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Agriculture Growth and Environmental Degradation in Vietnam: Do Natural Resources Play a Vital Role in this Regard

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The growth of agriculture in Vietnam has significantly transformed the country's socio-economic landscape, enhancing food security and boosting agricultural exports. However, this growth has also emerged as a leading contributor to environmental degradation. Additionally, Vietnam's rich natural resources, while facilitating economic development, have similarly played a pivotal role in environmental challenges. Therefore, it is essential to re-evaluate the interplay between agricultural growth, natural resource exploitation, and environmental degradation. To address this, the current study employs the conventional STIRPAT (Stochastic Impacts by Regression on Population, Affluence, and Technology) framework to analyse the effects of agricultural growth and natural resources on environmental degradation, operationalized through CO2 emissions in Vietnam from 1990 to 2020. The research not only aims to estimate the direct impacts of these variables but also investigates the moderating influence of natural resources on the relationship between agricultural growth and environmental degradation. The methodology employed is the Autoregressive Distributed Lag (ARDL) Bound Test approach, which allows for an assessment of both short-term and long-term relationships among the variables. The findings indicate that agricultural growth exerts a positive and significant impact on CO2 emissions in both the short and long term. Conversely, the influence of natural resources on CO2 emissions is found to be statistically significant and positive only in the short term. Furthermore, the analysis reveals that the moderating effect of natural resources on the relationship between agricultural growth and CO2 emissions is negative but statistically insignificant in both the short and long term. In light of these findings, the study suggests several policy recommendations aimed at achieving environmental sustainability in Vietnam. These policies are designed to balance agricultural development with environmental conservation, ensuring that the benefits of economic growth do not come at the expense of ecological health. Overall, this research contributes to the understanding of how agricultural practices and natural resource management impact environmental outcomes in Vietnam, emphasizing the need for integrated approaches to promote sustainable development.

Keywords: Agriculture Growth, Natural Resources, CO2 Emissions, Vietnam, ARDL Bound Testing Approach.

Introduction

Environmental degradation and climate change have become the serious issues due to higher atmospheric concentrations of greenhouse gases mainly the CO_2 emissions (CE) released by many anthropogenic activities such as industrialization, urbanization, deforestation and fossil fuel consumption (Liu et al., 2022). The rapid increase in CE is expected to have various serious ramifications for the global environmental quality which posit various catastrophic impacts on all segments of the economy society (Isfat & Raihan, 2022). Consequently, in order to promote sustainable development and lessen the adverse consequences of climate change, cutting CE and improving environmental quality have gained global attention (Raihan, 2023).

Although all of the countries around the world are facing the problems resulting from climate change, the developing world is the most affected by climate change because it has less capacity for adaptation and less access to alternative resources for environmentally friendly production. Vietnam is in a similar situation. Vietnam is the most vulnerable country to environmental degradation and global warming because of its dependence on agriculture, forestry and natural resource extraction (Huong et al., 2019). The Vietnam's economy is a rapidly expanding South East Asian economy that has achieved amazing growth over the years. In the future years, Vietnam's economy is expected to grow significantly as it is pursuing the goal to become a modern industrialized and one of the high-middle income countries in the world by the year 2035. However, in pursuing this goal, the country is causing significant challenges for global environmental sustainability. According to Global Carbon Atlas (2021), Vietnam is one of the top polluting countries of the world. The World Bank statistics reveal that the level of per capita emission has been continuously rising in Vietnam over the years (as shown in Figure 1), emitting approximately 5 metric tons in 2021. Because of this, the country's efforts to achieve environmental sustainability are severely hampered (Nguyen & Le, 2022).

