Nexus of Innovation, Renewable Consumption, FDI inflows, Economic Growth and CO2 Emission in The Technology Revolution 4.0 for Sustainability Economy—The Case of Vietnam

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Article

Nexus of Innovation, Renewable Consumption, FDI inflows, Economic Growth and CO_2 Emission in The Technology Revolution 4.0 for Sustainability Economy—The Case of Vietnam

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Abstract: Changing climate conditions and rapidly increasing carbon dioxide emissions have severely affected the global ecosystem and world economy. Governments around the world have paid attention to these resulting challenges and enacted many policies to reduce environmental pollution and carbon dioxide (CO_2) emissions. This study aimed to determine and understand the relationship between innovation, foreign direct investment, economic growth, renewable consumption and CO_2 emission in Vietnam. Information was collected annually based on the annual data of the General Statistics Office of Vietnam and World Bank from 2000 to 2022. Data processing was conducted using the STATA 17.0 software. The innovation affects Vietnam's environmental pollution. Innovation positively affect environmental pollution in Vietnam; if Vietnam's innovation were to increase by 1%, CO_2 emissions would increase by 0.68%. The empirical research results of this study also show that renewable energy consumption has a negative effect on environmental pollution in Vietnam; if renewable energy were consumed at a 1% increase, CO_2 emission would decrease by 0.51%. In addition, FDI inflows and economic growth have strongly positive affecting to environmental pollution; if Vietnam's FDI inflows were to increase 1%, CO_2 emissions would increase 1.39%; if Vietnam's GDP increase 1% then CO_2 emission would increase 1.26%. This paper also provides some recommendations that can assist Vietnam in developing a green and sustainable economy in the technology revolution 4.0 to achieve the United Nations Sustainable Development Goals (SDGs) over a long-term period.

Keywords: innovation (IN); technology revolution (TR); foreign direct investment (FDI); economic growth (EG)

1. Introduction

The relationship of innovation, renewable consumption, FDI inflows, economic growth and carbon dioxide emissions are not studied in recent time. Therefore, this paper refers to the relationship between these factors and how they affect each other. The policymakers and scientists almost care about the analysis of the factors affecting the environmental pollution to maintain the sustainability economy in the technology revolution 4.0.

Innovation can enable more efficient and sustainable production and consumption, which can help reduce environmental impact. However, innovation can be slowed down by a lack of investment and political will. Therefore, it is important for governments, businesses, and individuals to invest in research and development, promote innovation-friendly policies, and create an environment that encourages innovation [1–3].

The Fourth Industrial Revolution, or Industry 4.0, is a technological revolution that is transforming the way we live, work and interact with each other. It builds upon the digital revolution that began in the late 20th century and is characterized by a fusion of technologies that is blurring the lines between the physical, digital, and biological spheres. This revolution is expected to fundamentally alter the way we produce goods and services, creating new opportunities for growth and development across a range of sectors [3].

At its core, Industry 4.0 is about the integration of advanced technologies such as the Internet of Things (IoT), Artificial Intelligence (AI), Robotics, and Big Data analytics. This integration is enabling the creation of smarter, more connected, and more efficient systems that can learn, adapt, and respond to changing conditions in real-time. This revolution is being driven by the exponential growth of data and the ability to process and analyze it in real-time. One of the key aspects of Industry 4.0 is the development of smart factories. These are factories that are equipped with sensors and connected devices that enable them to communicate with each other and with the outside world. This communication allows for the optimization of production processes, reducing waste and increasing efficiency. Smart factories also enable the use of predictive maintenance, which allows for the identification and correction of potential issues before they become serious problems. Another important aspect of Industry 4.0 is the development of autonomous systems. These are systems that are capable of operating independently, without human intervention. Examples of autonomous systems include drones, self-driving cars, and robots. These systems are able to learn and adapt to changing conditions, making them increasingly useful in a range of industries [3].

The benefits of Industry 4.0 are numerous. It has the potential to increase efficiency and productivity, reduce costs, and improve quality. It can also create new jobs and spur economic growth. However, there are also some challenges associated with this revolution. One of the biggest challenges is the potential for job displacement as more tasks become automated. Another challenge is the need for a skilled workforce that can operate and maintain these new technologies [4].

Industry 4.0 represents a significant technological revolution that is changing the way we live and work. It is enabling the development of smarter, more connected, and more efficient systems that have the potential to revolutionize a range of industries. While there are challenges associated with this revolution, the benefits are clear, and it is important that we embrace this new era of technological advancement [5].

Renewable consumption is crucial for reducing carbon dioxide emissions and achieving environmental sustainability. As the world transitions towards a low-carbon economy, the use of renewable energy sources will become increasingly important. Governments, businesses, and individuals can play a role in promoting the use of renewable energy sources by investing in renewable infrastructure, incentivizing the development of renewable energy, and adopting renewable energy technologies in daily life [6] [7].

FDI inflows can bring in new technology and expertise to a country, which can lead to innovation and economic growth. However, FDI inflows can also have negative impacts on the environment if the investments are not made in a sustainable manner. Therefore, it is important for governments to implement policies that encourage sustainable practices and ensure that FDI inflows are aligned with environmental and social sustainability goals [8].

Economic growth can provide a pathway towards poverty reduction and improvement in quality of life. However, economic growth can also lead to increased energy consumption and higher carbon dioxide emissions if sustainable practices are not implemented. Therefore, it is important for economic growth to be decoupled from environmental degradation. This can involve implementing sustainable production and consumption practices, investing in renewable energy infrastructure, and promoting circular economy principles [9].

