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Factors Affecting CO_2 Emissions in Vietnam

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Abstract In recent years, the signs and consequences of climate change have become increasingly evident in every continent and country, and are expected to increase in the coming years, posing risks to human health, food security, and global economic development. Therefore, controlling and reducing greenhouse gas emissions, the basic cause of climate change, has become a hot issue for all countries, including Vietnam. CO_2 emission is considered one of the main components of greenhouse gases. This paper was conducted to identify factors driving the change in CO_2 emissions in Vietnam based on the extended IPAT model, decomposition method, and OLS regression analysis. The cross-sectional data in the model (including population, GDP per capita, energy intensity, emission intensity) were collected mainly from the World Bank and ourworldindata.org during the period 1986 - 2016. The analysis results show that GDP per capita is the variable that has the most significant influence on the increase in CO_2, followed by energy intensity and population, while emission intensity is the only factor that contributes to the reduction of CO_2 emissions. Based on these results, the study has proposed a number of policy recommendations to control and cut CO_2 emissions in Vietnam, better orienting future decisions to deal with the threat of climate change.

Keywords Air Pollution, IPAT Model, Vietnam, CO_2 Emissions

1. Introduction

Air pollution has always been one of the most pressing problems in the world. Today, 91% of the global population currently lives in places where air quality does not meet the recommendations of the World Health Organization. Although the development of science and technology along with the rapid urbanization process has met the needs of people in all aspects, at the same time, the environment is under heavy pressure, especially the environment. Fresh air is gradually becoming scarce due to increasingly severe pollution. Financially, premature deaths from air pollution cost about US$5 trillion in welfare losses worldwide [1].

There are many researchers studying factors affecting air pollution. Harte [2] argued that population growth influences carbon emissions as "multiplier". A 1% increase in population leads to a 2,665% increase in energy consumption [3]. Shahba et al. [4] suggested that a 1% increase in energy consumption will increase carbon emissions from 0.2333% to 0.3501%. Ehrlich and Holdren [5] were the first to argue that population, income, and technology determine emissions. They also considered environmental impact (I) as a product of population (P), affluence (A), and technology (T) in the IPAT model. Pani and Mukhopadhyay [6] used IPAT model with data from 1980-2007 to determine the influence of five factors, namely emission intensity, fuel substitution, energy intensity, income, and population on CO_2 emissions in 10 countries around the world. The results show that income and population increase emissions, while energy intensity, fuel substitution, and emission intensity decrease emissions. The effect of income is significantly higher than that of the general population. Energy intensity is the most influential factor contributing to the reduction of CO_2 emission. The main strength of IPAT is identifying the main factors that influence the environment and the relationship between factors and their effects. All factors (P, A, and T) do not independently influence environmental impact (I) because changes in one factor are multiplied by the other factors. An important implication is that no single factor can be solely responsible for environmental impacts. For example, if the population and technology of a country remain constant over some time while GDP per capita increases, it would not be correct to argue that the impact is due to GDP per capita because of population and technological level, even if they do not change, the size of the effects of changes in GDP per capita [7]. Among the approaches currently used by researchers, IPAT has become a popular tool for identifying air pollutants due to its simplicity, transparency, and fewer data requirements. Li et al. [8] showed that air pollution in Beijing from 1989 to 2012 mainly depends on GDP per capita and emission intensity. Chontanawa [9] focused on air pollution in ASEAN countries to identify the factors affecting CO_2 emissions based on an extended IPAT model with data from 1971 to 2013. The results showed that the increase in population and income made the biggest contribution to the increase in emissions. Moreover, fossil fuels were extremely popular and important, so replacing this fuel was very challenging. These results helped the government develop appropriate policies to control and reduce CO_2 emissions.

Therefore, the objective of this study is to assess the forces driving CO_2 emissions in Vietnam from the period 1986 to 2016. The data are mainly from the World Bank and ourworldindata.org. The extended IPAT model is applied to determine the forces driving CO_2 emissions in Vietnam.

2. Data and Method

This paper aims to analyze the main drivers of change in CO_2 emissions in Vietnam for the period 1986 - 2016 using IPAT model, decomposition method, and OLS method. The main variables are population, GDP per capita, energy intensity, and emission intensity. The data is collected mainly from World Bank and ourworldindata.org.

