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# Does Innovation and Foreign Direct Investment Affect Renewable Energy Consumption? Evidence from Developing Countries

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**ABSTRACT**

The purpose of the study to analyse the long-run and short-run effects of foreign direct investment, technological innovation, economic growth, and greenhouse gas emission has shown the impact in developing countries from 1991 to 2021on renewable energy. Applying dynamic panel ARDL technique, the outcomes confirm that, economic growth, foreign direct financing and technological innovations take a negative impact on sources of energy. However, greenhouse gas emission has a significant positive influence on renewable energy. The impression of economic growth, FDI, and technological innovation, is positive, fostering to energy use and greenhouse emissions in the developing countries. The practical remedies are exclusive and give policy suggestions; such as, financial markets in the developing countries must be encouraged for the reason that they are the core determinants of the renewable energy sector and economic growth, reducing greenhouse emissions. Moreover, investment in the R&D of technological innovations is much needed in these countries.

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## 1. Introduction

From the last few years, the major economic challenge is environmental sustainability and energy security which almost every country is facing. The increase in fossil fuel consumption caused to increase in carbon dioxide emission confirmed by The International Energy Agency(Assi, Isiksal, & Tursoy, 2021). Energy is considered an important element for long term growth of any country. In recent times, its demand increasing due to improved life style and change in needs of people result in increase in demand for energy consumption. Many elements which effect the energy demand are includes improved life style increases in population, economic competitiveness and manufacturing advancements. Therefore, overall Global Energy consumption increased by 46 percent in between 1970 to 2016 (Peters, Pyda, Menon, Suzuki, & Meara, 2019). Extreme Burning of in environment pollution discharge massive amounts of CO2 emission into the air, which in turn causing adverse environmental influences such as change in climate(Qayyum et al., 2021). In current years, carbon emissions, environmental pollution has turn into a globally and all over the world problem phenomena. Currently governments have been more conscious related to overall control of CO2 of greenhouse gases produced by industrialized concerns(Qayyum et al., 2021). Furthermore the European Union Commission making investment in several examination plans aimed at decreasing overall fossil fuel consumption, bringing advancements in energy efficiency, and developing new technological advances, Especially for Renewable Energy (Qayyum et al., 2021). Due to dependency on environmental pollution at a very big ratio all economies have the issue of renew energy apart from Environmental problems. Energy planning in the long term is important for sustainable projects to ensure supply of energy for economic success and development. In short word,

energy stability requires the supply of the preferred source of energy as well as stable costs to make easier and more affordable (Nalule, 2019).

In attaining energy diversity, a Renewable energy can be considered as a useful tool. Less dependence on Fossils fuel energy supplies shows greater dependency upon Energy market (Qayyum et al., 2021). Furthermore, RNWE creation has the potential to avoid additional environmental harm. But it is somehow difficult to Transferring from fossil-fuel-based energy to green energy(Qayyum et al., 2021). In world mostly Energy is generated through environment pollution so, there is a robust dependency on Non-renewable energy sources. The dependency on these energies have led towards environmental issues, which is including climate change, global warming and air pollution (Kasman & Duman, 2015; Koçak & Şarkgüneşi, 2017; Nejat, Jomehzadeh, Taheri, Gohari, & Majid, 2015; Salim et al., 2018; World Bank, 2017). The utilization of GDP consumption shows a very important part in CO2 emission. In most of the developing countries economic growth rates increased through industrialization, which in result also caused to increase in CO2 emission. Renewable energy which includes nuclear, hydropower, geothermal and solar can be used as an alternate source to environment pollution energy as it is have not any effect on climate change and energy related issues. Many countries are moving towards RNWE to evade variations in prices of oil, to decrease their dependency on GDP, also reduce EP (Bölük & Mert, 2015; Toklu, 2013). With the consumption of GDP greenhouse emission increased led the issue towards global warming. Thus, RNWE play a key role in reducing universal heating, increasing source of energy perform a key part in the hole world's energy using. By increasing new source of energy decreases the CO2 (emissions) and also save the atmosphere. In conclusion, burdens for energy consumption stay accumulative, and sources of non-renewable energy, fossil fuels like not lone contributing towards climate change and global warming, but are at danger of being diminish in the upcoming (Ocal & Aslan, 2013), so practice of using new way of making energy sources should be more fortified by administrations round the sphere.

