DECOUPLING ECONOMIC GROWTH AND ENVIRONMENTAL IMPACT: PERSPECTIVE OF ANALYZING CO2 INDEX

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Abstract: ***This study examines the drivers of CO2 emissions efficiency in Vietnam, focusing on the relationship between development private economic sector, industrial output, energy access, and urbanization. The study highlights the need for comprehensive urban planning and energy-efficient infrastructure to reduce emissions intensity while sustaining economic growth. Utilizing data from 1990 to 2020, the research employs econometric techniques such as ARIMA, ARDL to identify trends. Key findings reveal that CO2 emissions efficiency is heavily influenced by historical emissions patterns, industrial output, and urbanization. While significant progress in renewable energy and policy frameworks has been made, challenges remain in balancing industrialization with sustainable practices. These findings provide actionable insights for policymakers aiming to achieve Vietnam's environmental and economic goals especially in private economic sector.***

• Keywords: *economic growth; pollution; middle-income countries, CO2 emissions.*

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1. Introduction

Vietnam, a rapidly growing economy in Southeast Asia, has achieved significant economic growth over the past few decades. However, this growth has come with rising CO2 emissions, making environmental sustainability a critical concern. As Vietnam transitions from an agricultural to an industrial economy, balancing economic growth with environmental protection is a key challenge.

Measuring CO2 emissions efficiency defined as CO2 emissions per unit of GDP (in PPP $) provides a better understanding of Vietnam's environmental sustainability relative to its economic output. This research focuses on analyzing what drives CO2 emissions efficiency in Vietnam, allowing for targeted policy interventions.

Vietnam has made significant strides in renewable energy adoption and environmental regulations, but its CO2 emissions per unit of GDP remain higher compared to other countries with similar income levels. Understanding the factors driving these efficiency variations is crucial for formulating effective national policies. The relationship between economic growth, industrialization, and CO2 emissions is complex, with factors such as access to electricity, GDP growth rate, industrial output, and urbanization playing a significant role in emissions intensity. Rapid industrialization and urbanization, if coupled with fossil fuel reliance, can worsen emissions, while improving energy access and transitioning to renewable energy could decouple economic growth from emissions. This study aims to address the gap in research on how these factors influence CO2 emissions relative to GDP, providing insights to guide policies for sustainable growth and reduced carbon footprints.

2. Literature review

Several studies have examined the intricate relationship between foreign direct investment (FDI), urbanization, and CO2 emissions in Vietnam. FDI, while boosting economic growth, often increases emissions due to industrial expansion and energy-intensive manufacturing processes. Urbanization contributes further by escalating energy demand for transportation, housing, and infrastructure. For instance, Ngoc, Tuan, and Duy (2021) highlight the dual impact of FDI and urban development on environmental degradation, while Minh et al. (2023) emphasizes the role of urban population growth in amplifying energy consumption and emissions. These findings underline the need to balance economic

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development with sustainable urban planning.

Research on renewable energy and green finance highlights their potential to decouple economic growth from environmental harm. Studies like Hoffmann (2020) and Tran (2022) illustrate how green finance and investments in renewable energy sources, such as wind and solar, contribute to achieving CO2 reduction targets. Moreover, these measures support Vietnam's transition to a sustainable energy system while addressing the rising emissions associated with rapid industrialization and population growth. These findings align with the Environmental Kuznets Curve hypothesis, as explored by Vo et al. (2019), which suggests that emissions initially rise with economic growth but eventually decline with greater investments in sustainable practices.

Sector-specific analyses reveal that industrialization, agricultural practices, and export-driven growth are significant contributors to CO2 emissions in Vietnam. Structural decomposition studies, such as those by Nguyen (2012) and Raihan (2023), identify energy-intensive industries as major sources of emissions, while Nguyen (2007) highlights the role of renewable energy in reducing dependence on fossil fuels. Policy recommendations from this body of literature emphasize the importance of investing in renewable energy technologies, implementing stricter industrial emission standards, and fostering energy-efficient urban development. These strategies are critical for Vietnam to balance economic growth with environmental sustainability, ensuring long-term reductions in CO2 emissions while maintaining competitiveness in a globalized economy.

3. Data resource and Methodology

The study will use annual data from the World Bank World Development Indicators (WDI) for Vietnam, covering the period 1990–2020. Additional data on institutional quality will be obtained from the World Bank's Worldwide Governance Indicators (WGI). Energy consumption data, specifically on the share of renewables and the use of fossil fuels, will be sourced from the International Energy Agency (IEA).

The research employs econometric techniques such as ARIMA, ARDL to identify trends.

