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# Evaluating The Nexus Between Environmental Sustainability, Environmental Taxes, Environmental Innovation, And Energy Resources: A Case Study For South Asia

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**Abstract**

*This research evaluates the intricate dynamics between environmental sustainability, environment-related taxes, environment patents, and energy consumption (both renewable and non-renewable) in South Asia, for a time period of almost 2 decades. The region includes Pakistan, India, and Bangladesh. This study employed various econometric tools including the panel unit root test, cross-dependence test, Westerlund test, and the contemporaneous correlation techniques (PCSEs and FGLS) to get a more nuanced comprehension of the interaction of these [1]variables with one another. The empirical findings of this study revealed that levying environment-related taxes is at the heart of environmental policy, and gravely helps mitigate carbon-based consumption emissions (CBCO2). Countries that employ higher environment-related taxes are associated with increased sustainability. Contingent with environment-related taxes, investment in environmental patents leads to increased ecological sustainability and helps combat CBCO2 emissions. Moreover, the findings also illustrate that the consumption of energy from renewable sources is positively related to environmental sustainability and can help preserve the environment by reducing CBCO2 emissions, while the consumption of energy from non-renewable resources negatively impacts the environment. This study highlights the importance of levying environment-related taxes, increased expenditure on eco-friendly technology, and transition to clean energy to help achieve carbon neutrality in the sample region. This study also provides deep insights into understanding the different determinants of environmental sustainability, in South Asia. The findings of the study*

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*are consistent with the objectives of the sustainable development goals, therefore, providing a framework for the South Asian region to help attain Sustainable development goals, specifically SDG7 (clean and affordable energy), SDG9 (industry and innovation) and SDG13 (climate action).*

***Keywords:*** *Environmental Sustainability; Environmental Taxes; Environmental Innovation; Energy Resources; South Asia*

## 1. Introduction

Every country shares the same planet and therefore shoulders equal responsibility for safeguarding this environment. This is particularly because any one country's action can impact another country. For this reason, governments must ensure environmental sustainability which encompasses preserving the environment, stimulating economic growth, social security, ethical obligation, and long-term well-being of the Earth. In this context, multiple studies have been conducted to examine and evaluate various approaches that integrated the narrative of economic growth with ecological sustainability in the last 50 years ( Adebayo & Kirikkaleli, 2021).

To respond to the issue of climate change, the United Nations, formulated 17 extensive Sustainable Development Goals (SDGs) in 2015 and established a 2030 agenda that guided governments in eliminating poverty and stimulating economic growth. Taghizadeh-Hesary et al. (2020), eco-friendly investment and environment innovation and technology (Luo et al., 2021), diversification and transition of energy resources (Udemba & Tosun, 2022), and improvement of environmental quality (Kirikkaleli et al., 2022). The United Nations emphasized that without prompt action, the world will become prone to the adversities of climate change, surpassing the current intensity of the COVID-19 pandemic (Ali et al., 2023). Recent studies have recognized the potential causes of environmental degradation and have put forth different strategies to help mitigate emissions, particularly those as a result of consumption. For example, energy use has been recognized as a significant factor in ecological deterioration (Khan et al., 2020), urbanization (Wang et al., 2024), Foreign Direct Investment (FDI) (Irfan & Ojha, 2022), and financial development (Jianguo et al., 2022) are also recognized as drivers of CBCO2 emissions. In recent years, carbon emissions have increased exponentially and are now considered 50% higher than at the start of industrialization (Adebayo & Kirikkaleli, 2021). China, India, the United States, and Russia are the highest contributors to carbon emissions (Amin et al., 2020). Moreover, the core countries are heavily industrialized compared to low-income nations owing to their long-term economic activity and ample energy reserves (Peng et al., 2022). Their significantly high emissions rates can be attributed to their great industrial growth, which is an outcome of the exploration of eco-friendly energy resources within their established frameworks (Ali et al., 2021)

