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Nexus of Carbon Dioxide Emissions, Fossil Fuel, Foreign Direct Investments, and Exports to Renewable Energy: New Evidence from Singapore

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Abstract

This paper investigates the intricate relationship between carbon dioxide (CO2) emissions, fossil fuel consumption, foreign direct investments (FDI), exports, and the shift towards renewable energy in the context of Singapore. The study uses the unrestricted fixed and random panel data method. Data in this paper is collected from the World Bank from 2000 to 2022. This paper also investigates the intricate nexus of carbon dioxide (CO2) emissions, fossil fuel consumption, foreign direct investments (FDI), exports and renewable energy consumption, and Singapore's shift towards renewable energy. As a dynamic and rapidly growing economy, Singapore's lessons provide valuable insights into the challenges and opportunities of balancing economic development, environmental sustainability, and the global movement to renewable energy sources. Utilizing comprehensive data sets, statistical analyses, and econometric modeling, we explore the nexus between these critical variables to gain a nuanced understanding of Singapore's evolving energy landscape. The empirical results give the suggested policy implication for the Singapore government and lessons learned for other countries.

Keywords: *Carbon dioxide emissions, fossil fuels, Foreign direct investments, Renewable energy.*

1. Introduction

Singapore, a global financial hub and economic powerhouse, has achieved economic growth over the past few decades. However, this growth has come at the cost of increased carbon emissions, primarily driven by the reliance on fossil fuels for energy. As the world grapples with the urgent need to mitigate climate change, Singapore is at a crossroads, facing the challenge of reducing carbon emissions while sustaining economic development (Adebayo & Samour, 2023; Aftab et al., 2021; Aghasafari, Aminizadeh, Karbasi, & Calisti, 2021).

The modern era has witnessed unprecedented challenges related to environmental sustainability, economic growth, and global energy security. Central to this intricate web is the nexus between carbon dioxide (CO2) emissions, fossil fuel dependency, foreign direct investments (FDI), and the pivotal transition to renewable energy sources. While this nexus has been the subject of considerable scholarly attention, this study aims to

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contribute new evidence and insights within the specific context of Singapore, a dynamic and highly developed nation.

Singapore, known for its economic prowess and technological advancements, has achieved remarkable milestones in its journey toward becoming a global financial and trade hub. However, this success has come with environmental trade-offs, particularly concerning carbon emissions and fossil fuel dependence. As the world grapples with the urgent need for sustainable practices, Singapore finds itself at the intersection of economic growth aspirations and the imperative to mitigate environmental impact.

The rationale for this study lies in recognizing the symbiotic relationship between economic development, energy consumption, and environmental sustainability. Understanding how Singapore navigates this intricate nexus is crucial for the nation and the broader global discourse on sustainable development. By shedding light on the nuanced interactions between carbon emissions, foreign investments, and the transition to renewable energy, this research aspires to contribute to informed decision-making and policy formulation.

This paper aims to:

- Examine the historical trends in carbon dioxide emissions in Singapore.
- Analyze the role of fossil fuel consumption in contributing to carbon emissions and renewable energy.
- Investigate the effects of FDI- foreign direct investment inflows on carbon dioxide emissions and renewable energy consumption.
- Examine the exports to renewable energy in Singapore and assess Singapore's progress in transitioning to renewable energy sources.

This study also seeks to achieve the following objectives:

- To Analyze Carbon Dioxide Emissions Trends- examine historical patterns and trends in carbon dioxide emissions in Singapore, identifying key sources and assessing their implications.
- To Investigate Fossil Fuel Dependency- scrutinize the role of fossil fuel in Singapore's energy landscape, exploring dependencies, challenges, and potential mitigation strategies.
- To Examine Foreign Direct Investments in the Energy Sector- evaluate the impact of foreign direct investments on Singapore's energy policies, technological advancements, and overall sustainability efforts.
- To Explore Renewable Energy Exports- investigate Singapore's initiatives in exporting renewable energy technologies or expertise, assessing their impact on carbon reduction and economic growth.
- To Provide New Evidence- contribute novel evidence to the existing literature, filling gaps in our understanding of the interconnections between carbon emissions, fossil fuel use, foreign investments, and renewable energy export in Singaporeans.

Significance of the Study- This study is significant for several reasons. Firstly, it addresses the specificities of Singapore's unique position in the global energy landscape, considering its economic significance, geographic constraints, and commitment to sustainability. Secondly, it contributes to the academic discourse by offering new evidence in an area that has rapidly changed in recent years. Lastly, the findings are anticipated to provide valuable insights for policymakers, businesses, and researchers seeking to balance economic growth with environmental stewardship.

In illuminating the nexus of carbon dioxide emissions, fossil fuel utilization, foreign investments, and the transition to renewable energy, this study endeavors to contribute to the ongoing dialogue surrounding sustainable development, particularly within the vibrant context of Singapore.

Carbon Dioxide Emissions- Singapore, like many other developed nations, faces challenges related to carbon dioxide emissions. Emissions primarily come from industrial activities, transportation, and energy production (Al Afif, Ayed, & Maaitah, 2023; Alvarez-Herranz, Balsalobre-Lorente, Shahbaz, & Cantos, 2017).

Fossil Fuel Dependency- Singapore has traditionally depended on fossil fuels for energy consumption. The country imports a significant portion of its energy resources, including natural gas and oil (An et al., 2023; Andersen et al., 2010).