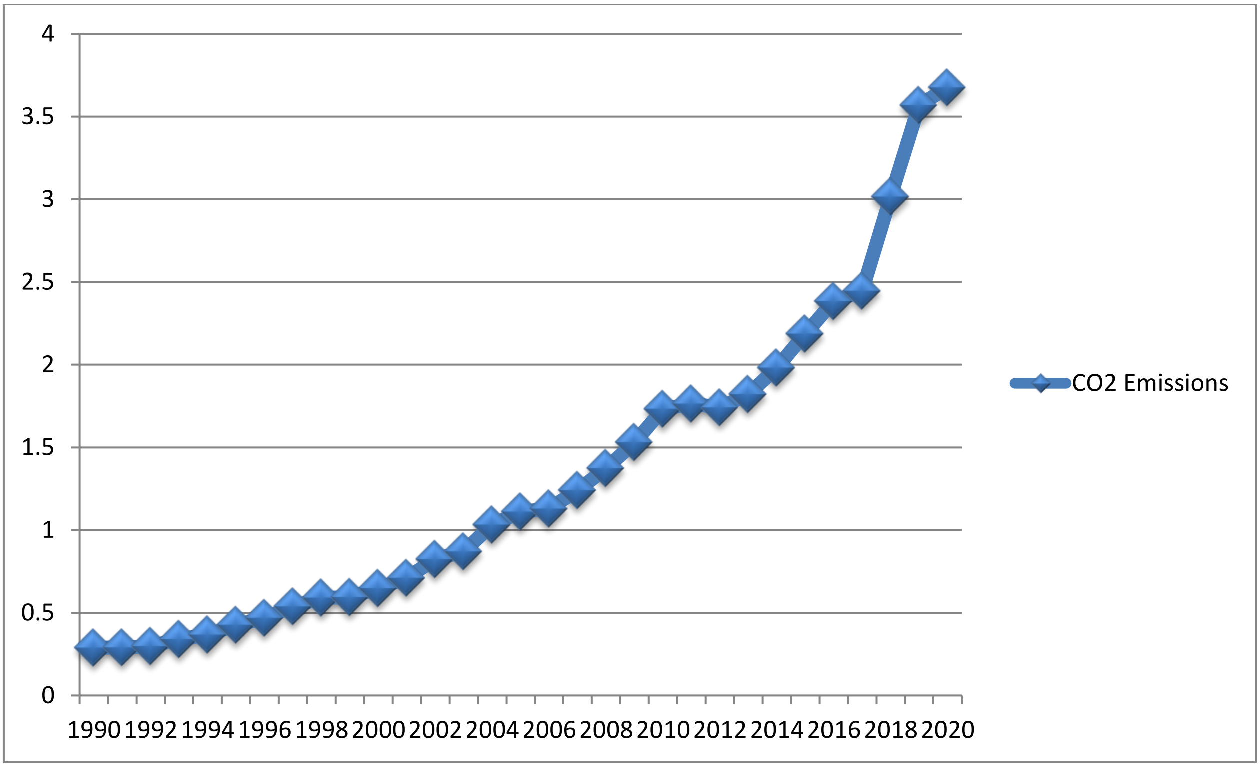

Figure 1: CO2 Emissions in Vietnam over 1990 to 2020 Period.

Previously, the literature has documented several determinants of environmental degradation such as FDI, globalization, energy consumption, urbanization etc., (Farooq et al., 2022; Lin et al., 2022; Muhammad et al., 2021; Sadorsky, 2014). Similarly, agriculture growth (AGRIG), besides being a victim of environmental degradation, also plays a significant role in environmental degradation. The agriculture sector has both positive and negative impact on environmental quality. The use of agriculture innovations and technology increases agriculture productivity and environmental sustainability. Oxygen production and provision of natural life are also among the positive effects of agriculture. On the other hand, negative impacts of agriculture on environmental quality from the use of chemical fertilizers, pesticides, burning grass, soil farming, etc. are becoming evident (Ali et al., 2022). According to U.S. Emission Inventory Statistics, the agriculture sector emits approximately 8% of the GHG emissions resulting from methane and nitrous oxide from livestock production and soil management practices. The agriculture sector produces between 14 percent and 30 percent of global GHG emissions by using intensive fossil fuel for irrigation and water pumping and using fertilizers high in nitrogen (Waheed et al., 2018).

Likewise, the economic activities are responsible for massive extraction and use of natural resources (NTR) which raise serious environmental concerns. Unsustainable resource usage causes serious environmental issues like deforestation, water scarcity, and climate change in both developed and developing economies (Baloch et al., 2019).The extraction of NTR require a lot of energy and the resulting waste chemicals are improperly disposed-off in the air, water, and land, which lead to environmental degradation (Kwakwa et al., 2020). In view of the discussion above, the study aims to empirically evaluate the role of AGRIG and NTR in environmental degradation in Vietnam over 1990 to 2020 period. Agriculture sector is one of the major sectors in Vietnam contributing about 1/5th of the GDP, employing about 50% of the workforce and providing income to 3/4 of the Vietnamese population (Trinh et al., 2018). For most households, agriculture is the main source of income, and its productivity is reliant on the exploitation of natural resources (Huong et al., 2019). However, the use of old fashioned techniques in farming, low literacy and inadequate transportation and infrastructure development, has not only declined the growth of agriculture sector over the years (see Figure 2), but also contributed to climate sensitivity of the country. Likewise, being abundant with variety of NTR such as woods, coal, oil, gas and bauxite, diversity in fauna and flora, Vietnam has reaped several benefits from the use of NTR. Vietnam is a major producer of coal and has the third largest coal power plant of the world after India and China. Vietnam's coal production reached 48.4 million metric tons in 2020 and 31% of the workers in mining and quarrying are working in coal mining (Tran et al., 2023). However, the country faces NTR depletion due economic expansion as shown in Figure 2 which may restrict the growth potential of the economy and raise serious concerns for the environmental quality. Therefore, it is necessary to identify the significant and practicable solutions for mitigating the rising CE. As a result, it is pertinent to analyse the role of NTR and AGRIG in environmental degradation in Vietnam. The impact assessment of NTR and AGRIG would help in explaining the issues and the timely formulation of plans to respond the issue immediately (Huong et al., 2019).

