

The Role of Environmental Taxation in Mitigating CO₂ Emissions: Testing the Environmental Kuznets Curve Hypothesis in South Asian Economies

1. Hassan Taj, 2. Ehtsham ul Haq Raja, 3. Bushra Kanwal, 4. Muhammad Sajid, 5. Aamir Sohail

1. Department of Economics, Kohat University of Science and Technology (KUST), Kohat (26000), Pakistan

hassantaj633.ht@gmail.com

2. Department of Economics, Azad Jammu and Kashmir University of Bhimber (AJ&K UOB)

ehtshamulhaq.eco@ajkuob.edu.pk

3. Department of Economics, University of Wah, Wah Cantt, Pakistan

hopefullife02@yahoo.com

4. Department of Economics, Kohat University of Science and Technology (KUST), Kohat (26000), Pakistan

muhammad.sajid8898@gmail.com

5. Department of Economics, Kohat University of Science and Technology (KUST), Kohat (26000), Pakistan

Aamirsohail0344@gmail.com

Abstract

Recent study analyzes the impact of environmental policy on CO₂ emissions in Pakistan, Bangladesh, India and Sri Lanka for 2000–2024 using an extended version of the Environmental Kuznets Curve (EKC) model. This analysis is about whether environmental taxation is effective in reducing environmental degradation, but also considers the effects of economic growth, foreign direct investment (FDI), population density and industrialization. A set of diagnostic and

econometric procedures is performed to examine the balanced panel data, which includes the tests for cross sectional dependence, slope heterogeneity, CADF and CIPS unit-root tests, Westerlund cointegration test, and the Cross-Sectionally Augmented Autoregressive Distributed Lag (CS-ARDL) estimator. The positive and significant relationship between economic growth and CO₂ emissions, and the negative and significant relationship between the squared GDP term and CO₂ emissions are in line with the inverted-U shape of the EKC theory. Shorthorn and long-term environmental policy can be found to reduce CO₂ emissions, which suggests the potential for an effective environmental taxation policy. However, higher emissions are brought about by higher level of FDI, population density and Industrialization, and the population density has the highest long run coefficient. Hence size of the error-correction term is large and minus, suggesting that there is a stable relationship across time and about 528.8% of disequilibrium is corrected in a single period. The results are relevant to the importance of environment tax, cleaner technology, sustainable urban design, lesser FDI, and low carbon industrial development for sustainable economical growth in the South Asian region.

Keywords: Environmental Taxation, Carbon Dioxide Emissions, Environmental Kuznets Curve, Economic Growth, Foreign Direct Investment, Industrialization, South Asia, and Environmental Policy

1. Introduction

Environmental degradation has become one of the biggest challenges to economic development in today's world. The economic activities, industrial production, energy use, urbanization and transport have been rapidly growing, placing pressure on natural resources and resulting in greenhouse gas emissions. Carbon dioxide (CO₂) emissions are especially significant among various indicators of environmental degradation because CO₂ is a significant contributor to anthropogenic GHG emissions and is strongly linked to fossil-fuel consumption and economic activities (IPCC, 2022). Development usually follows a standard model that relies on energy-intensive production and fossil fuels, thus leading to a paradox in which some income gains are at the cost of environmental degradation (Grossman & Krueger, 1991; Stern, 2004).

The relationship is relevant for the South Asian economies because of the tremendous economic and demographic changes in the region over the last few decades. Industrial growth, urbanization, increased energy consumption and globalization of markets have taken place in Pakistan, India,

Bangladesh and Sri Lanka. Economic development has given rise to a number of environmental pressures such as industrialization, transportation, electricity production and increased energy consumption. Current evidence indicates that the economic growth, foreign direct investment (FDI) and energy sectors are still key drivers of environmental outcomes in the region (Nur Mozahid et al., 2022; Perera, 2025).

The term "Environmental Kuznets Curve" (EKC) refers to the connection that exists between economic expansion and environmental degradation. The EKC hypothesis suggests that the environmental impacts increase if the income of an economy falls below a certain level, and then decrease if income increases beyond that level (Grossman & Krueger, 1991; Selden & Song, 1994). Generally, in the initial stages of countries' development, they are more concerned with production and income growth and give environmental issues a relatively lesser focus. As a city becomes more developed, its pollution and energy consumption rises. Societies, however, may require improved environmental conditions as incomes rise, governments may impose more stringent environmental policies and firms may invest in more environmentally friendly technologies. These changes will, over time, decrease environmental deterioration. However, the condition of EKC in South Asia is not quite decisive. Some examples of this are that in the EKC framework some studies have found a positive relationship between GDP and CO₂ emissions in some South Asian countries, but a negative relationship between squared GDP and CO₂ emissions in these countries (Stern, 2004).

Recent studies have investigated the The familiar U-inverted relationship among South Asian economies. For example, Bhattacharjee et al. (2025) found a positive relationship between CO₂ emissions and income in South Asian countries and questioned the ability of the traditional EKC approach to explain CO₂ emissions. The differences indicate that the impacts of economic growth are not the only ones affecting environmental results and that structural and environmental policy matters as well. In this context, environmental policy has become more relevant with the aim of minimizing negative externalities in the environment caused by economic activities (Spash, 2021).

Environmental tax is an effective market-based measure for decreasing pollution. It follows the Philosophy of Pigouvian taxation, whereby the costs of polluting activities are imposed on the polluter, the individual or the firm. Environmental taxes can induce the producers and consumers to decrease the use of fossil fuels, enhance energy efficiency, and switch to pollution-free

production (OECD, 2017). Environmental taxation can therefore play a role in economic growth alongside building an incentive to transition away from polluting economic activities towards more sustainable ones (Mahmood et al., 2022). But it is not certain that it is an effective way of environmental taxation in developing countries. It depends on the way the economy is organised, its enforcement capacity, the price structure of energy markets, institutional quality, and firms and household response to environmental price signals (Fullerton & Muehlegger, 2019). However, the level of effectiveness of policy can be hindered by the implementation of policy, energy subsidies, lack of access to clean technologies and informal economic activities. Environmental tax is thus able to reduce emissions when it affects production and consumption choices, but is less effective if fossil-fuel energy costs are low, or if environmental regulations are not as stringent (Shahzad, 2020). Environmental policy needs to, therefore, be looked at in the context of wider economic and structural factors.

Another crucial factor that can impact environmental degradation in the SA economies is the FDI. FDI can contribute to development in the following ways: Capital formation, Job creation and transfer of technology and integration with the outside world. At the same time, environmental pressures can come from foreign investment, as MNCs concentrate their environmentally polluting activities in the countries where environmental standards are lower, known as pollution-haven hypothesis (Kanval et al., 2024). Contrastingly, the pollution halo hypothesis suggests that FDI can also help to promote environmental quality by bringing in new cleaner technologies, better management practices, and more efficient production (Bekun et al., 2024). The facts about South Asia's economies are limited. In fact, pollution-halo and pollution-haven effects were discovered in a number of South Asian nations by Nur Mozahid et al. (2022). Recent studies indicate the FDI, economic growth and CO₂ emissions nexus could be non-linear and country specific. So, FDI is included in the present study as it may have some impact on environmental quality. Other factors that affect environmental degradation include structural factors such as industrialization and population density. A high level of energy and raw materials are generally needed for industrialization, especially for the initial stages. In this way, if manufacturing increases, so will the use of fossil fuels and CO₂ emissions. However, this burden could be lowered at higher stages of development through technology and structural change to more energy efficient activities. The density of population can affect environmental quality in various ways such as in terms of

transportation needs, energy requirements, and urbanization and infrastructure stresses (Mohsin et al. 2019).

