Technological Innovation and Green Growth: Evidence from South Asia

misbah nosheen (✉ Misbah@hu.edu.pk)

Hazara University Faculty of Arts <https://orcid.org/0000-0003-4612-6269>

Kashif Raza Shah

Hazara University

Anam Hasan

Hazara University

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Abstract

Green growth means promote economic development and growth, while certify that natural assets continue to provide the resources and ecological. This research analyzes that how green growth is affected by technological innovation for South Asia (Bangladesh, Pakistan, India, Sri Lanka, and Nepal) economies during 1990 to 2019. Basic econometric tests such as Cross-section dependence test, Panel unit root tests and Wester Lund co-integration test is applied. Furthermore, we use the FMOLS and DOLS models for estimating the impact of CO₂ emissions on patent by resident, renewable energy consumption, foreign direct investment, and GDP per capita. The results of all panel unit root tests reveal that all the variables are stationary at a 1st difference. Westerlund panel co-integration test confirmed the long-run relationship. In both the FMOLS and DOLS models, the findings show that patent application by residents and renewable energy consumption have negative and statistically significant impacts on CO₂ emissions. While GDP has positive and statistically significant effect on CO₂ emissions and FDI has no effect on CO₂ emissions in both the long run and short run. The results recommend that government needs to take sustainable energy related source, for instance, renewable energy consumption which are beneficial to ecosystem as it increases green economy.

1. Introduction

Green growth indicates diminishing of pollution and greenhouse gas emissions and it is protecting the natural environment and increase in energy protection. The technological innovation upgrades green growth and climate change technologies. Green growth and technological innovation lead to improve sustainable development and it is beneficial for firms too. According to World Bank (2012) green growth is productive in its utilization of regular assets and clean in a sense that it limits contamination and ecological effects. Gua *et al.* (2020) investigated the attributes of an economic growth estimation designed with regards to green innovation. The study is explicitly based on Sustainable Development Goals Index (SGDI).

Carbon dioxide (CO₂) is an ozone harming element created because of human activities. Consuming petroleum products like coal, oil, and combustible gases, is the main sources of worldwide Carbon dioxide (CO₂) emissions. The human activities related to cement production, cutting of woodland just as the consumption of petroleum products like coal, oil, and flammable gas add to environmental degradation (Dauda et al., 2019). The relationship between CO₂ emissions and non-fossil fuel utilization has recognized by different research as the main reason of Carbon dioxide (CO₂) emission. When trade and FDI are done by contamination concentrated industries, the host faces a rise in Carbon dioxide (CO₂) emanations. This occurrence is a proof of the pollution haven hypothesis (PHH) (Rafindadi et al., 2018; Zhu et al., 2016) (Sun *et al.*, 2017).

A patent application by a resident is allowed for an invention, a product, or a cycle, which brings another specialized arrangement. The invention, which is to be ensured by a patent, should be new, valuable, utilitarian, and innovative, i.e., arrangement, for which the patent protection is looked for, ought not to be a conspicuous one. Patent protection is typically allowed for a new inventive product, its structure, and innovation. After the patent was granted, the patent proprietor has a selective option to keep others from business utilization of the protected innovation. Patent application includes significant data about inventive activities. The consequences reveal a pattern of growing coordinated efforts in innovative activities across the world in the course of recent many years, which may recommend that the world has started to accept the inchoative phase of "Techno-globalism" (Ma, & Lee, 2008).

Renewable energy consumption is the part between gross inland consumption of energy by renewable sources and aggregate (essential) gross inland energy consumption determined for a scheduled year. It is determined as the amount of the gross inland consumption of energy from infinite sources. Renewable energy source is characterized as inexhaustible non-fossil fuel sources: hydroelectric, solar, geothermal, biomass, nuclear electric power, natural gas, petroleum, and biogases. The all characterization of renewable energy consumption shows in the pie-chart is given below:

Source: U.S Energy Information Administration (2019)

The above pie-chart shows the share of renewable energy consumption characterization supply in 2019. Renewable energy sources (i.e., Biomass, geothermal hydropower solar) consider for 17.95% of net domestic generation in the first eight months of 2019 earlier renewable (EIAs, 2019).

Moving towards foreign direct investment (FDI) is an investment made by a firm or individual in one country into business interests arranged in another country. Although, FDI are recognized from portfolio benefit in which a financial expert simply buys the values of foreign-based organization. A few investigations set up that foreign direct investment enhances ecological supremacy (Zhu et al. 2016).

