Technological Innovation and Environment Degradation in South Asian Countries

Ayesha Naz1, and Muhammad Ejaz2

1Department of International Economics, International Islamic University, Islamabad, Pakistan
2Department of Automation Engineering, Nanjing University of Aeronautics and Astronautics, Nanjing, China

Correspondence Author: Ayesha Naz (ayesha.naz@iiu.edu.pk)

Received June 08, 2022; Revised July 13, 2022; Accepted August 18, 2022

Abstract

This study is an attempt to analyze the impact of technological innovations on Environmental Degradation (ED) in selected South Asian countries over the period 1996 to 2019. The limited and inconclusive result on the association between technological innovation and the environment particularly in South Asia provides an impetus to explicitly reexamine this relationship. The current study is unique in using various greenhouse gases to measure environmental degradation. Moreover, technology is also bifurcated into all other technological innovations and environment-related technology (eco-innovation). Panel robust least square is used to obtain the results. The outcome shows that technological innovations and GDP is contributing to CO2 emissions. It means that these two variables have an unfavorable influence on the environment. However, eco-innovations appeared to be significant in reducing CO2 emissions and other greenhouse gases. Hence, eco-innovations are desirable to lessen the negative consequences on the environment. Low carbon technologies redefine the production and consumption pattern to offset the environmental damaging trend. Carbon emission rates critically depend on the future direction of technological innovations, hence, this study suggests increasing the degree of eco-innovations to protect the environment.

Index Terms: CO2 Emissions, Eco-Innovations, Environmental Degradation, Gross Domestic Product, Technological Innovations.

I. INTRODUCTION

Technology plays a critical role in accelerating growth to achieve socio-economic targets. Advancement in technology has taken the global scale of production and consumption to a significantly high level. The industrial revolution across the world has only become possible due to technological innovations. It serves as a powerful engine to meet the ever-increasing demand of the mass population. However, in order to achieve the target of high growth, the environmental quality has deteriorated [1]. For instance, more production creates more emissions of greenhouse gases which results in Environmental Degradation (ED). Therefore, multiple benefits of technology come with the cost to the environment in the form of pollution externality.

The current situation of the environment and the climatic condition is alarming. The balance of the natural ecosystem is disturbed by the pace of economic growth. Global warming and climate change has been felt earlier than expected. Environmental threats are a serious concern for all economies. Keeping in view the rapid depletion of natural resources now the researchers are more focused to achieve sustainable development. Moreover, low-carbon technologies are desirable to curb the negative impact on the environment. These technologies decrease the energy intensity in production activities, hence, reducing carbon emissions. Therefore, the role of environmentally related technological innovations is important for sustainability targets [2].

Innovations in technologies can enhance the level of emissions in the environment, or mitigate or substitute existing polluting activities. Past literature shows mixed and inconclusive results on the relationship between Technological Innovation (TI) and Environmental Degradation or ED. The reason may be the difference in sample size, measuring methodologies, or period of analysis. However, limited literature is found in South Asian countries regarding the impact of TI on ED. Therefore, in this study, we have addressed this issue in a selected sample of five South Asian countries. Furthermore, most of the previous literature has measured ED with CO2 emissions as it is considered the main pollutant. However, in this study, we are not only using CO2 emissions to measure ED but we have also taken other greenhouse gases which include nitrous oxide, methane, Hydro Fluoro-Carbons (HFC), Per Fluoro-Carbons (PFC), and Sulphur Hexa-Fluoride (SF6). Another contribution of the study is that it explicitly uses technological innovation and eco-innovations (environment-related technology) in the analysis to provide conclusive results regarding their impact on environmental degradation or ED.

Figure I shows the trend of CO2 emission in South Asian countries. It is evident from the graph that ED has increased in the South Asian region over the reported period. Among the five selected countries, India is at the top in creating CO2 emissions and thereby affecting the environment of the entire region. Most developing economies rely on non-renewable resources in order to achieve growth targets. However, the cost of this growth
results in rapid CO₂ emissions. Pakistan and Sri Lanka are almost at the same level with some fluctuations.

![Figure 1: Trend of CO₂ Emission in South Asian Countries](image)

Bangladesh and Nepal are generating a relatively low level of CO₂ emissions in the environment. In general, climatic conditions of this region have been severely affected by carbon emissions. In this study, we will analyze the impact of TI on CO₂ emissions and other gases. Output growth is also taken into consideration as more production also generates more emissions.