Fig.1: Per Capita CO2 emissions for 4 Asian Countries

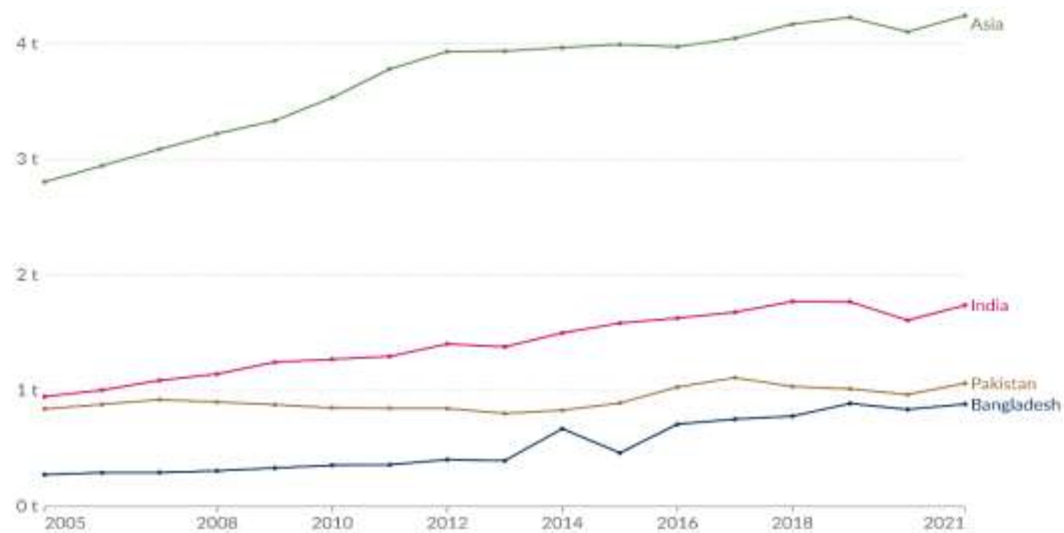



**Fig.1** Analyzes the emission levels of India, Pakistan, Bhutan, and Bangladesh. We can see that India was the highest contributor to carbon emissions (2t) in 2022 followed by Bhutan. Note that India illustrates an increasing trend, concerning the previous emission levels in 2012 (1.4t). Moreover, Pakistan (0.8t) and Bangladesh (0.6t) have a lower contribution to CO2 emissions.

Furthermore, goals such as affordable and sustainable energy (SDG7), eco-friendly technologies (SDG9), and the levying of environmental taxes to mitigate climate change (SDG13) have become imperative in the attainment of Sustainable development goals by 2030. Moreover, environment-related taxes are considered the most efficient policy tools to combat climate change and foster environmental sustainability (Zhen et al., 2023; Usman et al., 2023). Most developing nations are now considering levying environmental taxes and utilizing them as the basis for ecological sustainability and combating the challenges of climate change (Tao et al., 2021;Xin & Xie, 2023). Currently, India's environmental taxation as a share of GDP is the highest (1.39%), followed by Pakistan (1.05%). Bangladesh stands last with only (0.01%) environmental taxation a share of its GDP. Environmental taxes as a share of the total percentage of GDP.

Simultaneously with environmental taxes, encouraging environmental innovation and technology is important for environment-related policies. In the past years, environmental patents and technology have been recognized as an effective approach to mitigating the threats posed by climate change and attaining SDGs particularly SDG 9 in economies (Kirikkaleli & Ali, 2023). The importance of ETEC is significant to reduce CBCO2 emissions (Khan et al., 2020). ETEC ensures innovation in environmental-related technologies and simultaneously promotes the production processes that produce goods and services that reduce carbon emissions thereby combating environmental degradation (Kirikkaleli & Adebayo, 2021). Green technologies adopt eco-friendly practices and amalgamate them with their existing operations to maximize growth and minimize ecological degradation (Usman et al., 2021; Sharif et al., 2022).

