

1 **Economic complexity, greenfield investments, and energy innovation: Policy implications for**
2 **sustainable development goals in Newly Industrialized economies**

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23 **sustainable development goals in Newly Industrialized economies**

24 **Abstract**

25 The crucial role of environmental assessment quality has been recognised by environmental and sustainable
26 development goals in addressing climate change challenges. By focusing on the key identifier of environmental
27 assessment, progress can be made towards overcoming climate change issues effectively. The current study considers
28 environmental commitments under COP28 to study the role of economic complexity, greenfield investments, and
29 energy innovation in environmental degradation in newly industrialised economies from 1995 to 2021. We employ
30 novel panel estimations from CS-ARDL, CS-DL, AMG, and CCEMG to confirm that economic growth and greenfield
31 investments degrade environmental quality. On the other hand, energy innovation and urbanisation improve
32 environmental sustainability. Lastly, we confirm the EKC hypothesis for economic complexity as well. Given the
33 reported empirical findings, the study suggests policymakers must focus on economic complexity to transform
34 industrial sectors' economic potential. Furthermore, foreign investment projects must be linked with environmental
35 goals to increase renewable energy capacity.

36 **Keywords:** Newly Industrialised countries; Energy transition; Environmental degradation; Economics complexity;
37 Greenfield investment

38

39 **1. Introduction**

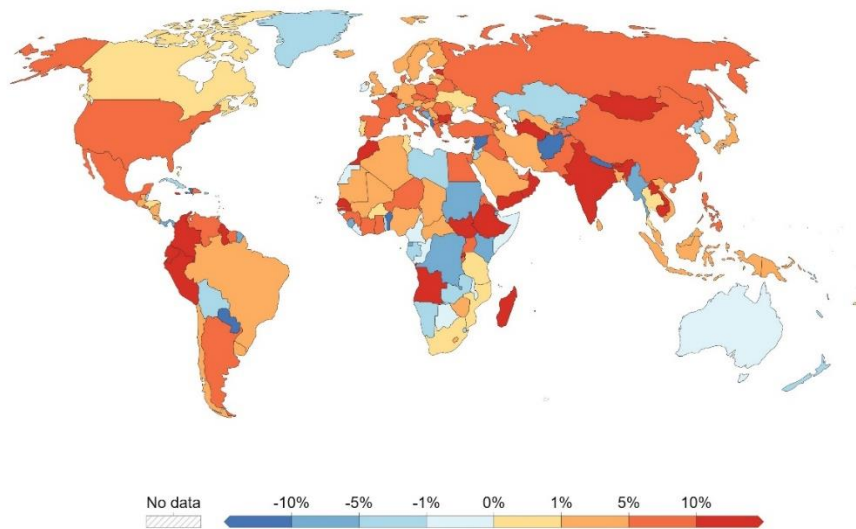
40 In past decades, rapid industrialisation has improved income levels, living standards, and health services, but such
41 economic transformation also had grave negative implications, such as environmental degradation and income
42 inequality (Bilgili et al. 2021). Global environmental issues are the most prominent examples of such negative effects
43 caused by pursuing industrialisation and economic development (Sadiq et al. 2022). Product manufacturing at an
44 industrial scale and peoples' willingness to consume have also exacerbated negative environmental implications. The
45 EKC hypothesis can more clearly state the concept of environmental degradation, which explains that countries focus
46 on economic growth in the initial phase and only improve environmental sustainability after reaching a certain
47 threshold. Consequently, there have been efforts to fight climate change, as it has serious implications for future
48 generations (Yilanci and Pata 2020). Global environmental forums such as the Conference of Parties (COP) and Kyoto
49 Protocols have attempted to outline global consensus and ensure environmental protection (IEA 2020). The
50 Conference of Parties (COP) was formed in Brazil in 1992 as 154 countries joined efforts to fight climate change. The
51 most recent COP meeting was held in Sharm El Sheikh, Egypt, where 190 countries expressed their support for the
52 United Nations SDGs, reducing fossil fuel consumption and limiting the rise in temperature to less than 2°C (Bashir
53 et al. 2023). Several studies have researched environmental quality to conclude that GHG emissions are the primary
54 contributors to the carbon footprint.

55 Research and technological advancements are expected to drive economic complexities within the environmental
56 discussion, which can serve as a pathway for openness towards green technologies and products (Majeed et al. 2022).
57 Available evidence suggests that mere focus on economic growth means that industrial and developing economies
58 push towards rapid industrialisation, which raises fossil fuel demand and has negative environmental implications
59 (Martins et al. 2021; Neagu 2021). As a result, researchers argue that economic complexity allows host countries to
60 increase industrial production and reduce their environmental footprint through green R&D and environmental
61 investments (Doğan et al. 2020). Because of the multifaceted attributes of economic complexity, a more intricate
62 economic landscape offers diversification and technological prowess, enabling adaptable transitions to eco-friendly
63 industries and innovations. Akadiri et al. (2022) discovered that economies of scale become attainable due to
64 economic complexity, reducing per-unit costs for green technologies to boost industrial production. Besides this,
65 advanced regulatory frameworks in such complex economies prompt environmentally conscientious practices.
66 Knowledge spillovers among industries accelerate green R&D, while improved access to capital further supports
67 sustainable initiatives. Furthermore, global trade integration fosters international cooperation and the adoption of eco-
68 friendly norms, enhancing competitiveness in the global arena. Thus, economic complexity is not merely about having
69 a wide array of industries but the depth and interconnectedness of the industries that foster innovation and
70 technological advancement. As global policies evolve, environmental sustainability and energy conservation have
71 become the focal point of the environmental agenda (He et al. 2021). This requires policymakers to integrate economic
72 complexity within the policy agenda to achieve industrialisation and produce industrial products with a less
73 environmental footprint.

74 Recent literature has also identified the role of greenfield investments and how they can impact environmental
75 sustainability in the host country (Bukhari et al. 2023). These investments can be integral in supporting environmental

76 projects, i.e., renewable energy, waste recycling, and electricity plants, to ensure the environmental agenda achieves
77 the desired outcomes (Bashir et al. 2022b). Urbanisation is another major indicator that, in recent decades, has
78 constrained available urban resources. However, rapid technological advancements have allowed policymakers to
79 balance economic and environmental agendas so that industrialisation can be achieved without sacrificing economic
80 growth. Moreover, recent technological advancements mean countries are more willing to replace traditional
81 technologies and use green technologies to improve their industrial footprint and mitigate climate change (Mahmood
82 et al. 2022). Hence, industrial transition, environmental innovation, and green finance can help reduce fossil energy
83 dependence and promote sustainable economic development.