Finally, addressing carbon dioxide emissions is crucial for mitigating the impacts of climate change. This can involve implementing policies and strategies that promote renewable energy and sustainable practices, increasing public awareness and engagement, and promoting international cooperation and collaboration [6].

In summary, the nexus of innovation, renewable consumption, FDI inflows, economic growth and carbon dioxide emissions is complex and interconnected. A comprehensive and coordinated approach is necessary to address these factors and create a sustainable and equitable future for all.

Developing countries most frequently preference strategies for increasing the export of goods and services and attracting foreign direct investment (FDI) to promote economic growth. However, the Sustainable Development Goals (SDGs) require strategies geared towards actions that reduce environmental pollution, such as taking urgent action to combat climate change and ensuring access to affordable, reliable, sustainable, and modern energy for all. The relationship between exports, FDI, and carbon dioxide emissions has been demonstrated by empirical evidence in countries such as those in the Middle East and North Africa [2].

Foreign direct investment inflows can increase work in the economy and economic growth in Vietnam. However, Vietnam has consistently attracted polluted FDI in recent years [8].

Multinational companies and international corporations want to put capital into Vietnam because the labor costs are cheap and the law does not place strict regulations on production technology, meaning that they can use old technology causing environmental pollution [10].

Economic growth coupled with environmental protection has been the main goal of the Vietnamese government in recent years. For example, farmers are interested in using more organic fertilizers so that they can label their products as clean vegetables and sell them at a higher price, in turn helping to reduce CO_2 emissions [11].

Policymakers in Vietnam have taken actions to reduce environmental pollution such as building solid waste treatment plants [9].

Xuan et al. examined the influence of foreign direct investment (FDI) on economic growth and environmental pollution in Vietnam [12–15]. The majority of exports from Vietnam are produced by FDI businesses, particularly those of electronic goods, where phone and component exports make up 99.1% of total exports. However, China's CO_2 emissions have risen because of the export of products and services. This means that China's export of products creates more pollution [6]. Based on this relationship, the Vietnamese government is therefore concerned about the problem of environmental contamination. The Vietnamese government announced its commitment to decreasing carbon emissions to zero by 2050 during the COP26 meeting in the United Kingdom.

As is evident from this pledge, Vietnam's government places a high value on creating jobs and GDP growth and attracting the inflows of foreign direct investment capital while also working to reduce CO_2 emissions in order to achieve sustainable development. Thus, economic growth, technical advancement, and the use of renewable energy sources are the elements that significantly influence Vietnam's ability to reduce pollution and combat climate change [16,17].

Therefore, there are the research gaps in analysis the factor affecting the environmental pollution in Vietnam for the sustainability economy. In this study, the authors use the regression model to estimating how innovation, renewable consumption, FDI inflows, economic growth affected CO_2 emissions in the period from 2000 to 2022 in Vietnam. The findings presented in this research are significant to the long-term efforts of Vietnamese policymakers to grow the GDP and the whole economy as well as safeguarding the environment in the context of the technology revolution 4.0.

This paper includes the following sections: Section 1, Introduction; Section 2, Literature Review, Section 3, Data Collection and Research Methodology; and Section 4, Results. The final section presents this study's conclusions and recommendations.

2. Literature Review

Numerous research papers have discussed the connection between economic growth, FDI, and environmental pollution. Joe et al. demonstrated a positive correlation between FDI and economic growth. They found that the more FDI attraction there was, the better the economic growth occurred [18]. They also discovered that differences in the characteristics of the host nation had an impact on economic expansion.

Nguyen also demonstrated that regional characteristics have an impact on Vietnam's capacity to attract FDI. He just focused on the attraction of FDI inflows in each province in Vietnam [19–21].

Thu et al. investigated the factors that contribute to environmental pollution in Asia and Vietnam. They found that the greater the renewable consumption is, the better the environmental condition has in Vietnam and Asia [22,23]. Raihan et al. referred to the connections that exist between green electricity consumption, the industrialization of the economy, forest area coverage, and CO_2 in the Russian context [24,25].

Fadly et al. discussed greening industry in Vietnam; environmental management standards and resource efficiency in small and medium-sized businesses were highlighted [10]. In addition, Liem et al. demonstrated that organic fertilizers can cut down on carbon dioxide emissions in Vietnam [26,27].

Nguyen et al. investigated the relationship between financial development and renewable energy in Southeast Asian nations where organic waste materials serve as the primary raw materials. Overall, there is still a research gap regarding the connection between innovation, the consumption of renewable energy, and carbon dioxide emissions in Vietnam [19–21].

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Le et al demonstrated that environmental pollution and FDI boost Vietnam's GDP. Le et al. demonstrated the connection between environmental pollution, economic expansion, and foreign direct investment. The non-linear ARDL co-integration approach provided them with these insights [9,26,27].

Andersen et al referred CO_2 emissions from the transport of China's exported goods. They noted that the transport of China's export goods and services increase the carbon dioxide emissions [2–5].

Ashizawa et al studied CO_2 emissions and economy of co-firing carbonized wood pellets at coal-fired power plants: the case of overseas production of pellets and use in Japan. They concluded that the production of wood pellets decrease the CO_2 emissions in Japan [5].

Wu et al researched the carbon-neutral energy consumption and emission volatility: the causality analysis of ASEAN region. They found that the green consumptions decrease the CO_2 emissions in Asean countries [28–31].

Fernandes et al referred urban metabolism-based approaches for promoting circular economy in buildings refurbishment. They noted that the circular economy needs to reduce the carbon dioxide emissions [11,32–34].