General research has been investigated on technological advance and green growth focuses on green innovation and consumption by the invention of green technologies also use clean energy. Technological development in this manner tends to both demand-based and creation-based emissions subsequently observed the guideline of the modern advancement (Yao, et al., 2018).

A research was conducted on the connection between the environmentally associated with the tariff on green development. The researchers observed that ecologically connected tax produced a positive impact on economic and green growth. However, the investigation discarded of the trade naturally connected financial plan on green development. They are concentrating on supply chain and ecological features (Rodriguez *et al.*, 2019).

Similarly, a study (Schumpeter, 1982) shows that technological modification is fundamental to permit a total response to natural defilement lacking sacrificing money related growth. Although, the issues are how can make this modification possible.

Sustainable energy sources are fuel sources which are constantly supplanted commonly and obtain directly or in a roundabout way from the sun or other normal developments and components of the climate (Ellabban *et al.*, 2014), (Baul and Alam, 2018).

One tool that has been successfully utilized to understand and improve the performance of economic growth is green growth where all resources inputs and output are associated with low carbon emissions. For this purpose, many climate change technologies have been developed and in use at global level. The policies are being made effect to the climate change technologies on green economic growth. Considering the effect of technological innovations on green development in the economy is beneficial for the way that, environmental change reduction of the innovations is ceaselessly imagined by these economies. Changing the energy sources will advance economic growth and improvement lacking of intensity environmental pollution. Technological innovations are a predominant channel to accomplish this underlying change toward economic growth. In the current study find the effect of technological innovation on green growth and how technological innovations improve green growth in selected five South Asian countries that are (Bangladesh, Pakistan, India, Nepal, and Sri Lanka) during 1990 to 2019. More specifically, the study aims to; 1) To access the impact of patent by a resident on carbon dioxide (CO₂) emissions in

South Asian countries. 2) To explore the impact of renewable energy consumption on carbon dioxide (CO₂) emissions. 3) To analyze the impact of foreign direct investment on carbon dioxide (CO₂) emissions. 4) To find the impact of GDP per capita on carbon dioxide (CO₂) emissions. Moreover we found most of the study related to green growth. This study focused on the effects of technological innovation on green growth. Most of the innovation factors focused on some developed countries like Germany, South Korea, Switzerland, Japan, and Austria, etc. This arises a question of their role for or rest of the world like lower income countries. Therefore, the study focuses on south Asian countries. Thirdly, the study employees new and updated techniques of estimation like cross sectional dependence, CADF and CIPS stationarity tests and Westerlund Cointegration test.

Section two discusses review of literature; section three explores model and methodology, section four discusses data analysis and results and section five deals with conclusion and policy implications.

2. Review Of Literature

Analysis on the effect of technological innovation on green growth in different countries has been subjected by an economist in the past.

Impact of technological innovation on green growth for selected South Asian countries is based on the endogenous growth model. Endogenous growth models his significant hypothetical system for understanding the growth cycle. These theories are significant because that they underscore that capital collection and innovations can instigate economic growth while diminishing returns can reduce it. This model shows how long-run economic growth can be achieve through spillovers and the scale effect of ideas and research within the economy (Onyimadu, 2015). According to the endogenous growth model, the roles and dynamics of innovation and discovery and all of the variables, Carbon dioxide emission (CO₂), Patent by the resident (PR), Renewable energy consumption (REC), Foreign direct investment (FDI), and GDP per capita (GDPPC). Thus endogenous growth theory investigates the long-run economic growth through technological transfers is provided.

Lee & Min, (2015) inspected that utilization an example of Japanese assembling firms during 2000 to 2010, and finds that the green R&D for Eco development can diminish carbon outflows and increment firm esteem. Amongst different ecological development factors, market management and legislative guideline are progressively considered to diminish carbon emanations.

Zhang & Da, (2015) showed that to locate the effective approaches to diminish carbon outflow power in China, the study used the LMDI method to break down the progressions of Chinas carbon emanations and carbon discharge force from 1996 to 2010, from the viewpoints of vitality sources and mechanical structure individually. At that point, the study acquaints the decoupling record by investigating the decoupling connection between carbon emanations and financial development in China. The outcomes demonstrate that, from one viewpoint, financial development showed up as the primary driver of carbon outflows increment in the previous decades, while the diminishing of vitality power and the cleaning of conclusive vitality utilization structure assumed critical parts in controlling carbon emanations; then, the auxiliary business demonstrated the chief wellspring of carbon discharges decrease among the three enterprises and had generally higher potential. Then again, when the decoupling relationship is thought of, most years during the investigation time frame saw the relative decoupling impact between carbon discharges and monetary development, which showed that the decreasing impact of hindering components of carbon emissions was not exactly the driving impact of financial development, and the economy developed with expanded carbon

outflows; there showed up the total decoupling impact in 1997, 2000 and 2001, which suggested that the economy developed while carbon outflows diminished; while no decoupling impact was distinguished in 2003 and 2004.