2.1. IPAT Model

IPAT model is a widely accepted method to analyze the impact of human activities on the environment (Ehrlich and Holdren, 1972). It helps identify factors affecting the environment, such as population growth, affluence, energy intensity, fuel substitution, emission intensity. This study evaluates the factors affecting the amount of CO_2 emitted into the environment in Vietnam using data for the period 1986-2016 with variables I, P, A, E, F. Table 1 lists the variables and sources of data used in the study. All data are normalized to 1 in 1986 to show the relative effects of changes in IPAT factors on changes in emissions as follows:

$$I_i(t) = P_i(t) \times (GDP_i/P_i) \times (FEC_i/GDP_i) \times (I_i/FEC_i)$$

Table 1. Variable description and sources

Variable name	Denotation & Calculation	Unit	Source
Population	P	Million people	World Bank
Affluence/ GDP per capita	A = GDP/P	USD per capita	World Bank
Energy intensity	F=FEC/GDP	mWh/million USD	World Bank Ourworldindata.org
Emission intensity	E=I/FEC	toe/mWh	Ourworldindata.org

2.2. Decomposition Method

To analyze the factors affecting CO_2 emissions, this paper used the decomposition method, which depends on IPAT model where emissions are expressed as a result of influencing factors. The IPAT model is based on the analysis that allows to determine the relationship between factors and influences on the environment as follows:

CO_2 emission 'i' at time period 't' can be expressed as:

$$I_i(t) = P_i(t) \times (GDP_i/P_i) \times (FEC_i/GDP_i) \times (I_i/FEC_i)$$

At time period (t+1), 'Ii' can be expressed as:

$$I_i(t+1) = P_i(t+1) \times A_i(t+1) \times E_i(t+1) \times F_i(t+1)$$

The following equation expresses the total variance of CO_2 emission between time 't+1' and 't'.

Total emission variance:

$$\Delta I_i(t) = \Delta P_i(t) + \Delta A_i(t) + \Delta E_i(t) + \Delta F_i(t)$$

Population variance:

$$\Delta P_i(t) = \Delta P_i(t) \times A_i(t) \times E_i(t) \times F_i(t)$$
$$= [P_i(t+1) - P_i(t)] \times A_i(t) \times E_i(t) \times F_i(t)$$

Affluence variance:

$$\Delta A_i(t) = P_i(t+1) \times \Delta A_i(t) \times E_i(t) \times F_i(t)$$
$$= P_i(t+1) \times [A_i(t+1) - A_i(t)] \times E_i(t) \times F_i(t)$$

Emission intensity variance:

$$\Delta E_i(t) = P_i(t+1) \times A_i(t+1) \times \Delta E_i(t) \times F_i(t)$$
$$= P_i(t+1) \times A_i(t+1) \times [E_i(t+1) - E_i(t)] \times F_i(t)$$

Energy intensity variance:

$$\Delta F_i(t) = P_i(t+1) \times A_i(t+1) \times E_i(t+1) \times \Delta F_i(t)$$
$$= [F_i(t+1) - F_i(t)] \times A_i(t+1) \times E_i(t+1) \times P_i(t+1)$$

According to the IPAT model, the equation is I = P × A × E × F (where P = pop, A = GDP/P, F = FEC/GDP, and I = CO_2/FEC). The emission drivers of Vietnam in 1986-2016 are shown in chart 4. All quantities are normalized to 1 in the year 1986 to show the relative impact of changes in the factors on the change in emissions. It can be seen that the increase in emissions growth rate (I) is a combination of population growth (P), GDP per capita (A), energy intensity (F) and emission intensity (E).

3. Results

Figure 1 shows the trends of the factors in the IPAT model (population, GDP per capita, energy intensity, and emission intensity). The result shows that the population factor increases slowly over the years, while GDP per capita and energy intensity are complicated by economic shocks such as crisis and inflation. The emission intensity factor does not change much and is almost unchanged, showing that CO_2 emissions per unit of fossil fuel are still well controlled.