Firth et al research the dynamics of soil organic carbon and CO_2 flux under cover crop and no-till management in soybean cropping systems of the Mid-South United State of America [33].

Hu et al studied effects of cover crops and soil amendments on soil CO_2 flux in a Mississippi corn cropping system on upland soil [35,36].

Visconti et al noted the spontaneous plants improve the inter-row Soil fertility in a citrus orchard but nitrogen lacks to boost organic carbon. They found that the organic fertilizer could reduce the carbon dioxide emissions [37,38].

Zickgraf studied political factors of immobility and climate change. He found that the political could reduce the carbon dioxide emissions and climate change [31].

Banerjee et al. conducted research on FDI flows in the energy industry with respect to the subregional links between the BCIM, BIM-STEC+1, and ASEAN+4 [7,8,39]. According to the findings of this study, renewable energy for sustainable development receives the majority of FDI in these nations' energy sectors. Using empirical evidence from energy-intensive nations, Huang et al. observed an inverse relationship between renewable energy and CO_2 emissions [36].

Fadly et al. highlighted Vietnam's green industry development. Environmental management standards and resource efficiency in small and medium-sized businesses were discussed [10].

Using empirical research, Khan et al. examined innovation ability, green electricity use, and CO_2 emissions in African countries [1]. Moreover, Nguyen studied Vietnam's export of goods and services and CO_2 emissions. With contextual evidence from both developing countries and developed countries, Shahzad also investigated CO_2 emissions and export diversification [40].

The relationship between renewable consumption, FDI inflows, economic growth, and environmental pollution is complex and can vary depending on the specific context and conditions. However, in general:

Renewable Consumption and Economic Growth: The use of renewable energy sources can lead to reduced dependence on non-renewable energy sources, such as fossil fuels, which can contribute to sustainable economic growth. Moreover, renewable energy technologies are becoming more cost-effective, which can create new opportunities for economic development and job creation in the renewable energy sector.

FDI Inflows and Economic Growth: FDI inflows can contribute to economic growth by bringing in capital, technology, and expertise, which can create new industries, expand existing ones, and increase productivity. This can lead to job creation, higher wages, and increased consumption, which can further stimulate economic growth.

FDI Inflows and Renewable Consumption: FDI inflows can also contribute to the development of renewable energy by providing the necessary capital, technology, and expertise. This can lead to increased investment in renewable energy projects and the adoption of new renewable energy technologies.

Environmental Pollution: Economic growth and FDI inflows can increase environmental pollution, particularly if there is a heavy reliance on non-renewable energy sources. However, the use of renewable energy sources can help reduce environmental pollution and promote sustainable development.

In summary, the relationship between renewable consumption, FDI inflows, economic growth, and environmental pollution is complex and depends on a range of factors. However, the adoption of renewable energy technologies can contribute to sustainable economic growth and help reduce environmental pollution.

Innovations in technology and business practices can help reduce carbon dioxide emissions by making production and consumption more efficient and sustainable. For example, the development of renewable energy technologies such as solar, wind, and hydro power, can help reduce the reliance on fossil fuels and reduce emissions [31].

Renewable consumption refers to the use of renewable energy sources in daily life, such as using solar panels to generate electricity for homes or driving electric cars. Increased renewable consumption can help reduce carbon dioxide emissions by reducing the demand for fossil fuels.

Carbon dioxide emissions are a major contributor to climate change and global warming. They are produced by burning fossil fuels such as coal, oil, and gas, as well as through industrial processes and land use changes. Therefore, reducing carbon dioxide emissions is crucial for mitigating the impacts of climate change.

The nexus of innovations, renewable consumption, and carbon dioxide emissions is important because it highlights the interconnectedness of these factors and the need for coordinated efforts to address them. By promoting and investing in innovative technologies and encouraging the use of renewable energy sources, we can reduce carbon dioxide emissions and create a more sustainable future.

Innovations can play a key role in reducing carbon dioxide emissions. For example, new technologies can make production processes more efficient, reduce waste, and optimize energy use. In addition, innovations in transportation can help reduce emissions by increasing the efficiency of vehicles and encouraging the use of low-emission alternatives like electric cars or public transportation [1].

Furthermore, the increasing use of renewable energy sources can have a significant impact on reducing carbon dioxide emissions. Renewable energy sources are sustainable and produce minimal greenhouse gases, making them an excellent alternative to fossil fuels. The deployment of renewable energy technologies has been growing rapidly in recent years, with solar and wind power being two of the fastest growing sources of electricity in the world. As more countries and companies shift towards renewable energy, the reduction of carbon dioxide emissions is becoming more achievable.

Another way to reduce carbon dioxide emissions is by promoting sustainable consumption patterns. This includes encouraging the use of products that are made with renewable materials, are energy-efficient, and have a low carbon footprint. Consumers can also make a difference by reducing their use of products that produce large amounts of carbon dioxide emissions, such as meat, dairy, and processed foods. By choosing to consume sustainably, individuals can contribute to reducing their own carbon footprint and encouraging others to do the same.

The nexus of innovation, renewable consumption, FDI inflows, and economic growth and carbon dioxide emissions is crucial to addressing climate change. By investing in innovative technologies, promoting sustainable consumption, and increasing the use of renewable energy sources, we can reduce carbon dioxide emissions and create a more sustainable future for all.

Thus, this paper used the linear model to study a connection between environmental pollution and renewable consumption, FDI inflows, economic growth, innovation. The following section details the data and research methods.