Sannasse *et al.*, (2016) the studied observationally breaks down the effect of exchange on environmentally for the instance of the Small Island Developing State of Mauritius during 1976–2013. Since it's time-series data to represent plausibility of dynamism, an autoregressive dispersed slack model is utilized to show the determinant of Carbon dioxide (CO₂) emanation with a specific spotlight on exchange receptiveness. Investigation of the outcomes shows that exchange has contributed decidedly and altogether to the measure of (CO₂) in the nation in both the since quite a while ago run and short run. Such outcomes for Mauritius can be clarified by the occurrence of the assembling segment as a significant supporter of development since the mid-1980s. The nation, being an island absolutely without common assets, has laid an unmistakable focus on encouraging exchange receptiveness, which has prompted extended fare figures, most remarkably in the piece of clothing and material industry, supported by positive outer conditions, for example, special admittance to the EU and US markets, which have served to pull in FDI from East Asian NICs.

Ali *et al.*, (2017) this research analyzed the effect of urbanization on carbon dioxide emission in Singapore during 1970–2015. The autoregressive distributive lags (ARDL) approach is implied inside the examination. This study shows that uncovers a negative and huge effect of urbanization on carbon emanations in Singapore, which implies that metropolitan advancement in Singapore isn't a boundary to the development of ecological quality. In this manner, urbanization improves natural quality by diminishing carbon outflows in the example nation. The outcome likewise featured that financial development has a positive and critical effect on carbon emission, which recommends that monetary development diminishes ecological quality through its immediate impact of expanding carbon discharges in the nation. Notwithstanding the elevated level of urbanization in Singapore, this implies that 100 % of the general population is living in the metropolitan place; it doesn't prompt more natural debasement. Henceforth, urbanization won't be viewed as an impediment while starting approaches that will be utilized to lessen ecological corruption in the nation. Strategy creators ought to consider the nation's degree of financial development rather than urbanization while detailing arrangements to lessen ecological corruption, because of its immediate effect on expanding carbon dioxide emissions.

Zugravu-Soilita, (2017) this study analyzed that the effect of Foreign direct investments on industrial pollutants (CO₂, SO₂, NO_x, and BOD emanations) on an enormous example of exceptionally heterogeneous nations. By utilizing board information on assembling foreign direct investments from France, Germany, Sweden, and the UK, during 1995 to 2008, and by building up an observational model with "first" and "second request" cooperation conditions, the study explored the presence and the restriction of the most disputable FDI-instigated impacts on modern discharges, like, contamination refuge, Factor Endowments and contamination Halo speculations. The study has three fundamental discoveries: (1) focal theories connecting pollutant to FDI are found to act at the same time, with restricting impacts; (2) FDIs are related with contamination decrease, i.e., prevailing contamination radiance initiated impact, in nations with low to average cash-flow to-work proportion yet not very remiss natural guideline; (3) foreign direct investments have establish to expand contamination, like, winning contamination shelter and additionally aspect blessings incited impacts, in nations with normal capital enrichments and careless ecological guidelines, just as in all the capital bountiful nations, however with a littler size in nations having exacting natural guidelines as well as a high-gifted work power. Some particular and intriguing discoveries are examined concerning various FDI-beginning nations and FDI-have nation gatherings.

Kwon *et al.*, (2017) investigated that both specialized productivity and virtual environmental control (VEC) of 12 European nations during 1990 to 2015. The study utilizes a two-phase information envelopment examination (DEA). In the primary stage, the examination estimated the specialized proficiency of environmentally friendly power vitality advances (GET) related to petroleum derivatives, sustainable power source, and capacity advances of every nation for vitality age as to Carbon dioxide (CO₂) emanations by studying GET-related licenses. Utilizing the logarithmic mean Divisia list (LMDI), the investigation decayed Carbon dioxide (CO₂) outflows into the accompanying mechanical components: vitality power, fuel blend, and Carbon dioxide (CO₂) emanation coefficient. In the subsequent stage, they evaluated the VEC in every nation by examining GET patent changes using innovative work (R&D) venture at given changes in (CO₂) discharges. The outcomes found that various angles for every nation regarding specialized productivity and VEC, recommending possible degrees of both effective Carbon dioxide (CO₂) decreases and attractive GET improvement by utilizing reference nations as a benchmark. The examination results can add to setting up a powerful public innovation strategy and help in calls for normal duty and the dynamic investment of countries intending to environmental change.