Foreign Direct Investments (FDI)- Singapore has been a hub for foreign direct investments, and the government actively encourages investments in various sectors. FDI can influence the energy landscape by shaping policies, technology adoption, and the overall economic structure (Ashizawa, Otaka, Yamamoto, & Akisawa, 2022; Balsalobre-Lorente, Contente dos Santos Parente, Leitão, & Cantos-Cantos, 2023).

Export to Renewable Energy- Singapore has been trying to transition towards renewable energy sources in recent years. This issue includes investments in solar power, wind energy, and the development of a more sustainable energy infrastructure (Balsalobre-Lorente, Ibáñez-Luzón, Usman, & Shahbaz, 2022; Balsalobre-Lorente, Nur, Topaloglu, & Evcimen, 2023).

Government Policies and Initiatives- the Singaporean government has introduced policies to reduce carbon emissions and promote sustainable practices. This problem includes the Sustainable Singapore Blueprint and initiatives to push the percentage of renewable energy consumption in the overall energy mix (Balsalobre-Lorente, Shahbaz, Murshed, & Nuta, 2023; Balsalobre-Lorente, Shahbaz, Roubaud, & Farhani, 2018; Banerjee, 2022).

International Commitments- Singapore, like many other countries, is likely to be influenced by global commitments to combat climate change. Agreements such as the Paris Agreement may shape the country's policies and priorities in reducing carbon emissions (Bassey Enya, James, & Friday Bassey, 2022; Borg, Kits, Junttila, & Uddin, 2022; Bui Minh & Bui Van, 2023).

The paper contains 08 sections: section one- introduction; section two- Literature Review; Section 3- data and Methodology; Section 6- Results and Findings; Section 7- conclusion; Section 8- Limitation and Future Study.

2. Literature Review:

The nexus between carbon dioxide emissions, fossil fuel utilization, foreign direct investments (FDI), and the export of renewable energy in Singapore has garnered scholarly attention in recent years. A comprehensive review of existing literature provides valuable insights into the global and regional trends, identifying gaps that this study aims to address.

2.1 Global Carbon Emissions Trends:

The urgency of addressing carbon emissions and mitigating climate change has been a focal point in international literature. Studies by the IPCC-Intergovernmental Panel on Climate Change highlight the rising concerns and call for collective efforts to reduce global carbon emissions. Insights gained from these global perspectives will be contextualized to Singapore's specific scenario (Wu et al., 2021; Xuan, 2020a, 2020b; Xuan, Thu, & Anh, 2020a, 2020b; Zhang, Li, & Cao, 2022).

2.2 FDI in the Energy Sector:

Checking the role of foreign direct investments in the energy sector provides a nuanced understanding of economic dynamics. Existing literature delves into the impact of FDI on energy policies, technological advancements, and the overall sustainability of a nation. Research by scholars such as (Tsai et al., 2021; Usman, Alola, & Akadiri, 2022; B. Wang & Wang, 2023; W. Wang, Liu, & Yang, 2022; X. Wang, Xu, Wang, & Skare, 2022; Wei, Liu, Ye, Chen, & Weng, 2023) contributes to our understanding of how FDI shapes energy landscapes.

2.3 Transition to Renewable Energy:

The global shift towards renewable energy consumption is a critical theme in the literature. Pioneering studies by (Stjepanovic, Tomic, & Skare, 2022; Thu, Huong, & Xuan, 2022; Thu, Xuan, & Huong, 2022) outline the feasibility and potential benefits of moving to 100% renewable energy. Regional perspectives, such as those discussed by (Shang, Han, Gozgor, Mahalik, & Sahoo, 2022; Shi, Cai, Ding, Di, & Xiao, 2020; Sinha, Balsalobre-Lorente, Zafar, & Saleem, 2022) in his examination of Southeast Asian renewable energy transitions, offer valuable insights that can be applied to Singapore's context.

2.4 Carbon Emissions and Fossil Fuel Dependency in Singapore:

Explicitly focusing on Singapore, the literature reflects the unique challenges its fossil fuel dependency poses. Works such as the Energy Market Authority's reports and studies by local scholars like (Samour, Adebayo, Agyekum, Khan, & Kamel, 2023; Sarwar, Shahzad, Chang, & Tang, 2019; Shahbaz, Balsalobre-Lorente, & Sinha, 2019; Shahzad, 2020; Shahzad, Fareed, Shahzad, & Shahzad, 2021; Shahzad, Ferraz, Doğan, & Aparecida do Nascimento Rebelatto, 2020) shed light on Singapore's historical trajectory, emphasizing the sources and implications of its carbon emissions.

2.5 Policy Interventions and Sustainable Initiatives:

The role of government policies in addressing carbon emissions and fostering a transition to renewable energy is a recurrent theme. Literature reviews, including analyses by (Raihan & Tuspekova, 2022a, 2022b; Ram, Gulagi, Aghahosseini, Bogdanov, & Breyer, 2022; Sahoo & Goswami, 2024) on the effectiveness of climate policies, provide a foundation for understanding how policy interventions contribute to sustainable practices. Specific to Singapore, reviews of the Sustainable Singapore Blueprint and related policies offer insights into the nation's commitment to sustainability.