This study examines the effects of environment-related taxes, eco-friendly technology and patents, and energy resources on environment sustainability in 3 major economies in the South Asian region. The research is centered around India, Pakistan, Bangladesh, and Bhutan, which are highly prone to the adverse effects of climate change and therefore must adhere to these environmental policy tools to take immediate climate action. The empirical analysis and consequent utilization of these eco-friendly policies and green energy will produce nuanced and valuable insights for these sample nations, providing a framework to meet the Sustainable Development Goals SDGs by 2030. We believe that our research will help in the attainment of ecological sustainability (SDG 7) by levying environmental taxes and will help promote environmental innovation (SDG 9) to manage resources sustainably (SDG 13). Hence, this study will help address the research gap that illuminates the nexus between Environmental taxes, Environmental patents, and consumption from renewable energy sources and non-renewable energy sources, environmental sustainability in Pakistan, India, and Bangladesh

## 2. Research Methodology

### 2.1 Data Sources, Variables and Methods

Panel data was sourced from our world in data.com and oecd.org from 2005 to 2022 for Pakistan, India, and Bangladesh. The study aimed to conduct an in-depth analysis of the South Asian region, however, due to the lack of sufficient data on many countries in South Asia, the countries were shrunk down to Pakistan, India, and Bangladesh.

Environment sustainability is proxy by Consumption-based emissions which are said to be the national or regional emissions that are adjusted for trade.

$$\text{CBCO2} = \text{Production Based} - \text{Exported} + \text{Imported Emissions} \ldots \ldots \ldots (1)$$

Renewable energy consumption: (share of primary energy consumption from renewables): Measured as a percentage of primary energy using the substitution method. Renewables include hydropower, solar, wind, geothermal, bioenergy, wave, and tidal. Environmental taxes encompass several attributes of taxes including revenue, tax base, tax rates, and exemptions. The attributes are utilized in the consumption of tax revenues associated with the environment.

Table 1: Variable Description

| Variable | Source | Unit |
|---|---|---|
| Environmental Sustainability | Our world in data | Tons per person |
| Renewable Energy Consumption | Our world in data | Measured as a percentage of primary energy |
| Environmental Tax | OECD | Percentage of GDP |
| Environmental Patents | OECD | Percentage of GDP |
| Non-Renewable Energy Consumption | Our world in data | Measured as a percentage of primary energy consumption |

Source: Author's compilation

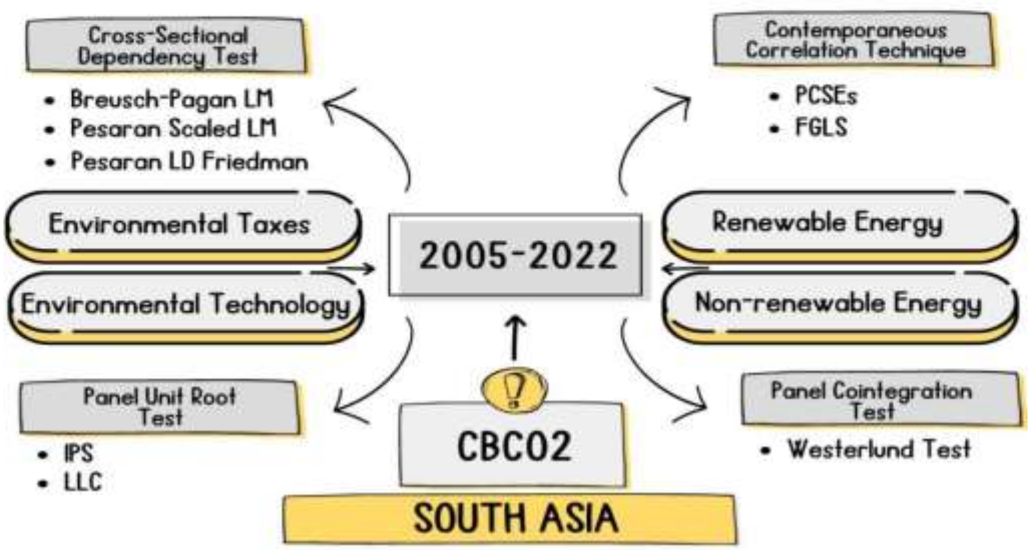
Environmental Patents and Technology includes advanced and foreign research and technology partnerships are essential in aiding local firms to acquire the latest and newest technological developments. Patent data presents numerous advantages when compared to other indicators of innovation. They may be measured, compared, and focused on producing results that are easily accessible. The data can be categorized into sub-parts making the analysis of environmental technologies easier.

