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Qianxiao Zhang

Xi'an Jiaotong University

Syed Ale Raza Shah (✉ shahsyedaleraza@stu.xjtu.edu.cn)

Xi'an Jiaotong University

Syed Asif Ali Naqvi

Government College University Faisalabad

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Is Achieved Economic Development Environment Friendly? A New Insight from Central and Eastern Europe

Qianxiao Zhang¹, Syed Ale Raza Shah^{2,*}, Syed Asif Ali Naqvi³

1 School of Economics & Finance, Xi'an Jiaotong University, Xian, 710061, China,

zhqxiao@mail.xjtu.edu.cn

2 School of Economics & Finance, Xi'an Jiaotong University, Xian, 710061, China,

shahsyedaleraza@stu.xjtu.edu.cn

3 Department of Economics, Government College University Faisalabad, Pakistan,

syedasif_1@yahoo.com

* Corresponding author

Abstract

Over the last few years, the linkage between economic development and environmental degradation has become a provocative question. Although this nexus has been studied vastly, some of the critical variables of economic development and their impacts on the environment need more focus. The present study explores the association between economic development, outward foreign direct investment, financial development, renewable energy consumption, natural resource rents, trade openness, and ecological footprint in Central and Eastern European economies. The panel data estimators such as augmented mean group and common correlated effect mean group are employed from 1990 to 2017. Empirical findings document that outward foreign direct investment, financial development, trade openness, natural resource rents, and renewable energy consumption increase economic development, implying that they positively affect economic development. Findings validate the inverted U-shaped EKC for concerned economies in case of the ecological footprint. The results show that the interaction term of GDPC with NR, outward foreign direct investment, and RE are eco-friendly indicators. The study results develop imperative policy implications for the selected region to attain sustainable development goals.

Keywords: OFDI; Renewable Energy; Natural Resource, EFP; GDPC

1. Introduction

Considering global and regional economic assimilation, multinational enterprises as participants of international direct investment have gradually become organizers and watchdogs of universal resource provision. Foreign direct investment has quickly developed since the 1980s. Outward foreign direct investment (OFDI) raised from 243.8 billion USD in 1990 to 1014 billion in 2018,

34 above international trade growth during the same period (Chen et al. 2020). Quick science and
35 progressive technology have fetched both adjustment and disintegration of universal production.
36 Nations worldwide are aggressively contributing to international economic and trade
37 collaboration both in depth and extent. Abridged trade obstacles deliver multinational
38 corporations with optimum resource apportionment on a worldwide scale.

39 The outcome of the universal macro tendency is catalyzing the microeconomic
40 internationalization process has witnessed an extraordinary scale within the composite scheme of
41 Central and Eastern Europe (CEE) nations (Radlo and Sass 2012). For these economies, the
42 indicated process instigated the transition of their post centrally planned nations into the free-
43 market economic system. These procedures result in the gradual growth of OFDI stocks, which
44 show the robust hysteresis that could be elucidated by Dunning and Narula's macroeconomic
45 investment development path theory (Dunning 1982; Dunning 2002) that is consistent with the
46 dynamical adaptive complex system (Kwapień and Drożdż 2012). The theory associates with
47 movements of per capita FDI and the level of economic development, which further deviate the
48 arrangement of market in terms of international trade patterns and regional supply chains.
49 According to Kolstad and Wiig (2012), investors of developed economies prefer to invest in the
50 countries with abundant natural resources (NR) and poor environmental laws.

51 Little literature prevails the influence of NR abundance on economic growth. The negative sway
52 of NR on the GDP was firstly introduced by the NR curse hypothesis (Sachs and Warner 1995).
53 Later on, Atkinson and Hamilton (2003) and Gylfason and Zoega (2006) suggested the role of
54 investment, and they estimated the impact of NRs on physical capital and GDP. Further, Smith
55 (2015) quantified the effect of NR reservoirs and mines since 1950 on GDPC. Likewise, trade
56 openness (TO) also plays a vital role in the progress of an economy, and there are different ways
57 by which TO increases real GDPC in resource-rich countries. It may be possible that an increase
58 in the level of trade helps to lessen the negative impact of NR rents on per capita income by
59 efficient resource management. Trade offers access to the international market and elevated
60 prices for their goods. Though, it helps to introduce modern technologies for more effective
61 abstraction of NR. With the use of innovative technologies, NR rich economies can manufacture
62 intermediate and final products from primary good and earn more profit. TO assists to update the
63 whole economy by upgrading of local infrastructure (Pedersen 2000), the financial sector (Braun

64 and Raddatz 2008), and the bureaucratic system (Dutt 2009). Generally, TO plays a vital role in
65 altering NR into a blessing rather than a curse.

66 Domestic finance creation can be seen as one innovation category that is capable to accelerate
67 GDP. Financial development (FD) has received a considerable attention in the empirical
68 literature. Cross-sectional studies found the positive effect of FD on growth [refers: Durusu-
69 Ciftci et al. (2017); Yang (2019); Erdoğan et al. (2020)], while, a case study found the negative
70 influence of FD on growth (Cheng et al. 2020). Consequently, development is strongly linked
71 with energy as it is considered driver of economy. Primary energy consumption has increased
72 approximately 2.2 percent (Dudley 2018). While the share of RE energy consumption is
73 significantly lower than NRE usage in the global energy portfolio. RE is a possible way for the
74 diversification of resources and less reliance on fossil fuels means greater tolerance to energy
75 shocks. However, it can be challenging to move from non-RE to RE production. The high initial
76 expense is one of the most significant issues for RE. In contrast with non-RE-based energy
77 expenditure, many financial barriers need to be met, including higher start-up infrastructure and
78 operating costs. Therefore, economies want to attain economic development across the world
79 while ignoring its harmful impact on environment.

80 To estimate the impact of achieved GDPC on the environment, we have used ecological footprint
81 (EFP) as a proxy of environment quality. The abundance of researches takes CO₂ as a proxy of
82 environmental degradation while studying the nexus of GDP and the environment (Wu et al.
83 2019; Awodumi and Adewuyi 2020). However, CO₂ is a proportion of all pollution, but it is
84 alone insufficient to count complete environmental degradation. Recently, the EFP of
85 Wackernagel and Rees (1998) is assumed as the new inclusive variable to measure the extent of
86 environmental degradation as it reflects cropland, grazing land, fishing grounds, forestland,
87 carbon footprint, and built-up land. The key objective is to examine the effect of economic
88 development and other variables of interest on the EFP for 1990-2017 in the selected 16 CEE
89 economies.