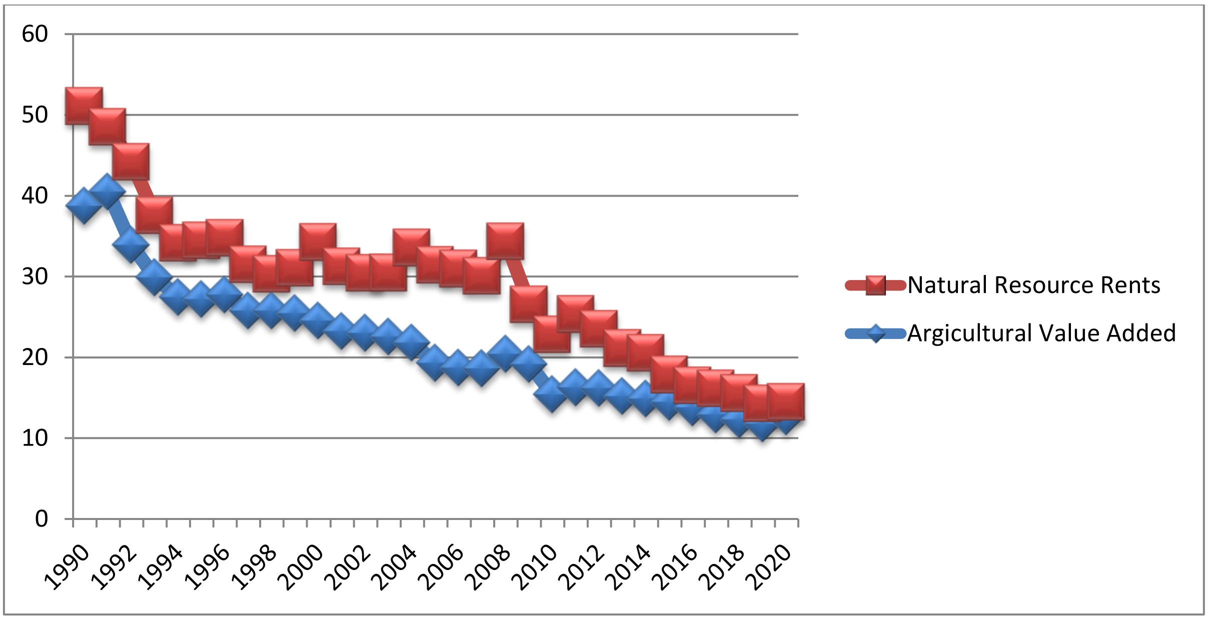

Figure 2: Agriculture Expansion and Natural Resource Consumption in Vietnam (1990 to 2020).

The study contributes to the literature as follows: First, to the author's best knowledge, the effect of NTR and AGRIG on environmental degradation has been extensively studied previously in the context of different countries, but not enough attention was paid for the empirical evaluation of these factors in Vietnam. Therefore, a fresh insight on the pertinent effect of NTR and AGRIG on environmental degradation would enrich the limited literature in the context of Vietnam. Second, in previous studies, the individual impact of NTR and AGRIG on CE has been explored, however, to the best of the author's knowledge, none of the existing studies have evaluated the joint impact of AGRIG and NTR on CE. The present study enriches the body of literature by estimating to moderating role of NTR in AGRIG and CE relationship. The abundance of NTR can provide significant support to agriculture sector. The availability of NTR such as fertile land, mineral resources such as potassium and phosphorous increases the productivity and yield of the products. Significant quantities of these minerals can provide farmers with a significant advantage and ultimately boost agricultural output (Ren et al., 2023). Interestingly, the way NTR affects the relationship between AGRIG and CE is not known yet. Therefore, the one of the primary goals of the present study is to empirically assess the moderating role of NTR in AGRIG and CE relationship as evaluating this moderation effect would enable the researchers to assess the individual and joint effect of NTR and AGRI on CE. The basic research questions to be answered by the study are as follows:

a. What is the effect of AGRIG on environmental degradation in Vietnam?
b. What is the effect of NTR on environmental degradation in Vietnam?
c. How NTR moderates the relationship between AGRIG and environmental degradation in Vietnam?