2.6 Gaps in the Existing Literature:

While the existing literature contains a solid foundation, specific gaps remain. The literature needs an in-depth exploration of recent evidence from Singapore incorporating the interplay of carbon emissions, foreign investments, and renewable energy exports. This study addresses this gap by providing new evidence and insights specific to Singapore's evolving energy landscape (Phan, 2022; Phan, Stachuletz, & Nguyen, 2022; Raihan, 2023).

This literature review establishes the broader context for the current study, offering a synthesis of existing knowledge while highlighting the gaps that the research endeavors to fill. By building upon the foundations laid by global and regional scholars, the study aims to contribute new evidence to the growing body of literature on sustainable energy transitions. A review of existing literature will provide context for understanding the global discourse on carbon emissions, fossil fuel consumption, and the role of foreign direct investment exports in shaping sustainable energy transitions. The literature review contextualizes the paper within the broader academic discourse on carbon emissions, fossil fuel consumption, and the role of foreign direct investments in sustainable energy transitions. Existing studies highlight the global imperative for nations to decouple

economic expansion from carbon emissions and the importance of foreign investments in shaping energy policies (Can, Balsalobre-Lorente, Adedoyin, & Mercan, 2023; Can, Dogan, & Saboori, 2020; Chen, Pinar, & Stengos, 2022; Chu, Doğan, Abakah, Ghosh, & Albeni, 2023; Chu, Doğan, Dung, Ghosh, & Alnafrah, 2023).

Scholars argue that the energy transition is a complex process influenced by economic, political, and technological factors. The other authors note the significance of international investments in fostering sustainable energy practices and reducing dependency on fossil fuels. This literature underscores the need for a comprehensive understanding of the interplay between economic development, foreign investments, and the transition to renewable energy (Chu, Ghosh, Doğan, Nguyen, & Shahbaz, 2023; Dai et al., 2023; Doğan, Balsalobre-Lorente, & Nasir, 2020; Doğan, Chu, Ghosh, Diep Truong, & Balsalobre-Lorente, 2022; Doğan, Driha, Balsalobre Lorente, & Shahzad, 2021; Doğan, Ghosh, Hoang, & Chu, 2022).

Government Reports and Publications- explore reports and publications from Singaporean government agencies responsible for energy, environment, and economic development. These sources often provide the latest data, policies, and initiatives (Dogan, Madaleno, Tiwari, & Hammoudeh, 2020; Doğan, Rao, Ferraz, Sharma, & Shahzadi, 2023; Doğan, Shahbaz, Bashir, Abbas, & Ghosh, 2023; Esmaeili, Balsalobre Lorente, & Anwar, 2023; Feng, Xiao, Zhou, & Ni, 2023; Fernandes & Ferrão, 2023; Firth et al., 2022).

Environmental Organizations- check reports and publications from environmental organizations operating in Singapore. They may offer insights into the current state of emissions, renewable energy projects, and environmental policies (Ganesan, Kor, Pattinson, & Rondeau, 2020; Ghasemi, Rajabi, & Aghakhani, 2023; Ghosh, Adebayo, Abbas, Doğan, & Sarkodie, 2023; Giang, Trung, Yoshida, Xuan, & Que, 2019; Hoa, Xuan, & Phuong Thu, 2023).

Academic research- look for academic studies and research papers focusing on Singapore's energy landscape. Academic institutions and researchers may provide in-depth analyses of the interplay between emissions, fossil fuel use, foreign investments, and renewable energy (Huang, Kuldasheva, & Salahodjaev, 2021; Jahanger et al., 2023; Johnathon, Agalgaonkar, Planiden, & Kennedy, 2023; Joo, Shawl, & Makina, 2022; Kartal, Samour, Adebayo, & Kılıç Depren, 2023; Keh, Tan, Tang, Sim, & Lee, 2023).

Business and Economic News- stay updated with news from reputable business and economic news sources. They often cover developments in the energy sector, including investments, policy changes, and emerging trends (H. Khan, Weili, Bibi, Sumaira, & Khan, 2022; M. K. Khan, Khan, & Rehan, 2020; M. K. Khan, Teng, & Khan, 2019; M. K. Khan, Teng, Khan, & Khan, 2019; Kocoglu, Jahanger, Awan, Barak, & Balsalobre-Lorente, 2023; Kuo & Wu, 2023).

International Organizations- explore reports from international organizations such as the IEA- International Energy Agency or the World Bank. These organizations often provide global perspectives and benchmarks that can be useful for understanding Singapore's position in the broader context (Le, Nguyen, & Phan, 2022; Leitão, 2021; Leitão, Dos Santos Parente, Balsalobre-Lorente, & Cantos Cantos, 2023; Leitão, Koengkan, & Fuinhas, 2022; Li, Samour, Irfan, & Ali, 2023).

Corporate Sustainability Reports- many companies in Singapore release sustainability reports that outline their efforts in reducing carbon emissions and transitioning to renewable energy. Reviewing these reports can offer insights into the private sector's role in the transition (Liem, Tashiro, Tinh, & Sakai, 2022; Madani & Carpenter, 2023; Martí-Ballester, 2022; Melane-Lavado & Álvarez-Herranz, 2020; P. T. Nguyen, 2022).

Government Announcements and Speeches- monitor official announcements, speeches, and statements from government officials about energy and environmental policies. These

sources can provide information on the government's priorities and plans (Nguyen Thi Ngoc, 2016; T. T. Nguyen & Nguyen, 2021; Overland, Juraev, & Vakulchuk, 2022; Pata & Samour, 2023; Payne, Truong, Chu, Doğan, & Ghosh, 2023).