The specific research questions which are addressed in this study are as follows:

- **RQ1**: what is the impact of TI on CO₂ emissions and other gases?
- **RQ2**: what is the impact of eco-innovation on CO₂ emissions and other gases?
- **RQ3**: How much output growth is contributing to ED?

These research questions will provide the guideline to mitigate uncertain future emissions rates. It will also determine the direction of TI in order to slow down the pace of ED. The remainder of this research study is organized as follows; the relation between TI and ED is discussed in detail in Section II of the literature review. The methodology is outlined in Section III while results are provided in Section IV. The last section provides the conclusion and policy suggestions based on the findings of the study.

II. LITERATURE REVIEW

The impact of TI on ED remained very much an open question due to ambiguous results of this relationship. The nature and scope of TI are significantly important in affecting environmental conditions. Sustainable development goals cannot be achieved without taking into account environmental considerations. Collective efforts are required at the national and international levels to protect the rapid depletion of environmental resources. On one side TI is achieving the production targets while on the other side it is also affecting the environment. The nexus between technological innovation and ED has been studied by various researchers. The existing literature is divided into two categories based on the impact of TI on ED. The first category of the literature shows the adverse effect of technology on the environment while the second category shows the favorable impact of TI in reducing ED.

Among the first category of literature, the relationship between TI and CO₂ emissions is examined in Japan [3]. The results showed a positive association between the two variables, hence, it implies that TI is damaging the environment. Moreover, similar findings have been reported in BRICS (Brazil, Russia, India, China and South Africa) countries [4].

A positive relationship is also established in some African countries [5]. In several emerging economies, it is observed that ED is increasing with new technologies [6]. Most countries across the globe are focused on such innovations which give more consideration to enlarging production capacity and the extent of eco-innovation is not in question. Therefore, the literature reveals that technological innovation contributes to CO₂ emissions and creates serious challenges for the environment. However, the second category of literature establishes a negative connection between technological innovation and CO₂ emissions. In this regard, the results of the study showed that TI is important in mitigating the effect of CO₂ emissions [7]. Similarly, another study also found a beneficial effect of TI on CO₂ in a selected sample of five OECD (Australia, Austria, Belgium, Canada, Chile, Colombia, Costa Rica, Czech Republic, Denmark, Estonia, Finland, France, Germany, Greece, Hungary, Iceland, Ireland, Israel, Italy, Japan, Korea, Latvia, Lithuania, Luxembourg, Mexico, the Netherlands, New Zealand, Norway, Poland, Portugal, Slovak Republic, Slovenia, Spain, Sweden, Switzerland, Turkey, the United Kingdom and the United States) countries [8].

The results of a study are also in line with the second category of literature [9]. TI may reduce ED through efficient utilization of energy. Moreover, it also reduces the demand for energy which can have a beneficial effect on ED. TI also transforms and replaces the traditional techniques of production into the most efficient modes with low emissions.

Some studies highlighted the importance of environmental innovations to lessen the most persistent environmental challenges [10-12]. Environmental-related technological innovations served as a major driver in decreasing CO₂ emissions in 30 provinces of China [13].

Furthermore, diversification and modification in eco-innovations are viewed as an important component in controlling environmental hazards in G-7 (Canada, France, Germany, Italy, Japan, the United Kingdom, the United States and the European Union) countries [14].

The aim of eco-innovation is to use such technologies which have low emission, low waste, clean production, and material efficiency [15]. It is also observed that eco-innovation may modify the production systems and unsustainable technologies [16], and [17].

Eco-innovations have restructured the composition of products, their processing, and organization. It also has changed the marketing approach that has brought multiple benefits to the environment.

Existing literature shows inconclusive results regarding the impact of TI on ED, therefore, it provides the rationale to examine this relationship in detail on a broader scale.
III. METHODOLOGY

The TI has a twofold effect on ED. First, it can help in lessening the CO₂ emissions and other greenhouse gases through low carbon technologies. Second, it may damage the environment if there is a usage of more non-renewable resources. There can be various channels through which the effect of TI can be studied on the environment. Green technology or environmentally friendly technologies helps in preventing the environment. However, the traditional modes of production are aimed at producing in bulk which requires intense use of energy. Therefore, it pollutes the environment. Technologies targeted at achieving higher growth are more focused on production capacity rather than sustainable development. The link between technology and ED is presented in figure II. Technology is forked into two groups i.e. TI and eco-innovations. TI shows all the technological innovations other than environment-related technology while eco-innovations take into account only environment-related technologies.

\[ ED_{index_{it}} = \alpha_1TI_{it} + \alpha_2EcoIN_{it} + \alpha_3GDP_{it} + \mu_{it} \] (3)

In eq. (3) the EDindex is showing the environmental degradation index which is constructed by aggregating different types of greenhouse gases along with CO₂ emissions. Nitrous oxide emissions, methane emissions, CO₂ emissions, and other greenhouse gases HFC, PFC, and SF6 are included in this index.