The rest of the study is structured as follows: Section 2 provides the review of previous literature. Data and econometric technique is given in Section 3. Section 4 gives results and their discussion and chapter 5 provides conclusion and policy recommendations.

Literature Review

This section of the study is divided into 2 sub sections to provide a brief review of the past studies related to the role of AGRIG and NTR in environmental degradation as follows:

Agriculture Growth and Environmental Degradation

Considering its relevance, a number of researchers have examined the agriculture sector's role in environmental degradation. Taking multiple case studies, different countries, regions, the outcomes of the studies provided mixed outcomes on the effect of AGRIG on CE. Some of the researchers found it to be the culprit for environmental degradation, while others have concluded it to be environmentally friendly (Usman et al., 2022). For instance, considering the South Asian countries, Usman et al. (2022) examined the effect of agriculture value added on environmental degradation over 1995 to 2017 period. FMOLS estimation approach was used and it was found that agriculture value added promoted CE in South Asian countries. Likewise, Agboola & Bekun (2019) analyzed the impact of agriculture on CE and tested the validity of agriculture induced EKC hypothesis in Nigeria over 1981 to 2017 period. According to the findings of ARDL Bound testing approach and Bayer and Hanck combined cointegration technique, an inverted U-shaped EKC hypothesis was found to exist in Nigeria, showing that agriculture production initially increased and later reduced CE. Similarly, Gurbuz et al. (2021) in case of Azerbaijan empirically tested the agriculture value added and CE relationship over 1992 to 2014. The outcomes of ARDL approach indicated that agriculture production reduced CE. In continuation, taking the panel of Belt and Road Initiative (BRI) economies, Hafeez et al. (2020) examined the impact of agriculture on environmental degradation over 1980 to 2017 period. Applying DOLS and FMOLS estimation approaches, the results revealed that agriculture increased environmental degradation. In case of Zambia, Phiri et al. (2021) studied the agriculture value added and CE relationship over 1975 to 2014 period. The results of ARDL approach revealed that agriculture value added promoted CE in Zambia. Likewise, Balogh (2022) studied the role of agriculture in CE in non-European countries over 2000 to 2018 period. Using FMOLS and DOLS regression approaches, the study found that agriculture contributed to increase CE in selected countries.

Natural Resources, Agriculture Growth and Environmental Degradation

Environmental quality has also declined as a result of human-caused resource depletion brought by social and economic activity (Iqbal et al., 2022). Therefore, over past several decades, the NTR and CE nexus has been the focus of attention among researchers, but like AGRIG, academicians and researchers did not reach any definite conclusion. Such as Khan et al. (2020) analyzed the effect of NTR on CE in 51 BRI economies over 1990 to 2016 period. Applying System GMM approach, the authors found NTR increased CE in selected countries. Iqbal et al. (2022) studied the impact of NTR on CE in Pakistan over 1980 to 2017 period. NARDL estimation approach revealed that NTR reduced CE. Likewise for developing countries, Jahanger et al. (2023) studied the role of NTR in environmental degradation over 1990 to 2018 period. 3SLS estimation technique was used in the study. According to the findings, NTR significantly reduced CE in developing countries. Similarly, Hung (2022) studied the impact of NTR on CE in Vietnam for the period 1990 to 2019. Using Wavelet coherence approach, NTR was found to reduce CE in Vietnam. In case of ASEAN countries, Nguyen et al. (2023) analyzed the impact of NTR on CE.

According to the results of panel quantile regression, NTR was found to increase CE. In case of Pakistan, Hanif et al. (2022) studied the nexus between NTR and CE using VAR approach. The outcomes revealed that NTR increased CE in Pakistan. Gyamfi et al. (2022) analyzed the effect of NTR rents on environmental degradation in G-7 countries over 1990 to 2016 period. Using FMOLS, DOLS and AMG techniques, the authors found NTR to promote the environmental degradation in selected countries. For developed, developing, BRICS and global panel of economies, Muhammad et al. (2021) empirically studied the role of NTR in CE over 1991 to 2018 period. Using dynamic Fixed Effects model and System GMM estimation techniques, NTR was found to enhance CE in all panels of the countries. However, the impact of NTR on AGRIG did not get attention of the researcher so far. Out of limited studies which explored the relationship between these two factors, Chopra et al. (2022) studied the role of NTR in AGRIG in ASEAN countries. The authors found that NTR decreased AGRIG in the selected countries. For China, Ren et al. (2023) analyzed the relationship between NTR and green growth in agriculture sector over 1970 to 2021 period. Using Beysian regression analysis, the authors found that NTR reduced green growth in agriculture sector in China.

