

Despite the model's strong predictive power, it exhibits some multicollinearity, particularly among RE and T, as indicated by their high Variance Inflation Factor (VIF) values. This multicollinearity suggests that these variables are highly correlated with each other, which may affect the reliability of the coefficient estimates. Addressing this issue through techniques like removing or combining variables, or using advanced methods like Ridge regression, could enhance the model's robustness.

In conclusion, the model provides valuable insights into the key factors driving CO_2 emissions, emphasizing the critical role of renewable energy in reducing emissions and the complex relationship between economic growth, trade, and environmental impact. However, further refinement to address multicollinearity would improve the reliability and applicability of the findings. As Renewable energy is an indispensable factor that can influence the CO_2 emissions and the Trade can be affected by GDP, so it is highly recommended that the model should exclude the T variable and we have the following results:

4.4. Result 4. CO_2 influenced by factors of RE, N, GDP2

The regression model for predicting CO_2 emissions demonstrates a high level of accuracy and reliability, with an R^2 value of 0.993 and an Adjusted R^2 of 0.992. This indicates that 99.3% of the variance in CO_2 emissions is explained by the predictors: GDP squared (GDP2), Natural Resources Rent as a percentage of GDP (N), and Renewable Energy as a percentage of total energy consumption (RE). The model's statistical significance is further confirmed by an F-statistic of 1250.114 and a

Table 5. Model 4 Regression Result CO_2 and RE, N, GDP2

Model Summary

Model	R	R Square	Adjusted R Square	Std. Error of the Estimate	Change Statistics				
					R Square Change	F Change	df1	df2	Sig. F Change
1	0.996[a]	0.993	0.992	8.41332	0.993	1250.114	3	27	0.000

a. Predictors: (Constant), GDP2, N, RE

ANOVA[a]

Model		Sum of Squares	df	Mean Square	F	Sig.
1	Regression	265463.842	3	88487.947	1250.114	0.000[b]
	Residual	1911.165	27	70.784		
	Total	267375.007	30			

a. Dependent Variable: CO_2

b. Predictors: (Constant), GDP2, N, RE

Coefficients[a]

Model		Unstandardized Coefficients		Standardized Coefficients	t	Sig.	Correlations			Collinearity Statistics	
		B	Std. Error	Beta			Zero-order	Partial	Part	Tolerance	VIF
1	(Constant)	158.569	12.742		12.444	0.000					
	RE	-2.143	0.161	-0.383	-13.271	0.000	-0.921	-0.931	-0.216	0.317	3.154
	N	1.976	0.704	0.068	2.805	0.009	-0.597	0.475	0.046	0.456	2.194
	GDP2	0.002	0.000	0.704	19.242	0.000	0.966	0.965	0.313	0.198	5.057

a. Dependent Variable: CO_2

p-value of less than 0.001, underscoring the robustness of the relationship between the predictors and CO_2 emissions.

Renewable Energy (RE) is particularly noteworthy, with a significant negative coefficient (-2.143), suggesting that increasing the share of renewable energy in total energy consumption substantially reduces CO_2 emissions. This underscores the critical role of renewable energy in mitigating environmental impact. Conversely, Natural Resources Rent (N) has a positive coefficient (1.976), indicating that higher exploitation of natural resources, as a percentage of GDP, leads to increased CO_2 emissions. GDP squared (GDP2) also shows a significant positive coefficient (0.002), highlighting the accelerating effect of economic growth on emissions.

The model's explanatory power is robust, as evidenced by the significant sum of squares explained by the regression (265,463.842) compared to the residual (1,911.165). The collinearity statistics show that while there is some multicollinearity among the predictors, it is within acceptable limits, with VIF values for RE (3.154), N (2.194), and GDP2 (5.057) indicating moderate multicollinearity. In conclusion, this model is highly reliable for understanding and predicting CO_2 emissions. It highlights the importance of renewable energy in reducing emissions and the complex interplay between economic growth and environmental impact. While addressing multicollinearity could further enhance the model's robustness, the current findings provide valuable insights for policymakers aiming to develop strategies to mitigate CO_2 emissions.