This research analyzes the part of technical innovation, greenhouse gases, EN (environmental pollution) and fossils fuel energy ingesting in major three countries e.g., China, India and Israel from the period 1960-2016. Earlier researcher has only focused on financial development, environmental pollution, CO2 and technological innovation while ignoring the variables of greenhouse gases and GDP consumption in relation with RNWC (renewable energy consumptions) in most of the previous researches. First, the relationship between variables and RNWC is investigated through intensive studies from previous articles, which ultimately help the policy makers of three selected countries to develop better and beneficial policies related to energy security. Secondly, this study studying this relationship in case of major three countries, India, Israel and China. These are one of the emerging and growth leading economies in the world.it is also one of the fastest growing middle-income countries. It has the 33$^{rd}$ world largest GDP in nominal terms. Thirdly, lastly the study results help the policy makers and providing insights about greenhouse gases, RNWC results of this paper are essential for giving appropriate policy insights about technological innovation, greenhouse gases, GDP consumption, and improvement in energy sector to secure the atmosphere from pollution.

## 2. Literature Review

Environmental pollution (EP) has been developed as a serious question for long-term development. Definitely, this growing trend brings many challenges for stakeholders in any country (Assi et al., 2021). The Kyoto protocol (1997) and The Paris Agreement (2015)are treaties signed to save the environmental quality (Assi et al., 2021). In recognition of these agreements countries objects to depend on more on renewable energy consumption to help for effective future, according to The International Renewable Energy Agency (IRENA) Increased reliance on Renewable energy consumption would lessen general prices and make more neat and clean cities, and a safer energy resource. The underpinning theory used in support of theoretical model is (E.K curve theory), is a traditional and ecological economic concept broadly used in economics to study CO2 and renewable energy consumption (Amri, 2018; Dogan & Seker, 2016). According to this theory while a country has a little stage of economic progression then grade of EP is also lower. On the other hand, when an economy has high level of income per capita then EP also increases gradually from low to extraordinary. It means that environmental pollution increases with progression of an economy. When stage of economic expansion and income per capita reaches its level the additional increase in per capita income sluggish depressed the curve of EP. Thus, playing an important part in restriction environmental issues.

### 2.1. Foreign Direct Investment and Renewable Energy Consumption

According to AlMulali et al., the expansion of dirty industries in the economies that host FDI raises CO2 emissions caused by FDI. 2015; (Qin & Ozturk, 2021). Also, it is thought that countries with a lot of environment pollution can expect to be ahead of the game when it comes to producing goods that cause a lot of pollution. Under such conditions, these countries can be a center for drawing in messy FDIs, by which these economies are almost certain to change into contamination shelters (Banerjee and Murshed 2020). In light of both the PHH and the PHEH, a number of studies have attempted to empirically shed light on the connection between FDI information and CO2 emissions. Pavlović et al. (2021) are one of the studies that found statistical support for the PPHH's validity conducted research on the Balkans from 1998 to 2019 and discovered a positive correlation between FDI information and CO2 emissions, confirming the PHH. M. A. Khan and Ozturk (2020) explored on 17 Asian nations for the period 1980 to 2014 and found that FDI inflows added to ecological contamination by helping the degree of CO2 discharges.

From most recent couple of many years, numerous specialists have been directed investigations and announced the very issue that higher the Fossil fuel energy utilization prompts higher fossil fuel byproduct all over the planet. As a result, a number of governments and policymakers emphasize the significance of using renewable energy and lowering carbon emissions. Subsequently, many investigations have been led to investigate the elements of CO2 and RNWE. According to a study by Jaforullah and King (2015) in the United States, the consumption of renewable energy has a negative impact on CO2. In addition, a 2017 study by Paramati, Sinha, and Dogan (2017) confirms that renewable energy cuts carbon emissions in 11 developing nations. The optimistic long-term co-integrated association among CO2 and renewable energy was found in several studies. Another American study demonstrates that CO and RNWE have a negative relationship. According to Samour, Isiksal, and Resatoglu (2019), there is no direct link between CO2 and renewable energy. Based on (Jensen, 1996), S. M. Khan and Saif-ur-Rehman ; Ilyas, Banaras, Javaid, and Rahman (2023); Usman, Rahman, Shafique, Sadiq, and Idrees (2023), Ullah, ur Rahman, and Rehman (2023). The availability of a well-developed financial sector encourages FDI inflows, which in turn encourage economic growth. As a result, pollution, CO2, and degradation of the environment are all exacerbated. Therefore, we speculate that:

## 2.2. Technological Innovation and Renewable Energy Consumption

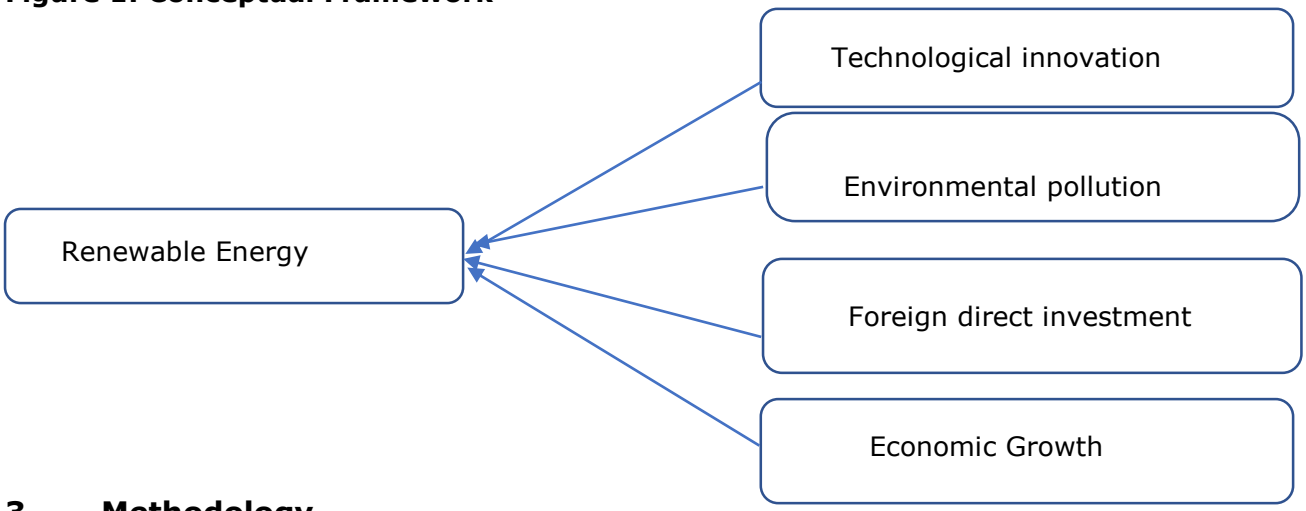
Energy market effected from two strategic approaches used in innovation are as follows radical innovation and incremental innovation. Radical invention states something which is original and unique such as LED lights, district heating system, E-vehicles, bio-methane used in gas grids. This technological invention lunch up entirely a fresh and innovative market such as RNWE market from natural sources which entirely rest on the generation of energy purely. Second innovation define as "Incremental innovation is an innovation that's improved the existing system by making them cheaper, quicker and improved". Examples of incremental innovation/techniques includes insulation, walls, fuel-efficient cars, lofts, double glazing, and energy-efficient appliances used by households includes washing machines, boilers, fridges (Altan & Hacıoğlu, 2020) (Hacioğlu, 2017). According to the study result of (Kocsis & Kiss, 2014) shows that there is an optimistic connection is available between R&D and RNWE consumption. While other researches show that increased in innovation reduced the demand for fossils fuel energy consumption as compared to demand of other energies. There is a reduction in fossils fuel energy due to innovation in renewable energy (Kurczewski & Lewandowska, 2010). On the other side, some studies shows decrease of investment in energy R&D causes a reduction in RNWE thus reduces RNWE consumption in the favor of fissile fuel (Nemet & Kammen, 2007). Thus, on the base of above discussion we can say that the more incremental innovation in technologies will result in more increase in fossils fuel energy consumption so in this regards we can develop the hypothesis as: H2: innovation supports to the escalation of the renewable energy usage.