Literature Gap

The review of the available literature reveals that the role of NTR and AGRIG in environmental degradation is not sufficiently covered for Vietnam in previous literature. Moreover, whether NTR moderates the relationship between AGRIG and environmental degradation is unexplored in the literature. Therefore, the present study aims to fill these gaps by analysing the role of NTR and AGRIG in environmental degradation as well as the moderating role of NTR in NTR and environmental degradation nexus in Vietnam.

Data and Methodology

The study estimates the impact of AGRIG and NTR on environmental degradation in Vietnam. For this purpose, time series data from 1990 to 2020 period is taken and the widely used Stochastic Impact by Regression on Affluence, Population and Technology (STIRPAT) framework provides basis for the model specification. STIRPAT model proposed by York & Rosa (2003) considers that environmental quality is influenced by three important factors namely population, affluence and technology. The basic form of the model is represented as follows:

I=P.A.T (1)

Where, I represents environmental impact, P represents population, A denotes affluence and T represents technology in the above equation. Linking this model to the present study, we measure *I* by CO_2 emissions, population by urban population, technology by technology innovations and affluence by economic growth measured by GDP.

One of the main advantages of the STIRPAT model is its flexibility to add other important factors affecting the environmental quality (Liao et al., 2024). Therefore, the present study extends the conventional STIRPAT model by adding AGRIG and NTR by taking the support from Hung (2022), Nguyen et al. (2023), Hafeez et al. (2020) and Usman et al. (2022). The study has formulated the basic model with understudy variables as follows:

CO_2 = f (AGRIG, NTR, GDP, URB, TI, NTR*AGRIG) (2)

And the econometric form of the model is expressed as follows:

$$CO_{2t} = \beta_0 + \beta_1 AGRIG_t + \beta_2 NR_t + \beta_3 GDP_t + \beta_4 TI_t + \beta_5 URB_t + \beta_6 NR * AGRIG_t + \varepsilon_t \ (3)$$

The detailed description of the variables is given in Table 1.

Table 1: Operational Measurement and Data Sources of the Variables.

Variables	Abbreviation	Measurement	Data Source
Environmental Degradation	CO_2	CO2 emissions (metric tons per capita)	WDI
Agriculture growth	AGRIG	Agriculture, fishing and forestry value added (% of GDP)	WDI
Natural Resources	NTR	Total natural resource rents (% of GDP)	WDI
Urbanization	URB	Urban population growth (annual percentage)	WDI
Technology Innovations	TI	No of Patents, residents	WDI

Econometric Method

Autoregressive distributed lag bond testing technique (ARDL) proposed by (Pesaran et al., 2001) is used in the present study as it is one of the most commonly used co-integration techniques in the literature. This technique can be used for assessing both the short-run and the long run results and therefore has number of advantages over other co-integration methods. This approach, for instance, works better with small-scale observational studies and can be used when the variables of the study have any order of integration. The ARDL approach is used in this study in consideration of the benefits which is based on the following equations.

$$\Delta CO_{2t} = \alpha_0 + \beta_1 CO_{2t} + \beta_2 AGRIG_t + \beta_3 NR_t + \beta_4 GDP_t + \beta_5 URB_t + \beta_6 TI_t + \beta_7 NR * AGRIG_t + \sum_{i=0}^{p1} \delta_1 AGRIG_t + \sum_{i=0}^{p2} \delta_2 NR_t + \sum_{i=0}^{p3} \delta_3 GDP_t + \sum_{i=0}^{p4} \delta_4 URB_t + \sum_{i=0}^{p5} \delta_5 TI_t + \sum_{i=0}^{p6} \delta_6 NR * AGRIG_t + \varepsilon_t \quad (4)$$

In equation (4), Δ shows the first difference, the short run dynamics of ARDL equation is shown by δ_i and β_{is} are the parameters. The short-run and long-run parameters can be illustrated using this ARDL equation.

$$CO_{2t} = \alpha + \sum_{i=1}^{p1} n_1 CO_{2t-1} + \sum_{i=1}^{p2} n_2 AGRIG_{t-1} + \sum_{i=1}^{p3} n_3 NR_{t-1} + \sum_{i=1}^{p4} n_4 GDP_{t-1} + \sum_{i=1}^{p5} n_5 URB_{t-1} + \sum_{i=1}^{p6} n_6 TI_{t-1} + \sum_{i=1}^{p7} n_7 NR * AGRIG_{t-1} + \varepsilon_t \quad (5)$$

The ARDL long-run equation shown above describes the long-term relationships between the variables.