4. Result and Discussion

Table 1: Correlation Matrix

	CO2	ELC	GDP	IND	URB
CO2	1.000000	0.587490	-0.086840	0.156366	0.557710
ELC	0.587490	1.000000	-0.165028	0.070982	0.898465
GDP	-0.086840	-0.165028	1.000000	0.084286	-0.170177
IND	0.156366	0.070982	0.084286	1.000000	-0.081251
URB	0.557710	0.898465	-0.170177	-0.081251	1.000000

The correlation matrix shows a moderate positive correlation between CO2 emissions and both Access to electricity (ELC) (0.587) and Urbanization Rate (URB) (0.558), indicating that as electricity access and urbanization increase, CO2 emissions relative to GDP also rise. However, there is a high correlation between ELC and URB (0.898), suggesting multicollinearity, which could distort the regression results. To avoid unreliable estimates, it is important to check for multicollinearity (e.g., using Variance Inflation Factor) and possibly adjust the model by removing or combining these variables before proceeding with further analysis.

Table 2: Descriptive Statistics

	CO2	ELC	GDP	IND	URB
Mean	0.269872	94.32793	6.750477	34.19244	27.81635
Median	0.272470	96.10000	6.787316	35.39036	27.28100
Maximum	0.321258	100.0000	9.540480	40.20875	37.34000
Minimum	0.215774	78.40000	2.865413	22.67429	20.25700
Std. Dev.	0.028547	5.748656	1.399387	4.495348	5.289959
Skewness	-0.055560	-1.013609	-0.226784	-1.002409	0.249353
Kurtosis	2.191584	3.386133	3.654157	3.243956	1.797666
Jarque-Bera	0.860099	4.258711	0.818457	5.268463	2.188490
Probability	0.650477	0.118914	0.664162	0.071774	0.334792
Sum	8.366041	2263.870	209.2648	1059.966	862.3070
Sum Sq. Dev.	0.024448	760.0821	58.74849	606.2445	839.5100
Observations	31	24	31	31	31

4.1. Test for Stationarity (ADF Test)

Table 3: Stationary testing

Method	Statistic	Prob.**	Cross-sections	Obs
Null: Unit root (assumes common unit root process)				
Levin, Lin & Chu t*	-0.96560	0.1671	2	60
Null: Unit root (assumes individual unit root process)				
Im, Pesaran and Shin W-stat	0.46056	0.6774	2	60
ADF - Fisher Chi-square	1.75372	0.7809	2	60
PP - Fisher Chi-square	0.95450	0.9166	2	60

*** Probabilities for Fisher tests are computed using an asymptotic Chi-square distribution. All other tests assume asymptotic normality.*

The results from the group unit root tests (Levin, Lin & Chu t*, Im, Pesaran and Shin W-stat, ADF-Fisher, and PP-Fisher) indicate that CO2 emissions relative to GDP are non-stationary since the p-values for all tests are greater than the common significance level (e.g., 0.05). For instance, the p-value for the Levin, Lin & Chu test is 0.1671, which means we fail to reject the null hypothesis of a unit root (non-stationarity).

4.2. Differencing the Data

Table 4: Differencing the data

		t-Statistic	Prob.*
Augmented Dickey-Fuller test statistic		-4.947487	0.0004
Test critical values:	1% level	-3.689194	
	5% level	-2.971853	
	10% level	-2.625121	

* *MacKinnon (1996) one-sided p-values.*

Augmented Dickey-Fuller Test Equation
Dependent Variable: D(D_CO2)
Method: Least Squares
Date: 10/18/24 Time: 07:20
Sample (adjusted): 1993 2020
Included observations: 28 after adjustments

Variable	Coefficient	Std. Error	t-Statistic	Prob.
D_CO2(-1)	-1.253053	0.253271	-4.947487	0.0000
D(D_CO2(-1))	0.310852	0.189259	1.642470	0.1130
C	0.003841	0.002906	1.321712	0.1982
R-squared	0.542055	Mean dependent var		0.000197
Adjusted R-squared	0.505420	S.D. dependent var		0.021265
S.E. of regression	0.014955	Akaike info criterion		-5.466618
Sum squared resid	0.005591	Schwarz criterion		-5.323881
Log likelihood	79.53265	Hannan-Quinn criter.		-5.422982
F-statistic	14.79588	Durbin-Watson stat		2.102020
Prob(F-statistic)	0.000058			

The Augmented Dickey-Fuller (ADF) test on the differenced CO2 series (D_CO2) shows a t-statistic of -4.947 with a p-value of 0.0004, which is smaller than the 5% critical value and statistically significant. This means we can reject the null hypothesis, indicating that the differenced series is stationary. The R-squared of 0.54 suggests a decent fit for the model, and the Durbin-Watson statistic of 2.10 shows no serious autocorrelation issue. Since stationarity has been achieved, the next step is to proceed with regression analysis using the stationary differenced series (D_CO2) and your chosen independent variables.