3. Data Collection and Research Methodology

3.1. Data Collection

We categorized data based on the World Bank and Vietnam General Statistics Office indicators from 2000 to 2022, such as the following:

Vietnam's environmental pollution is calculated by its CO_2 emissions, which are measured as a unit in millions of tons annually and by capital.

Innovation or high technology export value uses US dollar to measure the export of high-tech goods.

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The quantity of green energy produced annually, such as from wind electricity, water electricity, and solar electricity sources, is referred to as renewable consumption (TWh). Renewable consumption is also measured in relation to total energy consumption in percentage.

FDI inflows are measured by the US dollar.

GDP is measured US dollar and presented the economic growth.

3.2. Research Methodology

The research model used in this study is shown below in Figure 1.

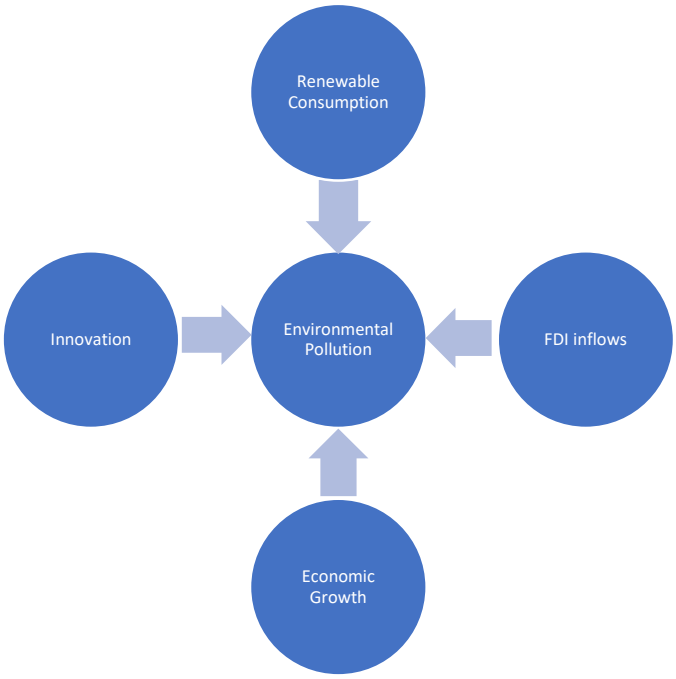

Figure 1. Nexus between renewable consumption, FDI inflows, economic growth and innovation regarding environmental pollution (Source: compiled by authors)

The study model used is detailed in the following section.

The function $Y = f(X_1, X_2, X_3, X_4\ldots)$ was used, in which the dependent and independent variables were the following:

Y: the CO_2 emissions measured by the million tons, which present environmental pollution;
X_1: the independent variable of renewable consumption, which measured by TWh;
X_2: the independent variable of FDI inflows, which measured by trillions US dollars;
X_3: the independent variable of economic growth, which measured by trillions US dollars;
X_4: the independent variable of innovation or high-technology export value, which measured by trillions US dollars;

This paper used the linear function of equation (1) as follows:

$$\mathbf{Y = Bo + B_1X_1 + B_2X_2 + B_3X_3 + B_4X_4 + \varepsilon} \qquad \mathbf{(1)}$$

Specifically, this research had the following hypotheses:

H_1: Renewable consumption negatively influences carbon dioxide (CO_2) emissions.

H_2: FDI inflows positively influence carbon dioxide (CO_2) emissions.

H_3: Economic growth positively influences carbon dioxide (CO_2) emissions.

H_4: Innovations or high-technology exports positively influence carbon dioxide (CO_2) emissions.

The independent variables of the research model are presented in Table 1.

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Table 1. Description of variables in the linear regression model.

Variable	*Definition*	*Expectation*
X_1	Renewable consumption or green energy	-
X_2	FDI inflows	+
X_3	Economic Growth	+
X_4	Innovations or high-technology exports	+

(Source: compiled by authors)

4. Results

An analysis of the independent and dependent variables in the linear model is presented in Table 2.

Table 2. Analysis of the variables in the regression model.

Variable	Obs	Mean	Std. Dev.	Min	Max
Country	Vietnam				
Code	VNM				
Year	23	2011	6.78233	2000	2022
CO_2 million tons	23	151.1594	69.23378	52.601	269.7901
Renewable Consumption	23	124.723	77.68318	40.419	288.9172
FDIUS	23	9.39×10^9	7.34×10^9	1.30×10^9	2.80×10^{10}
GDPUS	23	1.52×10^{11}	1.05×10^{11}	3.12×10^{10}	3.88×10^{11}
Innovations	23	3.67×10^{10}	4.38×10^{10}	1.83×10^{10}	1.34×10^{11}

(Source: compiled by authors)

There were 23 observations compiled as data that were collected in Vietnam in the period from 2000 to 2022. CO_2 emissions (dependent Y) had an average value of 151.1594 million tons per one year, the minimum value of 52.601 million tons in 2000, and the maximum value of 269.7901 million tons in 2022. The ratio of CO_2 emissions to total energy was 19.2% on average, with the lowest ratio of 12.8% in 2004 and the highest of 24.2% in 2017.

Independent variable X_1 was the consumption of renewable energy with a mean of 124.723 TWh, a lowest value of 40.419 TWh in 2000, and a highest value of 288.9172 TWh in 2022.

Independent variable X_2 was the FDI inflows with a mean of 9.39 billion US dollars, a lowest value of 1.3 billion US dollars in 2000, and a highest value of 28 billion US dollars in 2022.