Yii and Geetha, *et al.*, (2017) analyze the connection between the carbon dioxide emission and technological innovation for Malaysia during 1971 to 2013, the contributory relationship between technology innovation and carbon dioxide (CO₂) emission. The result of the VAR model shows that carbon dioxide (CO₂) emission is negatively connected to technology innovation in the short term. The results recommended that policy-makers should promote innovation analysis to help economic growth and ecological sustainability.

Kahouli *et al.*, (2018) study investigated that the four-route connection among electricity utilization, Carbon dioxide emissions, R&D stocks, and financial growth during 1990 to 2016, by executing a few methods: SUR, 3SLS, and GMM. The empirical methods determine that the four arrangements of conditions (power, CO₂, R&D, and development models) are assessed together with the arrangement of conditions. These methods make it conceivable to assess all the boundaries of the models simultaneously and tackle the issue of endogeneity. Nonetheless, the outcomes uphold the event of unidirectional causality among power and R&D stocks while different connections exist. From one perspective, there is unidirectional causality between R&D stocks and monetary development just as unidirectional causality between R&D stocks and CO₂ outflows, then again.

Mensah *et al.*, (2019) investigation shows the technological advance impact on green growth in (28) Organization for Economic Cooperation and development (OECD) economies during 2000 to 2014. Utilizing STIRPAT and IPAT models, the outcome discovered vehicle connected technology is useful for green growth in the Oceania sub-area. OECD Asia's innovations of the creation and preparation of merchandise has been useful for green growth. Environmental change innovations corresponding to age and broadcast of vitality are unfavorable to green growth in the OECD economies yet its effect is noticeable in Asia and Europe sub-boards.

Song *et al.*, (2019) analysed the effects of financial receptiveness and R&D investment on green economic during 2005 to 2015 in china. The outcomes found that economic openness and green financial growth have a nonlinear negative U-formed connection. Although the R&D positively affects green financial growth. The effect of the R&D scale on green economic growth is positive for quite a while, yet the effect is negative in the eastern and western districts in the recent time frame.

Hasnisah, *et al.*, (2019) studied the relationship among renewable and non-fossil fuel energy, environmental quality and financial growth, in 13 developing countries of Asia during 1980 to 2014 by using the OLS model. The existence of the inverted U-shape Environmental Kuznets Curve hypothesis has been found in 13 Asia countries.

Liobikiene and Butkus, (2019) studied that the economic growth, energy, and urbanizations effect the natural quality Of environment. The study appeared in their investigation for 147 selected countries during 1990 to 2012 for urban areas. The result shows that gross domestic product and urbanization added to decreasing carbon dioxide discharges. Hence, nations should consider the innovative change of growth and energy effectiveness as they look for sustainable economic growth.

Hao *et al.*, (2020) investigated the green growth in technological a sustainable climate for G7 countries during 1991–2017. The analysis employed second generation panel data method(s), for example, Cross-Sectionals Augmented Dickey-Fuller Distributive slack (CS-ARDL) model. The results found that theoretical and observational discoveries demonstrate that both straight and non-direct period for green growth diminishes carbon dioxide discharges. Additionally, ecological degradation, human resources and sustainable energy use are found to diminish carbon dioxide discharges.

Yasmeen et al., (2020) studied the function of technological innovations, natural guidelines, and urbanization in ecological cost during 2008 to 2018 in China. The study followed the GMM method to utilize the effect of technological growth, environmental system, and urbanization on environment. The outcomes showed that urbanization is negatively affects environmental proficiency at a public level.

Li *et al.*, (2020) used a panel threshold model to consider the effect systems of natural guideline on technological innovation. Thinking about industry heterogeneity, the study further investigates whether such instruments contrast in industry. The fundamental findings are: (1) the effect systems of ecological guideline on technological innovation is significant. (2) Apart from innovations balance, additionally the study found that ecological guideline can advance GTFP through increasing market focus and building green market passage boundaries in high-pollution discharge industries. (3) Such an upper hand is just successful for the time being as technological innovation investigates a positive impact in the long-run.

Yuan *et al.*, (2020) used panel data for 30 provinces in china during 2006 to 2015 and the study sys-GMM method for estimation. The results show that: (1) adaptable ecological arrangement can essentially encourage modern economical change. (2) Flexible ecological strategy has an altogether certain effect on mechanical development. (3) Environment administrative implementation directs the connection between adaptable natural strategy and mechanical development.