90 Several studies have focused the economic growth and environmental quality, but there is no
91 state of the art analysis which tries to estimate the impact of achieved economic development
92 and its determinants on EFP. Henceforth, this paper highlights the recent theoretical and
93 empirical developments in the sustainable environment domain and answers the question, which

94 is not yet addressed by literature, but researchers and practitioners are eager to know more about
95 it. Countries worry about per capita income to contend with other countries but ignore the
96 adverse environmental effects. This paper addresses the per capita income in the CEE economies
97 with environmental aspects and suggests how harmful consequences of economic development
98 can be reduced. In addition, this work is prevailing literature in three ways; firstly, this is the first
99 study to quantify the impact of different economic indicators on economic development to solve
100 whether selected indicators are enhancing economic development in the CEE economies?
101 Secondly, the main problem, of the world is environment pollution and this study answered the
102 critical question, is achieved economic development, with its determinants eco-friendly or not?
103 Thirdly, we have used the different advanced econometric techniques, i.e., Cross-sectional
104 dependency (CD) tests and Westerlund cointegration those permit for CD. After inspection of the
105 robustness of Westerlund, the Augmented mean group (AMG) and Common correlated effect
106 mean group (CCE-MG) are used to examine the long-run association in both models. While
107 addressing these goals, the results found in this study give the policy level information to device
108 the development, economic, and environmental policies to attain sustainable development.

109 Further, this paper contains four parts i.e. literature review, data and methods, results and
110 discussion, and in the last conclusion and policy recommendatios.

111 **2. Literature review**

112 Since the last decade, much work has been done to quantify the linkage between economic
113 growth, NR income, and the environment by ensuring the Environment Kuznets curve (EKC)
114 hypothesis. There is still a deficiency in the literature regarding the selection of environmental
115 indicators. Thus, current study emphasizes on nexus of OFDI, FD, NR rents, RE, GDPC and the
116 environment for selected CEE economies. Here, we will debate the studies, which are carried out
117 to assess selected macro-economic variables on economic development. Simultaneously, in the
118 second face, we have focused on economic development with its selected environmental
119 degradation determinants.

120 **2.1. Impact of OFDI, NR, TO, FD, and RE on Economic Development**

121 Scientists have directed widespread research to discover the link between the OFDI, NR, TO,
122 FD, and RE consumption with economic growth or development for time series and panel

123 studies. Different studies have different findings regarding growth or development indicators.
124 Even though preceding work has delivered some understanding of the belongings of concerning
125 indicators on growth. The studies yet have some shortcomings connecting to exclusions of
126 specific factors that are assumed to contribute to GDP.

127 Shakouri and Khoshnevis Yazdi (2017) studied the linkage between GDP and RE in South
128 Africa and supported the evidence of the positive association between the growth and RE. A
129 study by Li et al. (2017) for emerging economies and found OFDI as the main driver of growth.
130 Ohlan (2018) explored the positive association of energy use and growth. Dwumfour and Ntow-
131 Gyamfi (2018) exposed the positive relationship between economic development and NR. Later
132 on, Zaidi et al. (2019), explored a case study of 31 OECD economies, and found positive impact
133 of growth on FD. Further, a case study related to Sub-Saharan Africa economies estimated the
134 positive association of TO, FDI with economic growth due to strong institution (Asamoah et al.
135 2019). Similarly, Megbowon et al. (2019) measured the effect of OFDI of China on the Sub-
136 Saharan Africa industrialization level, and explored the no significant impact in SSA. Guan et al.
137 (2020) studied the effect of NR, GDP, human capital, and trade sector on FD in China, and the
138 results explained the existence natural curse hypothesis. Redmond and Nasir (2020) studied the
139 effect of NR abundance, FD, and trade on the economic development and showed the positive
140 influence of NR on economic development. Likewise, trade and FD have a negative association
141 with economic development.

142 **2.2. Impact of Economic Development and its Determinants on Environment Quality**

143 In the light of previous case studies, this section is divided into two different faces 1) deals with
144 those studies, which try to estimate the impact of growth on carbon emissions, 2) deals with past
145 studies, which attempted to evaluate the effect of growth on EFP. As a global issue, carbon
146 emission and generally greenhouse gas emissions have been studied extensively from a different
147 perspective. There has been much progress made in understanding the driving factors of carbon
148 emissions. Zaman and Abd-el Moemen (2017) quantified the incidence of EKC-phenomenon
149 and showed a positive association between emissions and energy consumption.

150 Similarly, there was a case study on different income groups showed the adverse effects of RE
151 on GDP and CO₂, respectively (Bhattacharya et al. 2017), while this study ignores the inclusion
152 of OFDI and NR. Likewise, Ciesielska and Kołtuniak (2017) estimated the effects of OFDI on

153 GDP, and supported the positive relationship between GDP and outward FDI. Another case
154 study related to BRICS nations by Dong et al. (2017) supported the EKC-phenomenon and
155 showed the negative association among NR, RE, and environmental quality (CO₂). Later on,
156 Balsalobre-Lorente et al. (2018) applied the partial OLS for 5-EU countries and found the N-
157 shaped linkage between GDP and emissions, while renewable electricity consumption was
158 hurting carbon dioxide. Yi et al. (2018) used the Markov Switching-regression approach and
159 found OFDI was increasing the level of emissions. Furthermore, Baloch et al. (2019) found the
160 EKC hypothesis for all economies except India; also, they found the NR help in the reduction of
161 CO₂. Jiang et al. (2020) found that the OFDI enhances emissions level, while ignored the NR.
162 Likewise, several studies tried to estimate the Natural Curse Hypothesis [refers: Badeeb al.
163 (2017); Ben-Salha et al. (2018); Adams et al. (2019); Xue et al. (2020)].

164 The second face tested the link between economic development with its determinants and EFP as
165 a substitute for the environment. It is associated with the EKC, which recommends that the link
166 between GDP and EFP is inverted and U-shaped. Charfeddine (2017) found the U-shaped EKC-
167 hypothesis, while urbanization and TO hurt EFP. Similarly, in the same year Charfeddine and
168 Mrabet (2017) found the EKC-hypothesis for oil and non-oil exporting MENA economies and
169 this phenomena also supported by Destek, et al. (2018) and Ulucak and Bilgili (2018). Besides,
170 Zafar et al. (2019) estimated the long-run association among NR, human capital, FDI, and EFP,
171 they found positive relation of human capital and NR with improved environmental quality
172 except GDP and energy use. Later on, a case study related to Turkey by Sharif et al. (2020)
173 found the RE reduces the ED. Likewise, several studies have tried to estimate the impact of
174 development on EFP with its different determinants (Nathaniel and Khan 2020; Pata 2020;
175 Nathaniel et al. 2020; Baz et al. 2020; Erdogan et al. 2020).