84 The global trends and pressure for industrialisation have sharply increased the demand for energy products.
85 Consequently, the socioeconomic policies of NIC¹ countries have undergone great scrutiny as these economies are
86 responsible for around 40% of global energy consumption (IEA 2020). On the other hand, recent industrialisation
87 means these countries have the financial resources to invest in green energy and lessen their fossil fuel dependence
88 through renewable energy (World Bank 2022). The UN SDG report issued in 2018 mentioned that China invested 45%
89 of total global green energy in transforming the domestic energy mix. However, NIC economies are still formulating
90 policy mechanisms to increase renewable energy by gradually switching towards green energy and balancing
91 economic and environmental growth as they remain dependent on fossil fuels. According to UN statistics, these
92 countries receive about 20% of global FDI and have used such resources to transform energy (Baek 2016; Adom et
93 al. 2019).



94

95

Figure 1: Total change in global energy consumption (Source: BP Statistics, 2022)

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While the existing environmental literature has identified various influential factors impacting environmental quality, our research seeks to address and expand upon several research gaps, contributing significantly to advancing the academic discourse on environmental issues. First, this study explores the interlinkages of economic complexity,

¹ Turkey, Thailand, South Africa, Philippines, Mexico, Malaysia, Indonesia, India, China, Brazil,

99 greenfield investments, and environmental innovation concerning environmental degradation in the NICs from 1995-
100 2021. Second, this study extends the environmental discussion by incorporating novel environmental degradation
101 proxies comprising six major environmental pollutants to provide a more holistic context about environmental
102 degradation and how different GHG sub-components affect environmental sustainability. Third, this study suggests
103 using greenfield investments in energy projects, a more accurate and comprehensive indicator than investment inflows
104 from FDI. Lastly, this research emphasises providing actionable policy recommendations and strategies for
105 policymakers, businesses, and stakeholders to actively promote and implement sustainable practices.

106 **2. Literature review**

107 The current section overviews the environmental literature regarding economic complexity, urbanisation, economic
108 growth, energy innovation, and environmental degradation. The selection of specific factors such as economic
109 complexity, greenfield investments, and energy innovation is driven by the assumption that they interact in shaping
110 the environmental trajectory of newly industrialised economies. Understanding their correlation with environmental
111 degradation is critical in extending environmental discussion. Furthermore, the analysis positions EKC within the
112 context of this study in order to provide more informed policy implications. Although several studies have explored
113 similar associations, the analysis relies on novel composite indexes of environmental degradation and environmental
114 technologies to extend the academic discussion. Besides this, the study has categorised the literature review into six
115 aspects of environmental degradation: economic complexity, economic growth, greenfield investments, technological
116 innovations, and urbanisation based on the multifaceted nature of environmental studies. This classification facilitates
117 a comprehensive understanding of the interconnectedness between environmental, economic, and technological
118 factors. It constructs a holistic view, enabling a more nuanced analysis of the complex interplay between these
119 variables.

120 **2.1. Environment Degradation - Economic Complexity**

121 Economic complexity is a critical indicator carrying influence over economic and environmental progress. Chu (2021)
122 investigated rising environmental challenges to report the u-shape association between ECI and environmental
123 pollutants. Doğan et al. (2021) and Leitão et al. (2021) researched the role of ECI in OECD and BRICS economies to
124 indicate that ECI lowers environmental footprint. Aluko et al. (2022) researched selected industrial economies from
125 1998 to 2017 to show that the economic level allows ECI to lower GHG and carbon emissions. However, Yu et al.
126 (2020) studied countries with the highest ECI to establish that ECI is a primary contributor towards ecological
127 challenges. Similar findings were reported by Lee et al. (2022), and Chu & Le (2022) confirmed the EKC hypothesis
128 for global panel and G7 economies to suggest that ECI gradually eliminates environmental degradation.
129 Moreover, Hassan et al. (2023) selected emerging economies to establish that ECI affects environmental
130 contamination. However, the researchers reported that technological innovation and RE consumption help overcome
131 ecological concerns.

132 In recent studies, Akadiri et al. (2022) investigated ECI in BRICS economies to show that economic complexity
133 reduces environmental degradation by promoting renewable energy in the industrial and household sectors. Li et al.
134 (2024) researched economic complexity and ecological challenges and reported that technological interagaition is key
135 to using economic and industrial transformation to improve ecological sustainability. Can and Gozgor (2017) studied

136 the French economy to conclude that energy consumption affects environmental sustainability, while ECI overcomes
137 environmental pollutants. Earlier, Okamoto (2013) performed extended econometric investigation to conclude that
138 industrial practices remain key to using ECI and ecological sustainability. Bashir et al. (2022a) examined ecological
139 challenges, energy consumption, and ECI to stipulate that economic complexity ensures ecological threats in emerging
140 economies. Moreover, RE lowers environmental deterioration and GHG emissions. Khezri et al. (2022) researched
141 APEC region by sampling CO₂, renewable energy consumption, and economic complexity to suggest that higher fossil
142 energy consumption means that developing economies are not able to benefit from economic complexity.

143 **2.2. Environmental Degradation - Greenfield investments**

144 We also focus on documenting how greenfield investments impact industrial and environmental reforms. Doytch &
145 Narayan (2016) explored foreign investments in 74 developing economies from 1985 to 2013 to show that it promotes
146 green energy projects in the long run. Doytch (2020) researched investment decisions by high-income economies to
147 reveal that such decisions are primarily made so that pollution-intensive industries are transferred to lower their
148 ecological footprint. Doytch & Ashraf (2022) studied greenfield investments and environmental degradation to report
149 that greenfield FDI deteriorates environmental quality. Another literature section concluded that unequal
150 ecological exchange in international trade leads to resource depletion in emerging economies and causes
151 environmental degradation. Moreover, environmental regulations influence investment decisions as high-income
152 transfers outdated technologies and industries with a higher ecological footprint (García-Quevedo and Jové-Llopis
153 2021).