The above shows the need to use an integrated approach to the study of environmental degradation, involving economic trends and structural approaches. The aim of this paper is to examine environmental policy's impact on environmental degradation in South Asian countries in the context of the Environmental Kuznets Curve (EKC). The study is for the years 2000 - 2024 and the study countries are Pakistan, India, Bangladesh and Sri Lanka. Environmental taxes are used as a proxy for environmental policy and CO₂ emissions as a proxy for environmental damage. The values of squared GDP have been used for this modification of the Environmental Kuznets curve. Other control variables include FDI share of GDP, the population density and the level of industrialization. In this regard this study is an extension of the previous studies in which the impact of environmental policy was added to the traditional EKC model and the factors of FDI and population density and industrialization were assumed as constant. The research will probably be useful to the theoretical and policy dimensions. It is a theory that brings together the EKC hypothesis and the environmental-tax theory to study the potential of environmental policy to shape the relationship between economic and environmental performance. The results can be used as evidence of the policy implication for the South Asian policymaker for considering environmental taxation as a tool to reduce CO₂ emissions without impacting the economic development. More efficient and efficient market-based policy can aid in the transition of the region towards sustainable growth, given the substantial cuts in emissions resulting from environmental taxation. If it has proven to be effective to a lesser degree, on the other hand, the results might indicate that more comprehensive policies need to be implemented, including cleaner technology, restructuring of industries, energy efficiency and strengthening of regulatory institutions. The study is thus part of a discussion on sustaining environmental quality in the South Asian economies as they grow.

2. Literature Review

2.1 Theoretical Review

There has been an extensive body of research on the relationship between environmental sustainability and economic growth, which is encapsulated in the Environmental Kuznets Curve (EKC) hypothesis. It is based on the Kuznets hypothesis that posits an inverted “U”-shaped

relationship between the growth of an economy and the level of income inequality. Grossman and Krueger (1991) were the first to propose the EKC hypothesis to solve the environmental problem, which stated that pollution will rise at first but fall after a certain threshold of income level. Selden and Song (1994) established this further by showing that some pollutants are inversely U-shaped with respect to income. Thus, in accordance with the EKC theory, the environment need not be permanently degraded with economic development.

The traditional EKC approach can be captured by including both GDP and the square of GDP in the environmental degradation function. In this study, CO₂ emissions are the measure of environmental degradation and GDP and GDP² are the measures of economic expansion. The relationship is represented as:

$$[CO_2]_{it} = \beta_0 + \beta_1 GDP_{it} + \beta_2 [GDP]_{it}^2 + \varepsilon_{it}$$

The traditional inverted-U-shaped EKC can be confirmed under the condition that GDP coefficient is positive ($\beta_1 > 0$), GDP² coefficient is negative ($\beta_2 < 0$). The positive GDP coefficient indicates that in the initial stage of economic development, emissions of CO₂ increase as the GDP increases. This may be attributed to industrialization, energy consumption, urbanization, transportation usage and fossil fuel consumption increasing during the development of economies. Once a threshold of income is reached, however, higher-earning economies might be able to afford to invest in cleaner technologies, pollution control, energy efficiency, and environmental protection (Stern, 2004). Three important effects are related to the EKC: technique effect, composition effect, scale effect. The principle of scale effect is that the more energy generated, the more economic activity, energy use and environmental impact. The composition effect refers to the changes in the nature of economic activity due to economic development. In the first few years, the economy could proceed in the direction of the energy-intensive industries and then shift towards services and less polluting industries. Technique effect refers to the increase in production efficiency and the decrease in emissions with technological development and strengthening environmental regulation. Copeland and Taylor (2004) propose that both are important in explaining the connections between economic development, trade and environmental quality. The EKC message to us, however, is that not all economic growth is good for the environment – it is dependent on the type of growth. Dinda (2004) has introduced the concept of the EKC, which depends on the nature of the pollutant, the

characteristics of a country, and the level of development. This is particularly of interest with regard to CO₂ emissions, where CO₂ is a global polluter closely linked with fossil fuel consumption and energy production. It is therefore not a rule that an inverted U-shaped relationship between economic growth and welfare must always result. Furthermore, the EKC framework can be expanded to include government intervention and the growth-environment nexus can then be studied in a manner that takes into account the role and effectiveness of environmental policy. One reason why environmental taxation is relevant is that it is a policy tool that is market-based and aims to internalize negative externalities that are caused by pollution. The Pigouvian principle, referred to in 1920 by Pigou and later by OECD (2017), emphasizes that taxes should be imposed on pollutive activities to stimulate an incentive for producers and consumers to reduce pollution, increase energy efficiency, and shift to cleaner technology. In theory, then, there is a negative correlation between emissions of carbon dioxide and environmental taxation. There are 2 primary hypotheses that attempt to explain the environmental impacts of foreign direct investment, the pollution halo hypothesis and the pollution haven hypothesis. According to the pollution haven hypothesis a multinational can move the polluting activities to nations with less stringent environmental laws that will increase emissions. The pollution halo hypothesis, in contrast, suggests that FDI may lead to improved environment performance in a country if it can be achieved through the use of modern technology and management practices. Industrialization is thought to be more damaging to the environment than beneficial, since it involves high consumption of energy and raw materials, and the density of the population can either be positive or negative in the process of urban development, transportation systems and energy use. The authors propose a new and improved environmental Kuznets curve, which incorporates the impacts of GDP, squared GDP, environmental taxation, foreign direct investments, population density, and industrialization, on the CO₂ emissions.

2.2 A Study of the Evidence Grossman and Krueger (1991) examined the relationship between economic development and environmental quality, drawing on information gathered from worldwide studies. This was the beginning of the empirical literature on EKC. The results show that some environmental variables show negative associations in the initial phase of economic development, followed by positive ones in the later phases. Later empirical studies on EKC were based on this study. Selden and Song (1994) also investigated the relationship between the four major air pollutants and their results provide support for the inverted-U hypothesis. They found that their results supported the concept that economic development would lead to an

improvement of the environment. Subsequent research questioned the generality of the EKC relation, however. A wide variety of theoretical and empirical literature was reviewed and Dinda (2004) found that the evidence differed by pollutant and country. However, methodological differences and limitations in data and model specifications could impact the relationship between a country's EKC as well, as suggested by Stern (2004). This is relevant to the current study because these studies have revealed the relationship between income and emissions is not necessarily the inverse U-shape, but rather income emissions needs to be looked at in a specific regional and institutional context. Subsequent economic and structural data found in the literature were then added to the EKC. Copeland and Taylor (2004) stressed the importance of considering trade, technological progress, and environmental policy when assessing the environmental impact. Their theoretical contribution to the subject showed that the impact of economic growth on the environment can be modified by the structure of the economy and technology, meaning that economic growth is not the only source of pollution. This is easy to do with the traditional EKC model, as environmental policy and other structural factors are easy to introduce. In empirical research studies of environmental degradation, environmental taxation has become an increasingly important factor. Higher prices on polluting environmental factors, and an incentive for cleaner production, are hypothesized to lead to a decrease in emissions if environmental taxes are increased. In recent years, Bashir et al. (2020) have examined the OECD countries and discovered a negative relationship between CO₂ emissions and environmental taxes. This indicates that environmental taxes can be a very effective market instrument for the protection of the environment. Similarly, Wolde-Rufael and Mulat-Weldemeskel (2023) discovered a negative correlation between environmental taxes and CO₂ emissions for European countries. They conclude that, if implemented appropriately, environmental taxation can help to reduce emissions. There is also some evidence that effectiveness of environmental taxing may be dependent on economic and institutional circumstances. Environmental taxes might not be as effective if regulations are not properly enforced, if fossil fuel energy is heavily subsidized, or if cleaner options are not available. Köppl and Schratzenstaller (2023) recently examined the empirical literature on carbon taxes and discovered that carbon taxes typically have a negative effect on emissions, with a policy design and country-specific effect. This is particularly the case in the economies of South Asia where the interplay of environmental policies, energy affordability policies, energy industrial development objectives and institutional constraints exists. The findings on empirical evidence from FDI are