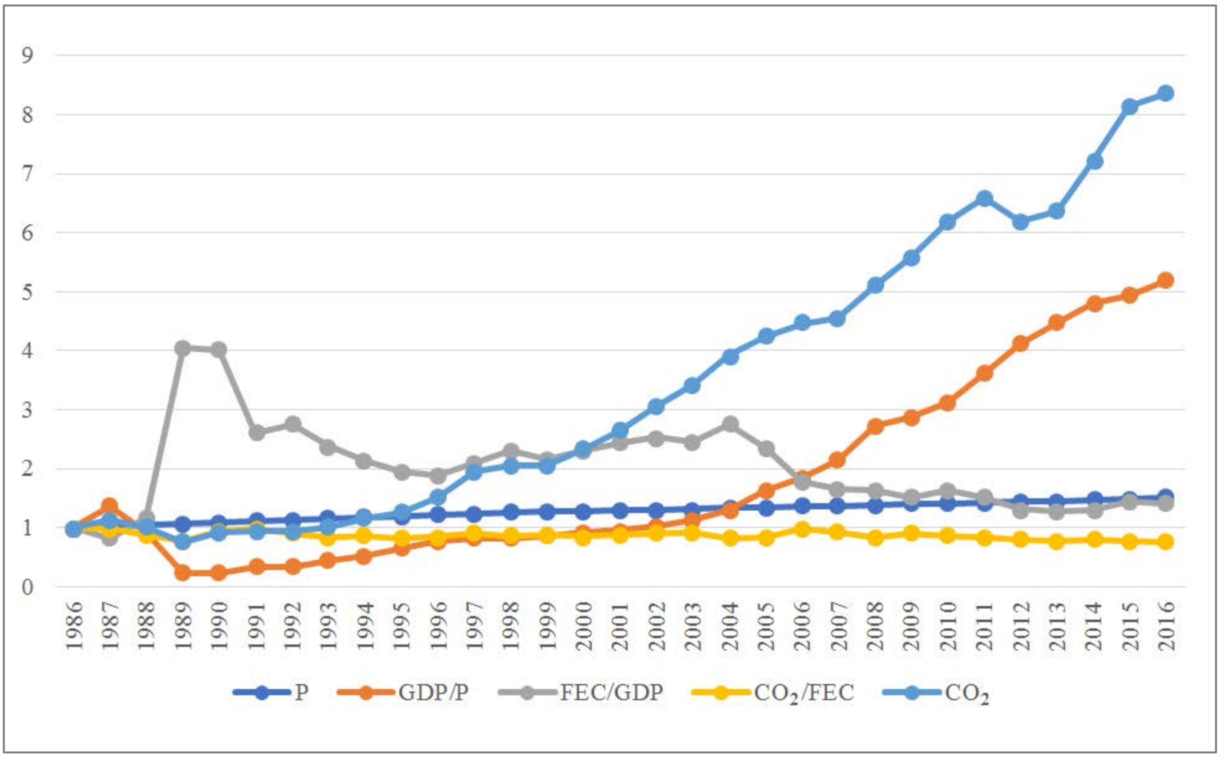

Figure 1. Factors in IPAT model in Vietnam

Table 2 and Figure 2 present the analysis of effects of CO_2 in Vietnam for 1986 -2016 using the IPAT model. Specifically, in the period 1986-1995: population and energy intensity are two factors that increase CO_2 emissions while GDP per capita and emission intensity have opposite effects. Energy intensity has an impact of more than three times on population, demonstrating that the growth rate of fossil fuel consumption is greater than that of GDP. The most remarkable achievement of Doi Moi is the shifting from a centrally planned economy to a mixed economy, helping the country get rid of the backward production methods. As a result, Vietnam attained some outstanding achievements such as high economic growth, positive economic restructuring, a decrease in the number of poor households, and economic integration, creating favorable conditions for foreign trade to develop, attracting FDI, and ODA capital. However, Vietnam's economy has not yet come out of the crisis because of hyperinflation taking place in 1985. Inflation continued in 1987 and 1988 at triple digits (323.1%) and 393%). Since mid-1989, hyperinflation has almost stopped. As a result, the economy gradually stabilized. The collapse of socialism in the Soviet Union (former) and Eastern European countries made the capital investment and import-export market in this region fall short, leaving the country in a second severe crisis, which lasted until 1994. Since 1995, the economy came out of the crise and achieved a relatively high growth rate with an average GDP increase of 8,2%/ year; industrial production increased by 13.3%/year; agriculture increased by 4.5%/year; the service sector increased by 12%/year. Several important events contributed to economic development such as: In November 1991, Vietnam officially normalized relations with China, thanks to which, Vietnam and China promoted cooperation in many sectors such as politics-diplomacy, economy, culture, science, national security for the sake of both countries; In July 1995, Vietnam became the 7th member of ASEAN, so that Vietnam could expand trade relations, attract investment, contribute to the economic development of the country.