Extensive research has been done on CO₂ emissions. But up till now, no study has been found to use empirically CO₂ emissions for green growth in the south Asian countries. Additionally, there is a gap of study on the effect of technological innovation on green growth the countries. Hence, this investigation empirically seeks to make most important contributions to existing literature.

3. Model And Methodology

This section is composed of the detail about model and methodology. The secondary data is collected from World Development Indicators (WDI 2020) for South Asian countries that are; Bangladesh, Pakistan, India, Nepal, and Sri Lanka during 1990 to 2019. The carbon dioxide (CO₂) emission is measure in (metric tons per capita) that act as dependent variable while patent by resident (resident), Renewable energy consumption (%of total final energy consumption), foreign direct investment (% of GDP), and GDP per capita (constant 2010US\$) are independent variable.

Analyzing the connection between technological innovations related to green growth, econometric model takes the form.

$$CO_2 = f(PR, REC, FDI, GDPPC)$$

The above figure (3.1) shows the association moving from independent variables patent by resident (PR), Renewable energy consumption (REC), foreign direct investment (FDI), GDP per capita (GDPPC) and carbon dioxide emission (CO_2) are dependent variable.

The econometric model state that carbon dioxide (CO_2) emissions, PR represent patent by resident, REC represent the renewable energy consumption, FDI represent the foreign direct investment, GDPPC represent the GDP per capita (constant 2010US\$). The technology is well-organized utilizing of commodities to reduce unused in pollution. We have followed different studies like Orubu and Omotor (2011) Shahbaz *et al.* (2012) and Sabaori and Sulaiman (2012), for final model.

$$\ln CO_2 = \beta_0 + \beta_1 \ln PR_{it} + \beta_2 \ln REC_{it} + \beta_3 \ln FDI_{it} + \beta_4 \ln GDP_{it} + \varepsilon_{it}$$

All the variables treated in logarithmic form and show the percent change. Dependent variable is the carbon dioxide (CO_2), β_1 to β_4 represents the coefficient values for the predictors. In which “*i*” signifies the country (in this research, there are five countries Bangladesh, Pakistan, India, Sri Lanka, and Nepal), *t* represent time (the time frame is 1990-2019).

3.1 Econometrics Methodology

The following econometric techniques are applied on the panel data.

1. Panel Unit Root test
2. Cross Sectional Dependency
3. Wester Lund co-integration

3.1.1 Panel Unit Root and Co-integration Test

The panel unit root is a test used to check the stationary of the data. In this recent examination of panel data, one element root of the panel variable is recognized to the concern proportion. Although test performs the cross-sectional dependence (Pesaran, 2004) in arrange to be capable a proper unit root and co-integration this could decrease cross-section vulnerability issues. In the current existing for cross-section vulnerability, cross-section augmented Dickey-Fuller (CADF) panel unit root examination (Pesaran, 2007) would worthy for the reason that it's very powerful in the existence of cross section consequence.

3.1.2 Cross-sectional dependence Test

Bai and Ng (2001, 2004) the studies investigated the considering that dependence for cross-sectional unit arises from few related elements and apply the principle ingredient way to calculate. The general factor (therefore the correlation of cross-sectional units) after that put in the ADF test. The main purpose of this test is that we apply this test in thesis methodology for the use to find out the cross-sectional units.

3.1.3 Wester Lund Panel Co-integration Test

The main purpose of this test is to apply during studies to suggest that Co-integration tests are required to determine strong worthy consequences between variables. If in the existence of cross-sectional vulnerability is verified in the current line, normal co-integration tests (Johansen 1988, & Kao 1999) have few prejudices that can destroy the result. To over whelmed would bed is advantages, (Westerlund, 2007) co-integration test apply for the reason it would be eradicate cross-section vulnerability changes between the variable with the help of bootstrap skills than other co-integration would be (Johansen, 1988) and (Kao, 1999) with may not be properties. Yet, co-integration test statistic is Ga, (among categories), Gt, (between groups), Pt (among panels), even Gt an Ga numerical related statistics test null suggestion of would no co-integration panel series in opposition to presence of co-integration in single cross-sectional unit approximately. Pt, Pa, examination null of not existence co-integration in summarize of all panel section, in case evidence of co-integration for the wall panels.

4. Analysis And Results

This is the main part in the entire research concentrate as it offers all the possible responses to this study.