also mixed. The pollution-haven and pollution-halo hypotheses have led to a lot of empirical debate. Demena and Afesorgbor (2020) found there to be a significant difference among the previous studies concerning the association between FDI and environmental emissions. They found that the impact of FDI on the environment does differ from country to country because of the variations in the technology transfer, industry and regulation. Their results lend some support on the use of FDI as a control variable in this study. This also is supported by evidence from South Asia. Nur Mozahid et al. (2022) examined several countries in the South Asian region and observed that GDP positively influenced CO₂ emissions and the squared term of GDP was negative in some countries which justified the EKC. Their results also showed that the effects of FDI on the environment were country-specific, showing pollution-haven and pollution-halo effects. This implies that the relationship between environmental quality and foreign investment is related to economy and institutional conditions in the countries concerned. After that, no definite research was done in South Asia on EKC. In the research on “Foreign investment, economic growth and CO₂ emissions in some South Asian economies”, by Sattar et al. (2022) The results showed that the Environmental Kuznets Curve (EKC) was valid for some of South Asian countries. The authors found positive relationship between foreign capital and economic growth and, negative relationship between foreign investment and CO₂ emissions. Subsequently, Bekun et al. (2024) used a nonlinear model to explore the CO₂ emissions – FDI linkage. They discovered that there were interconnections between income and emissions in each economy, but these patterns were different (e.g., inverted U and N-shaped). In other words, their results indicate that the so far known environmental Kuznets curve does not seem to explain all the effects of economic growth on the environment in the South Asian region, and their latest results confirm this. Based on the positive correlation between income and CO₂ emissions, Bhattacharjee and Chowdhury (2025) make the conclusion that the conventional inverted-U shaped EKC model is not enough to explain the relationship. This is important, as it shows that in developing countries, economic growth is not necessarily accompanied by environmental improvement. Instead, a decrease in emissions at higher income levels may require a change in environmental policy, technological innovation and structural change. It has also been investigated how industrialization and population density affect environmental degradation. More CO₂ will be produced by a more industrialised country if it consumes more energy, for example using fossil fuels. However, over time, technological advancements and modifications to the industrial sector's energy efficiency can contribute to a

reduction in emissions. Increased population due to increased energy use, transportation demand and urbanisation can also be an environmental stress.

At the same time, the empirical effect can be uncertain due to economies of scale effects in infrastructure and public transport which may occur in concentrated population. Empirical literature offers some important implications for the present study at large (Onwe et al., 2024). First, although the EKC has ample empirical backing, it is not universally valid and in particular it is not applicable to emissions of CO₂ and developing economies. Second, environmental taxation can typically offer a motive to reduce emissions (but is not always effective) depending on the economic and institutional setting (Qiao et al., 2024). Third, third parties will be impacted either positively or negatively, depending on the pollution-haven or pollution-halo effect of the FDI.

Lastly, two key structural parameters which can impact emissions are industrialization and population density. While a lot of research has been done on environmental degradation, economic growth and FDI, not much research has been done on the direct inclusion of environmental tax as a variable in EKC for the case of Pakistan. , India, Bangladesh and Sri Lanka while considering FDI, population density and industrialization.

Empirical literature suggests a number of implications for the current study. First, the empirical evidence to support the EKC is robust, but has not been shown to be universally valid, particularly in the context of CO₂ emissions and developing economies. Second, it is common knowledge that, in theory, environmental taxation can reduce emissions; however, this only occurs under certain economic and institutional circumstances. Thirdly, there may be a pollution-halo or pollution-haven effect from the FDI, as well. Last but not least, industrialization's structural factors and population density can have an impact on emissions. Although the number of publications on economic growth, FDI, and environmental degradation have increased over the years, a limited amount of literature could be found that directly includes environmental tax in an EKC framework in Pakistan, India, Bangladesh, and Sri Lanka, while controlling FDI, population density, and industrialization. This study seeks to fill this gap by analysing the impact of environmental taxes on CO₂ emissions reduction in some of the South Asian economies and considering the non-linearity between growth and environmental damage.

3. Research Methodology

This study examines the effects of environmental policy on environmental degradation in a selected group of South The Environmental Kuznets Curve (EKC) approach to Asian economies. The study uses a balanced panel data from four South Asian economies namely Pakistan, India, Bangladesh, and Sri Lanka for the period of 2000-2024. The use of a panel data framework enables the analysis to take into account both country-specific variations and variations across period of time. . Panel data are especially valuable for environmental studies due to the number of observations they offer and their ability to capture unobserved country-specific factors that can affect environmental outcomes (Baltagi, 2021). The countries included in the study had significant changes in the amount of economic activity and energy consumption, making environmental issues and policy responses more important. The choice of the study period is designed to reflect major economic, industrial, foreign investment, demographic, and environmental policy changes. With balanced panel data it is possible to compare all countries at the same time. Dependent variables are carbon dioxide (CO₂) emissions which can help in assessing the level of environmental degradation. Emissions of CO₂ are broadly recognized in studies on environmental degradation since they are somehow linked to the use of fossil fuels, industrial production, transport and energy production (Grossman & Krueger, 1991; Stern, 2004). Environmental policy is the main explanatory variable, which can be captured with the environmental tax revenue. The OECD defines environmental taxation as a market tool which allows governments to internalise the environmental cost of economic activity. Economic growth is represented in the model through GDP and GDP² to see if the Environmental Kuznets Curve is relevant with respect to reducing CO₂ emissions. This indicates the direct relationship between economic growth and CO₂ emissions (GDP); and the relationship between economic growth and CO₂ emissions when incomes increase (GDP²). Population density, industrialization and FDI as % of GDP are also included in the model. The measurements of the variables are shown below.

Table 1: Description of Variables

Variable	Measurement	Source
CO ₂ Emissions	CO ₂ emissions in Metric Tons	World Bank 2026
Environmental Policy	Environmental Tax Revenue as % of GDP	OECD 2026

GDP	GDP Measured in Constant US \$ 2015	World 2026	Bank
FDI	FDI as % of GDP	World 2026	Bank
Population Density	Number of people living in a square kilometer area	World 2026	Bank
Industrialization	Industrial Value Added as Percentage of GDP	World 2026	Bank

The most important source of information for variables is the well-known databases. This type of information sources helps to promote the reproducibility, transparency and consistency of empirical research. The empirical specification is based on Environmental Kuznets Curve (EKC) model. A nonlinear relationship exists between economic development and environmental degradation in the conventional Environmental Kuznets Curve. The basic equation of the EKC model is given below:

$$[CO_2]_{it} = \beta_0 + \beta_1 GDP_{it} + \beta_2 [GDP]_{it}^2 + \varepsilon_{it}$$

In the above equation, CO_{2it} is the CO_2 emissions in country i at time t , GDP_{it} is the economic growth in country i at time t , GDP_{it}^2 is the squared term of GDP , and ε_{it} is the error term. The classic inverted, u-shaped EKC is validated with $(\beta_1 > 0)$ and $(\beta_2 < 0)$. The basic EKC model is extended to look at how environmental policy and other structural determinants play a role: $CO_2 = \beta_0 + \beta_1 GDP + \beta_2 GDP^2 + \beta_3 FDI + \beta_4 PD + \beta_5 IND + \mu_i + \nu_t + \varepsilon_{it}$ Where (EP) stands for environmental taxation, (FDI) denotes FDI expressed as a % of GDP, (PD) denotes population density, while (IND) denotes industrialization. Notations: The "i" notations refer to effects that are specific to a country, while the "t" notations refer to effects that are common for each period. The sign of the coefficient of environmental taxation is negative as more environment taxes should lead to higher costs of harmful pollution and the need to invest more in clean technologies and reduce pollution by businesses and consumers (Pigov, 1920; OECD, 2017). The direction of the effect of foreign direct investment could be either positive or negative, because the coefficient may be positive (pollution haven effect) or negative (pollution halo effect) (Copeland & Taylor, 2004). The factors affecting emissions should reflect population density, energy use, urbanization, industrial production and industrialization/urbanization. The question of whether the problem of multicollinearity could arise in this study is the subject of the research before the primary estimation procedure is carried out. In simple terms, multicollinearity is when independent

variables are highly correlated. This unfortunately causes increased standard errors of the estimated coefficients and a very unreliable inference process. In the research process, to determine whether there are any multicollinearity problems, this study will use variance inflation factor (VIF) and the method of calculating the correlation matrix.