Energy Market Reports- explore reports from energy market analysis firms focusing on the Asia-Pacific region. These reports may provide market trends, investment patterns, and forecasts related to energy and sustainability in Singapore (Phan, 2022; Phan et al., 2022; Raihan, 2023; Raihan & Tuspekova, 2022a, 2022b; Ram et al., 2022; Sahoo & Goswami, 2024; Samour et al., 2023; Sarwar et al., 2019).

3. Methodology:

3.1 Data Collection:

We will utilize comprehensive datasets from government agencies, international organizations, and academic sources to compile information on carbon dioxide emissions, fossil fuel consumption, foreign direct investments, exports, and the adoption of renewable energy in Singapore. Significantly, the paper collected data from the World Bank from 2000 to 2022.

The research diagram used in this paper is shown below in Figure 1.

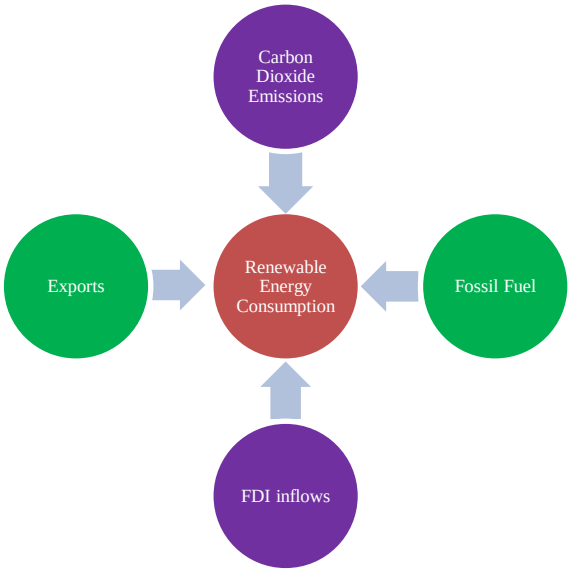

Figure 1. Nexus of carbon dioxide emissions, fossil fuel, FDI inflows, exports, and renewable energy consumption.

(Source: compiled by authors)

The study model used is detailed in the following section.

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

Y: the independent variable of renewable energy consumption, which is measured by TWh or percentage of total energy consumption;

X_1: the CO_2 emissions measured by the million tons, which present environmental pollution; these data were gathered based on the World Bank reports. This paper assumed that the higher the carbon dioxide emissions, the higher the environmental pollution in Asian countries. Although environmental pollution can be caused by various other sources, such as waste material, industrialization, and water pollution, this paper only collected data on CO_2 emissions to measure environmental pollution.

X_2: the independent variable of fossil fuel consumption, which TWh measures

X_3: the independent variable of FDI inflows, which is measured by trillions of US dollars;

X_4: the independent variable of exports of goods and services, which is measured by trillions of US dollars;

3.2 Statistical Analysis:

Statistical techniques, including regression analysis, will identify relationships and patterns within the data. This issue will facilitate a quantitative assessment of the nexus between carbon emissions, fossil fuel use, foreign investments, and the transition to renewable energy.

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

$$LnYi,t = Bo + B1LnX1 + B2LnX2 + B3LnX3 + B4LnX4 + \varepsilon i,t \quad (1)$$

The study model used is detailed in the following section.

The function Y = function (X1, X2, X3, X4…) was used, in which the dependent and independent variables were the following:

Data will be sourced from the World Bank and other reputable sources. Initial summary statistics and correlations will be presented. Data visualization techniques like heat maps and scatter plots will be employed.

The manuscript has the hypothesis in the research as follows:

H_1: Carbon dioxide emissions negatively affect renewable energy consumption.

H_2: Fossil fuel consumption negatively affects renewable energy consumption.

H_3: FDI inflows negatively affect renewable energy consumption.

H_4: Exports positively affect renewable energy consumption.

The independent variable is presented in Table 1 as follows:

Table 1. The independent and dependent variables used in the paper

Variable	Concept	Relationship
X1	Carbon dioxide emissions	-
X2	Fossil fuel consumption	-
X3	FDI inflows	-
X4	Exports of goods and services	+

(Sources: compiled by author)

The definition and symbol +/- in Table 2 means that carbon dioxide emissions negatively affect renewable energy consumption, fossil fuel consumption negatively affects renewable energy consumption, FDI inflows negatively affect renewable energy consumption, and exports of goods and services positively affect renewable energy consumption.

4. Results and Findings:

Table 2. Regression analysis model of carbon dioxide emissions (X_1), fossil fuel (X_2), FDI inflows (X_3), exports of goods and services (X_4), and renewable energy consumption (Y) for the period from 2000 to 2022 in Singapore.