154 Likewise, Bashir (2022) overviewed academic publications to validate the pollution haven hypothesis for developing
155 economies. Abu Bakar (2019) sampled empirical datasets from ASEAN economies to study the impact of greenfield
156 investments in environmental sustainability. The researchers used panel estimation techniques to confirm the PHH
157 hypothesis as greenfield investments degraded environmental quality in the region. Shahbaz et al. (2022) contradicted
158 these findings to suggest that foreign investments increase renewable energy consumption. Within the same discussion,
159 Adeel- Farooq et al. (2018) researched environmental performance in selected Asian economies to confirm a negative
160 association between environmental quality and greenfield investments. Recently, Ponce et al. (2022) validated similar
161 empirical estimates for low-income economies as foreign investments exacerbate environmental footprint in the long
162 run.

163 **2.3. Environmental Degradation- Energy Innovation**

164 As global economies push environmental agendas to comply with regional and global sustainable agendas, innovation
165 in environmental technologies has become a key instrument for ensuring energy transition and sustainable growth
166 (Álvarez-Herránz et al. 2017). Recent research has concluded that environmental innovation will be the most critical
167 indicator in overcoming global warming and climate change in developing economies (Mensah et al. 2018). However,
168 plethora of available studies are limited to either carbon or GHG emissions in explaining the role of technology over
169 environmental sustainability. Bashir et al. (2020) researched 29 OECD economies from 1995 to 2017 to contend that
170 energy innovations lower carbon emissions and ensure compliance with sustainable development goals. Some studies
171 also explored the extent to which technological innovation overcomes EFP. Ahmed et al. (2020) sampled data from

172 selected developed economies to conclude that technological innovations positively correlate with environmental
173 sustainability. Furthermore, the study confirmed a bidirectional causal association between environmental degradation
174 and technological innovations. In another study, Gormus & Aydin (2020) reported similar empirical findings for
175 OECD economies between EFP and energy innovation, especially for Finland, South Korea, and the United States.
176 However, country-wise findings for the UK, Switzerland, Holland, Israel, Germany, and Denmark contradicted such
177 estimates.

178 **2.4. Environmental Degradation - Economic Growth**

179 Reforms in the industrial sector have allowed rapid economic progress worldwide, but they also put pressure on
180 environmental quality. Bukhari et al. (2023) selected South Korean dataset to suggest that economic growth and
181 industrialisation degrade environmental quality. Al-Mulali et al. (2015) used ecological footprint as base criteria to
182 confirm the EKC hypothesis for developed countries, but it did not hold for middle-income countries. Furthermore,
183 the researchers concluded that trade openness and fossil fuel consumption have negative while banking development
184 has a positive association with environmental quality. Charfeddine (2017) researched economic openness, financial
185 development, and electricity consumption in selected industrial economies to suggest that industrialisation and
186 economic activities degrade environmental quality.

187 In another study, Charfeddine & Mrabet (2017) explored the MENA region to confirm the u-shape curve between
188 industrial growth and environmental degradation for non-oil exporting economies, while an inverted u-shape curve
189 for oil exporting MENA economies suggests that higher energy consumption by the industrial sector is the leading
190 cause of environmental pollution in the region. While, Mrabet et al. (2017) contested these findings for Qatar to report
191 that EKC does not hold GHG emissions and industrial activities as researchers informed positive relationship between
192 oil prices and GHG emissions while trade openness overcomes environmental challenges. Similarly, Dogan et al.
193 (2020) shared similar outcomes for BRICST economies. Other studies by Danish & Wang (2019) and Wang et al.
194 (2013) validated the EKC hypothesis for BRICS and high-income countries, respectively.

195 **2.5. Environmental Degradation - Urbanisation**

196 The rapid industrialisation in urban areas means that in recent years the rural migration toward cities has put pressure
197 on available resources and has significant implications for environmental initiatives. Consequently, several studies
198 have researched how urbanisation can impact the outcome of environmental challenges. Among these studies, Ahmed
199 et al. (2020) studied urbanisation in China to conclude that urbanisation and industrialisation in western provinces
200 have exacerbated environmental quality in recent years. Danish & Wang (2019) contradicted these arguments for
201 BRICS economies by analysing data from 1992 to 2016 to mention that urbanisation leads to greater acceptance of
202 renewable energy and positively affects environmental sustainability. Ahmed et al. (2020) sampled industrial
203 econometric data to mention that urbanisation and energy consumption exacerbate environmental challenges. Luo et
204 al. (2018) extended the discussion by sampling empirical data from Chinese provinces to claim that urbanisation
205 correlated with EFP and put excessive pressure on environmental quality from 2005 to 2014. In a recent study,
206 Nathaniel & Khan (2020) used AMG to analyse statistical data from ASEAN countries to contend that higher
207 urbanisation has negative implications for environmental sustainability. Lastly, Liang & Yang (2019) used Chinese

208 state-level data to suggest that industrial development has led to higher arrival of migrant workers in urban areas and
209 has significant negative implications for environmental quality in China.

210 Our evaluation of academic discussion to investigate environmental degradation, economic complexity, economic
211 growth, greenfield investments, technological innovations, and urbanisation indicates a lack of consensus on the nature
212 of the empirical association between these research areas. In this regard, we develop novel environmental degradation
213 and technological innovation indicators to offer further insights into how these selected variables influence the
214 outcomes of recent environmental reforms.

215 **3. Theoretical framework**

216 The current section details the theoretical arguments by which economic complexity, greenfield investments, and
217 energy innovation impact environmental sustainability in the existence of economic growth and urbanisation.
218 Investments in critical infrastructure are always significant, especially for developing economies that mainly depend
219 on foreign investment, and this may also affect the environment because the pollution haven hypothesis argues foreign
220 investors invest because of lower environmental regulations in developing economies; thus, foreign investment
221 degrades environmental quality. However, the pollution halo hypothesis stipulates that foreign investors bring
222 advanced technologies which help overcome environmental challenges in the host economy. This allows us to include
223 foreign greenfield investments to arrive at a conclusive argument regarding greenfield investments and ecological
224 sustainability.