176 **2.3. Criticism on past studies**

177 It is imperative to note that previous literature has discussed the different types of socio-
178 economic indicators such as energy use, fertility rate, life expectancy rate, FD, foreign direct
179 investment, inflows, NR to quantify the effect on economic development or environment. There
180 is no study on CEE-economies in the past literature, which tries to estimate the impact of
181 achieved economic development with its determinants on environmental quality. OFDI is mainly
182 neglected in the previous literature as a determinant of economic development and its impact on

183 environmental degradation, which may help the environment quality. So, there is a need to
 184 include such an exciting relationship to fill the gap of literature.

185 **3. Data and methodology**

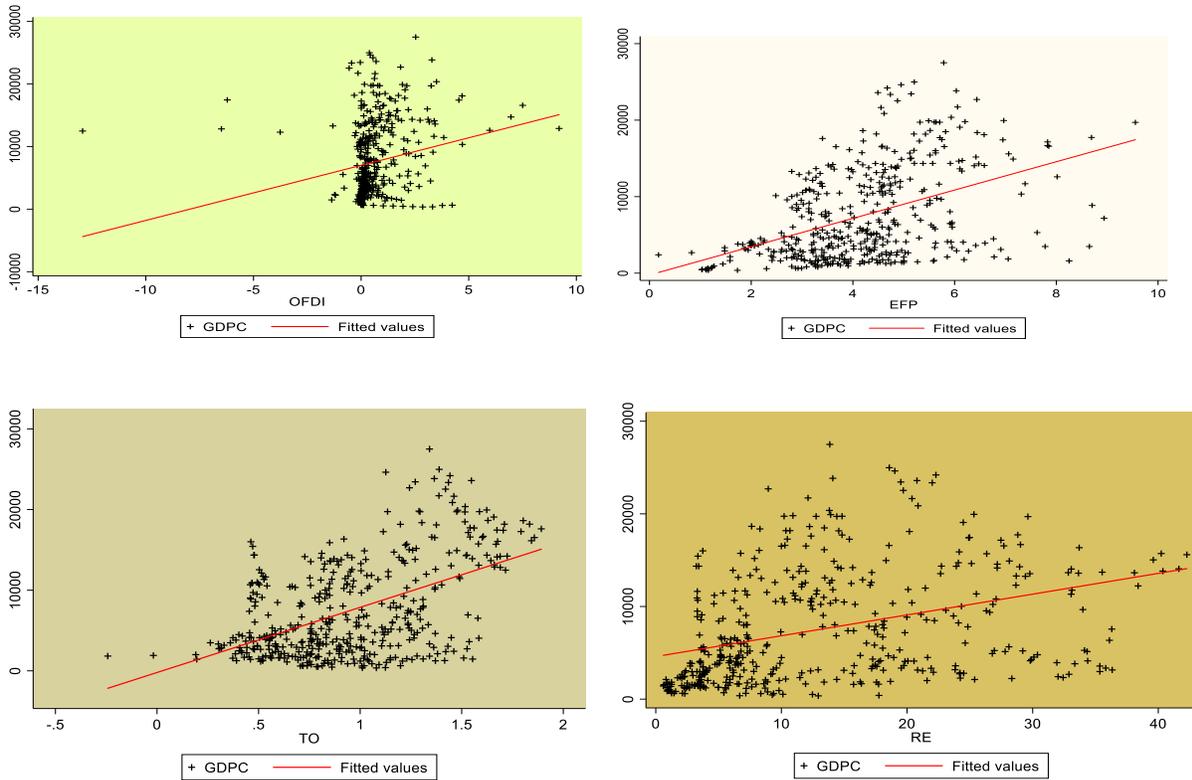
186 This study used the yearly panel data for the period 1990-2017 for 16 selected CEE countries
 187 (Appendix Table 10). These selected economies decided to ratify both global and regional goals
 188 to enhance the proportion of RE consumption compared to non-RE consumption and reduce their
 189 level of pollution. For case in a point, selected countries devoted to lessening environmental
 190 pollution below 1990 by 2020, which is also the basis for the EU global obligations under the
 191 Kyoto protocol's scope. Based on the impacts above, we emphasize the countries whose RE
 192 pathway is critical for meeting worldwide and local climate and RE goals.

193 To examine the determinants of economic development such as OFDI, NR rents, FD, and RE
 194 consumption and their impact with achieved economic development on the environment. This
 195 study's key objective is to find the reasons why countries care about only development by
 196 ignoring the quality of the environment. To answer this question, raised empirical research
 197 undertakes the yearly data gathered from different sources. The data regarding economic
 198 development (income per capita), FD, and TO variables are sourced from the World
 199 Development Indicators (WDI) online source. The data for RE consumption, EFP, and OFDI
 200 variables are collected from the Knoema data bank. Table 1 summarizes the variables and their
 201 explanations, and Fig. 1 shows the scatterplot trend between economic development and other
 202 indicators.

203 ***Table 1: summary of the variables***

Variables	Unit	Source
GDP	GDP (US current \$)/ total population	WDI
OFDI	Outward FDI (% GDP)	Knoema data source
NR	Natural resource rents (% of GDP)	WDI
FD	Domestic credit to private sector as % of GDP)	WDI
RE	RE consumption (% of total energy)	Knoema data source
EFP	Ecological footprint (global hectares per person)	Knoema data source
TO	Trade openness (US current \$)	WDI

204



205

206

207 **Fig. 1.** Scatterplot trend between economic development and other indicators

208 In Table 2, correlation coefficients of the study variables are given. In the light of both models,
 209 the income per capita is positively correlated to EFP at the one percent statistical significance.
 210 The correlation matrix also discloses that LEFP is negatively correlated with OFDI, and
 211 likewise, this behavior with RE consumption at one percent level of significance. We also
 212 described a positive influence of TO on EFP at a one percent level of significance, while a
 213 negative correlation among NR, FD, and per person EFP variables is also statistically significant.
 214 Furthermore, OFDI, RE consumption, LFD, and TO have a positive correlation with income per
 215 capita, while NR income has a negative association at a 1% level of significance. According to
 216 the given correlation coefficient outcomes, there is no correlation among the variables as they
 217 have moderate values, and to confirm this, we have used the variance inflation factor (VIF) (see
 218 Appendix Table 11 for details).

219 **Table 2: Matrix Correlation**

	LEFP	LGPC	LOFDI	LRE	LTO	LNR	LFD
LEFP	1						
LGPC	0.4921307	1					

LOFDI	-0.216621	0.456482	1				
LRE	-0.016160	0.507268	0.2777223	1			
LTO	0.284128	0.361718	0.2384069	0.134772	1		
LNR	-0.174055	-0.27435	-0.054880	-0.34372	-0.231247	1	
LFD	-0.180013	0.333745	0.262324	0.223850	0.0405990	0.0961400	1

220

221 **Model construction and Theoretical Background**

222 To quantify whether the selected determinants of economic development contribute to the
 223 achieved economic development or not, and what is the effect of achieved economic
 224 development with its determinants on environmental quality in CEE economies, the following
 225 models are devised. For quantification drive, we have assumed the role of economic
 226 development, OFDI, NR, TO, FD, RE consumption, and EFP as a primary determinant of
 227 sustainability. In light of the previous discussion, this paper steps up two models to measure the
 228 linkage between economic development and environmental degradation (Equation 1).