## 2.3. Environmental Quality and Renewable Energy Consumption

Greenhouse gas (EQ) refers to a gas that engross and produce healthy energy. The main greenhouse smokes on the ground thermosphere are gas, wind, CO2 etc. human activities on the earth are increasing the emission like EQ emission according to united nation organization. According to the study of Holmberg and Hellsten (2015) who analyze the energy consumption behavior and energy related discussion on twitter and social media influences of people over

time. they explore social media can be used as a tool to test society knowledge related to Facebook, twitter etc. According to M. Zhang, Zhang, Lee, and Zhou (2021) Energy consumption is a mix of different energies e.g., solar, wind, renewable, oil etc. RNWE consumption and energy sources have a significant impact on environment pollution and can be considered as an important element of low CO2 emission (D.-G. Zhang et al., 2020). Different method and techniques are used to EQ emission. RNWE consumption helps to reduced EQ emission as result also proved the same results so on the base of above discussion we can draw a hypothesis as:

**Figure 1: Conceptual Framework**




## 3. Methodology

### 3.1. Data and Statistical Analysis

The majority of prior studies used a variety of future sources of data that overall influence of that different variable independent moderate dependent. The individual use of the proxies was discovered to cause a Multicollinearity problem. The current study examines the relationship of four variables which is affected on environmental pollution, and help these are the variable how reduce the environmental pollution. The statistical data are collected from the web site of world development indicators. First variable is renewable energy (RE) by using different way to utilized the resources. Second variable is technological innovation (TI) the data picked from the WDI indicators which is help out how select variety of the resource for convert it in to renewable energy. Third related variable is Greenhouse gasses (EQ) which show the impact on renewable energy, statistical data is collected from the World bank indicators which show the effect on environmental pollution to clean the air. The fourth concerning variable is economic growth (GDP). All concerned variables data are collected from the world bank indicators taken proxies analysis in following tables.

As follows is the work done by (Table 1), Analysis shows the renewable energy resources that is efficiently reduce the environment pollution. These are resources effect industrial sectors. Consequently, the uses of fuel energy are falling down. Furthermore, renewable energy is alien with the research development in order to gain Technological innovations to increases the way of produce renewable different energy by using volatile T.I, so clean the environment to decrease the demand of fuel E. As a result, Technological advancements are beneficial. The following is the framework for this study's investigation of the relationship: The analysis reveals that renewable energy resources effectively minimize pollution in the environment.

$$LREC = F\,[LTI, LEQ, LGDP, FDI]$$

In the above equation, LREC is represent a main dependent variable which show the how increase the part of renewable energy by effected the other independent variable like LEQ that signify the proxy of greenhouse gasses. LTI that means the proxy of technological innovation. LFDI that characterizes the source of foreign direct investment, and LGDP that signifies the real economic growth to eliminate any possibility of non-homoscedasticity, all of data are turned into ordinary log. The Theoretical regression line is derived as given below

$$LREC = BO + B1LEQ + B2\,LTI + B3LGDP + B4LFDI + U$$

Where LIRE, LITI, LIEQ, LIGDP, LFDI represent the ordinary logarithms of the renewable energy catalogue, normal logarithms of the technological innovation, normal logarithms of greenhouse gasses catalogue, normal logarithms of the economic growth catalogue, normal

logarithms of the foreign direct investment catalogue and ordinary logarithms of Renewable energy.

$$LRECit = \mu \sum_{j-1}^{p1} \lambda ij\, LEQit - j + \sum_{j-1}^{p2} \partial ij\, LTI + \sum_{j-1}^{p2} \partial ij\ \text{LGDP+} \sum_{j-1}^{p2} \partial ij\, LFDI$$

## 4. Descriptive Analysis

In Table 1, the analysis results of a descriptive test of a few particular factors are presented. This graph displays the statistics' mean, median, and maximum values. Along with the results of the Jarque-Bera statistical test, this chart also shows the likelihood scores for each result. This examination is used to ascertain whether certain conditions are typical. All of the variables are ordinarily distributed, Jarque-Bera test conferring the findings, while the remaining variables item are not.

**Table 1: Descriptive Testing**

| | RE | TI | EQ | GDP | FDI |
|---|---|---|---|---|---|
| Mean | 10.27 | -9.14 | 1.08 | 10.81 | 9.80 |
| Median | 9.073 | -0.04 | 1.47 | 10.54 | 10.12 |
| Maximum | 20.46 | 1.88 | 7.33 | 19.737 | 11.13 |
| Minimum | 3.175 | -2.52 | -6.46 | 4.224 | 5.224 |