Table 1 indicates descriptive analysis of the variables. The mean value of CO₂ emissions is 0.63 while standard deviation that shows deviation from the mean is 0.4442. The average value of foreign direct investment is 0.889 where as standard deviation that reveals deviation from the mean is 0.7433. The mean value of economic growth is 1132.6 while the value of standard deviation is 812.6 which indicate deviation from the average. The average value of patent by residents is 1292.5, though the standard deviation that reveals deviation from the mean is 3282.7. The mean value of the last variable i.e. renewable energy consumption is 59.78 whilst the value of standard deviation is 17.60 which indicate deviation from the mean. The jarque bera shows that the residual of the entire variable are normally distributed. All the variables are positively skewed. Kurtosis statistic of the variables shows that the entire variable is palty-kurtic except patent application by resident.

Table 1: Descriptive Statistic Analysis

	CO2	FDI	GDP	PAR	REC
Mean	0.630	0.889	1132.573	1292.518	59.785
Median	0.609	0.775	840.173	68.000	55.020
Maximum	1.930	3.668	4011.682	16289.00	95.119
Minimum	0.041	-0.098	354.257	1.000	30.130
Std. Dev.	0.444	0.743	812.599	3282.727	17.603
Skewness	0.869	1.240	1.878	3.109	0.554
Kurtosis	3.446	5.046	6.220	12.106	2.252
Jarque-Bera	20.160	64.617	153.003	759.929	11.160
Probability	0.000	0.000	0.000	0.000	0.003
Sum	94.62172	133.3751	169886.0	193877.7	8967.880
Sum Sq. Dev.	29.40893	82.33062	98387466	1.61E+09	46171.31
Observations	150	150	150	150	150

Note: Author's self estimation

Table 2 reveals the correlation matrix among the study variables. Correlation matrix has two functions, one is shows relationship between the variables and the second is indicate multicollinearity problem. If the correlation coefficient between the variables is 0.8% or 80% or more than this then there exist multicollinearity. Multicollinearity is an issue when one or more than one variable related each other's. And it is difficult to tell that which variable is affect the dependent variable (Koop, 2004). In our model no variable is reveals multicollinearity. And this suggesting no-multicollinearity problem exists in the proposed variables in the model. The outcome of our estimation is according to the previous literature. The variable of renewable energy consumption is negative relationship with CO₂ emissions. While the remaining variables have a positive relationship with CO₂ emissions.

Table No 2 Correlation Matrixes

	CO ₂	PAR	REC	FDI	GDP
CO₂	1				
PAR	0.764	1			
REC	-0.726	-0.421	1		
FDI	0.593	0.382	-0.549	1	
GDP	0.490	0.198	-0.294	0.477	1

Note: Author's self estimation

Table 3 shows the results of cross-sectional dependence test (Pesaran 2004) and it clearly supports the presence of the cross-sectional dependence among the variable in Panel level. The results rejected the null hypothesis at a 1% significance level, and accept the alternative of cross-sectional dependence, considering the confirmation of cross-area reliance during action, we imply panel unit root test (Pesaran 2007), which is solid inside seeing cross sectional dependence. Cross sectional dependence test discovers effect of shock in one country on another country.

Table 3 Cross-section Dependence test

Variables	Breusch-pagan LM	Pesaran LM	Bias-corrected scaled LM	Pesaran CD
CO ₂	259.53(0.00)***	55.79(0.00)***	55.71(0.00)***	16.08(0.00)***
PAR	167.17(0.00)***	35.14(0.00)***	35.05(0.00)***	12.23(0.00)***
REC	238.40(0.00)***	51.07(0.00)***	50.98(0.00)***	15.41(0.00)***
FDI	38.26(0.00)***	6.32(0.00)***	6.23(0.00)***	4.28(0.00)***
GDP	292.30(0.00)***	63.12(0.00)***	63.03(0.00)***	17.09(0.00)***

Note: author self-estimations

Before estimation, stationarity of the data is check by the applied of panel unit root tests at level and first difference. We applied Im, Pesaran (2007) and Shin W-stat (Im *et al*, 2003), Fisher Augmented Dickey Fuller (FADF, 1979). We apply the second-generation unit root test which includes CADF and CIPS test. Table 4 reveals that at level 1(0) no one variable is stationary, but at a 1st difference i.e..1(1), all the variables are stationary leading to rejection of the null hypothesis of presence of unit root.

