RESEARCH ARTICLE

The environmental impact of industrialization and foreign direct investment: empirical evidence from Asia-Pacific region

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Abstract

Environmental degradation has been the main distress in recent years due to the drastic effect of climate change. To determine the gone thorough impact of industrialization and foreign direct investment on environmental degradation, this study utilized panel data of 55 countries of the Asia-Pacific region from 1995 to 2020 and it applies an autoregressive distributed lag (ARDL) model. The results showed that FDI, in general, has a significant negative impact on the environment and causes to increase in methane and CO_2 emissions. Moreover, industrialization has a positive and significant impact on the environment. However, the size of the impact is moderate. This study also concludes that in the Asia-Pacific region, the environment Kuznets curve (EKC) and pollution heaven (PH) hypothesis are accepted. Finally, this study suggests the strict implication of environmental guidelines or the adoption of a new policy would be the key to ensuring the quality of the environment. Furthermore, the results confirmed that most of the panel countries are developing countries and do not have strict environmental management guidelines.

Responsible Editor: Nicholas Apergis

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Introduction

The peculiarities of human existence and economic activity have been a source of environmental variability from all over the world. The Industrial Revolution, which began in 1750, is considered the introduction of climate change. Carbon dioxide (CO_2) emissions are significantly lower than before the inauguration of industrialization. Greenhouse gas (GHG) concentrations are significantly higher than they were at the beginning of the industrial era, meaning atmospheric CO_2 concentrations have reached 409.8 ppm (parts per million) in 2019, higher than at any point in at least the past 800,000 years (Lindsey 2020). The CO_2 concentration was 280ppm before the Industrial Revolution, and it has fluctuated between 180 and 280ppm, over the last few centuries. It has been seen that in the period of the 1950s, this figure was higher by about 0.7ppm per year, and over the past 10 years, it has increased even more to 2.1 ppm per year ((NOAA, 2013). In the past few years, developing countries have stepped up their efforts to achieve approval of industrial sector reform and very rapid growth in energy consumption

for the production of goods and services (Nazlioglu et al. 2011; Solarin et al. 2017).

Similarly, the Asia-Pacific region also experienced rapid and promising economic growth which create a radical environmental issue in this region; for instance, 50 % of global groundwater is used by India, Bangladesh, China, Pakistan, and Nepal for irrigation purpose which is far exceeded the sustainable limit (Rasul 2016). It has been established that densely populated Asia-Pacific experienced rapid economic growth at the cost of lost efficiency of natural resources during 1975–2005 (Schandl and West 2010). Due to alarming changes in the environment and rapid decrease in natural resources, Asia-Pacific became more vulnerable to natural disasters. Almost half of the world's natural disasters occurred in the Asia-Pacific in 2018 which affect 42 billion peoples in the region. Moreover, when world is leading towards poverty alleviation, Asia-Pacific region is facing high-income inequality with the rise in the GINI coefficient from 0.34 to 0.38 during 1994–2014 (Yang et al. 2020). Therefore, to achieve the 2030 Agenda for SDGs, it is necessary to address the social economic and environmental gaps in the Asia-Pacific region.

Moreover, the situation is now worse than in 2000 for climate action (Sachs et al. 2021). All sub-regions of Asia-Pacific regions aim to reduce greenhouse gas emissions, and have adopted national and local disaster risk reduction strategies achieving certain goals, but the region continues to produce half of global greenhouse gas emissions (Nansai et al. 2020).

The Organization for Economic Co-operation and Development (OECD) countries and International Energy Agency (IEA) have agreed to significantly raise the public budget for energy research and development to reduce greenhouse gas emissions. Several new agreements have been signed with the Mission Innovation (MI) and the Clean Energy Ministry (CEM) and to improve clean energy technology and increase 100% expenditures for accomplishments under major innovation areas and allied research and development (World Energy Outlook, 2019). The 38 member countries of OECD have also agreed to adhere to the Kyoto Protocol to reduce greenhouse gas emissions and address global environmental challenges. Consequently, to reduce dependence on fossil fuels, OECD members have high aspirations to increase overall energy R&D budgets to improve sources of clean energy. This is due to the increase in greenhouse gas emissions from fossil fuel combustion in 2015 which has been increased by 6% and is recognized as a major cause of environmental catastrophe degradation in OECD countries (Le and Ozturk 2020).

In many countries in the Asia-Pacific region, where large-scale production continues, there are serious threats to their health and the environment because national environmental protection and carbon dioxide control policies are not compatible with protection goals (Eskeland and Harrison 2003). In the race to achieve high output in the economies, the challenge is to achieve sustained economic growth, not just economic growth (Hanif et al. 2019). Zafar et al. (2020) explained that industrialization has a strong impact on carbon emission in the Asia-Pacific region. However, the intensity of the relationship between industrialization and environmental degradation is varying in various regions of Asia. Moreover, many Asian economies are experiencing rapid urbanization and intense competition for natural resources. Therefore, environmental stresses like high carbon dioxide emission, water wastage, drinking water pollution, deforestation, and climatic disasters are causing deterioration in the quality of life. Therefore, it is very important to study the main factors underlying the factors behind the formation of carbon dioxide emissions in developing countries in the Asia-Pacific region.

Identifying the factors responsible for high CO2 emissions will help policymakers to develop effective policies for controlling CO2 emissions, protecting the environment, and protecting human health in the region. Economically, the main challenges are poverty, unemployment, and low incomes, faced by developing countries, and the environmental protection agencies. In addition, efforts are being made to uplift the low-income households in developing countries, which will lead to new negative consequences in the form of global warming, depletion of natural resources, and environmental pollution.

It has been observed for the last hundred years that the concentration of greenhouse gases is significantly increasing and is the main cause of global warming. The main component of greenhouse gases is carbon dioxide which contributes almost 82% of all greenhouse gas emissions to the atmosphere (Pachauri et al. 2014). The main sources of CO2 emission are both natural sources and human sources, which include respiration, decomposition, cement production, transportation, natural gas extraction, combustion of fossil fuels, and ocean release. Since the emission of gases, the earth's temperature has risen by about 0.6°C, reaching the highest level in the last millennium. Carbon dioxide is a gas that lasts longer in the atmosphere as compared to other greenhouse gases and has consistently strewn all around the globe (Ahmed et al. 2021; Kaufman et al. 2002). During the COVID-19 pandemic, it has been observed that there is a significant reduction in greenhouse gas emissions, with a 17% reduction in carbon dioxide emissions by April 2020 as compared to April 2019, but the drop in carbon dioxide emissions was temporary and emissions rose as soon as lockdown measures were lifted and this trend is evident by China and India (Figs. 1 and 2).