Source	SS	Df	MS	Number of obs	= 23	
Model	.026375212	5	.05275042	Prob > F	= 0.0000	
Residual	.014154400	15	.00943630	R-squared	= 0.995	
				Adj R-squared	= 0.993	
Total	245.026002	22	11.1375455	Root MSE	= 0.36218	
Ln Renewable Energy	Coef.	Std. Err.	T	P>|t|	[95% Conf. Interval]	
Ln CO2 emissions	-0.010347***	0.032529	-6.2	0.0076	0.058987	0.07968
Ln Fossil fuel consumption	-0.035232***	0.018241	-5.93	0.0073	-0.074114	0.03648
Ln FDI inflows	-0.015674***	0.087851	-8.78	0.0045	-0.034399	0.03050
Ln exports	0.025596***	0.012247	8.09	0.0054	-0.507601	0.05169
_Cons	0.815596***	0.065506	12.45	0.000	0.6759729	0.95521

*** represent 1% significance, respectively

(Source: computed by Stata 16.0 software)

Table 2 displays the regression analysis results of carbon dioxide emissions (X1), fossil fuel consumption (X2), FDI inflows (X3), exports of goods and services (X4), and renewable energy consumption (Y) for the period from 2000 to 2022 in Singapore. According to the adjusted R-squared value of 0.9993, renewable energy consumption can be explained by 99.3% of the independent variable change.

The nexus of carbon dioxide emissions and renewable energy consumption is demonstrated by the p-value of 0.0076. Therefore, hypothesis 1 is accepted. The elasticity of renewable energy consumption to carbon dioxide emissions is 0.01. According to these findings, renewable energy consumption will rise by 0.01% if carbon dioxide emissions decrease by 1%.

Table 2 also displays the regression analysis results for renewable energy consumption (Y) and fossil fuel (X2). The nexus of fossil fuel and renewable energy consumption is shown by the p-value of 0.0073. Therefore, the hypothesis 2 is accepted. The elasticity of renewable energy to fossil fuel consumption is 0.035. The empirical results show a negative nexus between fossil fuel and renewable energy consumption. If the fossil fuel is down 1%, renewable energy consumption is up 0.035%. It means that the Singaporean

government cares about green growth, decreasing fossil fuel consumption, and protecting the environment in the future. Nowadays, Singapore has significant green growth and sustainable development.

The empirical results show a significantly negative nexus between Singapore's FDI inflows and green energy consumption. The results in this paper show that FDI inflows have affected renewable energy consumption in Singapore. Table 2 illustrates the regression analysis results for renewable energy consumption (Y) and FDI inflows (X3). The relationship between green energy consumption and carbon dioxide emission is shown by the p-value of 0.045. Therefore, the hypothesis 3 is accepted. The elasticity of green energy consumption to FDI inflows is -0.016

According to these findings, renewable energy consumption in Singapore would increase by 0.016% if the FDI inflows decreased by 1%. These figures demonstrate that renewable consumption has increased in Singapore; however, the FDI inflows make less renewable energy consumption.

Table 2 also displays the regression analysis results for renewable energy consumption (Y) and exports (X4). The relationship between exports and renewable energy consumption is shown by the p-value of 0.0054. Therefore, hypothesis 2 is accepted—the elasticity of green energy to exports equals 0.026. The empirical results suggest that if the exports increase by 1%, renewable energy will increase by 0.026%.

The findings suggest that Singapore's citizens care significantly about using green energy to export goods and services. Singapore must continue developing more renewable energy to reduce CO2 emissions per capita and maintain a clean environment to achieve sustainable development. The Singaporean government has succeeded in developing green energy and protecting environmental sustainability. The empirical results suggest that Singaporean policymakers should focus on decreasing carbon dioxide emissions to increase green energy consumption.

Based on the regression above, the articles have the function in equation (2) as follows:

$$LnY = 0.8155 - 0.01LnX1 – 0.035LnX2 - 0.016LnX3 + 0.026LnX4 \quad (2)$$

Equation (1) shows that if X1=0, X2=0, X3=0, X4=0, the renewable energy consumption is 0.8155. This equation also shows the slope of Y to X1= -0.01, the slope of Y to X2= -0.035, the slope of Y to X3= -0.016, the slope of Y to X4= 0.026;

These results help to compute the elasticity. Therefore, the results show that if the carbon dioxide emissions are down 1%, then the renewable energy consumption is up 0.01%; if the fossil fuel is down 1%, then the renewable energy consumption is up 0.035%; if the FDI inflows are down 1%, then the green energy consumption is up 0.016%; if the exports are up 1%, then the green energy consumption is up 0.026%;

Furthermore, CO2 emissions and GDP- a positive relationship was found in the short run, supporting the EKC hypothesis.

CO2 emissions and innovation- a significant negative relationship was found, indicating that innovation rankings growth exacerbates CO2 emissions.

CO2 emissions and renewable energy- a negative relationship was found, suggesting that increased adoption of renewable energy mitigates emissions.

Table 3 illustrates the correlation coefficients for the independent variables within the model. The observed correlation coefficients between these variables are minimal, and the variance inflation factor (VIF) remains below 5 for all variables. This low VIF signifies an absence of multicollinearity within the model.

Table 3. The correlation of the independence variables in the model

	Carbon dioxide emissions	Fossil fuel consumption	FDI inflows	Exports of goods and service
Carbon dioxide emissions	1			
Fossil fuel consumption	0.29	1		
FDI inflows	0.12	0.11	1	
Exports of goods and service	0.09	0.10	0.19	1

(Sources: compiled by author)

In summary, the paper presents findings related to:

- Trends in carbon dioxide emissions and their drivers.
- The role of fossil fuel consumption in Singapore's carbon footprint.
- The effects of foreign direct investment inflows- FDI on the energy sector and emissions.
- Progress and challenges in adopting renewable energy sources.