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Independent variable X_3 was the GDP of Vietnam with mean of 152 billion US dollars, a lowest value of 31.2 billion US dollars in 2000, and a highest value of 388 billion US dollars in 2022.

Innovations (as measured by the high-tech export of goods and services) composed independent variable X_4 with a mean value of USD 36.7 billion, the lowest value of USD 18.3 billion in 2000, and the highest value of USD 134 billion in 2022.

A graph of X_1 – renewable consumption and X_2 – FDI inflows, X_3 – GDP of Vietnam from 2000 to 2022 is shown in Figure 2.

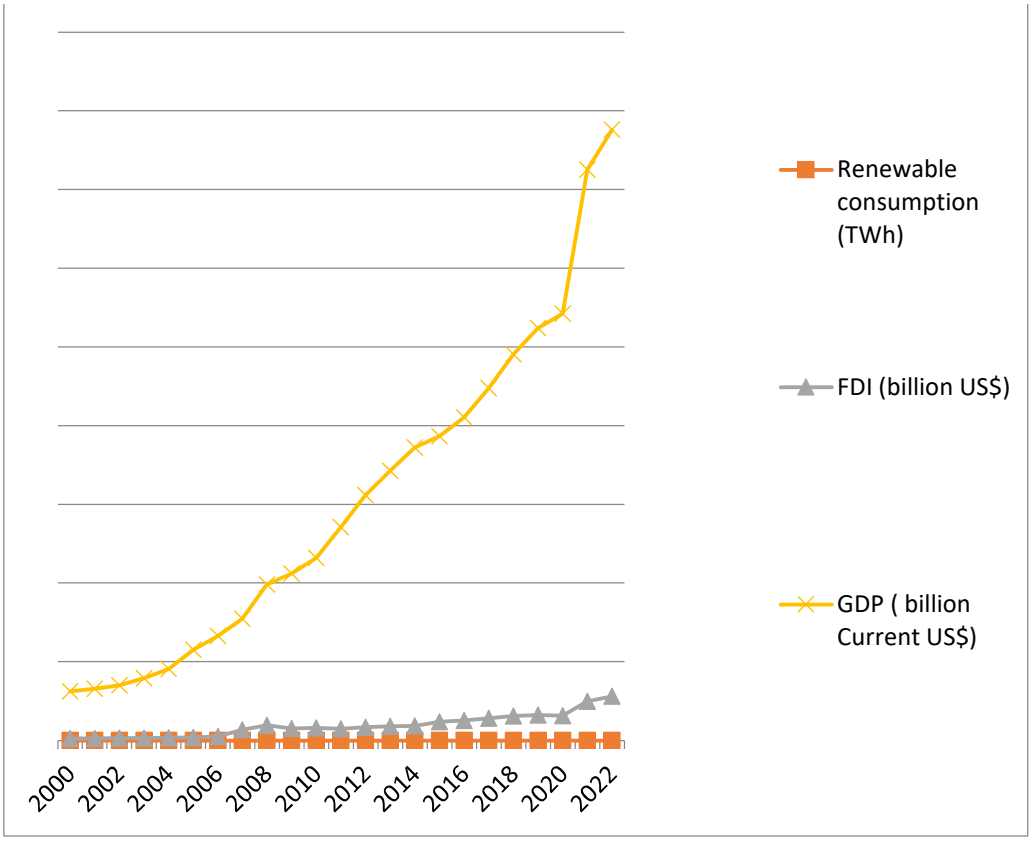

Figure 2. The green electricity (renewable consumption) (X_1), FDI inflows (X_2) and GDP (X_3) for the period from 2000 to 2022 in Vietnam

The renewable consumption and high technology export value are presented in figure 3.

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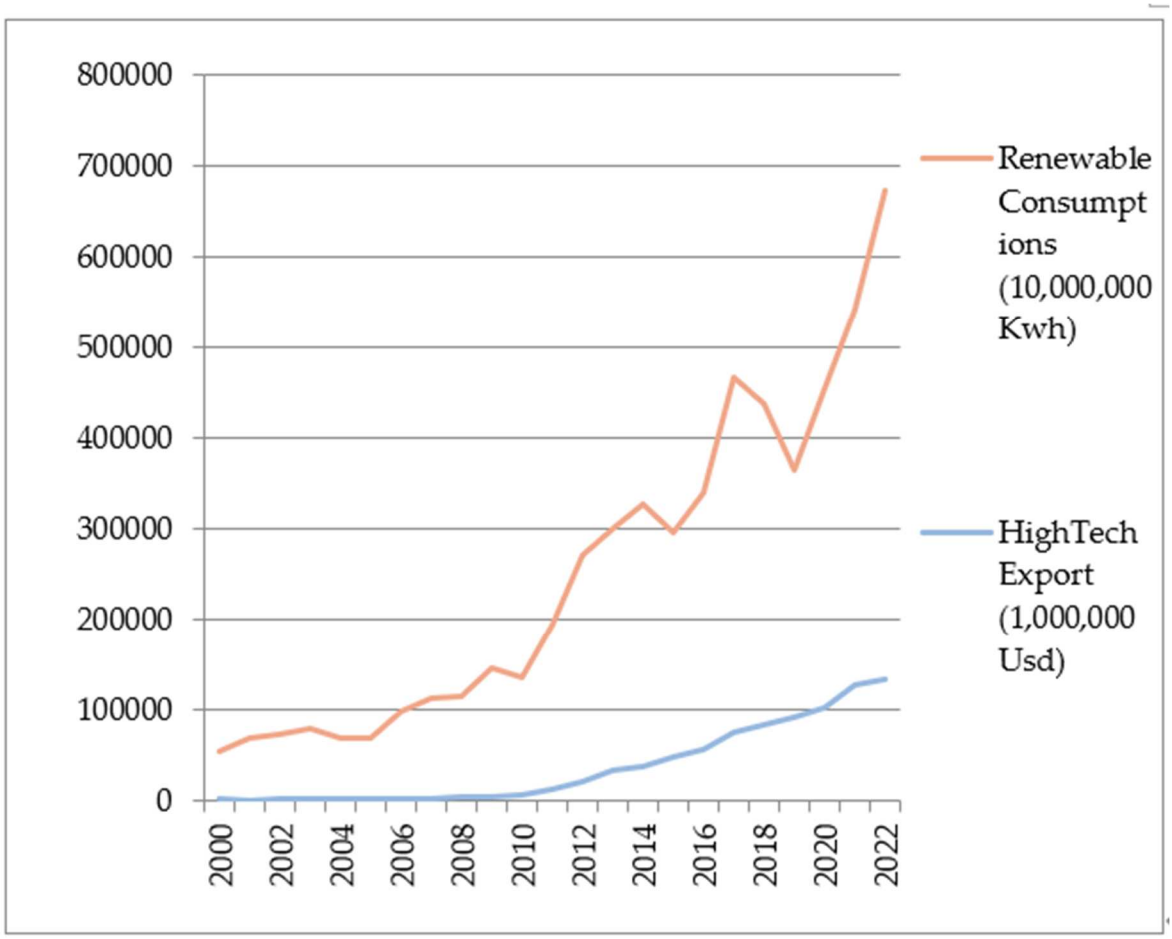