China has relaxed its lockout measures earlier than other countries, and the impact is far more significant. Despite the sharp decline in global emissions on January 21, China

Fig. 1 . CO2 emission in China. CO2 Emissions Variations (%): 2021 vs 2020. Available at https://carbonmonitor.org/
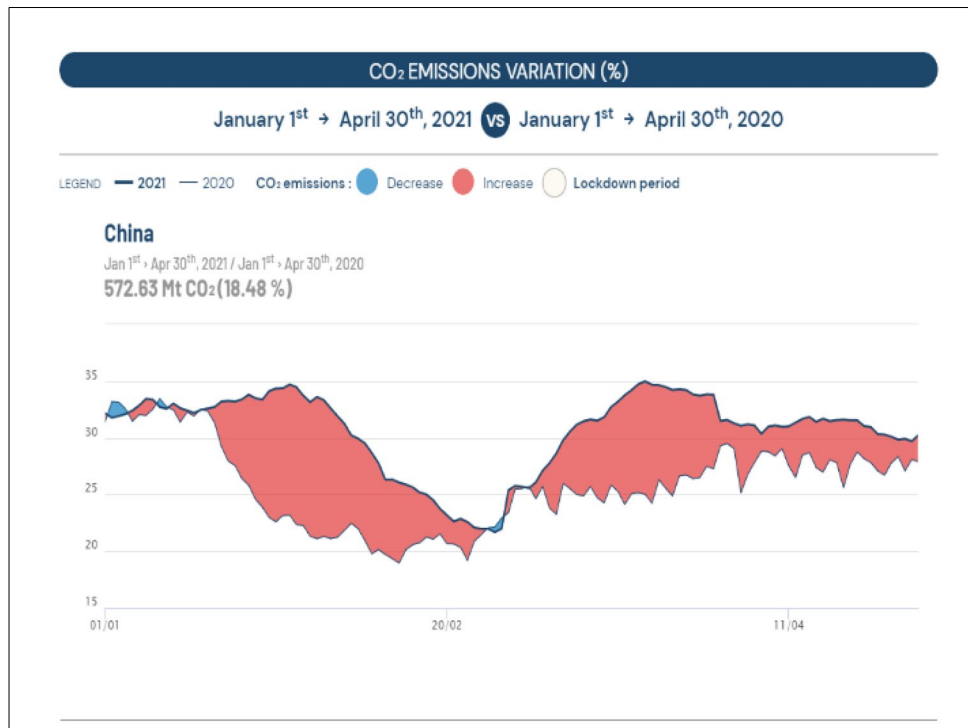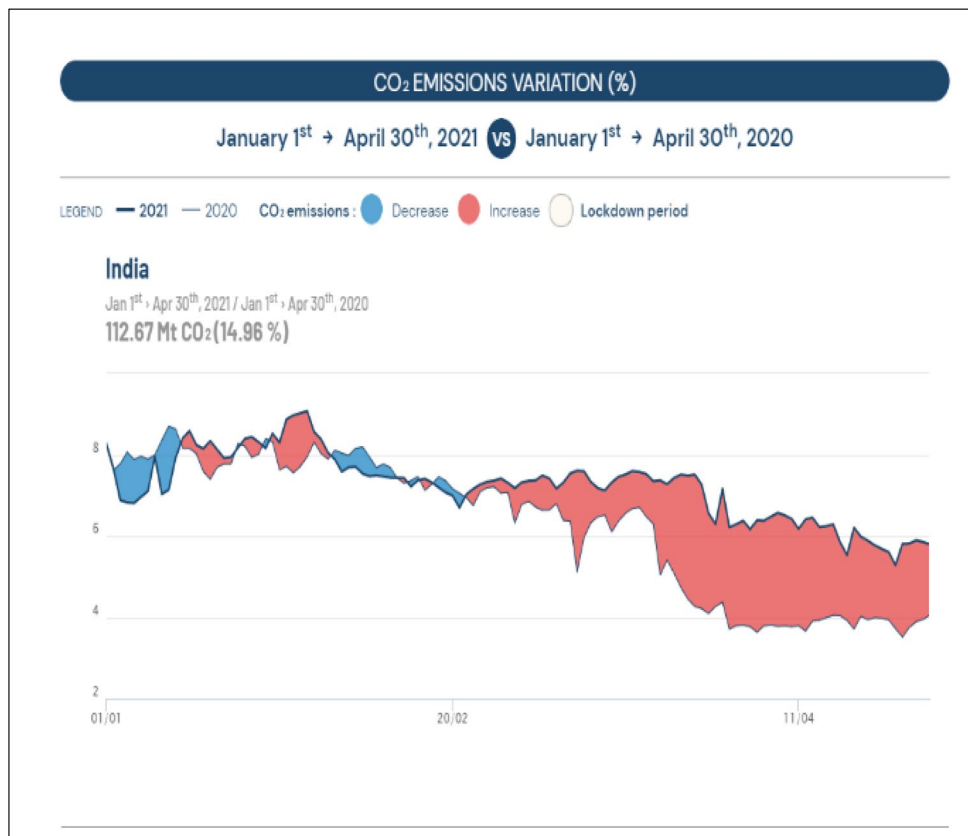

Fig 2 . CO2 emission in India

cites a record of carbon dioxide emissions from January to April of the current year that were comparatively higher than the same period of 2020, whereas carbon dioxide emissions in India were stated after February because India lifted the

lockdown in last week of Feb 21 (Wikimedia 2021). In terms of CO2 emissions, China is the largest emitter, with 10.06%, and India's contribution is 7% of total global CO2 emissions. This increased CO2 concentration drew the environment out of equilibrium. Irregular rains and a shortened winter season have had a lasting impact on the weather. A study of CO2 emissions will show that China and India, according to CO2 forecasts for growth, will continue to grow unless additional measures are taken to combat climate change (Lin and Raza 2019).