4. Discussion:

The discussion section will interpret the findings in the context of Singapore's unique socio-economic and geopolitical landscape. Policy implications, challenges, and potential strategies for a sustainable energy transition will be explored. The discussion section will provide an in-depth interpretation of the findings within Singapore's unique socio-economic and geopolitical context. This section aims to elucidate the implications of the observed trends and relationships, exploring the following aspects:

Policy Implications- analyzing how the identified patterns align with or challenge existing policies and proposing potential policy adjustments to enhance sustainability.

Challenges and Opportunities- Discuss the challenges faced by Singapore in reducing carbon emissions and transitioning to renewable energy, along with opportunities for innovation and improvement.

Global Relevance- considering the broader implications of Singapore's experience for other nations facing similar challenges and contributing to the world discourse on sustainable development.

Singapore has historically had a significant carbon footprint as an industrialized and highly urbanized nation. The city-state heavily relies on imported fossil fuels, primarily natural gas, to meet its energy needs. The combustion of fossil fuels sources for energy production, industrial processes, and transportation contributes to carbon dioxide emissions.

With a robust and business-friendly environment, Singapore has been a magnet for FDI-foreign direct investments. FDI is crucial in shaping the economic landscape, including the energy sector. The types of investments, especially in industries with high energy consumption, can influence carbon emissions.

Export to Renewable Energy- Singapore has been making strides in diversifying its energy mix and promoting renewable energy in recent years. This problem includes investments in solar energy projects, research into sustainable technologies, and efforts to increase energy efficiency. However, the extent to which these initiatives offset emissions from fossil fuel use depends on their scale and effectiveness.

The Singaporean government has implemented various initiatives to address climate change and reduce carbon emissions. The Sustainable Singapore Blueprint outlines the country's goals for environmental sustainability, including targets for reducing emissions intensity and increasing the percentage of renewable energy.

Singapore has been investing in research and development of clean energy technologies. This issue includes exploring innovations in energy storage, smart grids, and sustainable urban planning. Technological advancements play a crucial role in transitioning away from fossil fuels.

Singapore actively participates in international efforts to combat climate change. Being a signatory to agreements like the Paris Agreement, Singapore collaborates with other nations and organizations on climate-related initiatives, potentially influencing its approach to emissions reduction and renewable energy adoption.

Despite progress, Singapore needs help in fully transitioning to renewable energy. Factors such as limited land availability for large-scale renewable projects and the intermittency of specific renewable sources pose challenges. Balancing economic growth and environmental sustainability remains a complex task.

5. Conclusion:

The paper will conclude by summarizing key findings and proposing avenues for future research. Insights gained from this paper can inform policy decisions and strategies for other nations navigating the complex interplay between economic growth, carbon emissions, and the transition to renewable energy.

This paper summarizes the key empirical findings, emphasizing their significance in the broader context of sustainable development and the global transition to renewable energy. This section will also highlight avenues for future research, acknowledging the dynamic nature of the energy landscape and the need for ongoing inquiry into practical strategies for balancing economic growth and environmental responsibility.

Carbon dioxide emissions, fossil fuels, Foreign direct investments, and Renewable energy in Singapore are significant for Sustainability development, Climate change, and Econometric modeling.

This concluding section will reiterate the significance of the study's contributions to sustainable development. It will emphasize the actionable insights, potential policy interventions, and the broader impact of Singapore's experience on the global stage.

Reflection on Research Methodology- this section will critically reflect on the chosen research methodology, discussing its strengths and limitations. Addressing potential biases, data constraints, and alternative methodologies will enhance the transparency and robustness of the study.

Stakeholder Perspectives- this examines the perspectives of various stakeholders, such as government bodies, industries, environmental organizations, and the general public. This section will offer insights into the diverse interests and considerations shaping the energy landscape in Singapore. Understanding these perspectives is crucial for crafting inclusive and effective policies.

Technological Innovations and Emerging Trends- exploring recent technological advancements and emerging trends in renewable energy, this section will highlight opportunities for Singapore to leverage cutting-edge technologies. Discussing innovations like smart grids, energy storage, and advancements in solar and wind technologies can provide a forward-looking perspective.

Economic Impacts- assessing the economic impacts of transitioning to renewable energy, this section will delve into potential job creation, economic diversification, and the s overall economic health of the nation. Evaluating the costs and benefits will be essential for informed decision-making.

Social Equity and Environmental Justice- examining the distributional effects of environmental policies, this section will explore how the transition to renewable energy can address or exacerbate social inequalities. Considering environmental justice issues ensures that sustainability initiatives' benefits and burdens are equitably shared.

Case Studies- incorporating relevant case studies of cities or nations that have successfully transitioned to renewable energy will provide practical insights. Comparing the strategies and outcomes of these cases with Singapore's situation can offer valuable lessons.

Public-Private Partnerships- highlighting the role of collaborations between the public and private sectors, this section will discuss how fostering partnerships can accelerate the transition to renewable energy. Examining successful models and potential challenges will inform recommendations for effective collaboration.

The final section will present a compelling call to action, emphasizing the collective responsibility of governments, businesses, and individuals in achieving a sustainable energy future. It will encourage proactive measures and international cooperation to address the global climate crisis.

Public Perception and Behavioral Change- examining the role of public perception in driving behavioral change, this section will explore strategies to cultivate a more environmentally conscious mindset. Analyzing successful campaigns or initiatives influencing public behavior can provide insights for designing effective awareness programs.