Figure 3. The green electricity (renewable consumption) (X_1) and innovations (X_4) for the period from 2000 to 2022 in Vietnam. (Source: compiled by authors)

The renewable consumption compared to the total energy consumption is presented in figure 4.

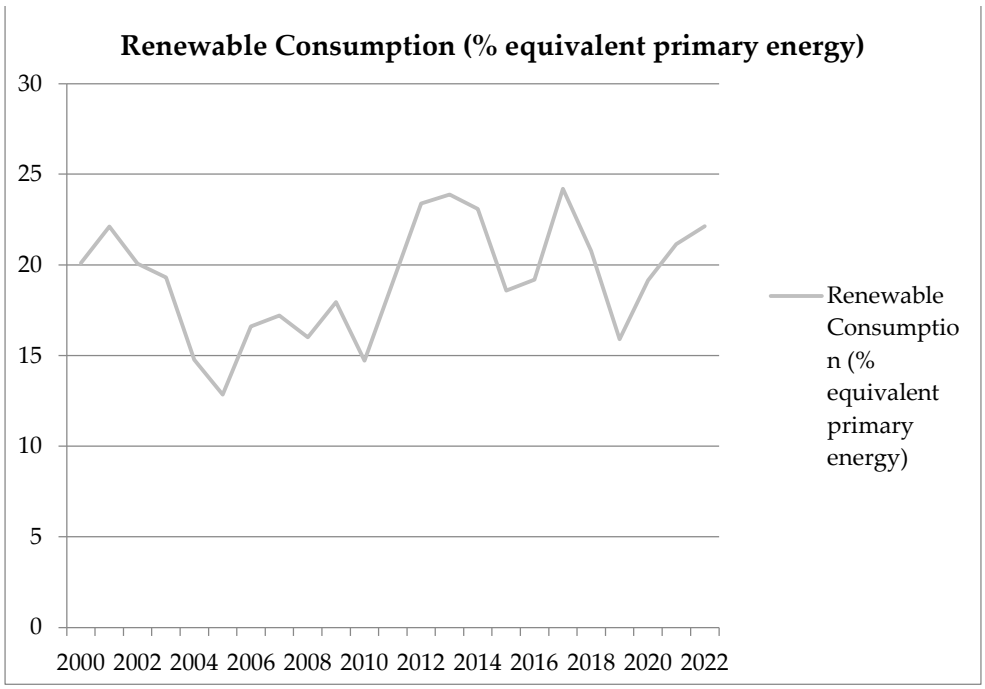

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Figure 4. Renewable consumption (% equivalent primary energy) for the period from 2000 to 2022 in Vietnam. (Source: compiled by authors)

Table 3 displays the regression analysis results for carbon dioxide (CO_2) emissions (Y) and renewable consumption (X_1). The relationship between green energy consumption and CO_2 emissions is shown by the *p-value* of 0.000. The adjusted R-squared value of 0.9509 indicates that the CO2 emissions can be explained by 95.09% of the variation in renewable consumption. Equation (2) allowed us to determine the elasticity of CO_2 emissions to green energy consumption in 2022.

$$Ex_1 = -0.0677x\ 22.1/2.95 = -0.51 \quad (2)$$

Table 3. Regression analysis model of green energy consumption (X_1) and CO_2 emissions (Y) for the period from 2000 to 2022 in Vietnam.