229
$$LGDP_{i,t} = \alpha_0 + \alpha_1 LOFDI_{i,t} + \alpha_2 LNR_{i,t} + \alpha_3 LTO_{i,t} + \alpha_4 LFD_{i,t} + \alpha_5 LRE_{i,t} + \mu_{i,t} \quad (1)$$

230 Here, *i* and *t* denote the economy and time in the panel estimation, as *i* = 1, 2, …, *n* and *t* =
 231 1, 2, …, *T* and μ is random error. The effect of OFDI and NR are determined by α_1 and α_2 ,
 232 respectively. Accordingly, statistically significant and positive α_3 directs that TO enhance the
 233 level of income per capita. The practitioner and policymakers have developed interesting
 234 scenarios since the last three decades between economic growth and environmental quality.
 235 Several studies have debated on economic growth and different proxies of environmental
 236 degradation, which covered different indicators for growth and environment situation (Brown
 237 and McDonough 2016; Pal and Mitra 2017; Kang et al. 2016).

238 This study extends the quadratic relationship with some interesting variables with an interaction
 239 term of economic development that may produce some interesting findings. This scene may raise
 240 the question of whether past policies are implemented efficiently. Evidence of the potential effect
 241 of achieved economic development with its determinants on environmental quality remained
 242 absent in the existing literature, and it suggests a new direction that needs to be introduced to
 243 policymakers. Achieved economic development may affect environmental quality with time.
 244 Previously scholars have developed two schools of thought regarding the role of growth in
 245 environment quality. Some studies support the evidence for a positive association between
 246 environmental degradation and economic development (Işık et al. 2019; Pata 2020; Halliru et al.

247 2020), while on the other hand, studies showed inverse effect among the said variables [refers:
 248 studies Dogan and Turkekul (2016); Aung et al. (2017); Yilanci and Pata (2020); Shah et al.
 249 (2020)]. Both groups of studies missed the concerned hypothesis. This study suggests that
 250 achieved economic development with its determinants may have a new direction for
 251 policymakers regarding environmental quality and development.

252 The vast body of literature has covered the relationship between economic development and
 253 environmental degradation proxies, and these studies have suggested various environmental
 254 regulations; however, these policies' implications and regulations seem ineffective in lowering
 255 environmental degradation. Diminishing effects can be tested by introducing interaction
 256 variables. The diminishing role is defined as the interaction of economic development variables
 257 with independent variables. To introduce the diminishing role of economic development with its
 258 determinants, we adopt interaction variables styled by Katircioğlu and Taşpinar (2017). Based on
 259 the above argument, the relationship between economic development and ecological footprint
 260 along with achieved economic development and its interaction with core variables is presented
 261 below (Equation 2).

$$262 \quad LEFP_{i,t} = \beta_0 + \beta_1 LGDPC_{i,t} + \beta_2 LGDP^2_{i,t} + \beta_3 LGDFD_{i,t} + \beta_4 LGDRE_{i,t} + \beta_5 LGDNR_{i,t} + \mu_{i,t}$$

263 (2)

264 Where, $LEFP_{i,t}$ of the ecological footprint of selected economies i at year t , economic
 265 development is measured by per capita income, $LGDFD$ denotes the interaction variable of
 266 economic development and OFDI ($LGDPC \times LOFDI$), $LGDRE$ indicates the interaction term
 267 between renewable energy consumption and achieved economic development ($LGDPC \times LRE$)
 268 and $LGDNR$ is for achieved economic development and natural resource rents ($LGDPC \times LNR$).
 269 Our analysis's contribution lies in introducing the interaction term of achieved economic
 270 development to control environmental degradation. Following, the above models, we aim to
 271 analyze the sensitivity of EKC and the natural curse or blessing hypothesis through numerous
 272 econometric specifications. The following section deliberates the assessment strategies
 273 implemented by the study.

274 **3.1. Estimation Strategy**

275 This study's baseline model is constructed on five steps as follows: the first step describes the
 276 CD test. Second is the unit root test to estimate the stationarity of the selected variables. The
 277 third step is about the estimation of cointegration panel estimation. The fourth step consists of
 278 long-run estimation techniques, and finally, the last step is the estimation of the causality
 279 relationship through Dumitrescu and Hurlin (D-H) Granger test.

280 3.2. CD tests

281 The basic step for estimation is to check the presence of CD. In the most recent empirical
 282 analysis, estimation of CD is the primary attention of all researchers, unlike the traditional panel
 283 techniques assuming the data as cross-sectional independence. The results obtained while
 284 ignoring the CD might lead to spurious quantification as most panel data influence each other.

285 Hence, three tests such as the CD test developed by Pesaran (2004), Friedman (1937), and Frees
 286 (1995), are used to finalize a plausible panel tool, though the mathematical forms of these CD
 287 ratio test can be elucidated as follows (Equation 3 to 5),

$$288 \text{CD} = \sqrt{\frac{2T}{N(N-1)}} \left(\sum_{i=1}^{N-1} \sum_{j=i+1}^N \hat{\rho}_{ij} \right) N(0,1) \quad (3)$$

$$289 \text{FRI} = (j-1) \left[\frac{2}{N} \sum_{i=1}^{N-1} \sum_{j=i+1}^N \gamma_{ij} + 1 \right] \chi^2 (j-1) \quad (4)$$

$$290 \text{FRE} = \frac{(j-1) \left[\frac{2}{N} \sum_{i=1}^{N-1} \sum_{j=i+1}^N \gamma_{ij} + \frac{1}{j} \right]}{SE(Q)} N(0,1)_{i,j} \quad (5)$$

291 The CD test has a drawback, such as lacking power under a situation where pair-wise
 292 correlations are zero. Therefore, to deal with this problem, Pesaran (2008) proposed the
 293 Lagrange Multiplier (LM) test by employing the mean and variance of Lagrange Multiplier (LM)
 294 statistics. The bias-adjusted LM statistics are given as Equation (6):

$$295 \text{LM}_{\text{adj}} = \sqrt{\frac{2T}{N(N-1)}} \left(\sum_{i=1}^{N-1} \sum_{j=i+1}^N \hat{\rho}_{ij} \right) \left[\frac{(T-k)\hat{\rho}_{ij}^2 - \mu T_{ij}}{v(T-k)\hat{\rho}_{ij}^2} \right] N(0,1) \quad (6)$$

296 Where K is denoted as a regressor, and $\hat{\rho}_{ij}^2$ and μT_{ij} are the mean and variance. Similarly, to test
 297 the slope homogeneity, Pesaran and Yamagata (2008) suggested the delta test that is valid for (N,
 298 T) $\rightarrow \infty$ and its hypothesis could be stated as (Equation 7):

299 $H_0 : \beta_i = \beta_j$

300 $H_1 : \beta_i \neq \beta_j$

301
$$\Delta_{adj} = \sqrt{N} \left[\frac{N-1S - E(z_{it})}{\sqrt{V(z_{it})}} \right] \quad (7)$$

302 Cross-sectional dimension N could be relative to time (t), where $E(z_{it}) = k$ and $V(z_{it}) = 2k$ ($T-k-$
303 $1)/(T+1)$.