Non-Renewable-Energy Consumption: (share of primary energy consumption from fossil fuels). Primary energy exists in the form of different resources including fuels utilized in power plants. Examples of this included uranium, oil barrels, and unburned coal. To illustrate the relationship between environmental sustainability, environment-related taxes, environmental patents, and energy resources, a basic panel model is constructed after a thorough review of the literature review which enabled the evaluation of how these different factors contribute to environment sustainability in the sample countries:

$$\mathrm{CBCO2}_{it} = \phi_i + \phi_t + \phi_1 \mathrm{ETAX}_{it} + \phi_2 \mathrm{ETEC}_{it} + \phi_3 \mathrm{RENCN}_{it} + \phi_4 \mathrm{NREN}_{it} + \epsilon_{it} \ldots \ldots (2)$$

where CBCO2 denotes consumption-based carbon emission, i denotes the index for the understudy sustainable economy, t represents the period, $\phi_i + \phi_t$showcases the intercept of the equations, $\phi_1 \ldots \ldots \phi_4$ are the independent variable's impact magnitudes, and ε is the error term. This research employed the co-integration analysis by using the unit root test. The unit root tests included the IPS and LLC tests. Moreover, the Westerlund test (2007) was conducted to check if the variables were stable and correlated in the long run. The contemporaneous correlation techniques included the FGLS and PCSEs test. The cross-dependence test served as a benchmark analysis for the contemporaneous correlation test.

Fig 2: Conceptual Model




**3. Results and Discussions**

The Panel Unit Test aims to underscore the stationary properties of environmental sustainability, renewable energy consumption, environmental tax, environmental patents, and non-energy consumption. The implications of this panel unit root test are to is to comprehend the stationary property of these variables, which is pivotal for framing their long-term relationships, leading the investigation into how environmental taxes, environmental patents, and energy resources impact environmental sustainability over time. The results of the unit root tests are important in displaying the stationary properties of each variable, therefore indicating a stable time series. Before applying the cross-dependence test, the order of integration of variables at Indicators level I(0) and first difference level I(1) can be evaluated. The Im, Pesaran and Shin Test (2003) (IPS) and Levin Lin & Chu (2002) (LLC) have been employed by our stationary tests. The null hypothesis (H0) indicates the presence of a unit root meaning that the variable is non-stationary. The alternative hypothesis states the opposite i.e., no presence of unit root meaning that the variables are stationary. The null hypothesis will be accepted if the IPS and LLC statistics are greater or in between the critical values, and the null hypothesis will be rejected if the IPS and LLC statistics value is less than the critical value.

Table 2: Panel Unit Root Test

| | | Indicators Level I (0) | First Difference I (1) | |
|---|---|---|---|---|
| **Im Pesaran Shin Test (IPS)** | | | | |
| | **Statistic** | **P-value** | **Statistic** | **P-Value** |
| ( Environmental Sustainability | 0.9151 | 0.8199 | -3.3705 | 0.0004*** |
| Renewable Energy Consumption | -1.2292 | 0.1095 | -3.8358 | 0.0001*** |
| Environmental Tax | -1.8572 | 0.0316** | -3.7650 | 0.0001*** |
| Environmental Patents | -1.0721 | 0.1418 | -2.6807 | 0.0037*** |
| (Non-Energy Consumption | -1.2917 | 0.0982* | -3.8531 | 0.0001*** |
| **Levin Lin & ChuTest (LLC)** | | | | |
| (Environmental Sustainability | -0.9527 | 0.1704 | -2.6702 | 0.0038*** |
| Renewable Energy Consumption | -0.8876 | 0.1874 | -4.2988 | 0.0000*** |
| Environmental Tax | -0.9110 | 0.1812 | -2.5675 | 0.0051*** |
| Environmental Patents | -1.5496 | 0.0606* | -2.5501 | 0.0054*** |
| Non-Energy Consumption | -0.7507 | 0.2264 | -4.5571 | 0.0000*** |

***p<0.01, **p<0.05, *p<0.10 Source: Author's Compilation

Table 2**,** therefore, showcases that environmental sustainability, renewable energy consumption, environmental patents, and non-renewable energy consumption require 1st difference I (1) to be taken before they become stationary. However, environmental tax requires the indicator's level I (0) to become stationary. All variables in the table showcased integration at mixed levels according to results.