$$\Delta CO_{2t} = \alpha + \sum_{i=1}^{p1} \gamma_1 \Delta CO_{2t-1} + \sum_{i=1}^{p2} \gamma_2 \Delta AGRIG_{t-1} + \sum_{i=1}^{p3} \gamma_3 \Delta NR_{t-1} + \sum_{i=1}^{p4} \gamma_4 \Delta GDP_{t-1} + \sum_{i=1}^{p5} \gamma_5 \Delta URB_{t-1} + \sum_{i=1}^{p6} \gamma_6 T\Delta I_{t-1} + \sum_{i=1}^{p7} \gamma_7 \Delta NR * AGRIG_{t-1} + \omega ECM_{t-1} + \varepsilon_t \quad (6)$$

The short run relationship between dependent and independent variables is given in Equation (6). The ECM value in the short-run equation indicates the adjustment speed and divergent and convergent from the long term equilibrium. The value of ECM must be negative, statistically significant and must have the value less than 1. The negative value of ECM shows the convergence positive sign shows the divergence of the model from long-run equilibrium (Azam et al., 2019). Moreover, to check the validity and accuracy of the regression model, we apply some diagnostic tests as well including residual normality, serial correlation and heteroscedasticity tests. Additionally, the CUSUM and CUSUMSQ tests are performed to verify the model's stability.

Results and Discussion

First of all, the summary statistics of all data series are given in Table 2. As per the findings, all of the series have positive mean values and the highest mean value is reported for TI and lowest for CO_2 emissions. The findings of standard deviation show that AGRI has the highest variability about mean while URB has the lowest variability about mean. Moreover, JB statistics indicate that only CO_2, URB and TI have normal distribution. Next, before proceeding to empirical estimation, it is mandatory to check the stationarity or unit root characteristics of the variables of the study. The application of ARDL Bound testing approach does not require any strict order of integration to be followed by the variables. The findings of the ADF and PP unit root tests are given in Table 3. According to the results, all of the series are integrated of order 1. At level, the series contain unit root, but become stationary after taking the first difference. After analysing the order of integration of the data series, the next step involves finding the presence of long run integration among study variables. For this, ARDL Bound test is used. According to the results, F-statistics is found to be greater than upper bound critical values at all significance level. This indicates that all of the selected variables are co-integrated. The findings of long run ARDL estimation are given in Table 4 which shows the changes in the dependent variable resulting from the changes in independent variables. The long run findings predict long run relationship between dependent and independent variables.

Table 2: Descriptive or Summary Statistics.

Variables	Mean	Standard Deviation	Minimum Value	Maximum Value	J-B Statistics
CO2	1.322	0.958	0.288	3.676	4.648*
AGRI	21.603	20.413	11.784	40.489	3.209
NTR	7.402	3.230	1.810	13.919	0.815
GDP	1.4911	8.281	4.511	3.24	2.673
URB	3.288	0.293	2.831	4.008	5.755*
TI	250.48	262.24	22.00	1021.0	7.373**

Table 3: ADF and PP Unit Root Tests.

At level	ADF	PP	Decision
CO2	3.382	5.464	
AGRI	-1.636	-4.880***	
NTR	-1.800	-1.709	
GDP	9.729	12.423	
URB	-2.225	-2.145*	
TI	4.655	4.080	
At First Difference			
CO2	-3.224**	-3.273**	I(1)
AGRI	-7.781	-------	I(0)
NTR	-7.048***	-7.032	I(1)
GDP	-3.466*	-3.689	I(1)
URB	-3.862*	-3.845*	I(1)
TI	-4.844**	-3.679*	I(1)

Where, ***, ** & * denote P=0.00, P<0.05 and P>0.05, respectively.

Table 4: Results of ARDL Bound Test.

Statistics	Value	K
F-stat	6.168	6
Critical values		
Significance	I(0)	I(1)
10%	1.99	2.94
5%	2.27	3.28
2.5%	2.55	3.61
1%	2.88	3.99

Table 5: Results of Long-Run ARDL Estimation.

	Coefficient	P-value
AGRI	0.148**	0.037
NTR	0.108	0.259
NTR*AGRI	-0.005	0.266
GDP	2.071**	0.002
URB	0.054	0.885
TI	-0.003**	0.023

Where, ** denotes P>0.01

The findings of the long run estimation reveal that AGRI has significant positive impact on CE in Vietnam. A unit increase in AGRI is found to increase CE by 0.148 units in the long run. The finding is consistent with Usman et al. (2022), Hafeez et al. (2020) and Balogh (2022). Thus, increase in AGRI is associated with rise in CE in Vietnam. Likewise, the long run findings reveal that NTR positively impact CE, but the effect is insignificant in the long run. For a unit increase in NTR, CE increases by 0.108 units. The findings are in-line with Shen et al. (2021), Muhammad et al. (2021) and Ali et al. (2021) who suggest that NTR has positive relationship with CE. Likewise, URB also has insignificant and positive impact on CE in long run consistent with the earlier estimations of Sadorsky (2014) and Muhammad et al. (2020). A unit rise in URB leads to 0.054 units increase in CE.