304 **3.3. Panel units root test**

305 To estimate the accurate outcomes, the first step is to observe the stationarity of factors. Widely
306 accepted methods are often used, such as the Levin-Lin-Chu test by Levin et al. (2002) and Im,
307 Pesaran and Shin (IPS) test by Im and Pesaran (2003), but the drawback of these test is that they
308 cannot accounts for the CD, and rely on cross-sectional independence hypothesis. This study
309 employs second-generation unit root tests, i.e., Covariate-Augmented Dickey-Fuller (CADF) and
310 augmented cross-sectional IPS (CIPS), to avoid the problem of CD. The key feature of these
311 tests is addressing the issues of CD and heterogeneity. The test statistics of CADF is expressed
312 as Equation (8):

313
$$\Delta X_{it} = \Phi_i + \delta_i X_{i,t-1} + \gamma_i \bar{X}_{t-1} + \Psi_i \Delta \bar{X}_t + \mu_{it} \quad (8)$$

314 Where \bar{X}_{t-1} represents the mean across each cross-section. Further, the CIPS test can be
315 presented as given in Equation (9):

316
$$CIPS = \frac{1}{N} \sum_{i=1}^N \delta_i (N, T) \quad (9)$$

317 **3.4. Panel cointegration tests**

318 After checking the stationarity of variables, the long-run association between variables can be
319 identified by putting on an error correction-based test (Westerlund and statistics 2007). Unlike
320 traditional cointegration techniques, this test accounts for heterogeneity and autocorrelation and
321 includes the stochastic shocks due to unobserved factors in panel data that simple methods
322 cannot do. The dependency results might be weak or strong, but if ignored, they lead to
323 inappropriate estimates. The cross-sectional error could result from common shock, spatial
324 effects, and omitted common effects that can add n error term. The practical form of Westerlund
325 cointegration can be expressed as Equation (10):

326
$$\Delta Y_{it} = \delta'_i d_t + \eta_i (Y_{i,t-1} - \beta'_i x_{i,t-1}) + \sum_{j=1}^{Pi} \eta_{ij} \Delta y_{i,t-j} + \sum_{j=0}^{Pi} \gamma_{ij} \Delta x_{i,t-j} + \mu_{it} \quad (10)$$

327 Where $\delta'_i d_t$ and η_i are the deterministic and coefficient of error correction terms. This test is
 328 based on two statistics, i.e., group (G_τ, G_a) and panel (P_τ, P_a). The null and alternate hypothesis
 329 can be expressed as:

330 $H_0 : \delta_i = 0$

331 $H_1 : \delta_i = \delta < 0 \quad (\text{for all } i)$

332 The rejection of H_0 means all the panel is cointegrated.

333 **3.5. AMG and CCE-MG econometric techniques**

334 The cointegration presence is the symbol to proceed to the next step of estimation, i.e., long-run
 335 relations between the variables. In this regard, we used the two-panel estimation technique to
 336 check the long-run association.

337 Phillips and Sul (2007) recommended that when models agonize from the CD,
 338 heteroskedasticity, and serial correlation, panel estimators, can mislead inferior and even
 339 inconsistent estimators. To remove these problems, Pesaran has recommended the Common
 340 Correlated Effects, which are further developed by Kapetanios et al. (2011) and Chudik et al.
 341 (2011). This approach has numerous advantages associated with the first-generation econometric
 342 methods; it does not contain the approximation of unobserved common factors and factor
 343 loading (Pesaran 2007). In this stage, our study will use the AMG algorithm proposed by Bond
 344 and Eberhardt (2013) and Dong et al. (2018). AMG is flexible and without limitation of non-
 345 stationary variables in the calculation (Destek and Sarkodie 2019). The study also uses the CCE-
 346 MG estimator (Pesaran 2007) to calculate the long-run estimate that accounts for the CD. The
 347 CCE-MG method is robust in reducing a limited number of solid features and an infinite number
 348 of weak attributes (Eberhardt 2012). Further, to estimate the casual linkages among variable have
 349 estimated by Dumitrescu and Hurlin (2012).

350 **4. Results and discussion**

351 In this section, the empirical results of the relationship between economic development and
 352 environmental quality are given for CEE economies for two different empirical models as

353 described above. Thus, for the empirical analysis, descriptive statistics plays an important role.

354 **Descriptive statistics**

355 The following Table 3 gives descriptive statistics of the variable for the selected panel under
 356 inquiry. Table 3 depicts no significant difference between the mean and median of all concern
 357 factors, and all variables show a considerable extent of attention.

358 **Table 3: Descriptive Statistics**

	LEFP	LGPC	LOFDI	LTO	LRE	LNR	LFD
Mean	0.59058	3.71383	-0.66712	-0.05365	0.96723	0.02261	1.78547
Median	0.62278	3.72288	-0.59850	-0.03631	1.00920	0.01771	1.84876
Max.	0.98018	4.43936	1.11181	0.27687	1.62607	1.33625	2.60982
Mini.	-0.74928	2.55291	-4.57017	-0.71927	-0.22142	-1.10823	0.06240
Std. dev.	0.17874	0.41184	0.83501	0.18347	0.39102	0.48117	0.38969
Skewness	-1.72665	-0.42127	-0.73514	-0.52115	-0.55888	0.41731	-0.94789
Kurtosis	10.8293	2.43330	4.18230	2.91674	2.85740	3.06154	4.47371
J-Bera	1357.70	19.1168	66.0004	20.2721	23.5429	12.9865	106.908
Prob.	0.0000	0.0000	0.0000	0.0000	0.0000	0.0015	0.0000

359

360

361 **4.1. CD of the selected variable**

362 Here, the findings of the CD tests are provided. Findings of CD tests have been given in Table 4.
 363 Results validate early perceptions since the different techniques assumed can strongly reject H_0
 364 of cross-sectional independence for both panels. As a result, our specific income groups showed
 365 CD, and thus, 2nd generation unit root and cointegration tests that accommodate the dependence
 366 problem are applied to attain consistent findings. In addition, findings of the test for homogeneity
 367 are given in Table 5.