**Table 2: Analysis of Panel Unit Root Test: The Unit Root of Individual Variables (Level)**

| AT LEVEL | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | Individual Intercept | | | | | Individual Intercept and Trend | | | | | |
| Variables | Common Unit Root | Individual Unit Root | | | HADRI | C Unit Root | | IUnit Root | | | HADRI |
| | LLC | IPS | ADF | PP | | LLC | BREITUNG | IPS | ADF | PP | |
| RE | 0.97 | 1.01 | 1.00 | 1.01 | 0.00 | 0.37 | 0.85 | 0.76 | 0.72 | 0.42 | 0.00 |
| TI | 0.25 | 0.75 | 0.71 | 0.40 | 0.00 | 0.27 | 0.52 | 0.03 | 0.03 | 0.03 | 0.00 |
| GDP | 0.01 | 0.15 | 0.07 | 0.53 | 0.00 | 0.21 | 0.48 | 0.77 | 0.77 | 0.96 | 0.01 |
| EQ | 0.13 | 0.64 | 0.61 | 0.42 | 0.001 | 0.20 | 0.42 | 0.04 | 0.03 | 0.04 | 0.00 |
| FDI | 0.14 | 0.54 | 0.41 | 0.32 | 0.001 | 0.30 | 0.22 | 0.03 | 0.04 | 0.03 | 0.00 |

In the table 2 shown the results of panal unit root tests which is described the different test run by different analytically, like first test which is run by (Hadri, 2000), 2nd test Pesaran and 3rd by shin W- statistics, likewise Lin, Levin and Chu, PP, ADF, and IPS. In Tabel 3 define the list of various variables used in models, while the first row show the test of unit root test like individual and intercept unit root of panel ARDL, each finding shown the empirical unit root tests. All variables shown the stationary result , some variable are stationary at (stage) level and some variable stationary at 1st difference. Therefor the study show the feasible empirical results. According to large number of earlier studies, it can be realistic the model variable are stationary at 1st difference after the studying of panel cointegration (Pesaran, Shin, & Smith, 2001).

### 4.1. Long Run Panel ARDL Estimation

In Table 3 panel ARDL model are displayed the forecasting of long-run also short-run results. The main target of the study remains to demonstrate the association among the consumption of renewable energy, FDI, EQ, technical advancement, and GDP

**Table 3: Panel ARDL Test Long Run and Short Run Estimation**

| Variable | Coefficient | Std. Error | t-Statistic | Prob.* |
|---|---|---|---|---|
| **Long Run** | | | | |
| RE | 0.198792 | 0.066559 | 2.986699 | 0.0034 |
| TI | -0.221036 | 0.033562 | -6.585856 | 0.0000 |
| GDP | -0.148148 | 0.067302 | -2.201233 | 0.0296 |
| EQ | 0.467412 | 0.095092 | 4.915383 | 0.0000 |
| FDI | -0.138713 | 0.058203 | -1.301453 | 0.0357 |
| **Short Run** | | | | |
| ECT | -0.367532 | 0.068719 | -5.348338 | 0.0000 |
| d(RE) | -0.069999 | 0.050700 | -1.380656 | 0.1699 |
| d(TI) | -0.008159 | 0.018758 | -0.434971 | 0.6644 |
| d(GDP) | 0.115031 | 0.141425 | 0.813369 | 0.4176 |
| d(EQ) | -0.321732 | 0.321128 | -1.001878 | 0.3184 |
| d(FDI) | -0.230641 | 0.230137 | -1.023795 | 0.2174 |

The Panel ARDL findings are presented in Table 3. At level of 5% of their relevance, the findings indicate a positive and important relationship among technical development then green

energy. In other arguments, for every part increase in technical innovation, renewable energy grows by 0.199 units. A contentious topic in scientific economic research is the show relationship long-term between TI and renewable energy. 5%, level of significance, we also found a significant and contrarian relationship between GDP and green energy. As a result, for every unit that GDP decreases, green energy increases by 0.221 units. However, we also found a persistent, significant inverse relationship between environmental health and renewable energy at a 5% threshold of significance. It implies that a rise in EQ causes a decline in renewable energy of 0.148 units. The results also a long-term indicates, unfavorable association among EQ then green energy, which is significant at a 5% level. This means that environmental pollution decreases by 0.467 units for every unit increase in EQ. Additionally, suggest a long-term, negative association among FDI then green energy show significance level a 5%. Conferring that, environmental contamination drops by 0.138 units for every unit increase in FDI. These concur with earlier studies conducted by (N. S. Hafiza et al., 2022; Li et al., 2022; A. U. Shahid et al., 2022; C. Shahid, Gurmani, Rehman, & Saif, 2023; Zulfiqar et al., 2022).