Likewise, the impact of GDP on CE is statistically significant and positive in the long run. A unit increase in GDP is found to increase the level of CE by 2.07 units. The findings of Ali et al. (2021) and Hassan et al. (2019) also suggest that GDP has the positive impact on CE. However, the long run results indicate that TI significantly reduces CE in long run as the effect of TI is evident to be negative on CE. In terms of the magnitude of the coefficient, a 1 unit increase in TI reduces CE by 0.003 units. Previously, the findings of Chen & Lee (2020), Wang & Zhu (2020) and Chhabra et al. (2022) strongly support our findings by arguing that TI reduce CE. After long run estimation, the findings of ARDL in short run are given in Table 5. First of all, the error correction term (ECM) fulfils all the three requirements, i.e., it is negative, statistically significant and the value of the coefficient is less than 1. Specifically, the ECM value which is 0.727 indicates that the adjustment speed towards long run equilibrium is 72% and the negative coefficient indicates that model would eventually reach towards long run equilibrium. Moreover, all of the variables have statistically significant impact on CE in short run.

Table 6: Results of Short Run ARDL Estimation.

Series	Co-eff	T-Stat	P- Value
ECM	-0.727***	-8.986	0.000
AGRI	0.097***	-8.110	0.000
NTR	0.061***	6.873	0.000
NTR*AGRI	-0.0011	-0.370	0.715
GDP	4.9511***	6.431	0.000
URB	0.704**	4.150	0.0016
TI	0.0018**	4.175	0.0015

Where, *** and ** indicate significance at 1 and 5% respectively.

The findings indicate that AGRI has statistically significant and positive impact on CE in the short run. This indicates that AGRI promotes environmental degradation in Vietnam. The possible justification of this positive impact is the use of machinery in agriculture production, which consumes large amount of the energy mainly derived from fossil fuels which is responsible for increasing the level of CE. Likewise, the methane and nitrous oxide produced from soil management and livestock practices are also the reasons for CE. Moreover, the use of nitrogen-rich fertilizer by farmers in agriculture sector is a major contributor to CE (Waheed et al., 2018). Second, the coefficient of NTR is significant and positive in the short run. This outcome reveals that NTR significantly enhances CE in Vietnam. This finding can be justified as the NTR extraction activities are usually unsafe and pollution causing.

Moreover, unsafe extraction activities makes the regrowth of NTR unable which causes bio-diversity to decline and increase in environmental degradation (Hanif et al., 2022). Third, the interaction term NTR*AGRIG is revealed to be statistically insignificant and having a negative sign in the short run ARDL estimation (See Table 6). This indicates that although both NTR and AGRIG individually impact

CE positively, their joint impact on CE is negative. This implies that when the moderating role of NTR is introduced in the regression, it reduces the negative impact of AGRIG on CE. This is because the availability of renewable natural resources can prevent the use of fossil fuels in several agriculture activities such as pumping water for livestock or irrigation, lighting the farm buildings, processing operations etc. which reduces its detrimental impacts on CE (Ali et al., 2012). As far as the control variables are concerned, the coefficient of GDP is statistically significant and positive in the short run, indicating that GDP is the leading cause of higher CE.

This finding is consistent with the phenomenon observed in several developing countries where the rapid industrialization linked with higher GDP leads to higher demand for energy, mainly fulfilled by fossil fuels. Increased emissions are a result of the transportation sector's expansion as well as population growth and changing patterns of consumption which result from increase in GDP. Furthermore, the environmental impact is increased by the expansion of energy-intensive infrastructure and the restricted adoption of clean technology (Maulidar et al., 2024). Second, URB is also found to have a statistically significant and positive impact on CE in the short run. This outcome justifies that URB increases the need for shelter, food, transportation, use of land, and energy consumption. These demands create major environmental problems like waste management, traffic congestion, and sanitation problems, among other things, which have a negative impact on both the environment and human health (Shahbaz et al., 2017).

And last, TI has statistically significant and positive impact on CE in short run in Vietnam. In contrast to long run, TI is found to contribute to CE in the short run. This unexpected finding can be justified by the role of TI in increasing the employment level, improving the living standard and business development. The increased production and business activities contribute significantly to rise in CE (Su et al., 2021). After short run and the long run ARDL estimation, some diagnostic tests are applied to prove the validity of the outcomes. The results of diagnostics tests are given in Table 7. The statistics of all diagnostics are found to be statistically insignificant which shows that there is no problem of serial correlation, heteroscedasticity and non-normality of residuals. Overall, these findings imply that the model is statistically robust, with well-fitting parameters and assumptions staying true a perfect combination for analysis's prediction precision and reliability. Moreover, the CUSUM and CUSUMQ tests provide the probability value less than 0.05, which confirms the stability of the coefficients of the model over time (see Figure 3).