368 **Table 4: CD tests**

	Model 1		Model 2	
	Value	P-value	Value	P-value
LGDP = f (LOFDI, LNR, LTO, LFD, LRE)			LEFP = f (LGDP, LGDP ² , LGDFD, LGDRE, LGDNR)	
Pearson (CD)	19.153	0.000	5.112	0.000
Frees (Q)	3.273	0.005	2.701	0.005
Friedman (CD)	166.788	0.000	82.282	0.000

369

370 **Table 5: Test for Homogeneity**

Model 1: LGDPC = f (LOFDI, LNR, LTO, LFD, LRE)			LEFP = f (LGDPC, LGDPC ² , LGDFD, LGDRE, LGDNR)			
	Delta	adj.		Delta	adj.	
Statistics (P-value)	7.525 (0.000)	8.532 (0.000)		7.976 (0.000)	9.044 (0.000)	
Dependent Variable	LM	LM adj*	LM CD*	LM	LM adj*	LM CD*
Statistics (P-value)	231.4 (0.000)	13.6 (0.000)	1.566 (0.001)	232.4 (0.000)	13.78 (0.000)	1.455 (0.145)

371

372 **4.2. Second-generation unit root tests**

373 Comprehensive findings of the panel unit root tests for both panels are presented here in Table 6.
 374 For the specific panels, the CIPS test results expose that LGDPC, LOFDI, LFD, LRE and LTO
 375 are stationary at the first difference, while NR and EFP are stationary at the level. The results of
 376 CIPS are also occupied with CADF test in the concerned countries.

377 **Table 6: Findings of CIPS and CADF tests**

Variables	CADF		CIPS	
	Level	1st diff.	Level	1st diff.
LGDPC	-1.114	-3.992***	-1.114	-3.458***
LOFDI	-1.583	-2.758***	-1.567	-2.999***
LNR	-2.184**	-5.157	-2.184**	-3.251
LFD	-1.222	-3.876***	-1.564	-3.946***
LRE	-1.436	-4.740***	-1.498	-3.478***
LTO	-1.134	-3.852***	-1.524	-3.996***
LEFP	-3.237***	-5.350	-3.278***	-3.661

378 Note: *** and ** represent the one and five percent significance level.

379

380 **4.3. Westerlund panel cointegration tests**

381 Cointegration association between the variables in models 1 and 2 by following the (Westerlund
 382 and statistics 2007) error correction model cointegration method are provided in Table 7. This
 383 cointegration test is in line with our selected data since it permits for the CD. Table 7 represents
 384 the result of the cointegration by comprising constant and trend as it can be seen from both
 385 models. G_t and P_t test statistics reject the H_0 of no cointegration with bootstrapped P-values at
 386 one and five percent statistical significance. Such as, the cointegration vectors are conformed for

387 both models. Study results depict the cointegration association between all concerned factors, as
 388 explained in the models of study.

389 **Table 7: Findings of Westerlund cointegration technique**

Statistic	Value	Z-value	P-value	Robust P-value
LGDPDC = f (LOFDI, LNR, LTO, LFD, LRE)				
Gt	-9.826	7.212	1.000	0.008
Ga	-2.451	8.363	1.000	0.254
Pt	-2.908	8.269	1.000	0.900
Pa	-12.997	6.910	0.056	0.000
LEFP = f (LGDPDC, LGDPDC ² , LGDFD, LGDRE, LGDNR)				
Gt	-9.931	-3.981	0.000	0.001
Ga	-0.251	8.254	1.000	0.975
Pt	-4.549	6.622	1.000	0.053
Pa	-0.361	6.793	1.000	0.768

390

391

392 **4.4. AMG and CCE-MG estimation outcomes**

393 In this sub-section, findings of the AMG and CCE-MG approaches are given for both models for
 394 the CEE economies. Discussion of analysis is given in two parts for both models separately.

395 **4.4.1. The long-run impact of selected macroeconomic variables on economic**
 396 **development**

397 Table 8 provides the AMG and CCE-MG regressions results for the selected explanatory
 398 variables on the economic development (per capita income) for the CEE economies. We start by
 399 debating the findings of concerned economies under both econometric specifications, i.e., AMG
 400 and CCE-MG for the first model. The outcomes attained exhibited that OFDI has a significant
 401 and positive influence on economic development. In the CEE economies, it is clear that the
 402 liaison between economic development and OFDI is positive. This shows that any action to
 403 progress OFDI has a significant positive impact on per capita income. Likewise, a 1% rise in this
 404 factor causes a rise in economic development by 0.4107% and 0.6517% at one percent level.
 405 Thus our findings are coherent with a case study of Sub-Saharan Africa by Obobisa (2019);
 406 another case study to BRICS economies also supports the positive association (Mohanty and
 407 Sethi 2019). Likewise, according to regression results, economic development and OFDI have a
 408 significant positive association with each other; the empirical investigation by Zhang (2013) by

409 employing the Solow model found the same results. This means that CEE economies' OFDI is
410 conducive to encouraging the concerned economies' economic development.

411 Regarding the factors of economic development, as one would expect, the coefficient of NR
412 income is a positive and highly significant impact indicating that NR has a growing effect on the
413 economic development under both specifications (AMG and CCE-MG). Alternatively, a one
414 percent rise in this factor (NR) would cause to augment the economic development by 0.9230%
415 and 0.1217%, respectively. This makes it clear that an abundant NR has a positive effect on
416 economic development. Seemingly, rich and high-quality NR can deliver security for sustainable
417 and stable economic development. In contrast with resource-poor states, countries with strong
418 NR have a better foundation for economic growth and can generate resources more rapidly. They
419 are best suited to cross-domain growth when synchronized with organizations, resources, and
420 other components. These results support the resource bless and go consistent with existing
421 literature, including Ben-Salha et al. (2018) and Wei et al. (2020).

422 Likewise, the positive impact of NR on economic development suggests that NR is a blessing for
423 GDP in the top resource's abundant economies. It aids in generating jobs that are more decent,
424 stimulating investment, and increasing FD. Besides, a positive relationship between NR and
425 GDPC suggests the rise of GDPC may incite governments to heighten their expenditure on the
426 exploration and extraction of NR, increasing the NR revenues in the long-run. In the same way,
427 higher economic growth levels are believed to help improve local infrastructure and then
428 increase domestic and international investments for exploration and extraction in the NR sector.