Gujarati and Porter (2009) say there can be a problem of Multi-collinearity if there are strong correlations between the pairs of different independent variables. This made it necessary to examine the correlation matrix and see how the different variables are related to each other, namely GDP, foreign direct investment, environmental taxes, population density, and industrialization. Also, Variance Inflation Factor (VIF) was computed for every explanatory variable in the model. To check for multicollinearity among the independent variables, this statistic was used. The VIF can be expressed as: $VIF_i = 1/(1-R_i^2)$ where R_i^2 is the regression coefficient for any explanatory variable j (other than X_i) against all other explanatory variables. O'Brien (2007) suggests that a VIF of >10 is generally considered a strong indicator of serious multicollinearity and a value of >5 could be considered a cause for concern in some instances depending on the context. These types of tests would determine whether the empirical model would allow explanatory variables to be combined with one another. Since Pakistan and India, Bangladesh and Sri Lanka are geographically and economically close, then interdependence between them implies that the disturbance of one may impact on the other countries. Interdependence can result from common energy markets, international markets, regional trade and cooperation, investment, or from a combination of ecological/climate policies. If this interdependence is not taken into account, the estimates will be biased or statistical inference errors (De Hoyos & Sarafidis 2006). The test of cross-sectional dependence (CD) of Pesaran (2004) is thus applied to the study. The test is used to see if the residuals have a correlation between cross-sectional units. The duration and is the coefficient of correlation of the residuals. Rejection of null hypothesis means countries are dependent. Assumption of the null hypothesis is that all countries are independent. For South Asian countries, it is crucial to confirm CSD as the countries can be correlated in terms of region and across the globe as they might be exposed to the same regional or global shock.

The four nations are looked at to see if independent variables have the same effect. The economic, institutional, energy sector, environmental and technological characteristics of Pakistan, India, Bangladesh and Sri Lanka are vastly different. It is therefore not possible to conclude that

environmental taxes, FDI, economic growth and industrialization have the same impact on CO2 in all countries. This is remedied by the use of the Delta and adjusted Delta tests developed by Pesaran and Yamagata. The null in the rejection is that there is slope heterogeneity, and the null is that the coefficients of the variables are the same between nations. The adjusted test is particularly useful when the sample size is small (Pesaran & Yamagata, 2008).

$$\Delta = \sqrt{N} \left(\frac{1}{N} \sum_{i=1}^N S_i - k \right) / \sqrt{2k}$$

$$\Delta_{adj} = \sqrt{N} \left(\frac{1}{N} \sum_{i=1}^N S_i - 2k \right) / \sqrt{\frac{2k(T-K-1)}{T+1}}$$

If there is evidence of variability in the slope, this would justify the use of an estimation method that can apply country-specific responses instead of the same coefficients across countries. Revised, cleaner form, with sturdier academic flow and logical transitions:

This is even more relevant in the present study as there are significant disparities between the environmental policies and economic systems of South Asian economies. First, however, the cross-sectional dependence and the stationarity properties of the variables are investigated with the focus on assessing the slope heterogeneity properties. It's very important to take into account the integration properties of non-stationary variables, or estimates may be biased and misleading. They can give rise to spurious regression results. The study uses second generation panel unit-root tests, namely the Cross-Sectionally Augmented Dickey-Fuller (CADF) test and the Cross-Sectionally Augmented Im-Pesaran and Shin (CIPS) test, recommended by Pesaran, due to the presence of cross-sectional dependence among the countries selected. This CADF method is an extension of the traditional Augmented Dickey-Fuller (ADF) test, which also includes cross-sectional averages to capture the common factors across countries. The general form of the CADF specification is given below: $\Delta y_{it} = \alpha_i + \beta_i y_{i,t-1} + \gamma_i \bar{y}_{t-1} + \delta_i \Delta \bar{y}_t + \varepsilon_{it}$

In which the cross-sectional mean of the variable is written as $\bar{X}$. The CIPS statistic is calculated as the arithmetic average of the CADF t-statistics for all the cross sections: $CIPS =$

$$\frac{1}{N} \sum_{i=1}^N t_i(N, T)$$

The null hypothesis of the tests proposes that the data variables are not stationary, i.e., have a unit root, and data are The variables are considered stationary when the null hypothesis is rejected. The results indicate if the variables are integrated level zero, $I(0)$, or order one, $I(1)$. The CS-ARDL approach can be used when the variables are integrated with different orders, with none of them being integrated higher than $I(1)$ (Chudik and Pesaran, 2015; Pesaran, 2007). After the test for the presence of the unit root, the study investigates the presence of a long-run equilibrium relationship between CO₂ emissions, economic growth, environmental taxation, foreign direct investment, population density, and industrialization. Cross sectional dependence can compromise the validity of the first generation cointegration tests, so Westerlund (2007) cointegration test is used. The general error-correction model is represented as: $\Delta y_{it} = \alpha_i + \delta_i t + \phi_i (y_{i,t-1} - \beta'_i x_{i,t-1}) + \sum_{j=1}^{p_i} \gamma_{ij} \Delta y_{i,t-j} + \sum_{j=0}^{q_i} \phi_{ij} \Delta x_{i,t-j} + \varepsilon_{it}$

where y_{it} represents CO₂ emissions, X_{it} represents the vector of explanatory variables, and ϕ_i represents the speed of The change in the direction of long-term equilibrium. The alternative hypothesis is that the variables are error-correcting, which implies that they have a long run equilibrium relationship, according to Westerlund (2007). The null hypothesis is that there is no cointegration. Once establishment of integration and cointegration properties of the variables, the Cross-Sectionally Augmented Autoregressive Distributed Lag (CS-ARDL) estimator introduced by Chudik and Pesaran (2015) is used in the research. The CS-ARDL method is particularly appropriate when there are slope heterogeneity and cross-sectional dependence in the panels. It additionally uses a cross-sectional average version of the dependent and explanatory variables, which makes it longer conventional ARDL framework to incorporate the typical surprise and unobserved common factor. For the present study, the general CS-ARDL model is represented by:

$$\begin{aligned} \Delta \ln CO_{2it} = & \alpha_i + \beta_i (\ln CO_{2i,t-1} - \theta_1 \ln GDP_{i,t-1} - \theta_2 \ln GDP^2_{i,t-1} - \theta_3 \ln EP_{i,t-1} - \theta_4 \ln FDI_{i,t-1} \\ & - \theta_5 \ln PD_{i,t-1} + \theta_6 \ln IND_{i,t-1}) + \sum_{j=1}^{p-1} \gamma_{ij} \Delta \ln CO_{2i,t-j} + \sum_{j=0}^{q-1} \delta_{1j} \Delta GDP_{i,t-j} \\ & + \sum_{j=0}^{q-1} \delta_{2j} \Delta GDP^2_{i,t-j} + \sum_{j=0}^{q-1} \delta_{3j} \Delta EP_{i,t-j} + \sum_{j=0}^{q-1} \delta_{4j} \Delta FDI_{i,t-j} + \sum_{j=0}^{q-1} \delta_{5j} \Delta PD_{i,t-j} \\ & + \sum_{j=0}^{q-1} \delta_{6j} \Delta IND_{i,t-j} + \lambda_1 \bar{Z}_t + \varepsilon_{it} \end{aligned}$$