225 Economic complexity is an critical indicator which is central to environmental strategies. First, the policy push to
226 achieve ECI and economic transition requires energy and fossil resources, which ultimately negatively impact
227 environment. While on the other hand, ECI stimulates industrial efficiency to gradually progress towards sustainable
228 development goals. Furthermore, ECI and higher education are integral in taking advantage from innovations to lower
229 EFP (Mealy and Teytelboym 2022). In addition, economies dependent on traditional production methods use non-
230 renewable energy resources and lack knowledge efficiency to limit the carbon footprint from industrial activities. Also,
231 several researchers have documented that resource consumption is responsible for environmental degradation (Bekun
232 et al. 2019), while others contradict such findings (Shahbaz et al. 2019).

233 Moreover, energy innovation is another main factor that has gained a significant role in energy and environmental
234 reforms as it helps evaluate technological innovation to overcome environmental challenges. Further, a more accurate
235 reflection of energy innovation reflects the extent to which R&D gets support from policymakers and how it can
236 impact upgradation in the industrial sector to minimise environmental footprint to help overcome environmental
237 efficiency, boost green exports, and assist structural transformation in easing transition towards ecological protective
238 industrialisation.

239 **3.2. Econometric model**

240 This study examines quantitatively the empirical association between economic growth, economic complexity,
241 greenfield investments, energy innovation, and urbanisation for environmental degradation in NICs from 1995 to 2021.

242 **The proposed linear model is given as:**

243 $ENVD = f(EG, ECI, GF, EI, URB)$ (1)

244 where EG= economic growth, ECI = economic complexity, GF = greenfield investments, EI = energy innovation,
 245 URB = urbanization, and ENVD = environmental degradation.

246 **3.3. Variables construction**

247 Current study tests the econometric linkage between economic growth, economic complexity, greenfield investments,
 248 energy innovation, and urbanisation on environmental degradation for newly industrialised economies. The data for
 249 economic progress is represented by GDP per capita (constant 2017 US\$), ECI is sourced from the Atlas Media
 250 database, greenfield investments are taken from UNCATD in greenfield FDI millions of dollars, and urbanisation is
 251 the total urban population from WDI. The novel composite index of ENVD consists of five major nitrous oxides,
 252 carbon dioxide, methane, greenhouse gases², and particulate matter. In addition, we tabulate EI by including the final
 253 count of patent submissions (PAT), trademark submissions (TM), technical fundings (GR), final count of R&D
 254 researchers (RES), and percentage of GDP expenditures (GOVEX). Our argument for formulating these indicators is
 255 that due to the complexity of the economic and environmental agenda, no single variable can provide a full account
 256 of environmental deterioration. Also, the varying impact of socioeconomic developments means that R&D
 257 expenditures (a traditional proxy for energy innovation) lack relevancy. Keeping in mind these arguments, we create
 258 ENVD and EI as:

259 $\ln ENVD_{it} = \alpha_{0it} + \alpha_{1it}CO_{2it} + \alpha_{2it}CH_{4it} + \alpha_{3it}N_2O_{it} + \beta_4PM_{2.5it} + \beta_{5it}GHGO_{it} + \varepsilon_{it}$ (2)

260 $EI_{it} = \beta_{0it} + \beta_{1it}PAT_{it} + \beta_{2it}TM_{it} + \beta_{3it}RES_{it} + \beta_4GR_{it} + \beta_{5it}GOVEX_{it} + \varepsilon_{it}$ (3)

261 Considering our theoretical and empirical arguments, equation 1 can be transformed as:

262 $\ln ENVD_{it} = \beta_1 \ln GDP_{it} + \beta_2 \ln ECI_{it} + \beta_3 \ln GF_{it} + \beta_4 \ln EI_{it} + \beta_5 \ln URB_{it} + \varepsilon_{it}$ (4)

263 In addition, we test EKC hypothesis, which transforms equation 4 as:

264 $\ln ENVD_{it} = \beta_0 + \beta_1 \ln GDP_{it} + \beta_2 \ln ECI_{it} + \beta_3 \ln ECI_{it}^2 + \beta_4 \ln GF_{it} + \beta_5 \ln EI_{it} + \beta_6 \ln URB_{it} + \varepsilon_{it}$ (5)

265 Equation 5 incorporates the linear and squared terms of ECI estimations. The integration of the EKC hypothesis posits
 266 a non-linear relationship between economic complexity and environmental degradation, reflecting an understanding
 267 that the relationship is not a straightforward, one-directional process but follows a more complex, inverted U-shaped
 268 curve. Moreover, the model includes various independent variables such as GDP per capita, ECI, greenfield
 269 investments, energy innovation, and urbanisation, indicators of different economic and social aspects. This
 270 multifaceted approach indicates an effort to capture the diverse factors that can influence environmental degradation.
 271 Also, the data transformation into natural logarithms and the composition of new indicators add layers to the analysis,
 272 acknowledging that environmental impact and innovation are multi-dimensional concepts. Besides this, the model is
 273 grounded in empirical data from various sources, reflecting a robust approach to capturing real-world economic and
 274 environmental phenomena.

² Hydrofluorocarbons sulphur, hexafluoride and perfluorocarbons

275

Table 1: Descriptive statistics

	ENVD	GDP	ECI	GF	EI	URB
Mean	0.201236	4.024786	0.540057	1.259446	0.329830	7.901148
Median	-0.392121	4.102978	0.469224	1.568043	0.314781	7.815963
Maximum	5.229749	4.497849	1.393506	2.959518	0.582623	8.945909
Minimum	-0.798023	3.322989	-0.351723	0.000000	0.181187	7.049754
Std. Dev.	1.312745	0.266491	0.441198	0.919951	0.111172	0.481325
Skewness	2.149879	-0.713658	0.277692	-0.279040	0.358598	0.475375
Kurtosis	7.164760	2.720121	1.916475	1.694512	1.974703	2.207288
Jarque-Bera	403.1229	23.80009	16.67787	22.67720	17.61304	17.23856
Probability	0.167329	0.329967	0.381239	0.118712	0.198150	0.221181
Observations	270	270	270	270	270	270