For the economic growth of the developing countries, both industrialization and foreign direct investment (FDI) are important factors and none of them can be underestimated. Foreign direct investment has been recognized as an important stimulus for economic growth due to its positive effects on the financial offer, integration of international trade, the technological impact, the formation of human capital, and improvement in economies of scale for the concerned markets (Gorg and Greenway 2004). In addition to the many benefits of foreign direct investment and industrialization that have affected economic growth, both have significant potential for environmental degradation because most of their activities are related to the production and exploitation of natural resources. According to United Nations Economic and Social Commission for Asia and Pacific (UNESCAP), in 2018, the Asia-Pacific region received a 45% share of global FDI inflows and it is also expected that this region will continue to serve as a major destination for FDI inflows in the upcoming years (Bhujabal et al. 2021). Moreover, as the Asia-Pacific region is at a growing stage both economically and technologically, so FDI is considered a major channel of transfer of technology and hence affects the economic and environmental structure of the receiving countries (Ahmed et al. 2020; Tang et al. 2014). Therefore, developing countries should design policies to attract FDI and accelerate industrial progress but not at the expense of the environment and the health of their residents (Tang et al. 2014).

Therefore, it is not surprising that given the largest influx of foreign direct investment, carbon dioxide (CO2) emissions are becoming alarming shortly.

Significance of the study

Examining the environmental effect of foreign direct investment and industrialization is the core objective of the study since both variables have great potential to contribute to environmental degradation as well as to the economic growth of the Asia-Pacific region. Due to the complex impacts of FDI on the economy and environment, a few studies examined the impact of FDI on CO_2 emission (To et al. 2019). It has been examined that developing nations especially Asian economies relaxed their environmental regulations to attract FDI and allow the investor to work

with tradition and outdated technology, which is harmful to the environment. Therefore, it is the need of the hour to investigate whether the FDI in South Asian economies is environmentally friendly or not to propose effective policy suggestions. Moreover, many studies explored the environmental impact by using only carbon dioxide emissions as a proxy for the environmental degradation, whereas in this study, the main proxy for the environmental indicator was CO2 emissions, whereas other proxies were methane, total greenhouse gases, and nitrous oxide emissions, which would help to understand the different dynamics of environmental degradation. This study will help in the development of literature related to environmental degradation. Moreover, this study will help the policymakers to design effective policy frameworks for monitoring and controlling carbon emissions in the region and help to achieve Sustainable Development Goal number fourteen "Climate Action."

Furthermore, no doubt industrialization is necessary for economic growth but at the same time, it is also the fact that it brings harmful impact on the quality of human life as well as the environment. It has been examined that rapid industrial growth affects the entire bio-network and components of a natural system like air, water, soil, and the surrounding ecosystem (F. Ahmed et al. 2021; Magsi 2014). Therefore, understanding the severity of the problem, this study is carried with more concentration and spirit.

Literature Review

In the field of environmental economics, many studies have developed several hypotheses to explicate the environmental impact of human and economic activities; conspicuous among these are environmental Kuznets curve (EKC) that explains the relationship between economic growth and environmental degradation; the pollution haven hypothesis (PHH) which explains the association globalization and environmental degradation; and the Stochastic Impacts by Regression on Population, Affluence, and Technology (STIRPAT) that asserts the relationship among population growth and environmental degradation.

Kahuthu (2006) investigated the relationship between economic growth and environmental degradation based on the environmental Kuznets curve model. The study confirmed the inverted U-shaped relationship between income growth and carbon emission. EKC postulated that as the economy grows, it increases the degradation of the environment in terms of greenhouse gas emissions. Moreover, the study established that at the initial level of development, environmental degradation is more dangerous because society is transforming its economic, social, and environmental structure which creates a greater demand for natural resources; for instance, more land is demanded for economic

activities. Hence, deforestation and pollution take place along with economic activities. However, at this stage, society is more concerned with the increase in income rather than environmental quality (Kahuthu 2006).

Grossman and Krueger (1991), who was the pioneer among those who explained EKC, established in his findings that economic growth affects environment quality differently in three different stages of growth. At the first stage of growth, due to scale effects, as growth increases demand for natural resources like land for economic activities, so economic activities badly affect environmental degradation; hence scale effect indicates the rising portion of inverted U-shaped EKC. Similarly, the second stage is the turning point of the U-shaped EKC; due to composition effects, the structure of the economy started to transform and the country started to prefer environmental-friendly economic activities. At the third stage which is the rising portion of U-shaped EKC, due to technical effects, a country replaced traditional technologies with environmental-friendly technologies in the production process. Moreover, following Grossman and Krueger (1991), many researchers conducted their study to verify the EKC in their context and found mixed results; for instance, some studies support the EKC hypothesis and found that EKC is established in the case of Pakistan, Ghana, Malaysia, Tunisia, France, and 99 high-, middle-, and low-income countries (K. Ahmed and Long 2012; Fodha and Zaghdoud 2010; Iwata et al. 2010; Saboori et al. 2012) while some studies found evidence against EKC hypothesis in China, Turkey, and Spain (Akbostancı et al. 2009; Roca and Alcántara 2001; Song et al. 2019).

Similarly, pollution haven hypothesis (PHH) postulates that trade liberalization and inflow of FDI are also responsible for high CO_2 emission. Pollution haven hypothesis established that multinational companies that come to low developing nations invest in pollution-intensive products due to convenient environmental regulatory policies and send heavy profit to their home countries. In this way, developed nations enjoy a high growth rate at the expense of bad environmental quality in poor nations (Cole 2004; Temurshoev 2006).

Poor nations adopt convenient environmental regulations due to certain reasons: first devising, implantation, and monitoring of environmental regulatory policy are expensive and difficult; second, the purpose of developing nations is high economic growth, not the quality of the environment; and third, developing nations are in the stage of transformation from an agrarian to industrialization which demands relaxed environmental regulations. Hassaballa (2013) conducted a study on developing nations related to environmental impacts of FDI and found that FDI brings beneficial environmental impacts to the developed countries while it brings negative impact to the environmental quality of poor or developing nations. The findings of the study

imply that FDI is beneficial in the presence of a well-planned environmental policy. As Kavzoğlu (2008) explained that industrialization is one of the major factors that affect the development of a country. This study established that due to uncontrolled and unplanned industrialization, it brings drastic impacts on the environment especially on the basic ecosystem, wildlife habitats, and global biodiversity.