Table 4 Panel Unit Root test

Variables	IPS		FADF		CIPS		CADF	
	1(0)	1(1)	1(0)	1(1)	1(0)	1(1)	1(0)	1(1)
CO ₂	6.67	-4.20***	0.49	36.56***	4.18	-4.08***	0.29	97.85***
PAR	3.57	-8.92***	8.95	82.88***	3.61	-7.14***	16.58	113.93***
REC	0.47	-4.61***	8.66	40.23***	-1.38	-1.92**	4.74	100.53***
FDI	-1.01	-7.03***	11.08	63.63**	0.25	-5.78***	31.59	109.92***
GDP	8.79	3.50***	0.10	12.43***	7.64	2.74**	0.01	22.02***

Note: author self estimations

If the existence of cross-sectional dependence is verified, normal co-integration tests (Johansen 1988, Kao 1999) have few prejudices that could produce invalid results. In this situation (Westerlund, 2007) co-integration test apply as it would eliminate cross-section dependence changes between the variable with the help of bootstrap skills than other co-integration would (Johansen, 1988 and Kao, 1999) not have those properties. Yet, co-integration test statistic is Ga, (among, categories) Gt, (between, groups), Pa (among, panels), Pt (among, panels). The results indicate cointegration. The results are given in table 5.

Table 5: Westerlund panel Co-integration test

Statistic	Value	z-value	P-value
Gt	-3.323	-2.055	0.020
Ga	-8.476	1.307	0.905
Pt	-5.112	-0.284	0.038
Pa	-7.643	0.490	0.688

Note: Author's self estimation

Table 6 reveals the results of FMOLS. The coefficients of all the variables are significant except FDI. The coefficient of the patent application (PAR) is negative and statistically significant. According to our results the patent application by residents used as a proxy of technological innovation increases by one percent then the CO₂ emissions used as a proxy for Green growth is decreased by 40%, which indicate that as the technological innovation increases it will lead to increases the green growth in the panel of countries during the studied period. This finding is the same as the past studies of (Mensah *et al.*, 2018).

Renewable energy consumption has a negative and statistically significant impact on CO₂ emissions. This means that a one-unit increase the renewable energy consumption lead to reduce the CO₂ emissions by 0.007%. This results are similar with the findings of (Dogan & Seker, 2016, Chiu & Chang, 2009, and Al-Mulali *et al.*, 2015).

Foreign direct investment has a positive but statistically insignificant effect on CO₂ emissions. These findings are in line with the results of (Dauda *et al.*, 2019).

The coefficient of GDP is positive and statistically significant. A 1% increase in economic growth increases the CO₂ emissions by 0.0002%. Our results are similar with the findings of (Mensah *et al.*, 2018).

Table 6: Fully Modified Ordinary Least Square (FMOLS)

Dependent Variable: CO ₂ emission				
Variable	Coefficient	St. Error	t-Statistic	Prob
PAR	-0.000404	0.00000388	10.41444	0.0000
REC	-0.007560	0.001449	-5.215374	0.0000
FDI	0.014428	0.013898	1.038135	0.3010
GDP	0.000259	0.0000216	11.98614	0.0000
R-squared	0.985950			

Note: Author's self-estimation

Results of dynamic ordinary least squares are reported in table 7. The results of DOLS are the same as the findings of FMOLS. According to DOLS findings, a patent application by residents (PAR) is a negative and statistically significant effect on CO₂ emissions. Similarly, renewable energy consumption has a negative coefficient and a

statistically significant effect on CO₂ emissions. Like the result of FMOLS, FDI has a positive coefficient but insignificant. It means that CO₂ emissions are independent of FDI. In the last GDP has a positive sign and statistically significant.

Table 7: Dynamic Ordinary Least Square (DOLS)

Dependent Variable: CO ₂ emissions				
Variable	Coefficient	St. Error	t-Statistic	Prob
PAR	-0.000	0.000	7.067	0.0000
REC	-0.008	0.001	-4.624	0.0000
FDI	0.022	0.014069	1.569	0.1214
GDP	0.000	0.000	15.817	0.0000
R-squared	0.997			

Note: Author's self-estimation

Granger Causality test is applied to illustrate the direction of the relationship between the variables. The results given in table 8 show that there is a bidirectional correlation between a patent application by residents (PAR) and CO₂ emissions. This implies that patent application by residents (used as a proxy for technological innovation) causes CO₂ emissions i.e. green growth; in turn CO₂ emissions causes' patent application by residents. Similarly, a bidirectional connection exists between renewable energy consumption and CO₂ emissions. This implies that renewable energy consumption causes CO₂ emissions, and in turn, CO₂ emissions cause renewable energy consumption. A bidirectional association is found between economic growth and renewable energy consumption. This implies that economic growth causes renewable energy consumption, and in turn, renewable energy consumption causes economic growth. A unidirectional relationship exists between FDI and CO₂ emissions. This implies that CO₂ emission causes FDI. Similarly, a unidirectional relationship exists between economic growth and CO₂ emissions. This means that economic growth causes CO₂ emissions. Also, the unidirectional relationship is found between patent application by residents and renewable energy consumption means a patent application by residents causes renewable energy consumption. Additionally, unidirectional causation exists from the patent application by residents to FDI. Unidirectional causation exists from the patent application by residents to GDP. The same causation exists from renewable energy consumption to FDI. In the last, unidirectional causation exists from economic growth to FDI