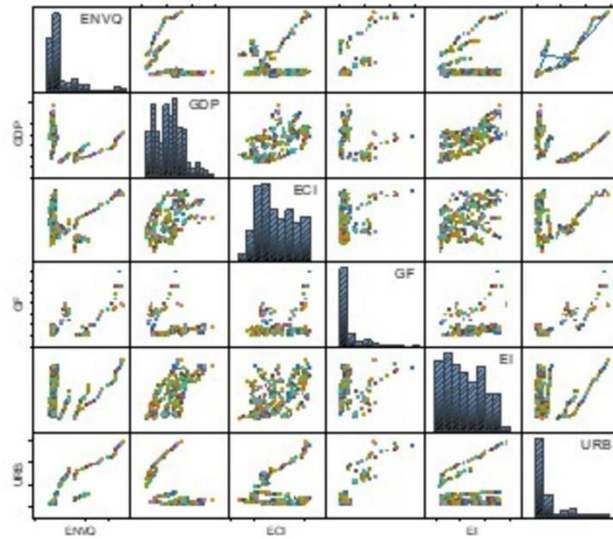
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277

Table 2: Correlation Matrix

	ENVD	GDP	ECI	GF	EI	URB
ENVD	1.000000					
GDP	0.231305	1.000000				
ECI	0.074215	0.473882	1.000000			
GF	0.282170	0.288402	0.318235	1.000000		
EI	-0.123401	0.510841	0.477102	0.402972	1.000000	
URB	-0.524577	-0.443640	-0.014459	0.316137	0.034502	1.000000

278



279

280

Figure 2: Scatter plot matrix

281 **3.4. Econometric strategy**

282 **3.4.1. Initial econometric tests**

283 Our initial econometric investigation begins with testing CSD, which generally affects modern economic data due to
 284 globalisation and common economic shocks. Moreover, an accurate assesment helps articulate unidentified shocks
 285 from social networks and geographical influences (Bashir et al. 2023). Laslty, CSD assesment empirical findings are
 286 consistent to overcome statistical biasness. Current research relies on Breusch-Pagan LM, Pesaran scaled LM, Bias-
 287 corrected scaled LM, and Pesaran CSD tests to check the existence of CSD. In addition, we test for empirical data's
 288 homogeneity through Pesaran and Yamagata test to accurately analyze data homogeneity of the co-integrated
 289 coefficients or if explanatory variables' coefficients vary from one unit to another.

290 Next, we proceed to using second generation tests to account for existence of unit root properties. The chosen test of
 291 CADF performs stationary tests by considering considers structural breaksfor every cross-section unit with the base
 292 assumption that time effect carries impact over data cross-sections; moreover, these tests dimensional autocorrelation.
 293 In addition to CADF, we use the CIPS unit root test, which assumes the existence of a correlation between the data
 294 series. Pesaran (2007) developed econometric models to overcome inter-serial correlation errors while examining the
 295 existence of stationary processes in panel datasets. Lastly, we analuze data cointegration to analyse the long-run
 296 affiliation within renewable energy and independent variables included in the experiment. Westerlund tests mainly
 297 tests data cointegration by provide accurate assesment of whether not error correction occurs for whole or different
 298 panel subsets.

299 **3.5. Long-run econometric strategy for determining long-run empirical coefficients**

300 The current study relies on CS-ARDL as the main empirical strategy, whereas CS-DL, AMG, and CCEMG have been
 301 included as a robustness check. First, we apply CS-ARDL as it can determine the short-run and long-run association
 302 between econometric variables by using a cross-sectional augmented ARDL approach. Moreover, it is also feasible
 303 as an econometric strategy as it deals with CSD and heterogeneity to provide more robust empirical findings from the
 304 perspective of endogeneity and non-stationary issues. CS-ARDL can be mathematically expressed as:

$$305 \Delta ENVD_{i,t} = \varphi_i + \sum_{j=1}^p \varphi_{it} \Delta ENVD_{i,t-j} + \sum_{j=0}^p \varphi'_{ij} AEV_{i,t-j} + \sum_{j=0}^p \varphi'_{ij} \bar{Z}_{t-j} + \varepsilon_{i,t} \quad (6)$$

306 In equation-6, the cross-section averages are evaluated by \bar{Z} , i.e., $\bar{Z}_t = (\overline{\Delta ENVD}_t, \overline{AEV}_t)'$, while AEV represents
 307 explanatory variables.

308 Current research also uses AMG, CCEMG, and CS-DL as secondary econometric approaches to further analyze data
 309 variables. First, the investigation strategy of AMG was proposed by Eberhardt & Bond (2009) and solves CSD issues
 310 through common dynamic effects. The econometric structure for AMG is closely related to CCEMG, which has been
 311 preferred to solve econometric issues within data statistics in more accurate manner. CCEMG generally estimates
 312 CSD linear pairings average, followed by using regression analysis to tielid data parameters. On the other hand, AMG
 313 uses two-stage phase to evaluate common dynamic effects. Lastly, we use CS-DL to cross-examine possible cross-
 314 sectional lags. CS-DL can be econometrically explained as:

$$315 y_{it} = \alpha_i + \beta_i y_{it-1} + \delta_{0i} x_{it} + \delta_{1i} x_{it-1} + \sum_{l=0}^{PT} \sigma'_{il} \bar{z}_{it-1} + \mu_{it} \quad (7)$$

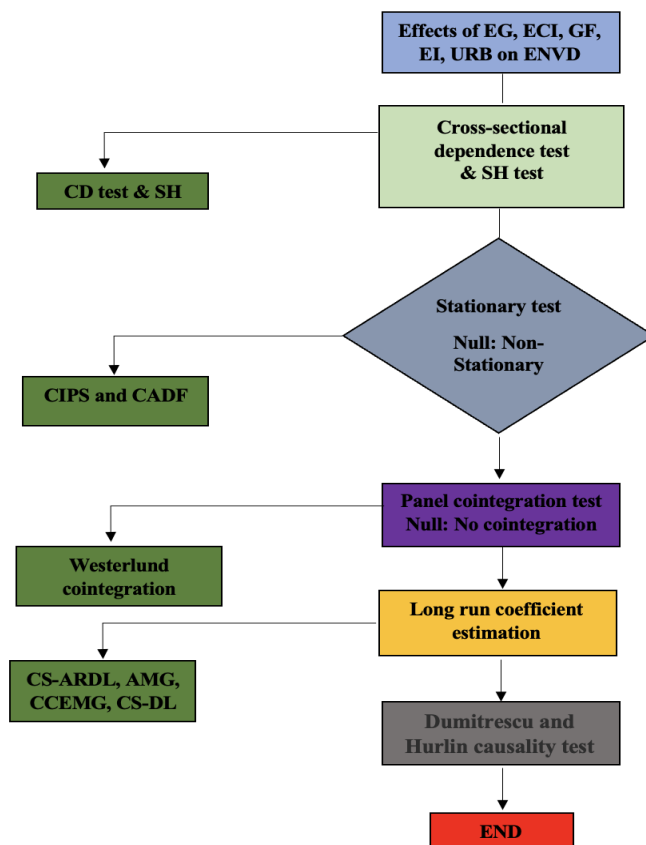
316 For $i = 1, 2, \dots, N$, and $\bar{z}_t = N^{-1} \sum_{i=1}^N Z_{it} = (\bar{y}_t, \bar{x}_t, \bar{f}_t)'$, where δ_0 and β_0 are arithmetic averages of least squares
 317 of δ_{0i} and β_i . The unobserved common factor with heterogeneous factor, intercept, and error term are explained by
 318 f_t , α_i and μ_{it} . Lastly, equation 8 can be used to estimate long-run estimates.