As Steinbach (2019) tested the EKC and PH hypothesis in the context of SAARC countries. This study utilized the data for the period of 1986-2014. Study concluded that in SAARC countries, EKC and PH hypothesis established. Fodha and Zaghdoud (2010) found support for the EKC in Tunisia, using panel data for the period 1961–2004. Shahbaz and Sinha (2019) conducted a study on EKC for CO_2 emission through literature and the results indicate that EKC estimation for CO_2 emissions remained inconclusive. However, Song et al. (2013) tested the application of EKC in china and found mixed results in various areas of China. Roca et al. (2001) did not find evidence to support the EKC hypothesis in Spain from 1972 to 1997. Liu et al. (2017) found that in the short run, EKC was not supported in selected ASEAN countries whereas it was confirmed in the long run. Contrary to PHH, the porter hypothesis emphasized the fact that in the presence of strict environmental regulations, trade openness and FDI help to improve environmental quality through clean and environmentally friendly production technologies (Mohr 2002).

Just like in Porter's theory, PHH's claim that the IDE is environmental damage has been called into question due to the "halo" effect and/OR hypothesis. OR argue that foreign companies have favorable environmental benefits for the host country because they are excellent eco-friendly technologies (Doytch and Uctum 2016). In this case, the positive environmental images are compared to those of you who never dreamed that positive work efficiency would compensate for the influx of foreign direct investment. Some experimental studies have shown a positive association between trade openness, foreign direct investment, and environmental degradation (Raeder et al. 2008; Sapkota and Bastola 2017)

The STIRPAT model examined the impact of population growth, economic growth (affluence), as well as technology on the post-industrial era's performance on the environment (Zhu and Peng 2012). On the empirical front, it has been shown changes in the overall performance of the industry. Akbostancı et al. (2011) found that industrialization is the main factor, influencing the change in CO2 emissions. This result is confirmed by several studies that have shown increased industrialization, increased emissions of harmful substances, and, as a result, environmental degradation (Akbostancı et al. 2011). Therefore, the above-mentioned literature review revealed that most of the studies related to industrialization, FDI, and environmental degradation have been conducted in China, Turkey, Spain, and Malaysia.

However, a few studies have been conducted in South Asian region related to globalization and environmental degradation (Sabir and Gorus 2019)

Justification of conceptual model

This study designed the conceptual framework following the model of human interaction with the environment which was proposed by Darling-Hammond and McLaughlin (1995). This model assumed four channels of interactions between human activity and the environment. First, human beings extract minerals, energy, food, fiber, and other natural resources and utilize them in economic activities which cause degradation of the biological system. Second, industrial activities transformed natural resources into products. During the production process, the industrial sector produces industrial wastes and throws these wastes into the environment. Third, the earth's ecosystem was planned by God in such a way that best suits human life. This unmanaged ecosystem provides essential life support services but as human activity expands and deteriorates the ecosystem, the ability of the environment to support human life decreases. Fourth, polluted water, air, and food directly and negatively affect the health and welfare of human beings. This model explains how human activities negatively affect environmental quality. Moreover, this model explicitly held human activities responsible for environmental degradation. This study, keeping in view the model of human interaction with the environment, EKC, and PHH, designed the following conceptual framework.

Conceptual Framework
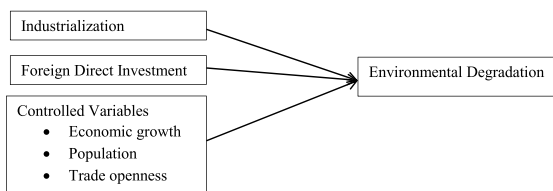
Research methodology

Model specification, variables, and data

When describing the model for assessing the impact of economic activity on the environment, three main assumptions are followed. The first is the EKC hypothesis that the ultimate "U" shape associates economic growth with the environment. Next is the PHH about the negative effects of foreign direct investment and trade openness on the

environment of developing countries, and the latest one is the STIRPAT hypothesis, which examines the environmental effects of industrialization, economics, and population growth. From these hypotheses, the independent variables of the study are economic growth, trade, FDI, industrialization, and population. The simple regression equations are as follows:

$$E = f\left(IND, FDI, Y, Y^2, POP, TO\right) \tag{1}$$

$$E = \alpha_1 + \alpha_2 IND_{it} + \alpha_3 FDI_{it} + \alpha_4 Y_{it} + \alpha_5 Y^2{}_{it} + \alpha_6 POP_{it} + \alpha_7 TO_{it} + \mu_{it} \tag{2}$$

In Equations (1) and (2), E represents environmental indicator, economic growth is donated by Y and economic growth squared by Y^2, FDI is foreign direct investment, TO is trade openness, IND represents industrialization, POP is denoting population growth, μ and t are error term and sample period, respectively, α denotes parameters, and i represents countries. The main environmental indicator is represented by CO2 emissions. This indicator is widely used as an environmental indicator in the EKC and PHH literature (Kivyiro and Arminen 2014; Opoku and Boachie 2020b; Sarkodie and Strezov 2019; Tang and Tan 2015) and the most environmental studies have used CO2 as a proxy or measurement of environment degradation. However nitrous oxide, greenhouse gases and methane gases which also greatly contribute in environment degradation are largely ignored, which leads to climate change around the globe, according to NASA (2019), CO2 leads to environmental degradation with 76% emission, followed by methane with 16% emission and nitrous oxide sharing in 6.2% (IPCC 2014).

Although methane and nitrous oxide are less important, the International Energy Agency (IEA) indicates that they are more susceptible to global warming. In this study, according to data from NASA, the Intergovernmental Panel on Climate Change and the International Energy Agency, in addition to carbon dioxide, emissions of methane, nitrous oxide, and greenhouse gases, are also used as the proxy of the environment. On the other hand, economic growth is measured based on GDP per capita and the square of GDP per capita to reflect EKC curvature (Kivyiro and Arminen 2014). FDI is measured as inward FDI as a ratio of GDP. Industrialization is measured by using industry value-added. Trade openness is measured as the ratio of total trade (export plus import) to GDP. Population growth is measured as the total population.

Data on the variables are sourced from the Climate Watch and World Bank. The data cover the period 1995–2020 for fifty-five selected countries of East and Pacific Asia, South Asia, and Europe and Central Asia, while some countries are

excluded from the study due to unavailability of the data.[1] In Appendix A, the definitions of the variables are summarized.

Empirical estimation

This study first examined cross sectional dependence test to select the appropriate methodology for empirical estimates, emphasized by current literature in panel data analysis that cross-sectional dependence analysis is important (Baltagi and Pesaran 2007), and for unit root tests, if cross-section dependence is ignored, then this may lead to negative results if the value is not dependent (Opoku and Boachie 2020a). This study employed Pesaran CD and Breusch-Pagan LM test to examine the cross-sectional dependence. Results are reported in Table 2, which indicates that there is no cross-sectional dependence in the defined sample.