Source	SS	df	MS	Number of obs	=	23
Model	9.90209321	1	4.9510466	Prob > F	=	0.0000
Residual	.462649348	20	0.023132467	R-squared	=	0.9554
				Adj R-squared	=	0.9509
Total	10.3647426	22	471124662	Root MSE	=	0.15209

CO_2 per capital ton	Coef.	Std. Err.	t	P>|t|	[95% Conf. Interval]	
Renewable consumption	-0.0677523	0.0119065	-5.69	0.000	-0.0925888	-0.0429159
_cons	1.933811	0.21012	9.20	0.000	1.495509	2.372114

(Source: compiled by authors)

According to these findings, the CO_2 emissions per capita in Vietnam would decrease by 0.51% if renewable consumption were to increase by 1%. These figures demonstrate that Vietnam's environmental pollution has been significantly reduced over time by renewable consumption. The findings suggest that these issues should be re-examined. Vietnam devoted more than two decades to expanding its use of renewable energy. Taking the environment into account and contributing to a cleaner environment are necessary actions. The analysis and empirical results of this paper denote the recommendation that Vietnamese policymakers place great emphasis on green energy consumption for long-time development. The nexus between CO_2 emissions and green energy consumption is significantly negative.

To achieve sustainable development, Vietnam needs to continue developing more renewable energy to reduce CO_2 emissions per capita and maintain a clean environment. The Vietnamese government has had success in the development of green energy and protecting environmental sustainability.

Table 4 displays the regression analysis results for carbon dioxide (CO_2) emissions (Y) and FDI inflow (X_2). The relationship between FDI inflows and CO_2 emissions is shown by the *p-value* of 0.000. The R-squared value of 0.9168 indicates that the CO_2 emissions can be explained by 91.68% of the variation in FDI inflows. Equation (3) allowed us to determine the elasticity of CO_2 emissions to FDI inflows in 2022.

$$Ex_2 = 1.34x10^{-8} \times 28x10^9/269.79 = 1.39 \quad (3)$$

Table 4. The linear regression model between the FDI (X_2) and CO_2 emission (Y) from 2000 to 2022.

Source	SS	df	MS	Number of obs	=23

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Model	578454.171	1	578454.171	F(1, 22) = Prob > F =	242.26 0.0000
Residual	52529.2575	22	2387.69352	R-squared=	0.9168
				Adj R-squared=	0.9130
Total	630983.428	23	27434.0621	Root MSE=	48.864

CO2 Million tons	Coef.	Std. Err.	t	P>|t|	[95% Conf. Interval]
FDIUS	$1.34x10^{-8}$***	$8.62x10^{-10}$	15.56	0.000	$1.16x10^{-8}$ $1.52x10^{-8}$

Note: *** P<0.01

(Sources: compiled by author).

The empirical results show that the relationship between the FDI inflows and environmental pollution is positive. If the FDI inflows up 1% then the environmental pollution up 1.39%. It means that the Vietnamese government should attract more the green FDI to protect the environment in the future. In the past, Vietnam attract so much the polluted FDI inflows with low technology and increase the CO_2 emission.

Table 5 displays the regression analysis results for carbon dioxide (CO_2) emissions (Y) and GDP (X_3). The relationship between GDP and CO_2 emissions is shown by the *p-value* of 0.000. The R-squared value of 0.9590 indicates that the CO_2 emissions can be explained by 95.90% of the variation in GDP. Equation (4) allowed us to determine the elasticity of CO_2 emissions to GDP in 2022.

Table 5. The linear regression model between the GDP (X_3) and CO_2 emissions (Y) from 2000 to 2022.

Source	SS	df	MS	Number of observations=	23
Model	605125.877	1	605125.877	F(1, 22) = Prob > F=	514.85 0.0000
Residual	25857.5518	22	1175.34327	R-squared=	0.9590
				Adj R-squared =	0.9572
Total	630983.428	23	27434.0621	Root MSE=	34.283

Co2Milliont	Coef.	Std. Err.	t	P>|t|	[95% Conf.	Interval]
GDP Current US	$8.83x10^{-10}$***	$3.89x10^{-11}$	22.69	0.000	$8.03x10^{-10}$	$9.64x10^{-10}$

Note: *** P<0.01

(Sources: complied by author).

$$Ex_3 = 8.83x10^{-10} \times 388x10^9/269.79 = 1.26. \quad (4)$$

The empirical results show that the relationship between the GDP and environmental pollution is positive. If the GDP is up 1% then the environmental pollution is up 1.26%. The results in this paper

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show that the economic growth much affects the environment pollution in Vietnam for a long time. The Vietnam government focused on the economic growth for more than 40 year and make the environment are more polluted. Nowadays, Vietnam need the green growth and sustainable development.

Table 6 displays the regression analysis results of the innovations (X_4) and CO_2 emissions (Y). The nexus of the innovations and CO_2 emissions is demonstrated by the *p-value* of 0.000. According to the adjusted R-squared value of 0.8762, the CO_2 emissions can be explained by 87.62% of the innovation change. We used the following equation (5) to determine the elasticity of CO_2 emissions to innovations in 2022 as follows:

$$E_{X4} = 1.47x10^{-11} \times 1.34x10^{11}/2.950 = 0.6677 \quad (5)$$

Table 6. Regression analysis model of innovations (X_2) and CO_2 emissions (Y) for the period from 2000 to 2022 in Vietnam.

Source	SS	df	MS	Number of obs	=	23
Model	9.13958587	1	9.13958587	Prob > F	=	0.0000
Residual	1.22515668	21	.058340794	R-squared	=	0.8818
				Adj R-squared	=	0.8762
Total	10.3647426	22	0.471124662	Root MSE	=	0.24154

CO_2 per capital ton	Coef.	Std. Err.	T	P>|t|	[95% Conf. Interval]	
High-Tech Export USD	$1.47x10^{-11}$	$1.18 x10^{-12}$	12.52	0.000	$1.23 x10^{-11}$	$1.72 x10^{-11}$
_cons	1.128472	0.0663579	17.01	0.000	0.9904733	1.266471

(Source: compiled by authors)

According to these findings, CO_2 emissions will rise by 0.68% if high-technology goods and services exports increase by 1%. The empirical results suggest that Vietnam policymakers should place their focus on the export of environmentally friendly high-technology goods and services. The nexus of CO_2 emissions and the high-tech export of goods and services will become negative as developed countries implement this strategy long term, and the more goods and services are exported, the lower CO_2 emissions will be. The nexus of CO_2 emissions and innovations will perhaps remain greater than zero for a short period due to the attraction of old, cheap technology that pollutes the environment.