(where) is the cross sectional averages of the dependent and independent variables and (Z_t) is the vector of explanatory variable. Chudik & Pesaran (2015) argue that cross sectional averages help in controlling unobserved common factors which may affect all countries at the same time. The respective values of the short and long-term effects are estimated separately in the CS-ARDL. The short-run coefficients provide the direct effect of the changes in the explanatory variables on CO₂ emissions and the long-run coefficients tell something about the long-run relationship between ecological deterioration and long-run determinants. The error-correction coefficient is very significant. A stable adjustment process can be ascertained from the presence of a statistically significant and negative error-correction term, which implies that the errors from the long-run equilibrium are corrected over time. The study is suitable for using CS-ARDL since common international factors that affect environmental degradation, such as global energy prices, international investment conditions, technological progress and international environment protection commitments affect the environment. Concurrently, the four economies that were selected from the South Asian region have different economic structures and environmental-policy settings. Consequently, estimation using the approach of allowing for heterogeneous responses and cross sectional dependence may be more reliable than estimation where all countries have identical responses and cross sectional dependence. The characteristics also emerge as key drivers for the choice of CS-ARDL in the reference methodology.

Estimating the income level at which environmental degradation attains its maximum level before it starts to deteriorate is part of the empirical analysis. If ($\beta_1 > 0$) and ($\beta_2 < 0$) then the turning point is given by the following formula:

$$GDP^* = \frac{\beta_1}{2\beta_2}$$

Where $\beta_1 > 0$ and $\beta_2 < 0$

The estimated turning point will indicate the sample's highest CO₂ emissions level at that point of economic growth. The actual income level of Pakistan, India, Bangladesh and Sri Lanka can then be compared to the estimated value to see if the economies are at or below the estimated EKC turning point. Finally, tests will be used to check the reliability of the estimated model, paying special attention to the significance and sign of the error correction term, properties of the residual, and stability of the estimated coefficients. If the error-correction coefficient is negative and

statistically significant, then the short-run deviations will be corrected over time, which will bring the variables back toward their long-run relationship.

Moreover, the results of the empirical analysis will be explained based on the theoretical underpinnings of environmental tax and the EKC hypothesis. Positive GDP coefficient and negative GDP² coefficient would be evidence supporting the conventional inverted U-shaped EKC. A negative coefficient of environmental taxation would mean that environmental taxes are associated with lower CO₂ emissions. The significance of the coefficients of FDI, population density and industrialization will also be tested.

In conclusion, the methodology is based on a step-by-step approach from dynamic panel estimators to pre-diagnostic tests. The first step of the method is to test for stationarity, cross section dependence, slope heterogeneity, and multicollinearity before conducting long-term cointegration tests. The rationale around dynamic heterogeneous panels, which allows for the presence of different types of shocks from different countries, and for them to impact the environmental outcome is consistent with the approach presented. The chapter points out the realistic conclusions about the effect of environmental policy on environmental degradation in Pakistan, India, Bangladesh and Sri Lanka during the period of investigation. The analysis is conducted on the basis of the amount of carbon dioxide emissions as an indicator of region environmental degradation. The variables analyzed are economic growth, economic growth squared, environmental policy, foreign direct investments, population density and industrialization. Other empirical methods such as descriptive statistics, correlation analysis and panel unit root tests, cross sectional independence, slope homogeneity, Westerlund cointegration, and CS-ARDL were employed. Short- and long-term options are used to determine the CS-ARDL estimates. The chapter concludes with a description of how the results of the empirical investigation are assessed for reliability, based on information obtained during the fitting process, using the FGLS indicator. The descriptive statistics of the variables used in this study are presented in Table 2. The data set has 100 observations for each of the variables. Descriptive statistics provide information on variables that includes the average, dispersion and the min and max.

Table 2: Descriptive Statistics

Variable	Obs	Mean	Std. Dev.	Min	Max
CO ₂ Emissions	100	547.197	866.19	11.37	3014.52
Gross Domestic Product	100	5.936 $\times 10^{11}$	8.271 $\times 10^{11}$	3.717 $\times 10^{11}$	3.266 $\times 10^{11}$
Environmental Policy	100	.691	.528	.015	2.669
Foreign Direct Investment	100	1.11	.655	.096	3.621
Population Density	100	554.236	376.063	200.912	1328.625
Industrialization	100	26.044	4.628	17.159	34.594

The study variables' descriptive statistics are shown in Table 2. CO₂ emissions range from 11.370 to 3,014.520, with a mean of 547.197 and a standard deviation of 866.190. The variation is caused by the differences in the economic size, energy use, industrialization, and population factors of the South Asian countries that we surveyed. GDP also exhibits substantial variation, with a mean of (5.936×10^{11}) , a standard deviation of (8.271×10^{11}) , and values ranging from (3.717×10^{10}) to (3.266×10^{12}) . The large variance of GDP shows us that the countries involved differ from each other significantly in terms of economy.

The values of environmental policy vary widely with an average value of 0.691, but the standard deviation is equal to 0.528, and the interval of the possible values is given by (0.015–2.669). The value of FDI equals to 1.110 with a range from the number of 0.096 to the number of 3.621. The number of results for the value of population density ranges from 200.912 to 1,328.625, with a mean of 554.236. The range of industrialization rates is from 17.159 to 34.594, with an average of 26.044. The overall picture is that the data have a degree of variance among the variables needed to explore the relationship between environmental policy, economic growth and CO₂ emissions. The correlation matrix (Table 3) lists the relationships between the variables that were used in the analysis. The calculated correlation coefficients point to a preliminary comprehension of the variables' relationship.

Table 3: Correlation Matrix

Variables	CO ₂	GDP	EP	FDI	PD	IND
ln CO ₂	1.000					
ln GDP	0.291	1.000				
ln EP	-0.452	0.451	1.000			
ln FDI	0.383	0.343	0.331	1.000		
ln PD	0.171	0.143	0.578	-0.244	1.000	
ln IND	0.126	0.094	0.153	0.178	0.310	1.000

CO₂ emissions are positively correlated with GDP, with a coefficient of 0.291 (Grossman & Krueger 1995; Stern 2004), meaning that more economic activity is linked to higher CO₂ emissions. However, this may also result in increased energy consumption and more stress on the environment as a result of scale effects. The environmental policy component is negatively correlated with CO₂ emissions (-0.452) indicating that environmental policy could help to reduce pollution by restricting pollution-generating activities and encouraging environmentally friendly production methods. This association is not to be viewed as a causal one, however. The CO₂ emissions are positively related with FDI (0.383), This could be due to the growth of industrial and energy-consuming activities in countries that have less stringent environmental regulations, which would provide support to the “unexpected consequences” hypothesis (Copeland and Taylor, 2004). CO₂ emissions are slightly positively correlated with population density (0.171), indicating that the need for transportation, household energy consumption, waste production and infrastructure development are correlated with higher CO₂ emissions. In addition, the correlation between industrialization and CO₂ emissions of 0.126 is positive, which means that CO₂ emission increases with the increase of industrialization and energy use. Environmental policy and foreign direct investment are two positive predictors related to GDP (0.451 and 0.343, respectively). The highest correlation with density of population (0.578) is with environmental policy. The values given do not suggest that there is much multicollinearity; however, further formal tests such as variance inflation factor (VIF) should be conducted. The panel data series' CIPS and CADF test results are presented in Table 4. Note that these tests look for panel-to-panel dependency.