### 4.2. Short Run Panel ARDL Estimation

The ECT value is -0.367 shown in Table 3, described every movement is show equilibrium is quickly corrected at 36.7% rate of speed. That conclusion implies that the long-term effects on environmental pollution may have a greater influence of the factors we designated. In Little bit behavior of ECT coefficient has a significant impact on the calculation. The accuracy in sign and significance of the error correction coefficients, or ECT, show that the variables have developed co-integrating relationships. Furthermore, demonstrates the relationship of variables how quickly the long-run equilibrium of coefficient in short term shock recorded, for example, disequilibria shock-induced in the value of ECT is 0.367 as a result, this year about 0.367 will have stabilized.

The short-period increase in TI revenue causes a 0.699-unit short-term decrease in renewable energy, according to the TI coefficient, which is -0.699. The outcome is in line with the TI-led growth theory, which postulates that increasing inbound. These are aligned with previous studies (Chaudhary, Nasir, ur Rahman, & Sheikh, 2023) (Dawood, ur Rehman, Majeed, & Idress, 2023; N. Hafiza, S., Rahman, S, U., Sadiq, A., Manzoor, M., Shoukat, Z., & Ali, M. , 2023; Rahman & Idrees, 2019; A. U. Shahid et al., 2022; ur Rahman, Chaudhry, Meo, Maqsood, & Sadia, 2022; Zahra, Nasir, Rahman, & Idress, 2023) TI activity could result in a decrease in renewable energy. According to the GDP coefficient, an increase in GDP of 1 unit will lead to a decrease in environmental waste of 0.008 units. The EQ coefficient states that each part increase in EQ causes a 0.322-unit decrease in renewable energy. The FDI coefficient states that for every unit increase in FDI, green energy is reduced by 0.230 units. The results of the short-run analysis are shown in Table 3 below, along with the magnitude of the error correction factors. The results are aligned with previous studies (Ali, ur Rahman, & Anser, 2020; Rahman & Idrees, 2019). The forecasting show the short term results earlier consist on sing-matching to the long term results. Significant affects RE in the short-term findings. The value of the ECM is −0.34, which suggests that any deviation from the equilibrium is adjusted with 34% speed.

## 5. Conclusion and Policy Implications

The study core aim is to examine the effect of FDI, GDP, technological innovations, and greenhouse omission on renewable energy in developing countries among 1991 and 2021. The study employing numerous econometric criteria, counting panel slope first- and second generation cross sectional dependence, homogeneity unit root tests. The Panel ARDL affirm that FDI, technological innovations and GDP have a negative and significant relationship with renewable energy, while greenhouse omission has a positive association with renewable energy consumption in developing countries. The outcomes accomplished since the existing study have abundant significant policy direction to be measured with the administration along with developing countries. In impartial to attain, an excessive quantity of renewable energy consumption should be funding and execute the innovative investments in renewable and cleaner energy systems; so, new and perceiving revenue system policies must be implemented with financial policies. The tax immunity strategies on renewable energy sources might also take development and growth on the renewable energy consumption procedure; likewise, the sponsored loans are granted to the stakeholders in green and renewable energy power plants.

### 5.1. Theoretical Implications

The recent study contributes in the field of economic growth by use impact of independent variable environmental pollution (greenhouse omission), economic growth, technology innovation, and FDI which helps to build a strong relationship to increase the growth of renewable energy. That is because of giving a proper way to clean the environmental pollution. This study contributes to the literature through a comprehensive interactive model However, this study is a rare work among studies focusing on environmental pollution has become a serious issue for long-term growth. Indeed, this increasing trend presents several challenges for policymakers in any country (Assi et al., 2021), this study adds knowledge theoretically by contributing to the context of renewable energy addressing the research gap by empirically testing.

### 5.2. Practical Contribution

In the last couple of decades, the major economic challenge is environmental sustainability and energy security which almost every country is facing. Technological innovation plays the role to help the increase renewable energy resources, technological innovation boosts the country's increase economy but at the same time it is increases environmental pollution. In environmental pollution is directly linked with greenhouse gases because when environmental pollution increases the pollutants of environment directly hit greenhouse gasses. The usage of renewable energy sources for fulfilling energy needs of industries houses etc.

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