Moreover, this study utilized popular techniques ADF Fisher chi-square test, the PP Fisher chi-square test, the Im-Pesaran and Shin W-stat, and Levin and Lin and Chu test to check the stationarity of the sample data. The stationarity of data ensures the reliability of data and prevents nonsense relationships. The tests are performed with and without deterministic trends of the specifications. The null hypothesis for all these tests is that there is a unit root in the panel data, whereas the alternative hypothesis is, there is no unit root in the panel data. Results of the unit root test have been reported in Table 3 and the results indicate that no variable has been integrated in the order I(2), so this study proceeds to verify the existence of a long-term relationship between environmental degradation and the independent variables by utilizing Pedroni, Kao, and Johanson Fisher panel cointegration test. The common null hypothesis is that all panels are cointegrated (Arouri et al. 2012). After confirmation of the cointegrating relationship among the variables, to evaluate the environmental impact of industrialization and foreign direct investment in the long run, autoregressive distributed lag (ARDL) model is employed (M Hashem Pesaran and Shin 1998). ARDL is an intermediary estimator concerning the outmoded pooled random and fixed effects estimators and also the generalization of the cointegrating autoregressive distributed delay limit (ARDL) test that is applied to panel data. It is assumed that ARDL may be heterogeneous for coefficients for cross-sections in the short term whereas in the long term, it is befitted as homogeneous. The dynamic generalized panel moment method (GMM) is known to allow coefficients with different constant terms to be similar between groups (Pesaran and Smith 1995). Moreover, the ARDL reviewer found that in the presence of large N and T panels, ARDL is the most appropriate technique to confirm the relationship between variables in a multivariate dynamic panel model.

Furthermore, five different models are evaluated due to the volatility of the environmental indicators and the measure for industrialization using the ARDL model; therefore, the following is the long-run and short-run cointegration equation for a dynamic panel:

$$\Delta E_{it} = \varnothing \left[E_{i,t-1} - \alpha_1 - (\alpha_2 IND_{it} + \alpha_3 FDI_{it} + \alpha_4 Y_{it} + \alpha_5 Y^2_{it} + \alpha_6 POP_{it} + \alpha_7 TO_{it}) \right]$$
$$- \left[\beta_1 \Delta IND_{it} + \beta_2 \Delta FDI_{it} + \beta_3 \Delta Y_{it} + \beta_1 \Delta Y^2_{it} + \beta_1 \Delta POP_{it} + \beta_1 \Delta TO_{it} \right] + \mu_{it} + \varepsilon_{it}$$

$$(3)$$

In Equation (3), $\varnothing$ is the coefficient of error correction term that measures the speed of adjustment towards equilibrium and is expected to be negative and statistically significant which will also confirm the existence of the long-run relationship. Δ is a difference operator, α_i and β_i are, respectively, vectors of the long- and short-run coefficients, and the country-specific effects are given by μ_{it}

Empirical results

Descriptive statistics

The descriptive statistics for the selected variables for the period 1995–2020 are shown in Table 1, which provides an overview of mean, standard deviation, median, skewness, maximum and minimum range, kurtosis, and Jarque-Bera. The value of Jarque-Bera indicates that the residuals are normally distributed.

Cross-sectional dependence

The section of the study displayed the finding of the cross-sectional dependency test (Table 2) for all the variables, excerpt by using Mohammad Hashem Pesaran (2015) and Breusch and Pagan (1980) tests. As per the results for all the variables, the null of "no cross-sectional dependence" is rejected even at a 1% level of significance, which reveals the existence of cross-sectional dependency.

Unit root test

The results of unit root tests (Table 3) showed that some variables are stationary, at a level I(0), while some are integrated at order one I(1). However, none of the variables integrated of order two I(2).

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[1] The countries include Albania; Australia; Austria; Azerbaijan; Bangladesh; Belarus; Belgium; Bhutan; Brunei; Cambodia; China; Cyprus; Denmark; Fiji; Finland; France; Germany; Greece; Hungary; Iceland; India; Indonesia; Ireland; Italy; Japan; Kazakhstan; Kiribati; Korea; Kyrgyz; LaoPDR; Malaysia; Mongolia; Nepal; the Netherlands; New Zealand; Norway; Pakistan; Poland; Portugal; Romania; Singapore; Slovak; Slovenia; Spain; Sri Lanka; Sweden; Switzerland; Tajikistan; Thailand; Tonga; Turkey; Ukraine; the UK; Vietnam; and the Philippines.

Table 1 Descriptive statistics

Variables	FDI	Y	Y^2	IND	Manu.	POP	TO	GHGs	CO_2	Methane	Nitrous oxide
Mean	5.54	2.90	29.49	28.0	15.19	0.84	91.90	374.53	279.6	63.18	25.39
Median	2.49	2.86	15.22	26.5	15.05	0.76	80.82	71.20	50.23	16.52	8.02
Maximum	280.1	33.00	1187.9	74.1	34.57	5.32	437.33	11705.	9663.	1242.	547.2
Minimum	−40.4	−17.93	0.00	6.75	3.85	−2.06	16.68	−178.71	−213.	0.02	0.00
Std. dev.	16.0	3.79	56.38	9.65	6.17	0.85	53.27	1143.7	917.8	158.9	67.07
Skewness	10.3	0.27	10.91	1.41	0.32	0.22	2.60	7.13	7.54	4.77	5.46
Kurtosis	1.64	0.54	1.45	1.65	1.63	0.59	1.89	0.75	0.93	0.69	1.27
Prob.	0.21	0.50	0.30	0.15	0.41	0.21	0.34	0.49	0.31	0.29	0.27
Obs.	1320	1320	1320	1320	1320	1320	1320	1320	1320	1320	1320

Table 2 Cross-sectional dependence test

Variables	Pesaran CD	Breusch-Pagan LM	Prob.	Hypothesis
Population	1.536373	8850.449	0	The hypothesis is rejected
GDP per capita	39.77402	4661.408	0	The hypothesis is rejected
GDP squared	17.79328	2639.428	0	The hypothesis is rejected
Manufacturing	42.91235	10039.22	0	The hypothesis is rejected
Industry	25.53531	10482.33	0	The hypothesis is rejected
FDI	13.69132	2952.619	0	The hypothesis is rejected
Trade openness	37.27973	11813.5	0	The hypothesis is rejected
GHGs	7.785413	14353.85	0	The hypothesis is rejected
CO_2	8.95062	13319.04	0	The hypothesis is rejected
Nitrous oxide	−1.118409	15209.94	0	The hypothesis is rejected
Methane	−0.384761	18928.28	0	The hypothesis is rejected

Panel cointegration test

The results of panel cointegration tests (Table 4) express that the outcomes of these three tests reveal that cointegration among the modeled variables of environmental degradation exists, so these outcomes halt to accepting the null hypothesis in most of the cases.