4.3. Linear Trend Model

Table 5: Linear Trend Model

Variable	Coefficient	Std. Error	t-Statistic	Prob.
C	0.000536	0.005814	0.092241	0.9272
@TREND	0.000112	0.000327	0.341842	0.7350
R-squared	0.004156	Mean dependent var		0.002272
Adjusted R-squared	-0.031410	S.D. dependent var		0.015287
S.E. of regression	0.015526	Akaike info criterion		-5.428313
Sum squared resid	0.006749	Schwarz criterion		-5.334900
Log likelihood	83.42469	Hannan-Quinn criter.		-5.398429
F-statistic	0.116856	Durbin-Watson stat		1.810763
Prob(F-statistic)	0.735022			

The results from the linear trend model suggest that the trend in differenced CO2 emissions (D_CO2) over time is not statistically significant. The p-value for the trend variable (@TREND) is 0.7350, indicating no meaningful relationship between CO2 emissions and time. Additionally, the R-squared value is extremely low (0.004), showing that the model explains almost none of the variability in CO2 emissions. The F-statistic confirms the lack of overall significance, with a p-value of 0.735. Given these findings, the linear trend model does not provide useful insight into CO2 emissions trends and suggests that other variables or models should be explored.

4.4. Autoregressive Model (AR)

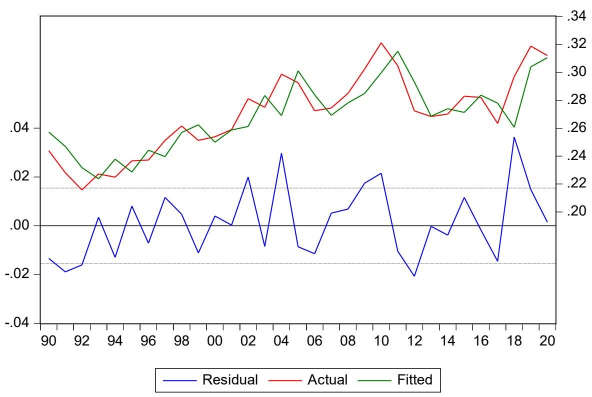
Autoregressive model for CO2:

$$CO2_t = \alpha_0 + \alpha_1 CO2_{t-1} + \alpha_2 CO2_{t-2} + \alpha_3 CO2_{t-3} + \varepsilon_t$$

Table 6: ARMA Model

Variable	Coefficient	Std. Error	t-Statistic	Prob.
C	0.271143	0.019070	14.21827	0.0000
AR(1)	1.072615	0.193336	5.547945	0.0000
AR(2)	-0.395299	0.269252	-1.468137	0.1541
AR(3)	0.186504	0.251091	0.742775	0.4643
SIGMASQ	0.000201	6.19E-05	3.241862	0.0032
R-squared	0.745616	Mean dependent var		0.269872
Adjusted R-squared	0.706480	S.D. dependent var		0.028547
S.E. of regression	0.015466	Akaike info criterion		-5.303966
Sum squared resid	0.006219	Schwarz criterion		-5.072678
Log likelihood	87.21147	Hannan-Quinn criter.		-5.228572
F-statistic	19.05193	Durbin-Watson stat		1.952730
Prob(F-statistic)	0.000000			
Inverted AR Roots	.86	.10+.45i	.10-.45i	

Figure 3: Actual, Fitted and Residual line of CO2 ARMA model



The AR(3) model for CO2 emissions shows a strong fit, with the first lag (AR(1)) being the only statistically significant predictor, indicating that last period's CO2 emissions are a strong influence on the current level. The model explains about 74.6% of the variance in CO2 emissions (R-squared =

0.7456), and the low residual variance (SIGMASQ = 0.000201) suggests accurate predictions with minimal unexplained noise. The Durbin-Watson statistic of 1.95 indicates no significant autocorrelation issues, confirming the model's stability. Overall, the model effectively captures most of the variability in CO2 emissions using past values, primarily driven by the most recent lag.