5. Conclusions and Recommendations

According to the statistical results of CO_2 emissions data, several nations have maintained stable CO_2 emission levels. However, from 2020 to 2022, CO_2 levels in Vietnam continued to rise. This demonstrates that the Vietnamese government has not yet successfully implemented long-term policies for green electricity and a green economy as have developed countries with low carbon emissions. However, other nations have placed great emphasis on and succeeded in developing a green economy. These countries will help Vietnam to learn lessons in the future. Vietnam has grown its economy by exporting high-tech goods, attraction of the FDI inflows, economic growth that pollute the environment. Increasing the consumption of renewable energy sources has the potential to preserve the environment.

Vietnam's exports from industries that rely heavily on fossil fuels (e.g., thermal power) have increased in recent years as CO_2 levels have continued to rise in using technology that is out of date.

This also suggests that Vietnam's use of clean energy is not as effective as its use in developed countries. Vietnam has many advantages with respect to the develop of clean energy such as wind, water, and solar electricity compared with other countries in the region. However, it is simpler to make full use of abundant fossil fuel resources because of their benefits. Therefore, there has been no immediate need to promote the development of clean energy.

This study demonstrates that Vietnam's FDI inflows, economic growth and export of high-tech goods make the CO_2 emissions increase and as a results, it make the environment in Vietnam is much polluted. Similar to the findings of Le et al. [9], our findings suggest that the country's economic expansion will be impacted over the long term by green growth. At the same time, research confirms that heavy industry or high fossil fuel consumption will hurt the economy over a long-term period. Moreover, when CO_2 is released into the environment, it only has an effect on the economy after one year. Thus, CO_2 emissions have no immediate effect on the economy, and the economy has not shown any signs of being affected.

Additionally, the findings of this research indicate that the lower the consumption of renewable energy sources, the greater the CO_2 emissions per person. Wind, solar, and water electricity are examples of clean energy sources that are advantageous in Vietnam. Vietnam needs to protect the environment and decrease carbon dioxide (CO_2) emissions. Empirical findings demonstrate that the Vietnamese government should increase its investments in renewable electricity. Over the past two decades, renewable energy development has reduced environmental impacts. In the future, the Vietnamese government must concentrate on the growth of green energy. To promote green energy, the government must take actions to establish a competitive electricity market. Additionally, in order to lay a solid foundation for the growth of the green energy market, the government must implement policies that encourage private investment in the construction of power transmission infrastructure.

Vietnam ought to enact policies that will encourage the green industry to attraction the FDI inflows, economic growth and export high-tech goods and services. Vietnam has been successful in attracting multinational corporations like Samsung, Apple, and Intel to innovate and export high-tech goods to other nations in recent years. To help stabilize the economy, Vietnam also uses foreign currency. However, the expansion of high-tech product exports results in an increase in CO_2 emissions. Green innovation and green industry ought to be the primary focus. As a result, investing in businesses that use a lot of energy is also not a good idea for long-term economic growth.

The nexus of renewable consumption, foreign direct investment (FDI) inflows, economic growth, innovation, and carbon dioxide emissions refers to the relationship between these factors and how they interact with one another.

Renewable consumption, as mentioned earlier, refers to the use of renewable energy sources such as solar, wind, and hydropower. FDI inflows refer to the investment by foreign entities in domestic companies and infrastructure. Economic growth refers to the increase in production and consumption of goods and services in a country. Innovation refers to the development and implementation of new technologies and processes that can improve efficiency and reduce environmental impact.

The nexus of these factors is important because they all play a role in shaping the path of a country's economic development and environmental sustainability. Renewable consumption can contribute to reducing carbon dioxide emissions and improving environmental sustainability. FDI inflows can bring in new technology and expertise to a country, which can lead to innovation and economic growth. Economic growth can provide a pathway towards poverty reduction and improvement in quality of life. Innovation can enable more efficient and sustainable production and consumption, which can help reduce environmental impact.

However, these factors are also interconnected and can have unintended consequences. For example, economic growth can lead to increased energy consumption and higher carbon dioxide emissions if sustainable practices are not implemented. FDI inflows can lead to environmental degradation if the investments are not made in a sustainable manner. Renewable consumption can be limited by the availability of resources and infrastructure. Innovation can be slowed down by a lack of investment and political will.

Therefore, it is important to have a comprehensive and coordinated approach to address the nexus of renewable consumption, FDI inflows, economic growth, innovation, and carbon dioxide emissions. This can involve policies and strategies that promote sustainable practices, encourage

investment in renewable energy and innovation, and provide incentives for companies to reduce their carbon footprint. It is also important to have public awareness and engagement in order to create a sustainable and equitable future.

The positive nexus found between innovations and environmental pollution in Vietnam represents a new contribution of this research. This study's empirical findings opposite results of Khan et al. [1]. In future studies, Vietnam should be compared to other nations with respect to green energy, FDI inflows, economic growth, innovations and carbon dioxide (CO_2) emissions. The nexus of those factors and environmental pollution in developed and developing nations could also be studied through additional research in the future.

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