After determining the cointegration relationship of the variables, by utilizing the autoregressive distributed lag model (ADL), five models are evaluated, due to the volatility of the environmental indicators and the ratio of industrialization (Opoku and Boachie 2020b). The results of the five models are presented in Tables 1, 2, 3, 4, and 5. For model A, carbon dioxide is used as the dependent variable to measure environmental degradation, and for measuring industrialization, manufacturing is employed. The estimation approach for model B is similar to model A, where the industry is used as a measure of industrialization. Similarly to measure the environmental degradation, greenhouse gas emissions, nitrous oxide emissions, or methane emissions has been used for model C to model E to be used as a reliability test, and significant industrious analysis. Since most of the coefficients were statistically insignificant, so the short-run estimates do not report here.

The results of model A (Table 5) indicate that industrialization, FDI, GDP square, and population have a significant and negative impact on CO2 emission. However, GDP per capita has a positive and significant effect on CO2 emission. Therefore, GDP and GDP square are consistent with the EKC hypothesis which claimed that initially as GDP increase, carbon dioxide emissions will increase, and after reaching a peak of economic development, GDP per capita increase and the emissions of CO2 began to fall. Similarly, significant FDI results confirm the existence of the PHH estimate because it has a negative correlation with CO2, which shows that in this case with a 1% increase in FDI, CO2 emissions are reduced by 0.17%. Only one variable, i.e., trade openness, is negatively insignificant with the environmental degradation.

Moreover, the results of model B (Table 6) indicate that industrial production and GDP per capita have a positive and significant association with CO2 emission in the long run while GDP per capita square has a negative and significant association with CO2 emission. Moreover, FDI, POP, and trade openness have an insignificant association with CO2 emission in model B. Therefore, this study accepts the EKC and PHH.

Table 3 Unit root test

Var.	Order of integration	Method	LLC	IPS	ADF	PP Fisher
POP	I(0)	Prob.	0	0	0	0.0002
		Statistic	−9.1691	−9.0409	303.58	169.99
GDP per capita	I(0)	Prob.	0	0	0	0
		Statistic	−13.97	−12.944	387.24	534.64
GDP squared	I(0)	Prob.	0	0	0	0
		Statistic	−10.88	−12.146	361.87	547.09
Manufacturing	I(0)	Prob.	0.0001	0.0364	0.0102	0.0001
		Statistic	−3.7683	−1.7941	147.29	172.64
Industry	I(0)	Prob.	0.0016	0.4703	0.6561	0.4493
		Statistic	−2.9498	−0.0744	103.5	111.23
FDI	I(0)	Prob.	0	0	0	0
		Statistic	−4.654	−7.53	243.08	361.28
TO	I(0)	Prob.	0.0001	0.1135	0.0875	0.4855
		Statistic	−3.788	−1.2081	130.62	109.87
GHGs	I(0)	Prob.	1	1	0.9999	0.9999
		Statistic	3.99779	6.20689	62.899	62.464
	I(1)	Prob.	0	0	0	0
		Statistic	−11.418	−13.549	400.11	828.56
CO_2	I(0)	Prob.	0.9999	1	0.9999	1
		Statistic	3.8867	5.66459	61.748	61.367
	I(1)	Prob.	0	0	0	0
		Statistic	−12.265	−13.649	401.52	778.04
Nitrous oxide	I(0)	Prob.	0.0314	0.9364	0.7716	0.5151
		Statistic	−1.8612	1.52531	98.7	108.77
Methane	I(0)	Prob.	0	0.8635	0.2485	0.0004
		Statistic	−4.6292	1.09627	119.68	166.4

Table 4 Panel cointegration test

	Within dimensions (panel)				Between dimensions (panel)			Decision
	V	rho	PP	ADF	rho	PP	ADF	
Statistic	3.062825	−5.2754	−15.200	−6.61469	−3.4627	−20.671	−6.9777	Cointegration exists
Prob.	0.0011	0.0000	0.0000	0.0000	0.0003	0.0000	0.0000	

(Kao 1999) cointegration test							Decision
	ADF						
t-Statistic	−18.0102						Cointegration exists
Prob.	0.0000						

Johansen Fisher panel cointegration test						
	None	At most 1		At most 2		At most 3	Decision
Fisher stat	611.0	266.8		152.6		165.5	Cointegration exists
Prob.	0.00	0.00		0.0045		0.0005	

Furthermore, in model C (Table 7), this study utilizes greenhouse gas (GHG) as a dependent variable or environmental indicator. This model has failed to generate significant results. Only one variable that is GDP per capita is highly significant with GHG with a positive sign, so once again ECK hypothesis is accepted. Increasing economic growth is accompanied by the changes in the economic structure and generally increases greenhouse gas emissions.

In this model, nitrous oxide is used as environmental degradation and statically significant with all the variables (Table 8). The results suggest that industrialization, which is measured by the manufacturing factor,

Table 5 ARDL model A

Dep. Var = CO2				
Ind. variable	Coefficient	Std. error	t-Statistic	Prob.*
Long-run estimates				
Manufacturing	−0.0313*	0.0059	−5.3164	0.0000
FDI	−0.0018*	0.0005	−3.7521	0.0002
GDP per capita	0.0168*	0.0041	4.0738	0.0001
GDP squared	−0.0015*	0.0004	−3.4553	0.0006
Population	−0.0400*	0.0162	−2.4715	0.0137
Trade openness	−0.0008	0.0005	−1.6157	0.1065

*Indicates the level of significance at less than 5%

Table 6 ARDL model B

Dep. Var = CO2				
Ind. variable	Coefficient	Std. error	t-Statistic	Prob.*
Long-run estimates				
Industry	0.1341*	0.00815	16.4539	0.000
FDI	−0.0004	0.0008	−0.553	0.5804
GDP per capita	0.03834*	0.01095	3.50101	0.000
GDP squared	−0.071*	0.00123	−57.7235	0.001
Population	−0.0271	0.04102	−0.6614	0.5085
Trade openness	−0.001	0.00138	−0.7136	0.4757