B. Data and Variables

The study uses annual data from selected five South Asian countries. The sample includes Bangladesh, India, Pakistan, Nepal, and Sri Lanka. Afghanistan and Maldives have been dropped from the analysis due to data availability issues in these countries. The study is conducted over the period from 1996 to 2019. Data on CO₂ emissions (metric tons per capita) and GDP per capita are collected from the database of the World Bank (www.worldbank.org). Data on technological innovation (patents statistics) and eco-innovation (patents in environment-related technologies) are extracted from the OECD database (stats.oecd.org). ED index is the aggregation of nitrous oxide (thousand metric tons of CO₂ equivalent), methane emissions (kt of CO₂ equivalent), F-gases (Hydro Fluoro-Carbons and Per Fluoro-Carbons), Sulphur Hexa-Fluoride (SF6), and CO₂ emission. The ED index is constructed by taking a simple average of the above-mentioned gases. Data are obtained from the World Bank database. The data of all the variables are publicly available and can be extracted through given web addresses.

C. Estimation Method

A standard panel data estimation procedure is used to examine the impact of TI on ED. First, panel unit root tests are applied to check the stationarity of the data. In this regard, various tests are available which include Pesaran and Maddala types tests [18], and [19]. Coefficients are then estimated by using panel robust least squares. Robust least square is applied to obtain reliable estimates as it overcomes the issue of influential observations and outliers [20]. Robust least square is preferred over ordinary least square as it can be applied with less restricted assumptions. Data set with non-normality, missing values, outliers or having the problem of multi-collinearity produces biased results. However, a robust least square procedure may accommodate these issues. Eq. (2) and eq. (3) are transformed into log forms to avoid unit biasness.

IV. RESULTS AND DISCUSSION

A. Unit Root Test

The first step is to test the stationarity of the series. The results are presented in table I.
The result shows that all the series are stationary at the first difference (1) except TI, which turns out to be stationary at level I (0).

The next step is to estimate the coefficients. In order to obtain the estimated value, a robust least square is applied to generate this result. The outcomes are presented in Table II.

<table>
<thead>
<tr>
<th>Variable</th>
<th>Coefficient</th>
<th>St. Error</th>
<th>t-Stat</th>
<th>Prob.</th>
</tr>
</thead>
<tbody>
<tr>
<td>TI</td>
<td>0.285***</td>
<td>0.019</td>
<td>14.55</td>
<td>0.000</td>
</tr>
<tr>
<td>EcoIN</td>
<td>-0.068***</td>
<td>0.043</td>
<td>-1.99</td>
<td>0.048</td>
</tr>
<tr>
<td>GDP</td>
<td>0.696***</td>
<td>0.064</td>
<td>10.82</td>
<td>0.000</td>
</tr>
<tr>
<td>R-Squared</td>
<td>0.801</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Adjusted</td>
<td>0.796</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

The results show that all the variables are significant and effecting CO2 emissions. TI is significant at a 1% level and shows a positive relationship with CO2. It implies that if TI increases by 1%, it will pollute the environment by 0.285% through CO2 emissions. However, eco-innovation indicates a negative association with CO2. It shows that a 1% increase in eco-innovation results in CO2 reduction by 0.068%.

There are several channels through which eco-innovation can directly or indirectly affect environmental conditions. For instance, eco-innovations develop efficient advancements in technology that can directly influence energy efficiency and consequently reduce energy consumption. Low carbon technologies achieve the target of growth without putting pressure on the environment. Furthermore, another important channel through which eco-innovation can control the depletion of natural resources is economic restructuring and optimization. It changes the traditional factors of production into an innovation-driven approach that significantly helps in the reduction of CO2 [21], and [22].

Eco-innovation also moderates the negative environmental influences through refinement and modification of the existing products and services. It applies new procedure and process that reduces the environmental threats and the negative effects on resources [23].