Risk Assessment and Contingency Planning- considering potential risks associated with the transition to renewable energy, this section will discuss methods for risk assessment and the development of contingency plans. Addressing issues such as energy security, supply chain disruptions, and geopolitical considerations will enhance the resilience of the energy transition process.

Cultural and Ethical Considerations- this study acknowledges the cultural and ethical dimensions of the energy transition. This section will explore how cultural values and ethical frameworks influence adopting renewable energy practices. Understanding and respecting cultural nuances is essential for designing policies that align with societal values.

Monitoring and Evaluation Framework- the paper proposes a robust monitoring and evaluation framework. This section will outline key performance indicators and metrics for assessing the effectiveness of renewable energy policies over time. Establishing a systematic approach to evaluation ensures adaptive management and continuous improvement.

Education and Capacity Building- highlighting the importance of education and capacity building, this section will discuss strategies for enhancing the knowledge and skills necessary for a sustainable energy future. Collaboration between educational institutions, industry, and government bodies can be pivotal in building a skilled workforce.

Green Financing and Investment Strategies- examining the role of green financing in supporting renewable energy projects, this section will discuss strategies to attract investments from domestic and international sources. Exploring financial instruments and incentives can contribute to the economic viability of sustainable initiatives.

The Role of Multilateral Organizations- analyzing the potential contributions of multilateral organizations in supporting Singapore's transition to renewable energy, this section will explore partnerships with entities such as the United Nations, World Bank, and regional organizations. Leveraging global expertise and resources can amplify the impact of local efforts.

Media Influence and Communication Strategies- addressing the influence of media in shaping public opinion, this section will discuss effective communication strategies for promoting renewable energy. Collaborating with media outlets and influencers can amplify the reach of sustainability messages.

International Cooperation and Diplomacy- this section will explore how Singapore can engage in international collaborations and diplomatic efforts to address global climate challenges. Analyzing existing partnerships and suggesting avenues for strengthened cooperation will be essential for a comprehensive approach.

Technological Transfer and Knowledge Exchange- examining the importance of technological transfer, especially from countries with advanced renewable energy infrastructure, this section will discuss strategies for acquiring and implementing cutting-edge technologies. Facilitating knowledge exchange through international partnerships can accelerate Singapore's transition.

Climate Diplomacy and Policy Advocacy- addressing the role of climate diplomacy, this section will discuss how Singapore can actively engage in advocating for progressive climate policies on the global stage. Contributing to international forums and dialogues can shape global policies favoring sustainable practices.

Challenges in the Transition Process- identifying and discussing challenges encountered during the transition to renewable energy is crucial for a realistic assessment. This section will delve into potential obstacles such as policy resistance, technological constraints, and socio-economic barriers, offering insights for mitigation strategies.

Opportunities for Green Innovation- highlighting opportunities for green innovation and entrepreneurship, this section will discuss how Singapore can foster a vibrant ecosystem for green startups and technological innovation. Exploring successful models from other regions can inspire local initiatives.

Public-Private Collaboration in Research and Development- discussing the significance of collaboration between the public and private sectors in research and development (R&D), this section will outline how joint initiatives can spur innovation. Encouraging R&D partnerships can lead to the development of breakthrough technologies.

Long-term Vision and Adaptive Strategies- proposing a long-term vision for Singapore's sustainable energy future. This section will discuss the importance of adaptability in the face of evolving challenges. Crafting strategies that allow for adjustments based on emerging technologies and changing global dynamics will enhance the nation's resilience.

Ethical Consumption and Corporate Social Responsibility- addressing the role of ethical consumption and corporate social responsibility (CSR), this section will explore how businesses can contribute to sustainability. Discussing successful CSR initiatives and ethical business practices can inspire a more responsible corporate sector.

6. Policy Implications:

This section will offer practical recommendations derived from the study's findings. It will address how Singapore can align its policies to achieve a more sustainable and environmentally conscious energy framework. Specific focus areas may include:

Incentivizing Renewable Investments- this paper proposes policies to attract more investments in renewable energy projects through financial incentives and regulatory support.

Energy Efficiency Measures- suggesting strategies to enhance energy efficiency across sectors, thereby reducing energy consumption and carbon emissions.

International Collaboration highlights the importance of international cooperation in fostering sustainable practices, including technology transfer and knowledge sharing.

Comparative analysis- to enrich the discussion, this section may involve a comparative analysis with other nations that have successfully navigated the transition to renewable energy. Drawing parallels and contrasts will provide a broader perspective on adequate strategies and potential pitfalls. It recognizes the role of public perception and engagement. This section will discuss the importance of raising awareness and increasing a sense of responsibility among the public. It may explore the potential for community-based initiatives and educational programs to drive sustainable practices.

The interplay between carbon dioxide emissions, fossil fuel reliance, foreign direct investments (FDI), and Singapore's transition to renewable energy necessitates a nuanced approach to policy formulation. As this study unfolds new evidence, the following policy implications emerge, offering actionable insights for sustainable development strategies.

6.1 Carbon Emissions Reduction Policies:

Singapore's commitment to reducing carbon emissions should be underpinned by comprehensive policies that target key sectors contributing to emissions. Policies should incentivize and facilitate the adoption of cleaner technologies and energy-efficient practices in industries, transportation, and urban planning. Strengthening regulatory frameworks and emissions standards can play a pivotal role in achieving tangible reductions.