*Indicates the level of significance at less than 5%

Table 7 ARDL model C

Dep. Var = greenhouse gas				
Ind. variable	Coefficient	Std. error	t-Statistic	Prob.*
Long-run estimates				
Manufacturing	−0.0136	0.0086	−1.5773	0.1151
FDI	−0.0005	0.0007	−0.7138	0.4755
GDP per capita	0.0203*	0.0077	2.6182	0.0090
GDP squared	0.0001	0.0008	0.1070	0.9148
Population	0.0127	0.0208	0.6124	0.5404
Trade openness	v0.0004	0.0010	−0.4178	0.6762

*Indicates the level of significance at less than 5%

is significant with nitrous oxide and possesses with the embryonic to decrease the emissions of nitrous oxide by 152% if the manufacturing increases by 1%; this seems virtuous towards the betterment for the environmental condition of the Asian countries. GDP per capita is highly significant with nitrous oxide so, yet again, ECK hypothesis is not rejected. In general, it has been observed that economic growth destroys the environment by increasing emissions. Conversely, most of the countries in the region would reach a high level of economic growth and environmental standards. Whereas FDI is statically significant

Table 8 ARDL model D

Dep. Var = nitrous oxide				
Ind. variable	Coefficient	Std. error	t-Statistic	Prob.*
Long-run estimates				
Manufacturing	−1.5284*	0.3291	−4.6436	0.0000
FDI	0.1813*	0.0557	3.2546	0.0012
GDP per capita	2.9313*	0.4630	6.3312	0.0000
GDP squared	−0.1304*	0.0286	−4.5640	0.0000
Population	5.4937*	1.1289	4.8665	0.0000
Trade openness	−0.2251*	0.0359	−6.2635	0.0000

*Indicates the level of significance at less than 5%

Table 9 ARDL model E

Dep. Var = methane				
Ind. variable	Coefficient	Std. error	t-Statistic	Prob.*
Long-run estimates				
Manufacturing	6.8015*	0.8264	8.2299	0.0000
FDI	−0.6503*	0.2235	−2.9095	0.0037
GDP per capita	3.0088*	0.7721	3.8971	0.0001
GDP squared	0.1561*	0.0717	2.1784	0.0296
Population	0.6599	2.1927	0.3009	0.7635
Trade openness	−0.9573*	0.1195	−8.0080	0.0000

*Indicates the level of significance at less than 5%

with environmental degradation with positive relationship, so PHH is rejected. It is found that the coefficient of the population is positive and statistically significant at a 5% confidence level. A 1% increase in the region's population could increase nitrogen oxide emissions by 54%, meaning that population growth is deteriorating. The STIRPAT hypothesis is not rejected for this model. The results for trade openness displayed that increase in emissions is dependent on the rise in trade which strengthens the PHH.

Similarly, in model E (Table 9), the study utilized methane emission as the dependent variable; the estimated results of the model revealed that environmental indicator is statistically significant along with negative coefficient for FDI and trade openness which implies the same results. PHH and EKC hypothesis is accepted, as economic growth also positively and significantly affects environmental degradation. Increased population growth is associated with ever-expanding infrastructure and enormous energy demand, which could harm the environment (Shahbaz et al. 2014). A growing population is to lead to increased demand for transport and increased deforestation, which has an impact on the environment.

Table 10 Fully modified OLS results

Ind. variables	Dependent variable							
	CO2		Greenhouse gas		Nitrous oxide		Methane	
	Coefficient	Prob.	Coefficient	Prob.	Coefficient	Prob.	Coefficient	Prob.
	Long-run estimates							
Manufacturing	−1.7901*	0.0030	−1.6130	0.0082	1.6686	0.0000	4.2370	0.0000
FDI	2.2359	0.0763	3.3982	0.0098	−0.0326	0.8697	0.2394	0.6536
GDP per capita	7.8877*	0.0000	6.2631	0.0003	1.5402	0.0004	4.9636	0.0000
GDP squared	−0.6145*	0.0000	−0.4428	0.0025	−0.0576	0.2506	−0.3411	0.0000
Population	−3.0048*	0.7008	−7.4631	0.3840	−3.6070	0.0020	−10.4738	0.0008
Trade openness	0.0803*	0.6341	0.1225	0.5129	−0.0632	0.0315	−0.3172	0.0000

*Indicates the level of significance at less than 5%

Results of fully modified ordinary least square (OLS)

To check the robustness of the results, FMOLS is used for testing the proposed hypotheses and evaluating long-run coefficients. The results of fully modified OLS in Table 10 revealed the positive and significant effects of economic growth on dependent variables in all four models, and results confirmed the existence of EKC. The coefficient of industrialization is found to be statistically significant with all variables used that are used as a proxy of the environment. However, in the long-run estimation, the effects of FDI on pollution are not consistent with the outcomes of the ARDL, as it depicts a positive relationship and insignificant status with employed environmental indicators (Waqih et al. 2019); these results are enough evidence to unconfirm the PHH while trade openness showed dependence on environmental indicators appertaining with the PHH. The greenhouse gas emissions, carbon dioxide emissions, methane emissions, and nitrous oxide emissions are expected to increase as the population grows but results of the fully modified ordinary least squares estimator showed ballpark figures. The STIRPAT hypothesis is also confirmed based on robust results.

Discussion

However, it is a summary of the results obtained and it is concluded that the CO2 emissions, which are the most important proxy of environmental degradation, have been associated with economic growth, foreign direct investment, and industrialization in the long run. Short-term projections are not included in the study, due to the fact that most of the coefficients are statistically insignificant ((Opoku and Boachie 2020a). Greenhouse gas emissions and the emissions of CO2, methane, and nitrous oxide are significantly and positively associated with economic growth. The literature moreover appears that, within the long run, economic growth will lead to an increment within

the CO2 emissions that contaminate the environment (Balli 2021). It appears that the influence of industrialization (measured in terms of manufacturing and industry) on environmental indicators is predominantly positive and significant. Results of this study are consistent with Cherniwchan (2012) who established that industrialization is a significant determinant environmental quality: a 1% increase in industry's share of total output is associated with an 11.8% increase in the level of CO_2 emissions per capita. As developing nations transformed from agrarian economies to industrialization, initially, pollution-intensive industrial production increases and largely contributes in environment degradation (Patnaik 2018).