4.5. Autoregressive Integrated Moving Average (ARIMA) Model (1,1,2)

$$\Delta CO2_t = \varphi \Delta CO2_{t-1} + \theta_1 \varepsilon_{t-1} + \theta_2 \varepsilon_{t-2} + \varepsilon_t$$

The ARIMA(1,1,2) model for differenced CO_2 emissions shows a statistically significant constant term, indicating a slight upward trend, but both the AR(1) and MA terms are statistically insignificant with very high standard errors for MA terms, suggesting they add little predictive value. The low R-squared (0.27) implies limited explanatory power, and estimation issues indicate possible model instability. The Durbin-Watson statistic of 1.94 suggests no major autocorrelation, yet the model's challenges in convergence and high residual uncertainty suggest that an alternative, simpler model may be more appropriate for reliable forecasting.

Table 7: ARMA Maximum Likelihood

Variable	Coefficient	Std. Error	t-Statistic	Prob.
C	0.002413	0.000686	3.519077	0.0017
AR(1)	0.410652	0.422550	0.971843	0.3404
MA(1)	-0.553336	2153.166	-0.000257	0.9998
MA(2)	-0.446664	2657.773	-0.000168	0.9999
SIGMASQ	0.000166	0.116014	0.001427	0.9989
R-squared	0.266951	Mean dependent var		0.002272
Adjusted R-squared	0.149663	S.D. dependent var		0.015287
S.E. of regression	0.014097	Akaike info criterion		-5.453194
Sum squared resid	0.004968	Schwarz criterion		-5.219662
Log likelihood	86.79792	Hannan-Quinn criter.		-5.378485
F-statistic	2.276032	Durbin-Watson stat		1.936572
Prob(F-statistic)	0.089401			
Inverted AR Roots		.41		
Inverted MA Roots	1.00		-.45	

4.6. Autoregressive Distributed Lag (ARDL) Model (1,1,1,1,1)

Table 9: ARDL Model

Variable	Coefficient	Std. Error	t-Statistic	Prob.
C	0.277963	0.181753	1.529350	0.1501
D(ELC)	-0.002999	0.002817	-1.064888	0.3063
D(GDP)	0.005512	0.003467	1.589955	0.1359
D(IND)	-0.003547	0.002724	-1.302074	0.2155
D(URB)	-0.033826	0.186250	-0.181617	0.8587
CO2(-1)	-0.221192	0.223497	-0.989687	0.3404
ELC(-1)	-0.005326	0.002704	-1.969441	0.0706
GDP(-1)	0.000114	0.004888	0.023280	0.9818
IND(-1)	0.002793	0.002328	1.199782	0.2516
URB(-1)	0.007213	0.002998	2.406307	0.0317
R-squared	0.627593	Mean dependent var		0.002641
Adjusted R-squared	0.369772	S.D. dependent var		0.016369
S.E. of regression	0.012995	Akaike info criterion		-5.549462
Sum squared resid	0.002195	Schwarz criterion		-5.055769
Log likelihood	73.81881	Hannan-Quinn criter.		-5.425300
F-statistic	2.434225	Durbin-Watson stat		2.437222
Prob(F-statistic)	0.070680			

The regression analysis with the dependent variable as the first difference of CO_2 emissions (D(CO2)) reveals that the model explains approximately 63% of the variation in CO_2 emissions, with an adjusted R-squared of 0.37. The results show that most of the variables, including electricity access (D(ELC)), GDP (D(GDP)), industrial output (D(IND)), and urbanization (D(URB)), do not have statistically significant short-term effects on CO_2 emissions, as their p-values are above the common significance threshold of 0.05. The lagged variable for CO_2 emissions (CO2(-1)) is also not significant. However, lagged electricity access (ELC(-1)) has a marginally significant negative effect on CO_2 emissions at the 10% level, while lagged urbanization (URB(-1)) has a positive and significant effect on CO_2 emissions at the 5% level. The F-statistic (2.43) is marginally significant, indicating some explanatory power for the model, but the p-value (0.0707) suggests that further improvements or more data might be needed for stronger conclusions

Figure 4: Actual, Fitted and Residual line in ARDL Model

The analysis reveals several key findings regarding the relationship between CO2 emissions efficiency and Vietnam's economic and structural variables. The Augmented Dickey-Fuller (ADF) test shows that CO2 emissions relative to GDP are non-stationary but become stationary after first differencing, confirming the need for data transformation to ensure reliable analysis. The AR(3) model demonstrates that past emissions significantly predict current emissions, with the first lag (AR(1)) explaining most of the variance, accounting for approximately 74.6% of total variability. However, the ARIMA(1,1,2) model faces estimation challenges, with insignificant parameters and low explanatory power, suggesting it may not effectively capture the dynamics of CO2 emissions.