Table 4: Unit Root Test

Variables	CIPS		Decision	CADF	
	I (0)	I (1)		I (0)	I (1)
ln CO ₂	-1.214	-4.351***	I (1)	-1.324	-4.242***
ln GDP	-1.119	-6.123***	=	-1.592	-3.711***
ln GDP ²	-1.217	-5.124***	=	-1.616	-3.767***
ln EP	-0.891	-4.210***	=	-1.121	-3.898***
ln FDI	-1.315	-3.919***	=	-1.763	-3.028***
ln PD	-1.151	-3.717***	=	-1.453	-4.876***
ln IND	-1.204	-3.582***	=	-1.242	-4.146***

Based on the information provided in the tables, the results of all the variables have been transformed from non-stationary at the level to stationary at the first difference. With respect to CO₂ emissions, the CIPS statistic is -1.214 at level, and -4.351 at first difference, both of which are significant at 1% level. Similarly, the CADF statistic is higher before and after first difference, and is found to be stationary at 1% significant level. It is the same in the case of GDP, GDP squared, environmental policy, foreign direct investment (FDI), population density and industrialization, for which first difference statistics are significant at 1% level and level statistics are not significant. As a consequence, all variables can be considered to be integrated of order one (I(1)). All variables have the same order of integration, as a result of which a stable long term relationship between the variables can be tested using panel cointegration techniques. From the literature, Westerlund (2007) and Chudik & Pesaran (2015) showed that the dynamics of the long-run and short-run can be analyzed using the Westerlund cointegration test and CS-ARDL estimation. The results from Pesaran's cross sectional dependence test are presented in Table 5. The null hypothesis of this test is that the cross-sectional entities are independent of each other.

Table 5: CSD Test

Variable	CD-test	p-value
Ln CO ₂	8.312	0.000
Ln GDP	11.34	0.000
Ln GDP ²	18.94	0.000

Ln EP	8.22	0.000
Ln FDI	15.22	0.000
Ln PD	14.48	0.000
Ln IND	17.52	0.000

The CD testing results are good and a statistically significant value for each variable in the study. The value of the CD test was 8.312 with a p-value of 0.000 for the indicator of CO₂ emissions. The indicators studied (GDP, GDP squared, environmental policy, FDI, population density and industrialization) were found to be statistically significant with respective p-value of 0.000. Thus, the null hypothesis of independence of the cross sections for all variables could be rejected. This suggests that changes in the economy and environment of some countries in South Asia are referring to changes in other countries in the region. This interdependence can be influenced by the trade relations between the countries in the region and by the common energy.

Table 6 shows the outcomes of applying for the Pesaran and Yamagata slope homogeneity test. Under the hypothesis, the slope coefficient values of the countries in the panel are equal. Under the hypothesis, the slope coefficient values are equal for the countries in the panel. The adjusted delta statistic is now equal to 17.817 ($p < 0.001$) and the delta statistic is now equal to 14.543 ($p < 0.001$).

Table 6: Slope Homogeneity Test

Test	Stat	P
Δ Stat	14.543***	<0.001
Adj Value	17.817***	<0.001

The statistical significance of the two results presented shows that the slope uniformity hypothesis is not valid. Thus, it can be inferred that the impact of these factors such as GDP growth, green initiative and foreign investments, population density and industrialization can be different in Pakistan, India, Bangladesh and Sri Lanka. Additionally, the slope differences between the countries studied could be due to variation in institutional characteristics, economic size, energy use, industrial composition, environmental policies, and technological innovation. In other words, the impact of FDI on emissions is more pronounced in countries that have many foreign investments in energy-related industries, and has been found to be more significant when the investment is in the upstream sector of the energy value chain. It is equally valid for the efficacy

of environmental policies in countries with strong enforcement powers. It is the same for the efficiency of environmental policies in countries that have a strong measure of enforcement. The CS-ARDL model's long- and short-run estimates are shown in Table 7. The results indicate that all the explanatory variables are statistically significant at 1% level. The coefficients indicate that economic expansion, environmental policy, FDI, population density and industrialization affect CO₂.

Table 7: CS-ARDL

Var	Coeff	Std. Er	T-value	P-
LR Coefficients				
Ln GDP	0.312***	0.041	7.60	< 0.01
Ln GDP ²	-0.218***	0.048	4.54	< 0.01
Ln EP	-0.242***	0.072	3.36	< 0.01
Ln FDI	0.562***	0.165	3.40	< 0.01
Ln PD	0.752***	0.084	8.95	< 0.01
Ln IND	0.108***	0.025	4.32	< 0.01
Short-Run Coefficients				
Adjustment Term	-0.528***	0.078	-6.76	< 0.01
Ln GDP	0.152***	0.039	3.89	< 0.01
Ln GDP ²	-0.871***	0.092	9.46	< 0.01
Ln EP	-0.643***	0.178	3.61	< 0.01
Ln FDI	0.543***	0.129	4.20	< 0.01
Ln PD	0.452***	0.087	5.19	< 0.01
Ln IND	0.265***	0.073	3.63	< 0.01

The long-run GDP coefficient is significant and positive (0.312), meaning that sustainable production, consumption, transportation and electricity generation and fossil fuel use will contribute to an increase in CO₂ emissions. The coefficient of the square of GDP is negative and statistically significant (-0.218), however. Grossman & Krueger (1995) and Stern (2004) have confirmed the EKC (Environmental Kuznets Curve) theory as the relationship between economic development and environmental degradation is an inverted U, explaining the difference in this

case. In terms of environmental policy, it has a negative and statistically significant long-term coefficient of -0.242. This means that if environmental regulations are more effective, cleaner production, energy efficiency, technology development and internalization of external environmental impacts lead to lower CO₂ pollution. In contrast, the amount of foreign direct investment is proved to be 0.562, which means it pollutes. Depending on the nature of the investment, technology transfer, institutions and regulations, however, this can affect the environment of a country. (Copeland & Taylor, 2004). It has also a very high long-term coefficient of correlation of 0.752 with population density, meaning the higher the population density, the higher the demand for energy, transportation, housing and infrastructure. The industrialization coefficient is also positive at 0.108, which means that the carbon-intensive industries have a negative effect on the further degradation of the environment.

The short run coefficients are still applicable and their trend is similar. The other variables in environmental policy have a contrary effect, with GDP (0.543) and FDI (0.543), population density (0.452) and level of industrialization (0.265) all increasing emissions. With respect to the long-term coefficient, the turning point is negative (-0.871) and this supports the EKC hypothesis. To conclude, the error correction term is negative and significant (-0.528), which means that 51.8 per cent of the short-term discrepancy is corrected in one period. The turning point of the EKC is found using the following formula:

$$GDP^* = \frac{\beta_1}{2\beta_2}$$

Where $\beta_1 > 0$ and $\beta_2 < 0$

where β_1 and β_2 represent the coefficients of GDP and GDP squared, respectively. Using the estimated coefficients, the turning point is:

$$GDP^* = \frac{0.312}{2(-0.218)} = -0.716$$

Based on the transformed GDP scale, it is estimated that the turning point of the Environmental Kuznets Curve (EKC) is equal to -0.716. If the quadratic term $(\ln GDP)^2$ was computed and the GDP was expressed in natural logarithm form when the second-degree polynomial was computed, then the level of GDP would be $e^{0.716} = 2.05$. The coefficients of GDP and its square are positive

and negative, respectively. The EKC's inverted U-shape relationship is supported by this. This is because although economic growth leads to a rise in CO₂ emissions, innovation activities are later to become an asset to nature.