6.2 Energy Transition Planning:

Transitioning from fossil fuel demand dependency to renewable energy consumption requires a well-defined and adaptive energy transition plan. Policymakers should consider a phased approach that aligns with technological advancements, infrastructure development, and the evolving needs of industries. Incentivizing renewable energy adoption through subsidies, tax breaks, and research and development grants can accelerate this transition.

6.3 Enhancing Foreign Investments in Sustainable Practices:

The study leverages FDI for sustainable development; policies should encourage investments in renewable energy projects and technologies. Financial incentives, streamlined regulatory processes, and partnerships with research institutions can attract foreign investors committed to environmentally responsible practices. Policy frameworks should emphasize transparency and accountability in the environmental impact assessment of FDI projects.

6.4 Strengthening Renewable Energy Export Initiatives:

Singapore's efforts to export renewable energy technologies present a unique opportunity for economic growth and global environmental impact. Policies should focus on fostering innovation and research in renewable energy technologies, supporting local companies to

export sustainable solutions. Bilateral and multilateral collaborations can further enhance Singapore's global renewable energy market leader position.

6.5 Inclusive Policies for a Just Transition:

The study recognizes the potential social and economic disruptions accompanying the transition; policies should prioritize inclusivity. This issue involves upskilling the workforce for jobs in the renewable energy sector, supporting industries transforming, and ensuring a just transition for communities affected by the shift away from traditional fossil fuel-related activities. Social equity considerations should be embedded in policy frameworks to avoid disproportionate impacts.

6.6 International Collaboration for Climate Resilience:

Given the global nature of climate change, Singapore should actively engage in international collaborations to address shared challenges. Policymakers should advocate for cooperative frameworks, information sharing, and joint research initiatives. Participation in international agreements and commitments aligned with the Paris Agreement principles can enhance Singapore's contribution to global climate resilience efforts.

6.7 Periodic Policy Review and Adaptation:

The dynamic nature of the energy landscape and technological advancements necessitate periodic reviews of existing policies. Policymakers should adopt an iterative approach, regularly assessing the effectiveness of policies, incorporating new evidence, and adapting strategies to align with emerging trends. This adaptive governance approach ensures that policies remain relevant and responsive to evolving challenges.

6.8 Public Awareness and Engagement:

Effective policy implementation requires public understanding and support. Policymakers should invest in communication strategies to raise awareness about the importance of sustainable practices, the benefits of renewable energy adoption, and the rationale behind policy decisions. Engaging with the public and stakeholders in decision-making increases a sense of ownership and collective responsibility.

In conclusion, the above policy implications aim to guide Singapore's journey towards a sustainable and resilient future. By integrating these considerations into policy frameworks, Singapore can foster an environment conducive to economic expansion, environmental stewardship, and global leadership in sustainable practices.

7. Limitations and Future Research:

The authors acknowledge the study's limitations; this section discusses any constraints in the data, methodology, or scope of analysis. It also suggests future research directions, identifying areas that warrant further exploration and refinement. The paper will discuss how the findings align with and contribute to broader sustainable development goals, considering the economic, social, and environmental dimensions. This problem may involve addressing poverty reduction, clean energy access, and environmental preservation.

One of the challenges in studying this nexus is the availability and accuracy of data. Data on carbon dioxide emissions, foreign direct investments, and renewable energy production may only sometimes be comprehensive or up-to-date. Addressing data gaps and improving accuracy is crucial for a more nuanced analysis.

Studies often focus on specific aspects of the nexus, such as emissions from energy production or foreign investments in renewable projects. A more comprehensive understanding would involve a complete lifecycle analysis, including the extraction,

transportation, and processing of fossil fuels and the manufacturing and disposal of renewable energy technologies.

The impact of these interrelated factors on the socio-economic fabric of Singapore needs to be explored. Future studies could explore the social implications, including the distribution of benefits and burdens among different population segments. Policies have a crucial role in shaping the trajectory of carbon emissions and renewable energy adoption. Understanding the dynamics between policy formulation, implementation, and their impact is essential. This issue includes assessing current policies' effectiveness and identifying improvement areas.

The rapid pace of technological advancements may outpace existing studies. Future research should consider the impact of emerging technologies on the nexus, including breakthroughs in renewable energy, carbon capture, and storage.

Conduct longitudinal to track changes over time. This issue could involve analyzing trends in carbon emissions, foreign investments, and the development of renewable energy infrastructure to identify patterns and assess the effectiveness of interventions.

Integrated Models- develop integrated models considering the dynamic interactions between carbon emissions, fossil fuel use, foreign investments, and the transition to renewable energy. Comprehensive models can provide a more holistic understanding of the nexus.

Scenario Analysis- conducts scenario analyses to explore potential future developments under different policy and investment scenarios. This issue can help policymakers anticipate the consequences of various decisions and plan for resilient and sustainable outcomes.

Stakeholder Engagement- includes a more robust analysis of stakeholder perspectives, including the views of local communities, industries, and investors. Understanding diverse perspectives can inform policies that are more inclusive and sustainable.

Policy Evaluation- evaluates the effectiveness of existing policies in achieving carbon reduction and renewable energy targets. Identify barriers to implementation and propose policy adjustments for enhanced impact.

International Comparisons- compare Singapore's approach with other countries facing similar challenges. This comparative analysis can provide insights into best practices and potential strategies for improvement.

Incorporate Climate Resilience- consider the resilience of Singapore's energy infrastructure in the face of climate change. Assess the vulnerability of existing systems and propose measures to enhance adaptability.

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