These findings underscore the complex interplay between economic growth, energy access, and environmental sustainability in Vietnam. The strong dependence of current CO2 emissions on historical values highlights the persistence of emissions trends, driven by structural and energy-related factors. High correlations between electricity access and urbanization raise concerns about multicollinearity, which could affect model reliability. Moreover, the limited causality results suggest that these variables may influence CO2 emissions through indirect or nonlinear pathways, necessitating further exploration using advanced techniques. Policymakers should focus on improving energy efficiency, particularly in urban areas and industrial sectors, while addressing the challenges of balancing economic growth with environmental sustainability. These insights provide a foundation for designing policies that decouple economic progress from environmental harm.

5. Conclusion

The research underscores the complexity of reducing CO_2 emissions relative to GDP in a rapidly developing economy like Vietnam. Despite advancements in renewable energy and environmental regulations, industrial output and urbanization remain key drivers of emissions intensity. The persistence of historical emissions trends further complicates mitigation efforts, emphasizing the importance of innovative policies to decouple economic growth from environmental degradation. By prioritizing energy-efficient technologies, stricter emissions standards, and sustainable urban planning, Vietnam can enhance its environmental efficiency without compromising economic expansion. This study offers a foundation for developing targeted interventions to support Vietnam's transition toward a low-carbon, sustainable future.

6. Policy Implications

For Vietnam's Environmental Policy:

Vietnam's environmental policies should prioritize enhancing energy efficiency and promoting renewable energy adoption to reduce CO2 emissions while supporting economic growth. Policymakers should strengthen incentives for cleaner technologies in industrial sectors and expand financial support for renewable energy projects. A key strategy is to implement stricter emissions standards for industries and encourage the adoption of low-carbon technologies through subsidies and tax breaks. Additionally, investments in research and development for green energy solutions, combined with public awareness campaigns, can foster long-term shifts toward sustainable energy consumption. Improving governance and monitoring systems to ensure compliance with environmental regulations will further enhance emissions efficiency.

For Urban Planning

Urban planning should integrate energy-efficient infrastructure and prioritize sustainable transportation systems to address the rising CO2 emissions associated with urbanization. Cities must focus on increasing public transit availability, developing walkable urban areas, and implementing green building standards to minimize energy demand. Expanding renewable energy usage in urban areas, such as through solar installations and energy-efficient grids, is critical for sustainable urban growth. Furthermore, urban planners should promote mixed-use developments that reduce the need for long commutes, thereby lowering transportation-related emissions. These initiatives, paired with robust policies supporting urban greening and waste management systems, will help Vietnam manage urban growth while minimizing its environmental footprint.

References:

Hoffmann, C., (2020). A power development planning for Vietnam under the CO2 emission reduction targets. Energy Reports, 6(2), 19-24 https://doi.org/10.1016/j.egyr.2019.11.036.

Minh, T.B., Ngoc, T.N. & Van, H.B., (2023). Relationship between carbon emissions, economic growth, renewable energy consumption, foreign direct investment, and urban population in Vietnam. Heliyon, 9(6). https://doi.org/10.1016/j.heliyon.2023.e17544.

Ngoc, H.T., Tuan, B.A. & Duy, N.V., (2021). Impact of foreign direct investment and urbanisation on CO2 emissions in Vietnam. Journal of Business, 27(3), pages 313-332.

Nguyen, K.Q., (2007). Impacts of wind power generation and CO2 emission constraints on the future choice of fuels and technologies in the power sector of Vietnam. Energy Policy, 35(4), 2305-2312. https://doi.org/10.1016/j.enpol.2006.06.023

Nguyen, T.K.A., (2012). Structural decomposition analysis of CO2 emission variability in Vietnam during the 1986–2008 period. VNU Journal of Economics and Business, 28(2), 115-123. http://repository.vnu.edu.vn/handle/VNU_123/14132

Raihan, A., (2023). An econometric evaluation of the effects of economic growth, energy use, and agricultural value added on carbon dioxide emissions in Vietnam. Asia-Pacific Journal of Regional Science, 7, 665-696. https://doi.org/10.1007/s41685-023-00278-7

Tran, Q.H., (2022). The impact of green finance, economic growth and energy usage on CO2 emission in Vietnam – a multivariate time series analysis. China Finance Review International, DOI:10.1108/CFRI-03-2021-0049

Vo, A.T., Vo, D.H. & Le, Q.T.T., (2019). CO2 emissions, energy consumption, and economic growth: New evidence in the ASEAN countries. Journal of Risk and Financial Management, 12(3), 145. https://doi.org/10.3390/jrfm12030145