319
$$\hat{\theta}_{cs-DL} = \frac{\sum_{l=0}^{\alpha} \hat{\delta}_{il}}{1 - \sum_{l=1}^{\rho} \hat{\beta}_{il}} \quad (8)$$

320 Lastly, we also include DH causality test to study the relatedness of causal association between explained and
 321 explanatory indicators (Dumitrescu and Hurlin 2012). According to recent studies, DH approach is suitable as this
 322 approach negates heterogeneity, CSD and is applicable for data investigation involving unbalanced panels as well.

323
$$Y_{it} = \varphi_i + \sum_{k=1}^K \tau_i^{(k)} Y_{i,t-k} + \sum_{k=1}^K \delta_i^{(k)} X_{i,t-k} + \varepsilon_{i,t} \quad (9)$$

324 In the above-mentioned equation, φ_i , K and $\delta_i^{(k)}$ determine intercept, lag length, and slope coefficients.
 325 $\tau_i^{(k)}$ characterises $\delta_i = \delta_i^{(1)}, \delta_i^{(2)}, \dots, \delta_i^{(k)}$ as the lag parameter and $\tau_i^{(k)}$ & $\delta_i^{(k)}$ differences amongst cross-section units.
 326 The null hypothesis of the DH test rejects the existence of the causal association.



327

328

Figure 3: Econometric Strategy

329 **4. Empirical Findings**

330 As explained earlier, have selected CSD and table 3 showing variable significance as sampled economies are
 331 interconnected and caution must be performed before proceeding to main empirical investigation and attempt to solve
 332 issues related to economic shocks. In addition, we use table 4 to conclude the existence of heterogeneity where the
 333 delta and its adj. delta showing significance at 1%.

334 **Table 3: Cross-sectional dependence**

	ENV D	GDP	ECI	GF	EI	URB
Breusch-Pagan LM	1020.922*	1042.135*	601.8542*	1120.717*	1158.611***	1202.861*
Pesaran scaled LM	102.8712**	105.1073*	58.69759*	113.3905*	117.3849**	122.0493*
Bias-corrected scaled LM	102.6789*	104.9150*	58.50528*	113.1982*	117.1926**	121.8569**
Pesaran CD	31.90389*	32.210958*	6.260833**	33.45844*	34.03236**	34.68200*

335 Note: *, **, *** indicate P<0.01, P<0.05, and P<0.1.

336 **Table 4: Slope heterogeneity**

	Statistics	p-value
Delta	13.195	0.000
adj. Delta	15.730	0.000

337 Note: Values are significant at P<0.01.

338 The findings reported in Tables 3 and 4 necessitate the urgency to perform unit root analysis through second generation
 339 tests due to their higher econometric efficiency in dealing with data issues. The estimates in Table 5 show mixed order
 340 where variables are significant allowing us to accept alternate hypothesis.

341 **Table 5: CIPS and CADF Unit root tests**

Variables	CIPS		CADF	
	Level	Difference	Level	Difference
ENV D	-2.408**		-2.279***	
GDP	-1.428	-3.381**	-2.106	-2.808*
ECI	-2.337**		-2.143	-3.955*
GF	-3.379*		-2.633*	
EI	-1.430	-3.651*	-2.172	-2.773*
URB	-1.238	-3.078*	-2.358**	

342 Note: *, **, *** indicate P<0.01, P<0.05, and P<0.1.

343 As a last step of initial econometric strategy, we proceed with cointegration analysis between explained and
 344 explanatory data variables. We use Westerlund cointegration test, where the findings in Table 5 confirm data
 345 cointegration and giving us freedom to move with mian econometric approach and estaimte econometric findings.

346 **Table 6: Westerlund cointegration test**

Statistics	Value	Z-value	Robust P-value
G_{τ}	-1.347*	3.344	0.000
G_{α}	-0.909	4.909	1.000
P_{τ}	-2.781*	3.302	0.000
P_{α}	-0.379*	3.477	0.000

347 **Note:** * indicates $P < 0.01$.

348 We determine main econometric findings through CS-ARDL as the long-run estimator to study the impact of
349 economic growth, economic complexity, greenfield investments, energy innovation, and urbanisation on
350 environmental degradation in NICs from 1995 to 2021. The findings related to economic growth and environmental
351 degradation helps us understand indicating that economic growth deteriorates the environment and is in line with the
352 previous studies of Bukhari et al. (2023), Bashir et al. (2022a) and Ma et al. (2023b). This is an policy issues as
353 developing economies have introduced introduced aggressive economic reforms raise nominal income, achieve
354 industrialisation, but doing so may endanger ecological sustainability. Another reasonable clarification for such impact
355 is the model of the energy mix in NICs, where higher consumption of fossil energy has been the leading contributor
356 of environmental degradation, and policymakers give preference to energy and economic agenda so that rapid energy
357 transition may not hinder economic and social transformation. The aforementioned positive association endanger
358 progress for UN SDGs related to climate change mitigation, responsible energy consumption, and access to a clean
359 environment (Ma et al. 2023a).