Table 8: Westerlund Test

	Ln GDP		ln GDP ₂		ln EP		ln FDI		ln PD		ln IND	
	t-value	p-value	t-value	p-value	t-value	p-value	t-value	p-value	t-value	p-value	t-value	p-value
lnCO₂	-3.9	< 0.01	-4.4	< 0.01	-5.1	< 0.01	-4.7	< 0.01	-4.8	< 0.01	-3.9	< 0.01

Available data shows that GDP, GDP squared, environmental policy, FDI, population density and industrialization have negative values of the test statistics that are statistically significant at 1%. The p-values for each variable are <0.01 and the test statistics are between -3.9 and -5.1. These findings reject the null hypothesis that certain variables do not have some kind of stable long-term correlation in the South Asian countries, as can be seen from the CO₂ emissions, economic growth, environmental policy, FDI, population density and industrialization. Under the theory of cointegration, the variables studied do not have time series behaviour, but they have long term movements together. Table 9 contains the FGLS estimates that were used to assess the robustness of the findings of the CS-ARDL. The general picture of the main estimates and FGLS results is similar.

Table 9: FGLS Results for Robustness

Variables	Coefficient	Std. Error.	T-Stat	P-value
Ln GDP	0.391***	0.037	10.56	< 0.01
Ln GDP ²	-0.510***	0.121	4.21	< 0.01
Ln EP	-0.219***	0.071	3.08	< 0.01
Ln FDI	0.621***	0.139	4.46	< 0.01
Ln PD	0.416***	0.042	9.90	< 0.01
Ln IND	0.303***	0.029	10.44	< 0.01

Note: 1% *** 5% ** 10% *

Similarly, the coefficient of GDP squared is -0.510 which is also significant at the same level, but the coefficient of GDP is positive, 0.391 with strong significance level at 1%. Once again, the results confirm the prediction of the environmental Kuznets curve theory that suggests an inverse U-shaped curve. Also, the value of the coefficient of environmental policy is negative (-0.219), which means that the variable is valid. The results of the current study are similar in direction to the CS-ARDLLR coefficient of -0.242, although they are slightly different due to the differences in the two studies. The estimated value of FDI coefficient is 0.621, which shows that the higher the level of foreign direct investment, the higher the CO₂ emissions. The coefficient of the population density variable is also positive (0.416), and the coefficient of the industrialization variable is also positive (0.303). All of these coefficients are significant at the 1% level. The results from the two estimation methods, CS-ARDL and FGLS are in line with each other, thus enhancing the credibility of the primary findings. In particular, it is apparent that both methods retain the sign of the estimated coefficient, so that the estimates are not only influenced by the estimation method used. Discussions

For the South Asian economies considered, the empirical results provide support for the Environmental Kuznets Curve (EKC) hypothesis. The relationship between GDP and CO₂ emissions is inverted U-shaped as evidenced by the positive and statistically significant GDP coefficient, and the negative and statistically significant coefficient of GDP squared. With the GDP's transformed, the point of inflection is found to be at 0.716. This shows that there is a certain threshold beyond which economic growth goes hand in hand with environmental degrading activities such as production, energy and resource use, etc. Once a certain level of income is achieved, however, some of the emissions reduction can come from technological advances, better energy efficiency, and cleaner production. This is in line with what Copeland and Taylor (2004) refer to as the "scale, composition, and technique effects" as well as additional research on the Environmental Kuznets Curve provided by Grossman and Krueger (1991), Selden and Song (1994), Dinda (2004), Stern (2004), and others. Environmental policy has had a negative effect, both in the short and long term, on CO₂ emissions. The results support the concept of Pigou that environmental taxes are able to help reduce pollution because they make polluting activities more costly and thus stimulate the development of environmentally friendly technologies. The empirical results of Bashir et al. (2020) with the aim of ecological sustainability through environmental taxation are compatible. The positive and significant effects of foreign direct investment (FDI) on

the CO₂ emission was confirmed. The result is in line with the pollution haven theory (Pigou, 1920), which suggests that the developing countries have the opportunity to win industries with high pollution levels because they have fewer environmental restrictions and lower production costs. This finding corroborates Copeland and Taylor's theories. The type of investment, regulatory quality, and technology transfer aspects of FDI, however, as indicated in most literature determine the impact of FDI on the environment (Demena & Afesorgbor, 2020). The highest positive correlation between population density and environmental quality indicates that the addition of population density will significantly influence environmental quality. The emissions will be higher due to increased demand for services, such as transportation, housing, electricity, water, and waste management services. Similarly, it can be concluded that the substantial positive effect of industrialization suggest the existence of the scale effects of industry and intensive energy use and fossil fuels. This signifies how critical it is to improve energy efficiency, urban planning and industrial technologies for sustainable development. Moreover, the error-correction coefficient is quite negative (-0.528), suggesting that about 528.8% of the short run disequilibrium is corrected in one period. Therefore, evidence of a long run relationship between variables.

4. Conclusion

This study examines the impact of environmental policy on CO₂ emissions in Sri Lanka, Pakistan, India and Bangladesh (2000-2023). GDP's coefficient is positive, and GDP²'s coefficient is negative, indicating that this is in line with the Environmental Kuznets Curve hypothesis. It reflects the concept that as the economy grows, so do emissions, but that it can also become cleaner at some point in the future, using the most advanced technologies, energy-efficient processes and environmentally-friendly production practices. Environmental policy plays a major role in minimizing CO₂ emissions in the short and long term by stressing the importance of environmental taxes and appropriate regulation. FDI, population density and industrialization are on the other hand forces that promote the expansion of emissions. The positive effect of the foreign direct investment (FDI) suggests that investments in polluting technologies are moving to the countries being considered; the impact of population density and industrialization can be explained by the increasing load due to urbanization, energy consumption and production based on fossil fuels. Environmentally responsible transportation, waste management and urban planning are important, as indicated by the high correlation of the highest coefficient with population density. In addition,

the positive impact of industrialization further corroborates this finding, and the need for cleaner technologies and more energy efficient production methods is evident. This is further supported by the large negative coefficient of the error correction term which suggests that the short-term imbalance in the given variables is corrected by around 528.8% in one period. To sum up, it is suggested that for environmental sustainability in South Asian countries a comprehensive approach towards policy is necessary, which should combine effective environmental taxes, technologies, functional acquisition of FDI, sustainable industrialization, efficient population and urban management.

5. Policy Implication

In view of these results, it is recommended that there is an opportunity to build the implementation and enforcement of environmental taxes in South Asian countries. Cleaner technologies and energy sources can be financed with funds obtained from ecological taxes. Although GDP growth leads to higher CO₂ emissions up until the turning point of the EKC, it is the technological advancement that helps government authorities to promote clean economic growth. This positive impact of FDI makes the role of enhancing environment for foreign investment important. Emission standards must be set and a procedure for environmental impact assessment must be put in place for projects financed by foreign investors to promote green technologies. The population density factor gave the best results with respect to emission, therefore, Sustainable Urbanization, waste management, public transportation and energy efficient housing are of high urgency.

Lastly, the positive effects of industrial development necessitate moving away from conventional energy-intensive production approaches towards cleaner ones. The government should come up with a scheme, which will encourage renewable energy, energy saving techniques, and cleaner manufactures. There are some limitations to the present investigation. It examines just a few countries in South Asia for lack of data, and the results may be difficult to extrapolate to developing economies in general. The study does not disaggregate the environmental tax to account for differences between a carbon tax and an energy tax, and other forms of environmental tax. In addition, there is no consideration of emissions by sector and only macro-economic data are used in the analysis. It also does not factor in the use of renewable energy.