429 Regarding the other determinants of economic development, TO has a statistically noteworthy
430 and positive association with economic development for the panel of specified economies. One
431 percent increase in TO increases the GDPC around 0.1849% under the AMG specification and
432 nearly 0.2288% under CCE-MG specification. These outcomes are concurrent with Nigeria and
433 Ghana's case study by Khobai et al. (2018) and another study of China by Kong et al. (2020). In
434 other words, TO shows a significant effect on economic development, endorsing the trade-
435 induced growth hypothesis. Our findings support the prevailing literature and empirical
436 confirmation presented by a case study of SADC nations by Maune (2019), a study related to
437 Turkey by (Alsamara, Mrabet et al. 2019), and a study of BRICS economies by Rani and Kumar

438 (2019). Likewise, some studies contrasted with our findings, such as Olaifa et al. (2013) and
439 Khobai et al. (2018).

440 Similarly, FD is considered as another determinant for economic development. A one percent
441 increase in FD would cause to rise in economic development by 0.029% and 0.0717% under
442 both specifications. An upsurge in FD plays a vital role in long-run economic development. If an
443 easy monetary policy is pursued by the central bank, which corresponds to a higher inflation
444 scenario, commercial banks are asked to increase the borrowing cost in terms of interest rate on
445 both consumer and producer loans. Such orthodox tight monetary policy lowers the level of debt
446 given to the economy's different sectors. This clarification also shows that a negative shock in
447 banking sector growth will create predictable rationality for customers and investors, thereby
448 restricting further credit expansion. Therefore, the potential development of loans issued by the
449 banking sector appears to be even more vigilant. This boosts actual economic development and
450 growth. Our findings are in support of a study of middle-income economies by Yang (2019),
451 another study related to Next-11 economies by Erdoğan et al. (2020).

452 The last indicator of economic development in the first model is RE consumption. From the
453 results of AMG and CCE-MG, it is clear that the coefficient (0.3911 and 0.2997) of RE
454 consumption has a positive link with the GDPC which shows that a one percent increase in this
455 factor (RE) would increase economic development by 0.3911% and 0.2997% under both
456 specifications. If per capita income crosses the threshold value, the RE demand increase has a
457 more favorable economic growth effect. In realistic terms, higher per capita income is necessary
458 to stimulate technical progress, boost productivity, and enhance innovation potential for a
459 country's research, development, and educational expenditure. Simultaneously, high-tech,
460 foreign capital, and talent inflows can be readily drawn to bring benefits from the advancement
461 of RE technology and encourage technology reforms and energy efficiency. As a result, the
462 buoyant weight of promoting RE usage on economic development is more significant. These
463 results are concurrent with relevant available literature such as by Destek and Aslan (2017),
464 Adams et al. (2018), Charfeddine and Kahia (2019), Bao and Xu (2019), and Dogan et al.
465 (2020).

466 ***Table 8: Long run results of AMG and CCE-MG estimators***

AMG	CCE-MG
-----	--------

	Coef.	Std. Err.	P> z	Coef.	Std. Err.	P> z
	Wald chi ² [19.17 (0.000)]			Wald chi ² [43.58 (0.000)]		
	LGDPC = f (LOFDI, LNR, LTO, LFD, LRE)					
LOFDI	0.4107	.01225	0.037	0.6517	0.3174	0.000
LNR	0.9230	0.0280	0.000	0.1217	0.0356	0.001
LTO	0.1849	0.0744	0.000	0.2288	0.0968	0.018
LFD	0.0209	0.4756	0.001	0.0717	0.0554	0.006
LRE	0.3911	0.0830	0.005	0.2997	0.1100	0.000
Cons.	3.2385	0.12941	0.000	-1.0053	0.1773	0.000
	LEFP = f (LGDPC, LGDPC ² , LGDFD, LGDRE, LGDNR)					
	Wald chi ² [34.13 (0.000)]			Wald chi ² [48.28 (0.000)]		
LGDPC	1.1690	1.6600	0.001	3.2752	1.6809	0.051
LGDPC ²	-.72780	.21003	0.000	-.34634	.22067	0.007
LGDFD	-.002692	.00162	0.006	-.00541	.00282	0.055
LGDRE	-.041029	.01580	0.000	-.04635	.04092	0.000
LGDNR	-.014941	.01032	0.022	-.06754	.04168	0.001
Cons.	--2.5318	3.2695	0.039	-6.5770	2.6191	0.012

467

468

469 **4.4.2. Impact of determinants of economic development (achieved) on environment**
470 **quality**

471 The second panel of Table 8 represents the estimations through AMG and CCE-MG to achieve
472 economic development on environmental quality. Likewise, in the second model, the EFP is
473 taken as the dependent variable to estimate environmental degradation due to attainable
474 economic development with the interaction terms of LGDFD, LGDRE consumption and
475 LGDNR. For understanding the effect of economic development on environmental degradation,
476 we have used income per capita as a proxy for achieved economic development. To answer this
477 question raised at the start of the study, we have taken help from Environment Kuznets curve
478 hypothesis theory, which is well known. For the understanding of EKC-hypothesis, the GDPC² is
479 introduced for the EFP.

480 Likewise, the co-efficient of GDPC ($\beta_1 > 0$) and the GDPC² ($\beta_2 < 0$) recommended that one
481 percent increase in this factor can cause an escalation of 1.169% in the dependent variable while
482 the square of GDPC can cause a reduction of 0.7278% in the EFP for the AMG-specification. A
483 one percent increase in concern factors [GDPC and GDPC²] would lead to an increase of 3.275%
484 and a decrease of 0.346% in the EFP, respectively, for CCE-MG. In other words, in the early
485 phases of growth, income levels increase the environmental destruction and decrease as income
486 reaches a turning point. (Sarkodie 2018) explained that a decrease in environmental degradation

487 versus economic development could be due to a structural variation in GDP and technological
488 encroachment. As the income level increases, environment cognizance rises, thus driving the
489 population to demand a clean environment causing the enforcement of environmental laws,
490 policies, and regulations, which reduces environmental degradation (Sarkodie and Strezov 2019).
491 Thus, such kind of association between development and EFP shows that economic development
492 is a guarantee to achieve clean environment in selected economies. These findings confirm
493 inverted U-shaped EKC-hypothesis and are coherent with the existing studies, such as a case
494 study related to 31 provinces of China (Li et al. 2016), analysis related to the USA also support
495 the evidence of inverted U-shaped EKC (Aslan et al. 2018), same is suggested by Shahbaz et al.
496 (2019) and a case study of 50 top tourist economies also showed same results (Fethi and
497 Senyuçel 2020).