In 1996-2000: population, GDP per capita, and energy intensity are two factors that increase CO_2 while emission intensity has opposite effects. GDP per capita contributes to the increase of CO_2 emissions more than twice as much as energy intensity, although compared to 1986-1995, energy intensity increases by 2907 Mtoe. Emission intensity does not significantly contribute to CO_2 reduction, which is considered essential for the industrialization and modernization of the country. Despite facing many challenges and severe impacts from the Asian financial crisis (1997) and consecutive severe natural disasters, Vietnam still maintained the average GDP of 1996 - 2000 reached 7%. GDP in 2000 increased more than twice compared to 1990 when Vietnam joined the Asia-Pacific Economic Cooperation (APEC) forum on November 15, 1998. Participating in APEC gives Vietnam the opportunity to cooperate with potential economic partners in the world, deepen bilateral relations, attract foreign investment, and access advanced technology in the world. Due to socio-economic development strategy 2001 - 2010 and 5-year plan 2001 – 2005, Vietnam attained an average growth rate of 7.5%/year. Specifically, the economy's GDP in 2005 reached 837.8 trillion VND, double that of 1995. In 2005, Vietnam ranked first in the world in exporting pepper; ranked second in rice, coffee, cashew nuts; 4th in rubber.

In the 2006-2016 period: population and GDP per capita are two factors that increase CO_2 while energy intensity and emission intensity decrease CO_2. Compared to the period 1986-1995 and 1996-2005, emission intensity has decreased significantly. However, the impact of GDP per capita increased by almost five times compared to 1996-2005; therefore, CO_2 emissions still increased. During the period, Vietnam, one of low-income countries, has become a middle-income country (low). Average GDP in 5 years reached 7%. In 2007, Vietnam joined the World Trade Organization (WTO). Therefore, despite being affected by the global financial crisis (2008-2009) and the public debt crisis, Vietnam's export growth reached between 12-14% per year. Export turnover in 2016 also increased 3.5 times compared to 2006. The real GDP in 2010 reached 101.6 billion USD, 3.26 times higher than in 2000. In addition, after ten years of joining WTO, Vietnam attracted more than 22,000 FDI projects of world's leading corporations such as Honda, Samsung, LG, Toyota, and so on. Total realized FDI capital reached nearly 45 billion, more than 2.7 times higher than the plan and more than seven times higher than the 2001 - 2005 period. Total committed ODA capital reached over 31 billion USD; more than 1.5 times higher than the set target.

Table 2. Decomposition results of CO_2 emissions in Vietnam from 1986 - 2016

Variable	1986-1995	1996-2005	2006-2016	1986-2016
Population variance	4,676.490	2,878.325	3,343.898	11,618.944
Affluence variance	-9,587.196	42,825.477	204,066.000	145,267.000
Energy intensity variance	17,201.129	20,108.798	-66,819.720	72,907.998
Emission intensity variance	-6,291.212	-2,997.386	-58,273.959	-60,216.930
Change in CO_2 emissions	5,999.212	62,815.214	82,316.566	169,577.000