360 Next, the statistical association between ECI and ENVD offers interesting outcomes. Our estimates allow us to inder
361 that ECI initially negates environmental quality; however, the negative impact from ECI^2 validates the role of
362 economic complexity within environmental initiatives. Our findings are supported by Li et al. (2024) and Bashir et al.
363 (2022a). On the other hand, Rafei et al. (2022) and Kosifakis et al. (2020) provided opposition to these empirical
364 estimates. Li et al. (2024) researched a global panel dataset to report that ECI degrades environmental quality. This
365 allows us conclude that gradual improvements within energy efficiency and manufacturing processes through
366 integrated economic agenda can improve ecological sustainability. Our findings settle that ECI increases resource
367 efficiency and overcomes environmental hurdles. Moreover, economic complexity increases industrial capacity
368 through renewable energy consumption, environmental technology, and efficient utilisation of resources. As NICs
369 rely on fossil industry, however, reaching a certain threshold and economic transformation will enable enable
370 policymakers to use novel policy mechanisms to solve ecological challenges (Swart and Brinkmann 2020). The
371 findings of ECI draw new policy implications within COP 28 and how achieving a net-zero pathway would require a
372 shift in economic and environmental reforms to adopt green technologies.

373 Next, we report empirical findings for greenfield investments, which carry a positive association with environmental
374 degradation, as a 1% change in greenfield investments increases environmental degradation by 0.024% in newly
375 industrialised economies. Our primary justification is that most greenfield investment projects rely on fossil fuel
376 energy resources; hence, such initiatives negatively affect environmental quality and green energy development.
377 Moreover, NICs are top energy consumers, and the abundance of fossil and hydrocarbon resources has resulted in
378 formulating energy policies on fossil fuels. This also means that countries like Russia, India, and Saudi Arabia are
379 among the top emitters of emissions. All of this leads to negative environmental impacts in the long run. Our findings
380 are similar to Abu Bakar (2019) and Yahya & Rafiq (2020), who reported that greenfield investments contribute to
381 environmental degradation and lower renewable energy consumption.

382 Next, energy innovation has a negative association with environmental degradation. We attribute these findings to the
 383 fact that the recent environmental agenda under UN SDGs reforms has allowed greater integration of environmental
 384 technologies within the green agenda, limiting environmental degradation. Moreover, developed economies' reliance
 385 on industrial transformation through fossil fuel consumption has led to significant environmental issues. These
 386 countries have been pushed to pursue renewable and alternative energy strategies that utilise environmental
 387 technologies. Such integration within socioeconomic policies will lead to higher efficacy of energy innovation as it
 388 will further align pro-development policies with sustainable development goals. In recent literature, Kihombo et al.
 389 (2021), Destek & Manga (2021), and Ke et al. (2020) have provided similar arguments.

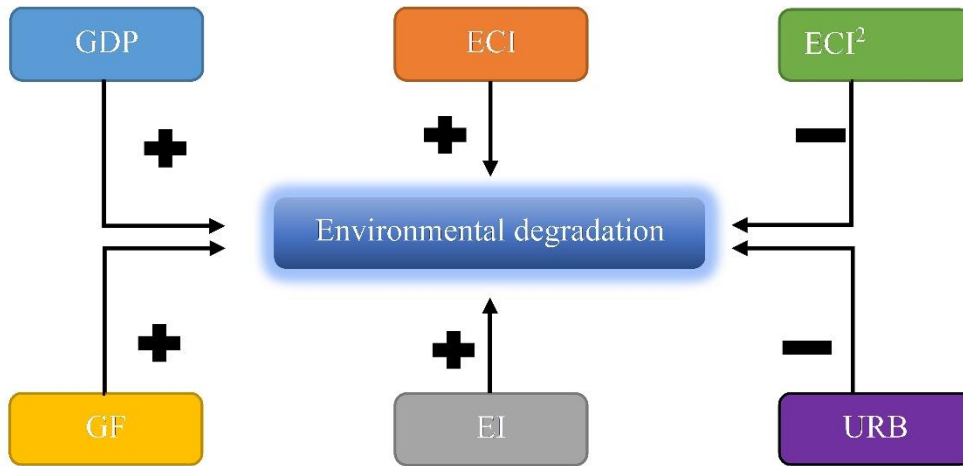
390 Lastly, urbanisation has a negative impact on environmental degradation as a 1% increase in urban population lowers
 391 environmental pollutants in the sampled dataset. NICs have faced the dilemma of urban migration in recent years, but
 392 this also means that these countries have been allowed to promote renewable energy with greater efficiency. Another
 393 justification is that higher income opportunities allow urban residents to have income flexibility to use renewable
 394 energy consumption. Lastly, limited supply of fossil fuels, unsustainable extraction, and environmental conscience
 395 have shifted focus on environmental quality and use of energy resources with little or no environmental footprint.
 396 Recent publications by Al-Mulali & Ozturk (2015), Long et al. (2017), and Ahmed et al. (2020) reported similar
 397 findings.

398 Table 7 also provides long-run empirical findings similar to short-run outcomes. For example, economic growth and
 399 green fields positively correlate with environmental degradation, mainly due to the desire to transform the domestic
 400 economy, and dependence on fossil fuels has negative environmental implications. Also, urbanisation and energy
 401 innovation decrease environmental degradation mainly because integrated environmental and energy reforms,
 402 availability of green energy resources, and emphasis on environmental technologies help achieve environmental
 403 sustainability. Lastly, the EKC hypothesis remains valid for NICs. In addition, we use figure-4 to report graphical
 404 summary of main empirical findings.

405 **Table 7: CS-ARDL long-run and short-run analysis**

Short-run Est.	Short-run findings		Long run findings	
	Coefficient	p-value	Coefficient	p-value
GDP	0.190**	0.007	0.241**	0.003
ECI	0.226**	0.012	0.142***	0.072
ECI ²	-0.163***	0.061	-0.122***	0.053
GF	0.024***	0.090	0.012**	0.028
EI	-0.584**	0.008	-0.243**	0.009
URB	-0.709**	0.034	-0.717***	0.058
ECT-1	-0.228*	0.000	-	-

406 **Note:** *, **, *** indicate P<0.01, P<0.05, and P<0.1.



407
408 **Figure 4: Main empirical summary**
409

410 We further rely on CS-DL, AMG, and CCEMG as robustness checks to critically evaluate findings from CS-ARDL.
411 The findings from CS-DL validate earlier findings with a positive association between GDP and greenfield
412 investments. At the same time, there is a negative association between energy innovation and urbanisation towards
413 environmental degradation. Lastly, the EKC hypothesis for ECI is also proven like CS-ARDL. The findings from
414 AMG and CCEMG are also in line with Table 7, with the sole exception of the positive impact from EI on
415 environmental degradation reported by AMG.