**3.1 Cross-dependence tests:**

A cross-dependence test is an econometric tool employed to examine the dynamics and dependencies between the various variables in a dataset. It allows us to evaluate how changes in one variable can bring about a change in another variable, therefore providing detailed insights into the intricate interactions within a system. Moreover, the results of the cross-dependence tests use different statistical approaches to examine the relationship between the variables in a dataset.

| **Test** | **Statistic** | **Prob.** |
|---|---|---|
| Breusch-Pagan LM | 12.38426 | 0.0062 |
| Pesaran scaled LM | 3.831109 | 0.0001 |
| Pesaran CD | 1.037069 | 0.2997 |
| Friedman's test | 18.719 | 0.001 |

Table 3: Cross-dependence tests:

Source: Author's Compilation

Table 3 illustrates that the Breusch-Pagan LM test has a statistical value of 12.38426 and a probability of 0.0062. The low probability signifies a notable rejection of the null hypothesis of no cross-dependence (correlation), illuminating significant evidence of correlation amongst the variables. Similarly, the Pesaran scaled LM statistic value is 3.831109 accompanied by a probability value of 0.0001, once again this small probability value leads to a rejection of the null hypothesis further reinforcing the presence of cross-dependence. Similarly, Friedman's test has a statistic value of 18.719 and a probability value of 0.001. This significantly low probability value leads us to reject the null hypothesis, once again supporting the evidence of cross-dependency among variables. However, the Pesaran CD has a statistical value of 1.037069 and a probability value of 0.2997. The probability value provides a lack of evidence to reject the null hypothesis, illustrating that while there might be cross-dependence it might be negligible.

Hence, we can conclude that looking back at these results of the cross-dependence test, specifically from the Breusch-Pagan LM, Pesaran scaled LM, and Friendman's test, provides evidence for the existence of meaningful correlation amongst these variables. These results provide insights into how a change in one variable can influence or correlate with a change in another variable, illuminating the overall dynamics of the dataset.

### 3.2 Westerlund Test

The Westerlund test for co-integration is an econometric test used to evaluate whether a non-stationary time series has a stable relationship in the long run. The test examines whether the variables in a dataset are co-integrated. Cointegration reflects a long-term relationship amongst the variables in the dataset and showcases if the variables move in the same direction in the long run. The Westerlund test has few restrictions compared to other tests for co-integration. It tests for the null hypothesis of No co-integration, but the alternative hypothesis is slightly different, meaning, that only some of the panels are co-integrated not all.

Table 4: Wester-Lund test

| | Statistics | P-Value |
|---|---|---|
| Variance Ratio | 2.9559 | 0.0016 |

Source: Author's compilation

It can be seen from table 4 that the Westerlund test has a statistics value of 2.9559 and the P-value is 0.0016. The significantly low P-value leads to the rejection of the null hypothesis of no co-integration among panels. This provides substantial evidence of the presence of co-integration amongst certain panels.

**3.3 Contemporaneous Correlation Techniques:**
The contemporaneous correlation technique is a statistical concept that allows us to quantify and measure the correlation among the variables in a time-series dataset. The Contemporaneous correlation suggests that the variables are interdependent and must be estimated together. The contemporaneous correlation implies the existence of dependency across the cross-sectional units in a panel dataset. Here, we employed the panel-corrected standard error (PCSE) and feasible generalized least squares (FGLS).

Table 5: Contemporaneous Correlation Techniques

| | Prais Winsten Test (PCSEs) | | Cross-sectional FGLS test | |
|---|---|---|---|---|
| | Coef. | t-value | Coef. | t-value |
| Renewable Energy Consumption | -0.077** | -2.270 | -0.110** | -2.170 |
| Environmental Tax | 0.409*** | 3.990 | 0.720*** | 8.490 |
| Environmental Patents | -0.002 | -0.690 | -0.007** | -2.020 |
| Non-Energy Consumption | -0.071** | -2.260 | -0.094** | -2.070 |
| Constant | 7.725** | 2.450 | 9.906** | 2.180 |
| | R-Squared =<br>Chi-square= | 0.808<br>37.711*** | R-Squared=<br>Chi-square= | 0.812<br>22.938*** |