The final suggested equation is:

$$\mathbf{CO_2 = 158.569 - 2.143 \times RE + 1.976 \times N + 0.002 \times GDP2}$$

From the equation we can state that 158.6 is the baseline level of CO_2 emissions when all predictor variables (RE, N, and GDP squared) are zero. It addresses the net zero emissions Strategy of Vietnam for 2050 is extremely difficult to implement. However, for each unit increase in the share of renewable energy in total energy consumption, CO_2 emissions decrease by 2.143 units. This indicates that increasing the use of renewable energy sources significantly reduces CO_2 emissions, highlighting the positive environmental impact of renewable energy adoption. Concerning the natural resources, for each unit increase in natural resources rent as a percentage of GDP, CO_2 emissions increase by 1.976 units. This suggests that higher exploitation of natural resources, which often involves activities like mining and deforestation, is associated with increased CO_2 emissions. Concerning the GDP, for each unit increase in GDP squared, CO_2 emissions increase by 0.002 units. This reflects the accelerating impact of economic growth on CO2 emissions, where higher levels of GDP lead to disproportionately higher emissions, likely due to increased industrial activities and energy consumption, while the urbanization has mostly no significant impact on the accelerating the CO_2 emissions. It suggests that a slight increase in GDP may lead to extreme effect of CO_2 emissions explosion without taking into consideration the renewable energy sources.

5. CONCLUSION AND POLICY RECOMMENDATIONS

This research applies the EKC to a study of the environmental sustainability of Vietnam from 1990 to 2022, focusing on the impacts of alternative energy usage, natural resources, and GDP. All variables are converted to their natural logarithms before being used in the estimating process. The EKC model seems to be non-applicable with the Vietnam situation since the factors GDP and GDP squared are extremely multicollinear. This finding explains the significance of renewable energy sources, as well as natural resources to environmental sustainability. Sustainability in Vietnam show no declines as economic development advances as suggested by EKC model. While the renewable energy and natural resources play an indispensable role for the reduction of CO_2 emissions.

Balancing societal benefits and environmental impacts is crucial when exploiting natural resources. Natural resource policy aims to balance these factors equitably. Biodiversity protection shares these concerns, with property rights playing a key role. However, designing effective property rights systems is complex, involving fair distribution, progress metrics, and deadlines. Resource allocation policies face the challenge of equitable distribution, which is particularly intricate in biodiversity policies. While external concerns about ecosystem threats are valid, protective measures are ineffective without local landowners' support. Effective resource protection requires adherence to rules and procedures, yet natural resource systems often have compliance loopholes. Critics who ignore the distributional impacts of property rights hinder the evolution of more equitable systems. Lack of resources fosters rent-seeking, weakening institutions. Sustainable practices like reduced tree cutting and reforestation are essential. With a growing population, conserving resources like trees, metals, and water is urgent.

True economic progress is best measured by GDP growth, but other indicators like improved education, infrastructure, poverty reduction, and healthcare quality are also necessary. Economic development policies should aim for a robust economy with low inflation and healthy growth. Supply-side measures such as privatization, deregulation, tax cuts, and reduced regulation can attract private investment. Diversifying the economy beyond agriculture allows for greater investment in public goods like schools, roads, and hospitals, benefiting overall economic health. The Vietnamese Authorities should implement the following strategies:

Increase Renewable Energy Adoption:

- Policy Implementation: Governments should implement policies that promote the use of renewable energy sources such as solar, wind, and hydroelectric power. This could include subsidies, tax incentives, and grants for renewable energy projects.
- Infrastructure Investment: Invest in the infrastructure needed to support renewable energy, such as smart grids and energy storage systems, to ensure a reliable and efficient energy supply.

Sustainable Natural Resource Management:

- Regulation and Enforcement: Enforce stricter regulations on the exploitation of natural resources to minimize environmental degradation. This could involve setting limits on deforestation, mining, and other extractive activities.
- Sustainable Practices: Promote sustainable practices in industries that rely on natural resources. For example, sustainable forestry management and responsible mining practices can reduce the environmental impact.

Economic Growth with Environmental Considerations:

Green Technologies: Encourage the adoption of green technologies that enhance energy efficiency and reduce emissions in industrial processes. This can be achieved through incentives for research and development in clean technologies.

Environmental Impact Assessments: Integrate environmental impact assessments into economic planning and development projects to ensure that growth does not come at the expense of the environment.

Public Awareness and Education:

Education Campaigns: Launch public awareness campaigns to educate citizens and businesses about the benefits of renewable energy and sustainable practices.

Community Engagement: Engage communities in local renewable energy projects and natural resource management initiatives to foster a culture of sustainability.

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