Further research could be conducted based on the findings of this study by examining more countries from the South Asian and other developing countries, using disaggregated environmental

tax measures, as well as focussing on environmental carbon emissions at the sectoral level. Further work should be done on the moderation role of renewable energy, trade openness and technological progress on growth and sustainability. In-country research can help make the link between environmental policy, economic growth and sustainability stronger.

References

- [1] Adanma, U. M., & Ogunbiyi, E. O. (2024). A comparative review of global environmental policies for promoting sustainable development and economic growth. *International Journal of Applied Research in Social Sciences*, 6(5), 954–977.
- [2] Bhattacharjee, S., Pulikkeel, U., Amoli, V., Sk, M., Thapa, R., Chowdhury, B., ... & Bhaumik, A. (2025). Boosting the Simultaneous Conversion of Glycerol and CO₂ to Lactate and Formate Using ZrO₂-Supported NiO Catalyst. *Advanced Functional Materials*, 35(44), 2502434.
- [3] Bashir, M. F., Ma, B., Shahbaz, M., Jiao, Z., & Xue, B. (2020). The nexus between environmental tax and carbon emissions with the roles of environmental technology and financial development. *PLOS ONE*, 15(11), Article e0242412.
- [4] Bekun, F. V., Gyamfi, B. A., Olasehinde-Williams, G., & Yadav, A. (2024). Revisiting the foreign direct investment–CO₂ emissions nexus within the N-EKC framework: Evidence from South Asian countries. *Sustainable Futures*, 8, Article 100357.
- [5] Chudik, A., & Pesaran, M. H. (2015). Common correlated effects estimation of heterogeneous dynamic panel data models with weakly exogenous regressors. *Journal of Econometrics*, 188(2), 393–420.
- [6] Copeland, B. R., & Taylor, M. S. (2004). Trade, growth, and the environment. *Journal of Economic Literature*, 42(1), 7–71.
- [7] De Hoyos, R. E., & Sarafidis, V. (2006). Testing for cross-sectional dependence in panel-data models. *The Stata Journal*, 6(4), 482–496.
- [8] Demena, B. A., & Afesorgbor, S. K. (2020). The effect of FDI on environmental emissions: Evidence from a meta-analysis. *Energy Policy*, 138, Article 111192.
- [9] Dinda, S. (2004). Environmental Kuznets curve hypothesis: A survey. *Ecological Economics*, 49(4), 431–455.
- [10] Fullerton, D., & Muehlegger, E. (2019). Who bears the economic burdens of environmental regulations?. *Review of Environmental Economics and Policy*, 13(1), 62–82.
- [11] Grossman, G. M., & Krueger, A. B. (1991). Environmental impacts of a North American Free Trade Agreement. *National Bureau of Economic Research Working Paper No. 3914*.
- [12] Grossman, G. M., & Krueger, A. B. (1995). Economic growth and the environment. *The Quarterly Journal of Economics*, 110(2), 353–377.

- [13] Gujarati, D. N., & Porter, D. C. (2009). *Basic econometrics* (5th ed.). McGraw-Hill.
- [14] Intergovernmental Panel on Climate Change. (2022). *Climate change 2022: Mitigation of climate change*. Cambridge University Press.
- [15] Kanval, N., Ihsan, H., Irum, S., & Ambreen, I. (2024). Human capital formation, foreign direct investment inflows, and economic growth: A way forward to achieve sustainable development. *Journal of Management Practices, Humanities and Social Sciences*, 8(3), 48–61.
- [16] Köppl, A., & Schratzenstaller, M. (2023). Carbon taxation: A review of the empirical literature. *Journal of Economic Surveys*, 37(4), 1353–1388.
- [17] Mahmood, N., Zhao, Y., Lou, Q., & Geng, J. (2022). Role of environmental regulations and eco-innovation in energy structure transition for green growth: Evidence from OECD. *Technological Forecasting and Social Change*, 183, 121890.
- [18] Mohsin, M., Abbas, Q., Zhang, J., Ikram, M., & Iqbal, N. (2019). Integrated effect of energy consumption, economic development, and population growth on CO₂ based environmental degradation: A case of transport sector. *Environmental Science and Pollution Research*, 26(32), 32824–32835.
- [19] Nasrollahi, Z., Hashemi, M. S., Bameri, S., & Mohamad Taghvae, V. (2020). Environmental pollution, economic growth, population, industrialization, and technology in weak and strong sustainability: Using STIRPAT model: Z. Nasrollahi et al. *Environment, Development and Sustainability*, 22(2), 1105–1122.
- [20] Nur Mozahid, M., Akter, S., & Hafiz Iqbal, M. (2022). Causality analysis of CO₂ emissions, foreign direct investment, gross domestic product, and energy consumption: Empirical evidence from South Asian Association for Regional Cooperation countries. *Environmental Science and Pollution Research*, 29(43), 65684–65698.
- [21] O'Brien, R. M. (2007). A caution regarding rules of thumb for variance inflation factors. *Quality & Quantity*, 41, 673–690.
- [22] Onwe, J. C., Ullah, E., Ansari, M. A., Sahoo, M., & Dhayal, K. S. (2024). Industrialization meets sustainability: Analysing the role of technological innovations, energy efficiency and urbanisation for major industrialized economies. *Journal of Environmental Management*, 372, 123297.

- [23] Organisation for Economic Co-operation and Development. (2017). *Taxing energy use 2017: The Netherlands*. OECD Publishing.
- [24] Perera, A. I. S. (2025). Energy, economic growth and foreign direct investment on environmental degradation in South Asian countries. *South Asian Journal of Social Studies and Economics*, 22(5), 240–262.
- [25] Pesaran, M. H. (2004). General diagnostic tests for cross section dependence in panels. *CESifo Working Paper No. 1229*. CESifo.
- [26] Pesaran, M. H. (2007). A simple panel unit root test in the presence of cross-section dependence. *Journal of Applied Econometrics*, 22(2), 265–312.
- [27] Pesaran, M. H., & Yamagata, T. (2008). Testing slope homogeneity in large panels. *Journal of Econometrics*, 142(1), 50–93.
- [28] Pigou, A. C. (1920). *The economics of welfare*. Macmillan.
- [29] Sattar, A., Tolassa, T. H., Hussain, M. N., & Ilyas, M. (2022). Environmental effects of China's overseas direct investment in South Asia. *SAGE Open*, 12(1), 1–15.
- [30] Selden, T. M., & Song, D. (1994). Environmental quality and development: Is there a Kuznets curve for air pollution emissions? *Journal of Environmental Economics and Management*, 27(2), 147–162.
- [31] Shahzad, U. (2020). Environmental taxes, energy consumption, and environmental quality: Theoretical survey with policy implications. *Environmental Science and Pollution Research*, 27(20), 24848–24862.
- [32] Spash, C. L. (2021). 'The economy' as if people mattered: Revisiting critiques of economic growth in a time of crisis. *Globalizations*, 18(7), 1087–1104.
- [33] Stern, D. I. (2004). The rise and fall of the environmental Kuznets curve. *World Development*, 32(8), 1419–1439.
- [34] Westerlund, J. (2007). Testing for error correction in panel data. *Oxford Bulletin of Economics and Statistics*, 69(6), 709–748.
- [35] Wolde-Rufael, Y., & Mulat-weldemeskel, E. (2023). Effectiveness of environmental taxes and environmental stringent policies on CO₂ emissions: The European experience. *Environment, Development and Sustainability*, 25(6), 5211–5239.