416 **Table 8: Robustness Check: CS-DL, AMG, CCEMG**

CS-DL	CS-DL		AMG		CCEMG	
	Coefficient	p-value	Coefficient	p-value	Coefficient	p-value
GDP	0.326**	0.012	0.659**	0.041	0.892**	0.012
ECI	0.141***	0.053	0.297***	0.052	0.075**	0.046
ECI ²	-0.081**	0.006	-0.074***	0.092	-0.070***	0.051
GF	0.011***	0.078	0.041**	0.014	0.022***	0.078
EI	-0.200***	0.091	0.127***	0.057	-0.360***	0.088
URB	-0.840***	0.079	0.849***	0.061	-0.611**	0.014

417 **Note:** *, **, *** indicate P<0.01, P<0.05, and P<0.1.

418 We conclude our econometric investigation by reporting findings from DH causality analysis, where environmental
419 degradation, energy innovation, and ECI have a bidirectional casual association with economic growth. Also, ECI and
420 energy innovation report a bi-directional causal association with energy innovation. ECI also reports a similar
421 association with urbanisation. Furthermore, ENVD has a unidirectional association with EI, ECI, and URB, which
422 also carry a unidirectional causal association with ENVD. URB and GF also reported a similar causal association with
423 economic growth. Lastly, URB also unilaterally granger causes GF.

424 **Table 9: Dumitrescu-Hurlin Panel Causality Analysis**

	ENVD	GDP	ECI	GF	EI	URB
ENVD	-	3.63408***	2.43417	2.09235	4.95568**	3.00954
GDP	4.67899**	-	3.62223**	1.71699	5.80165*	2.65335
ECI	4.10328**	4.70256**	-	3.05870	4.25596**	5.97223*
GF	3.32042	3.68725***	2.99100	-	3.46536	1.41926
EI	3.44184	4.23480**	4.18392**	1.73242	-	6.12660*
URB	6.85223*	10.1145*	4.78128**	11.2558*	9.97687*	-

425 *, **, *** indicate $P < 0.01$, $P < 0.05$, and $P < 0.1$.

426 5. Conclusion and policy recommendations

427 The recent COP27 conference in Sharm el-Sheikh, Egypt, further emphasised the importance of sustainable
428 development in achieving carbon neutrality in the upcoming decades. The event reaffirmed the consensus that
429 sustainable development is crucial in this endeavour. The current study extends academic discussion concerning
430 sustainable theory by studying environmental degradation, economic growth, economic complexity, greenfield
431 investments, energy innovation, and urbanisation for NICs. We begin our empirical analysis with Pesaran scaled LM,
432 Pesaran CSD, Bias-corrected scaled LM, Breusch-Pagan LM, and slope heterogeneity test. We use CIPS & CADF
433 unit root tests and Westerlund cointegration tests before proceeding to CS-ARDL as the main econometric approach
434 to study short-run and long-run empirical associations for variables included in the dataset. We additionally use CS-
435 DL, AMG, and CCEMG as robustness checks. Lastly, we use DH causality analysis to report causal associations
436 among variables.

437 Confirming cross-sectional dependence and cointegration from CD tests and Westerlund cointegration allowed us to
438 proceed to CS-ARDL, CS-DL, AMG, and CCEMG as the main econometric analysis. Our findings from CS-ARDL
439 indicate that economic growth and greenfield investments promote environmental degradation, while energy
440 innovation and urbanisation ensure environmental sustainability. Moreover, we confirm the EKC hypothesis for ECI
441 in NICs. Our findings from CS-DL, AMG, and CCEMG align with empirical findings from CS-ARDL. Lastly, we
442 use the DH causality test to investigate the bidirectional causal association among data variables.

443 Based on long-term empirical estimates, we suggest that NICs must focus on structural changes to ensure the
444 transformation to “energy-efficient technologies” and overcome climate challenges. We also propose that instead of
445 “energy innovation imports”, NICs must link environmental policy goals with technological and human infrastructure
446 to ease environmental pressure and ensure sustainable economic growth. In this regard, selective tax changes must be
447 part of fiscal policies to increase renewable energy development. Another policy option is subsidising renewable
448 energy and increasing investments in renewable energy projects. Besides these, NICs should focus on low-carbon
449 efficient energy resources by synchronising cross-border renewable energy cooperation.

450 In conclusion, we indicate that structural changes in the industrial sector must be associated with energy innovation
451 and greenfield investments to ensure long-term environmental sustainability. Our empirical analysis also allows us to
452 propose that environmental regulations must establish a policy framework to create coherence between economic
453 complexity, energy innovation, and green energy resources to strengthen the energy-efficient industrial structure.

454 Lastly, our findings show that domestic economic reforms must focus on ECI to reshape energy and trade policies in
455 the long run.

456 Although we extend academic contribution in several ways, there are some limitations which future studies can
457 investigate. First, the current study suffers from data availability as data limitations mean that our research scope is
458 limited to 1995-2021. To add new research directions, future research can consider financial globalisation, trade
459 policies, and financial credit policies within econometric frameworks. Another research dimension will be to
460 simultaneously evaluate the asymmetric effects of green investments, renewable energy, and sustainable growth on
461 the environmental degradation of emerging and industrial economies to analyse policy differences in these panels.
462 Lastly, ecological footprint and load capacity factors can be considered determinants of environmental sustainability.
463 The load capacity factor highlights the sustainability thresholds, indicating the limits within which an environment
464 can sustain human activities without long-term deterioration, and highlights the need for balancing economic growth
465 with environmental sustainability. Likewise, the ecological footprint provides a comprehensive environmental impact
466 assessment by measuring human demand for natural resources. These metrics are crucial for policy relevance,
467 broadening the scope of environmental impact analysis beyond traditional metrics, providing concrete targets for
468 environmental impact reduction and guiding sustainable policy decisions.

469

470 **Ethical Declaration**

471 **Ethical approval**

472 N/A

473 **Consent to participate**

474 N/A

475 **Consent to publish**

476 N/A

477 **Author Contribution:**

Author	Contribution
Muhammad Farhan	Conceptualization; Roula Inglesi-Lotz
Bashir	Methodology; writing draft; writing-revision
Ummara Razi	Writing draft Luqman Shahzad

Data Curation; writing draft,

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