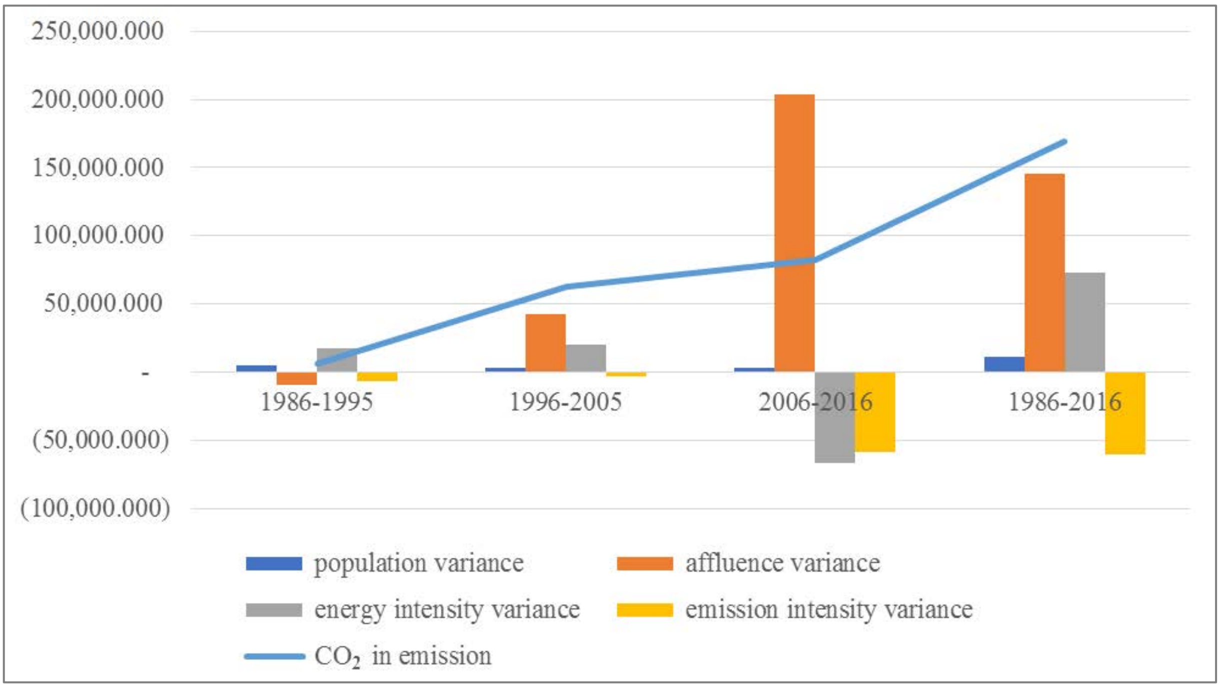

Figure 2. Decomposition results of CO_2 emissions in ASEAN from 1986 - 2016

Table 3. Fossil fuel consumption in Vietnam from 2005 to 2015 (KTOE)

Fossil fuel	2005	2009	2010	2011	2013	2014	2015
Coal	19,076	24,684	24,646	26,102	22,985	22,998	23,231
Crude oil	18,901	16,687	15,266	15,489	17,039	17,740	19,121
Gas	6,204	7,290	8,316	7,560	8,522	9,124	9,551

Source: Vietnam Energy Outlook Report 2017

Vietnam can rapidly develop industrial infrastructure and raise living standards in the country because of higher economic growth. With technological advances and foreign direct investment in the manufacturing and service sectors, the domestic energy intensity also improved from 0.61 (toe/1000 USD) in 1990 to 0.49 (toe/1000 USD) in 2016 - a significant decrease of 18.6%. However, the share of renewable energy sources is still low in the national energy structure because of greater dependence on fossil fuels (mainly coal and oil). In 1990, fossil fuels accounted for 20.5% of the total primary energy supply, while in 2016, they accounted for 45.1%. The increasing share of fossil fuels in energy sector, economic growth, and accelerated industrialization encourages the rapid carbonization of the economy. From 2005 to 2015, coal production increased by 21.78%, crude oil production increased slowly by 1.16%, and gas production increased the fastest by 53.94% (Table 3).

Similarly, emission intensity has also increased in Vietnam due to the increasing consumption of non-renewable energy sources. From 1990 to 2016, emission intensity increased from 4.75 to 5.12 ($MtCO_2$ per ktoe of fossil fuels), indicating that higher emissions were emitted. Factors affecting emission intensity include increased industrial restructuring, inefficient renewable energy use, inefficient use of fossil fuel resources, and lack of energy conversion technology in power plants. Furthermore, the early 1990s saw a decrease in emissions intensity mainly due to industrial restructuring efforts in Vietnam.

Thus, for the period 1986 - 2016, the change of CO_2 is 169,577 Mtoe, in which population, GDP per capita, and energy intensity contribute to the increase of CO_2 respectively by 11,618.944 Mtoe, 145,267 Mtoe, and 72,907.998 Mtoe, and emission intensity contributes to CO_2 reduction 60,216.930 Mtoe. Economic growth is the factor that has the most substantial impact on the change of CO_2.