Table 7: Results of Diagnostics Tests.

Tests	Coefficient	P-Value	Decision
Breusch-Godfrey LM Test	1.226	0.338	Absence of Serial Correlation
Jarque-Bera	0.667	0.716	Residuals have normal distribution
Breusch-Pagan-Godfrey Test	0.589	0.841	Absence of heteroscedasticity

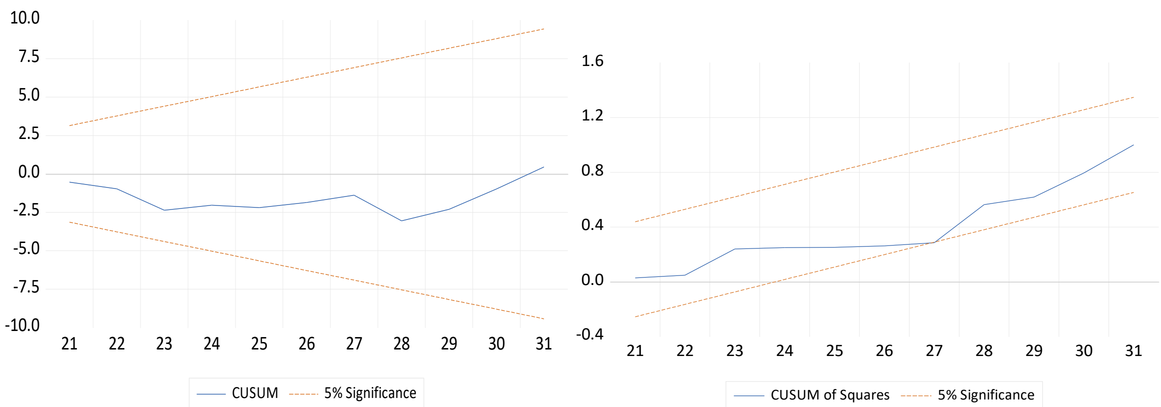

Figure 3: CUSUM and CUSUMSQ Tests for Parameter Stability.

Conclusion and Recommendations

The present study analyses the role of AGRIG in environmental degradation under the moderating effect of NTR in Vietnam under the conventional STIRPAT framework. To estimate the interdependencies among the variables, time series data spanning over 1990 to 2020 is analyzed by applying ARDL Bound Testing approach as the results of ADF and PP unit root tests indicate the series to be integrated of order 1. Based on the long run and short run findings of ARDL estimation, AGRIG has the significant positive effect on CE. The impact of NTR is evident to be positive and significant only in the short run but has insignificant impact on CE in the long run. Moreover, the moderating role of NTR in AGRIG and CE relationship was evident to be negative but statistically insignificant in the short and the long run. Thus the study concludes that both AGRIG and NTR enhance CE in Vietnam and NTR does not significantly reduce the positive effect of AGRIG on carbon emissions.

The outcomes of the study have important policy recommendations on the basis of the findings. Firstly, as AGRIG is evident to be harmful for environmental quality, the government should make major agriculture reforms in Vietnam to reduce its detrimental effects such as the implementation of the policies aimed at curbing the use of fossil fuels in agriculture activities, use of solar tube wells for irrigation, organic and tunnel farming etc., to control CE from agriculture sector production. To maintain sustainable farming and reduce emissions, excess fertilizer and pesticide use must be minimized, and green agriculture must be given priority. Second, NTR also has a positive role in environmental degradation in Vietnam, government must implement stringent policies to restraint the exploitation and extraction of resources that heavily cause environmental pollution. This would not only reduce environmental degradation but help in protecting renewable resources which can be utilized efficiently in energy sector and agriculture sector to curb the negative impact of AGRIG on environmental quality.

The study has provided significant findings for Vietnam, the significant limitations still exist. First, the study used yearly data for empirical estimation; future research studies can use monthly or weekly data to observe the effect of seasonal fluctuations. Second, the study mainly focused on the impact of AGRIG and NTR on environmental degradation, future research studies can consider several other important determinants of environmental degradation such as green technology innovations, mineral resources, globalization, FDI, etc. to estimate their contribution to environmental degradation. Third, several individual countries and panel of countries can be considered by future studies to provide a comprehensive analysis of the subject matter. Furthermore, using advanced econometric techniques for cross country analysis and metropolitan comparisons could improve understanding in this domain.

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