Furthermore, the outcomes of the estimation indicated FDI has a significant and negative impact on CO2 emissions; results are consistent with Hanif et al. (2019). However, results are contradicting Sabir et al. (2020) who have concluded that in South Asian nations, FDI significantly increases environment degradation because foreign investor imparts tradition production technologies which increases concentration of CO2 in the environment.

Contrary, the results of this study are consistent with other stance of literature which argued that due to FDI inflow, it become possible for developing nations to invest in research an innovation sector and have access to the cleaner and environmental-friendly technology which facilitates and accelerates production process (Jalil and Feridun 2011; Sabir et al. 2020). The statistics of the long run demonstrate that a decrease in CO2 emissions may be due to technology compatibility and ways to improve the environment. This can be attributed to the use of modern contaminant separation technologies and approaches, such as nitrification-enriched activated sludge (NAS) in biomembrane reactors (MBR) (Sepehri and Sarrafzadeh 2018).

Similarly, the existence of the EKC hypothesis has been confirmed according to the results of FMOLS

(Waqih et al. 2019) and also failed to reject in model estimation by using the ARDL model. The trade openness has a mixed effect on environmental degradation but their negative relationship along with the negative relationship of FDI with dependent variables supports the PHH from rejection in model estimation whereas the results of FMOLS have enough evidence to unconfirm the PHH. And the STIRPAT hypothesis is confirmed based on reliable research results.

Conclusion and recommendations

Environmental degradation has been the main distress in recent years due to the drastic effect of climate change. To determine the thorough impact of industrialization and foreign direct investment on environmental degradation, this study utilized the data of fifty-five countries of the Asia-Pacific region from 1995 to 2020. The main proxy for the environmental indicator was CO2 emissions, whereas other proxies, methane, GHG, and nitrous oxide emissions, are also used to measure environmental degradation. According to the literature, the results show that FDI, in general, has a significant negative impact on the environment and causes to increase in methane and CO2 emissions. In general, the effects of industrialization, measured in terms of industrial and manufacturing variables, on the environment, were significantly associated with the environment but the size of the impact is moderate. The EKC hypothesis has been described in most of the results by independent variables, particularly economic growth that found statistically significant along with positive relationship, which postulates that economic growth is a cause for the degradation of the environment by increasing emissions of GHGs, CO2, methane, and nitrous oxide. It is also found that population growth puts the environment at risk, but long-term FMOLS statistics are not consistent with ARDL estimates of population parameters. The environmental impact of opening to trade varied and the impact depended on the environmental proxy used. Second, PHH is visible in the long-term results of the ARDL and the cross-sectional results of the data analysis, suggesting that FDI contributes to emissions. It is necessary to ensure that strict environmental laws guarantee to not harm the environment with the influx of FDI into the sector. Therefore, the strict application of environmental guidelines or the adoption of a new policy is the key to ensuring the quality of the environment. Furthermore, the results confirm that most of the panel countries are developing countries and do not have strict environmental management guidelines.

The agenda of investment policymakers is to attract more international investors to participate in the development of these countries or regions and to attract cleaner technologies and energy saving through foreign direct investment. Pay attention to FDI, as it has the potential to improve economic growth and the environment policymakers should also strive to encourage the flow of foreign direct investment in technology-intensive and environmentally friendly industries. As in many developed countries, lawmakers may enact environmental laws to set the limits of environmental degradation so the companies that pollute the environment above the certain optimal levels must pay fines. Because foreign direct investment has a positive impact on economic growth, it has been linked to its competence in increasing efficiency and improving environmental management, which has helped the region and countries. It is also possible to eliminate clean technology in the region to attract foreign direct investment from developed countries. This requires joint efforts among the countries to enhance low-carbon technologies and develop renewable energy systems.

Regarding the validation of the EKC hypothesis has been evaluated in different models of the study. On the basis of results, it is recommended that countries should increase the real GDP andthe production of goods and services. With this continuous development, countries would advance their economies and simultaneously achieve environmental quality. However, since higher growth would also increase energy consumption in this context, it may lead to a deterioration of the environmental condition. Moreover, as a matter of urgency, reducing greenhouse gas emissions in the region is an important step in preventing climate change, as half of the greenhouse gas emissions come from Asia and the Pacific. Some of the region's largest economies will need to reverse current trends over the next decade to meet their zero-carbon commitments. Consequently, developing countries need to develop sustainable strategies and they must also focus on green investment. As such, the findings encourage policymakers to be more careful in defining trade policy as the effects of trade openness are mixed. The safest way would be to promote cost-effective innovations, as well as to add value to natural resources to trade policy.

economic growth? Evidence from South Asian countries. Borsa Istanbul Review (In-Press).

Appendix

Table 11 ESPR Paper Appendix A

DEFINITION OF VARIABLES

Variables	Description	Data Sources
Industry	This is another proxy for industrialization, measured as industry value added.	World Bank
FDI	This is a ratio of the inflow of foreign direct investment to GDP	World Bank
GDP per Capita	This represents the per capita Gross Domestic Product of each country.	World Bank
GDP squared	This represents the square of the Gross Domestic Product of each country.	World Bank
Manufacturing	This is a proxy for industrialization, measured as manufacturing value added.	World Bank
Greenhouse gases	This variable represents emissions of greenhouse gases, measured in kilotons.	Climate Watch
CO2	It represents carbon dioxide emissions measured in kilotons.	Climate Watch
Nitrous oxide emissions	Nitrous oxide emissions measured in kilotons.	Climate Watch
Methane emissions	Methane emissions measured in kilotons.	Climate Watch
Population	The descriptive number of the population of interest.	World Bank
Trade openness	This is the trade to GDP ratio. It is measured as imports plus export to GDP.	World Bank

Author contribution **Farhan Ahmed**—conceptualization, literature review, and methodology (25%)

Imtiaz Ali—literature review, data analysis, and drafting (25%)

Shazia Kousar—data, methodology, reviewing, and policy recommendations (25%)

Saira Ahmed—analysis, conclusion, and reviewing (25%)

Data availability The data used in this study can be provided by the corresponding author on reasonable request.

Declarations

Ethics approval All the sources have been cited appropriately and there is no such issue during this study.

Consent to participate All the authors will participate in review and publication process.

Consent to publish All the authors have given their consent to publish this study.

Conflict of interest The authors declare no competing interests.

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