Table 4 presents the regression analysis of factors (including population, GDP per capita, energy intensity, emission intensity) affecting CO_2 emissions based on IPAT model with 31 observations from 1986 to 2016. The result shows that GDP per capita, population, energy intensity, and emission intensity positively impact CO_2 emissions. When these factors tend to increase, CO_2 emissions also increase. The regression coefficient of variable A is 3,036,184, which means that an increase of 1% of GDP per capita leads to a 3,036,184% increase in the amount of CO_2. The regression coefficient of P is $2.62*10^9$, which means that the population increases by 1%, the amount of CO_2 increases by 2.62. 10^9%. The regression coefficient of E, 61,313,827, shows that per 1% increase in the energy intensity causes an increase in the amount of CO_2 by 61,313, 827%. The relationship between the emission intensity and the amount of CO_2 is explained by the regression coefficient of F, $2.27*10^8$. This figure implies that an increase of 1% of the emission intensity leads to an increase of $2.27*10^8$%. Thus, according to OLS, the variable population has the most influential impact on CO_2 emissions, and GDP per capita has the most limited impact.

GDP per capita, population, and energy intensity all have p-value < 0.05 while the emission intensity factor has p-value = 0.057 > 0.05 because emission intensity has little effect on CO_2 emissions. Another reason is that the sample is 31 years (1986-2016), so the data do not fully reflect the problem. R-squared = 0.982927 means the independent variables included in regression model can explain approximately 98% of the variation of the dependent variable.

Thus, the result of the OLS method is different from that of the decomposition model. For OLS, population has the most considerable impact on CO_2 emissions while GDP per capita has the lowest impact. For the decomposition method, GDP per capita has the most influential impact on CO_2 emissions, and the contribution of population factor is low. These are because IPAT model and decomposition method focus on analyzing the main drivers of change in CO_2 emissions in each period while the OLS method determines the effect in the entire period from 1986 to 2016. The IPAT model and decomposition method bring more objective results by considering the changes of each period, thereby giving the weak points the most considerable impact on CO_2. This paper employs the OLS method to supplement the IPAT model, proving that the independent variables provided by the IPAT model affect in the same direction on the dependent variable.

Table 4. Result of OLS method

Dependant Variable: I
Method: Least Squares
Date: 01/28/21 Time: 15:20
Sample: 1:31
Included observations: 31

Variable	Coefficient	Std.Error	t-Statistic	Prob.
C	-2.64E+11	3.59E+10	-7.370977	0.0000
A	3036184.	1166441.	2.602946	0.0151
P	2.62E+09	2.94E+08	8.919638	0.0000
E	61313827	5196480	11.79911	0.0000
F	2.27E+08	75207374	3.012271	0.0057
R-squared	0.982927	Mean dependent var		7.90E+10
Adjusted R-squared	0.980300	S.D. dependent var		5.59E+10
S.E. of regression	7.85E+09	Akaike info criterion		48.55122
Sum squared resid	1.60E+21	Schwarz criterion		48.78251
Log likelihood	-747.5440	Hannan-Quinn criter		48.62662
F-statistic	374.2084	Durbin-Watson stat		0.958387
Prob (F-statistic)	0.000000			

4. Conclusions

The study analyzes the factors affecting CO_2 emissions in Vietnam from 1986 to 2016 with four explanatory variables: population, GDP per capita, energy intensity, and emission intensity. The result shows that GDP per capita has the most influential impact on CO_2 emissions, followed by energy intensity and population. Meanwhile, the remaining variable, emission intensity, shows the adverse effect, reducing CO_2 emissions. This result implies that, over a long time, from the reform and change of the economic mechanism in 1986 to 2016, Vietnam still tends to focus more on the goal of economic growth. This trend is not out of the general situation of many developing countries, sacrificing resources, even exchanging environmental and social values for economic growth. To still achieve the goal of national sustainable economic development, that is, without neglecting social and environmental aspects, Vietnam needs to strictly control the manufacturing process, the amount and type of emissions, and the emissions treatment methods of enterprises. Besides, instead of accepting foreign investment projects massively, setting targets on quantity instead of quality, Vietnam needs to have a better strategy in selectively accepting foreign direct investment projects that meet the standards of green FDI in the future. In addition, the energy intensity increases emissions mean that Vietnam's economy is still heavily dependent on fossil fuels. The effect of emission intensity on CO_2 reduction means that the amount of CO_2 per unit of fossil fuel consumed gradually decreases. Businesses in Vietnam need to innovate technology, take advantage of emissions as input materials, reduce dependence on fossil fuels, and prioritize using renewable energy sources. Effective energy management is also one of the most crucial measures to maintain economic growth and population growth, helping Vietnam forward sustainable development goals.

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