Hence, eco-innovation contributes to the reduction of CO2 emissions. Moving further in the table, GDP per capita is also showing a positive link with CO2 emissions. In this analysis, economic growth has appeared as a cause of ED. Higher production of goods and services is linked to higher pollution as the focus of the economies is to grow without taking into account the environmental cost. Therefore, achieving the growth target rapidly depletes natural resources with excess carbon emissions.

However, negative consequences on the environment can be curtailed through eco-innovations. The model is a good fit as it is confirmed by the values of R-Squared and Adjusted R-Squared. These values should be high and closer to 1.

Table III: Panel Robust Least Square Estimate of eq. (3)

<table>
<thead>
<tr>
<th>Variable</th>
<th>Coefficient</th>
<th>St. error</th>
<th>t-Stat</th>
<th>Prob.</th>
</tr>
</thead>
<tbody>
<tr>
<td>TI</td>
<td>0.655***</td>
<td>0.041</td>
<td>15.75</td>
<td>0.000</td>
</tr>
<tr>
<td>EcoIN</td>
<td>-0.068***</td>
<td>0.031</td>
<td>-2.19</td>
<td>0.000</td>
</tr>
<tr>
<td>GDP</td>
<td>1.356***</td>
<td>0.136</td>
<td>9.95</td>
<td>0.000</td>
</tr>
<tr>
<td>R-squared</td>
<td>0.720</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Adjusted</td>
<td>0.782</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Table III shows the results of eq. (3). In this equation a comprehensive EDindex is used rather than using a single indicator to measure ED. The results are similar to the previous findings. However, the magnitude of GDP per capita is slightly high in comparison with the earlier finding. In short, the results show that eco-innovation is an effective technology to reduce the adverse effect on the environment whether it is CO2 emissions or other greenhouse gases. The results are clearly indicating that other technological innovations are harmful to the environment as these advancements are not focused to tackle environmental issues. Therefore, it is a need of time, to invest in eco-innovations and to expand the use of these technologies at every level ranging from domestic to commercial. All types of greenhouse gas emissions can be curtailed through eco-innovations. Moreover, the negative effect of growth on ED can be decreased by replacing the traditional technologies with efficient environment-friendly technologies.

V. CONCLUSION

In the modern world, the importance of technology is evident in every sphere of activity. However, its impact on the environment is a debatable issue as some studies show an adverse effect of technology on the environment while other shows beneficial results. Hence, in this study, we have reexamined the relationship between these two variables. One of the reasons for this research is the availability of limited literature on the association between technology and ED particularly in the case of South Asian countries. Second, most of the previous literature has used a single proxy of CO2 emissions in order to measure ED. However, in this study, we have used various other greenhouse gases for ED. In this regard, the aggregation of CO2 emissions, nitrous oxide emissions, methane emissions, HFC, PFC, and SF6 are used to measure ED. Moreover, this study deviates from the existing by dividing the TI into two
groups. Hence, the analysis is carried out to determine the impact of technological innovation and eco-innovation separately on ED. The study constructs two models in eq. (2) and eq. (3) to analyze the impact of TI on the environment using CO2 emissions and EDIndex respectively. A standard panel data procedure is followed to obtain results. Panel robust least square is used to estimate equations. The results show that all other technological innovations have a negative effect on the environment while eco-innovations are appeared to be a powerful tool to reduce ED. The future direction of TI is critically important in affecting the environment. If the focus is not shifted to low carbon technologies, particularly in the South Asian region, then future emissions rates may result in environmental disasters. Hence, ED is sensitive to all types of technological innovations. Compromising behavior towards the environment to achieve growth targets can increase the severity of the environmental challenge. Generally, environmental issues are not the priority of middle-income and low-income countries because they have to achieve the production targets for domestic needs. Therefore, they invest in such technologies having production capacity rather than environment-friendly technologies. Individuals and collective efforts are required to slow down the environmental threats and more and more investment in eco-innovation can make the earth a better place for future generations.

Acknowledgment
The authors would like to thank almighty Allah first and then the management of International Islamic University, Islamabad, Pakistan, for their support and their assistance throughout this study.

Authors Contributions
Each author has equally contributed to achieving the objectives of this research study.

Conflict of Interest
The authors declare no conflict of interest.

Data Availability Statement
The data sources are provided in the study.

Funding
This research received no external funding.

References