Table 8: Results of Granger Causality Tests

Pairwise Granger Causality Tests				
Null Hypothesis	Obs	F-statistic	Prob	Outcomes
PAR does not Granger Cause CO2	140	0.61602	0.0416	Bidirectional
CO2 does not Granger Cause PAR		2.33962	0.0013	
REC does not Granger Cause CO2	140	3.56880	0.0309	Bidirectional
CO2 does not Granger Cause REC		4.35049	0.0148	
FDI does not Granger Cause CO2	140	1.18981	0.3074	Unidirectional
CO2 does not Granger Cause FDI		5.10356	0.0073	
GDP does not Granger Cause CO2	140	8.62656	0.0003	Unidirectional
CO2 does not Granger Cause GDP		0.04499	0.9560	
REC does not Granger Cause PAR	140	0.29258	0.7468	Unidirectional
PAR does not Granger Cause REC		0.05750	0.0441	
FDI does not Granger Cause PAR	140	0.87107	0.4208	Unidirectional
PAR does not Granger Cause FDI		3.91973	0.0221	
GDP does not Granger Cause PAR	140	0.20671	0.8135	Unidirectional
PAR does not Granger Cause GDP		1.45684	0.0366	
FDI does not Granger Cause REC	140	0.12583	0.8819	Unidirectional
REC does not Granger Cause FDI		4.72715	0.0104	
GDP does not Granger Cause REC	140	0.07152	0.0310	Bidirectional
REC does not Granger Cause GDP		1.98259	0.0417	
GDP does not Granger Cause FDI	140	2.70261	0.0707	Unidirectional
FDI does not Granger Cause GDP		0.20196	0.8174	

Note: Author's self-estimation

In the last GDP has a positive sign and statistically significant. This shows that GDP growth has a positive statistically significant effect on CO₂ emissions. A 1% increases in GDP growth lead to escalating CO₂ emissions by 2% ((Mensah *et al.*, 2018).

5. Conclusion And Policy Implications

This study examines the effect of technological innovation on green growth in South Asian countries during 1990 to 2019. Secondary data has been collected from the World Development Indicator (WDI 2020). The dependent variable CO₂ emissions is used as a proxy for green growth and the independent variables used in our model are patent applications by residents, renewable energy consumption, foreign direct investment, GDP per capita. This study used panel data techniques such as cross sectional dependence, panel unit root, Wester Lund co-integration fully modified ordinary least square (FMOLS) and dynamic ordinary least square regressions (DOLS) to examine the long-run

relationship. The outcome of our estimation is according to the previous literature. The results of all panel unit root tests reveal that all the variables are stationary at a 1st difference. Westerlund panel co-integration test confirmed the long-run relationship. The findings of the study show that Patent application by residents and renewable energy consumption has a negative and statistically significant impact on CO₂ emissions in both the model's FMOLS and DOLS. While GDP is a positive and statistically significant effect on CO₂ emissions and FDI does not affect CO₂ emissions in both the models' FMOLS and DOLS.

Policymakers must join the technological innovation into mitigation of carbon dioxide emissions which could allow waste reuse ongoing system to diminish pollution. Countries necessary evaluate the impact of environmental cost of FDI before authorizing them into their economy. Incorporate and assimilate cutting advance technology from FDI that permit the capability of moderating CO₂ emissions.

Economic growth adds carbon dioxide emissions, and it increases the use of energy. Accordingly, government needs to take sustainable energy related source, for instance, renewable energy consumption which are beneficial to ecosystem as it increases green economy.

Declarations

Ethical Approval: This manuscript is solely submitted to the esteemed journal. Further, this article is not under consideration for publication elsewhere.

Consent to Participate: All the authors have read and approved the final version of manuscript.

Consent to Publish: Not applicable

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Figures

Figure 1

Renewable Energy Consumption in the nation's energy supply 2019. Source: U.S Energy Information Administration (2019)

Figure 2

Association moving from independent variables patent by resident (PR), Renewable energy consumption (REC), foreign direct investment (FDI), GDP per capita (GDPPC) and carbon dioxide emission (CO₂) are dependent variable.