***p<0.01, **p<0.05, *p<0.10 Source: Author's Compilation

According to the results, renewable energy consumption assumes a negative coefficient value of -0.077 in the PCSE test, along with a negative t-value of -2.270. The value of the coefficient (-0.084) and t-value (-3.010) is negative in FGLS as well, undermining that renewable energy consumption has a negative relationship with environmental sustainability. This seems contradictory. Alternatively, these results could imply that the measurement is conducted in an environment where higher consumption leads to less favorable outcomes. Moreover, environmental tax has a positive coefficient value of 0.409 accompanied by a positive t value of 3.990 in the PCSE test. Similarly, in the FGLS test, the coefficient value for environmental tax is 0.217 along with a t-value of 2.380 illustrating those higher environmental taxes result in enhanced environmental quality. Furthermore, environmental patents have a negative coefficient value (-0.002) in both PCSE and FGLS and -0.690 and -1.000 t-values, respectively. This means that an increase in environmental patents can decrease environmental sustainability. Lastly, non-energy consumption has a negative coefficient value of -0.071 and a negative t-value of -2.260 in the PCSEs test. In the FGLS test, the coefficient value of non-energy consumption is -0.086, and the t-value is -3.300 signifying that an increase in non-energy consumption is detrimental to environmental sustainability. Lastly, the R-squared values in both tests are very high (0.808) and (0.812), demonstrating a significant explanation of the variability in ecological sustainability.

**4. Conclusion:**

This research evaluated the relationship between environment-related taxes, environmental patents, renewable and non-renewable energy resources, and consumption-based carbon emissions (CBCO2) for the South Asian region from 2005 to 2022. The countries included in this research are Pakistan, India, and Bangladesh. This study employed various econometric tools including the panel unit root test, cross-dependence test, and Westerlund test to get a more nuanced comprehension of the interaction of these variables with one another. The contemporaneous correlation techniques (PCSEs and FGLS) were used to check the robustness of the results in the long run. The outcomes of this study revealed that environmental taxes play an imperative role in mitigating consumption-based carbon emissions (CBCO2), and therefore can be used as an important policy tool for climate action. Moreover, this study also revealed that environmental patents and eco-friendly technologies are significantly and negatively related to CBCO2 emissions and utilization of environmental patents can significantly improve the quality of our environment. Furthermore, the findings of this study also revealed that consumption of energy from renewables can substantially help recover the environment and fortify it against the adversities of climate change. On the other hand, utilization of non-renewable energy sources positively relates to consumption-based carbon emissions, and therefore, can lead to increased environmental degradation in the sample region. As the South Asian region hopes for sustainable development, it is essential to understand and tackle the factors contributing to consumption-based carbon emissions. This study, characterized by its customized methodology and focus on regional emphasis, establishes the framework for extensive policy interventions. These measures can successfully aid in mitigating consumption-based carbon emissions and enhance environmental sustainability in the specific region.

As observed from the results of this study, environment-related taxes, environmental patents, and utilization of renewables have a positive and significant impact on environmental sustainability. Simultaneously, the consumption of non-renewable energy leads to increased carbon emissions resulting from consumption. Contingent upon these findings, we provide the following comprehensive policy recommendations to government officials and policymakers:

- Environment-related taxes, environmental patents, and energy resources can be utilized as effective policy measures to combat adverse environmental externalities. Similarly, countries should allocate heavy funds towards different environment-related projects that will help reduce the adverse impacts of taxed sources, such as fossil fuels.
- Significant subsidies or tax reductions should be provided by the government for the adoption of eco-friendly technologies. This will encourage corporations to incorporate green practices into their existing operations.
- Greater public expenditure in research and development of eco-friendly technology should be encouraged. These eco-friendly technologies can help reduce greenhouse gas emissions and therefore, restore the environment.
- The revenue generated from levying environment-related taxes should be put towards supporting sustainable development through different measures, especially the transition

towards using clean and affordable energy and green innovations. Such initiatives will help these nations in attaining the objectives of sustainable development goals, especially SDGs 7, 9, and 13.

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