498 Interaction variables LGDFD has a negative link with EFP under the specifications of AMG and
499 CCE-MG. Alternatively, a one percent rise in this variable would decrease the level of
500 environmental degradation by 0.0026% (AMG) and 0.0054% (CCE-MG), respectively. In other
501 words, raising the level of LGDFD will decrease environmental degradation in concerned
502 economies, which demonstrates the presence of LGDFD reverses the technology overflow.
503 Domestic firms have reduced their use of resources by consuming international businesses'
504 innovative manufacturing technologies after expanding foreign direct investment. These
505 outcomes are consistent with the prevailing literature, which tried to estimate the association
506 between OFDI and environmental degradation, such as by Kan and Huang (2019), Xin and
507 Zhang (2020), and Ding et al. (2017).

508 The interaction variable LGDRE's effect on environmental degradation is negative and
509 statistically significant at one percent level of significance under both econometric techniques. It
510 is noted that a one percent rise in LGDRE consumption leads to a 0.0410% and 0.0463%
511 decrease in the level of environmental degradation for the CEE economies. By way of
512 explanation, the empirical findings of this study propose that the incorporation of RE
513 technologies in the CEE economies energy mix upgrades the environment quality. The reason
514 was perceptible to burnable waste in RE consumption reconnoitered; however, this indicator was
515 pronounced to emit less environmental degradation compared to non-RE use. That is why our
516 findings support the recent environment policy thrust of nations across the world as fine-turned

517 by the Kyoto Protocol arrangements and the inter-governmental panel on climate variations.
518 These findings are also supported by several existing studies (Ulucak and Khan 2020; Naqvi et
519 al. 2020; Destek and Sinha 2020; Altıntaş and Kassouri 2020).

520 The coefficient of interaction term LGDNR concerning EFP is -0.0149 and -0.0675, respectively,
521 for both specifications. The results infer that LGDNR significantly and negatively affects the
522 level of environmental degradation. This shows that a decrease in environmental degradation
523 equivalent to 0.0149% and 0.0675% is due to a one percent increase in LGDNR. The positive
524 role of LGDNR in sustainable environmental degradation is combined with consumption and
525 production, the rate of depletion, and environmental stress reduction, thus cause LGDNR to
526 regenerate. Moreover, as natural resource exploitation moves from an obsolete technology to
527 technology that combines recycling, manufacturing, creativity, value change, and artificial
528 resource replacement, NR growth will be driven economically and boost environmental
529 sustainability (Bekun et al . 2019). The abundance of NR decreases reliance on fossil fuel
530 imports, and NR abundance is adequate to satisfy energy demands and, ultimately,
531 environmental pollution can be minimized. These results are consistent with existing literature
532 like Zafar et al. (2019) and Ulucak and Khan (2020).

533 **4.5. D-H panel causality test**

534 Along with the long-run connotation between models' variables, it is vital to explore the causal
535 relations among them. This paper uses a newly developed pair-wise D-H panel causality test
536 proposed by Dumitrescu and Hurlin (2012). It is the advanced version of the Granger non-
537 causality method for the panel data. Also, this tool includes two statistics, such as W-bar and Z-
538 bar statistics. Thus W-bar statistics yield the average test statistics, while the standard normal
539 distribution is embodied by the Z-bar statistics (Dumitrescu and Hurlin 2012). Lastly, the track
540 of causality will help policymakers standardize suitable economic policies and economic
541 approaches in the selected economies.

542 ***4.5.1. The causal association between economic development and its factors***

543 The D-H panel causality test outcomes are provided in the following Table 9. This table is
544 divided into six columns; the first three columns A, B, and C are for the first model, while D, E,
545 and F are for the second model as before explained in detail. In the first model, the long-run two-

546 way causality feedback exists between economic development and TO. The directional of
547 causality shows TO causes the change in economic development, and improvement in the
548 LGDPC causes TO. The findings support the feedback hypothesis, which means that economic
549 development in selected economies strongly correlates with TO. Also, any change in economic
550 development will positively affect the trade sector in CEE economies and vice versa. TO causes
551 the finding of economic growth, and vice versa supports the trade-led growth hypothesis in the
552 case of specified economies. These findings are in line with the previous case study South Africa
553 by Shakouri and Khoshnevis Yazdi (2017). Likewise, the casual results in light of the first model
554 also support the bidirectional causality between RE and economic development. This means that
555 any fluctuation in LRE replicates the economic development immediately, while LGDPC
556 stimulates RE in the long run.

557 Furthermore, the incidence of feedback hypothesis between RE and economic development
558 provides their mutual interdependence, which increases the usage of LRE and positively impacts
559 economic activities. The RE sector's advancement is suitable due to its positive effect on
560 declining the level of environmental degradation and helping out in sustainable development
561 (Apergis and Payne 2012). Similarly, the outcomes also support the two-way causal association
562 between FD and OFDI, which means policies relevant to FD and outward FDI work jointly.
563 Thus all concerned policies applicable to FD and OFDI should be efficient in the long run. Also,
564 there has been a bi-directional causality relationship between TO and NR, and these results
565 support a case study of OECD economies by Zaidi et al. (2019). Further, results showed a bi-
566 directional relationship from FD and RE consumption to TO and FD to RE consumption in
567 specified economies. Above and beyond, unidirectional causality was deducted from income per
568 capita to outward FDI, NR, and FD, and from TO to outward FDI.

569 ***4.5.2. The casual relationship among achieved economic development, its determinants***
570 ***and EFP***

571 In Table 9, columns D, E and F are related to the second model when EFP is considered a proxy
572 of environmental degradation. The D-H test findings reveal that there is two-way causality
573 between the LGDNR and LEFP. The results expose that any change in LGDNR will cause a
574 change in environmental degradation. In addition, feedback relation exists from LEFP to
575 LGDNR, which shows that a variation in environmental degradation can have a considerable

576 effect on LGDNR. Overdependence on NR triggers the level of environmental degradation in an
 577 NR-dependent economy. Diversification, and structural variation in economic development are
 578 needed to attain sustainable development.

579 Similarly, the results indicate that LGDRE consumption can significantly cause variation in the
 580 level of environmental degradation in the selected CEE economies. In contrast, the feedback
 581 relationship from LEFP to LGDRE consumption shows that any fluctuation in the environmental
 582 degradation will affect the LGDRE. Further, Granger causality results suggest a bi-directional
 583 causal association between LGDRE consumption and LGDNR, which means that policies
 584 relevant to LGDRE and LGDNR are working jointly. Finally, unidirectional causality is
 585 deduced from economic development and its square to LEFP, LEFP to LGDFD, LGDPC to
 586 LGDFD, economic development to LGDRE and LGDNR. The graphical representation for both
 587 models is given in appendix Fig. 2.

588 **Table 9: D-H panel causality test**

	Model 1			Model 2			
	A	B	C		D	E	F
Null Hypothesis	W-Stat	Z-bar Stat.	Prob.	Null Hypothesis	W-Stat	Z-bar Stat.	Prob.
LOFDI \gg LGDPC	3.04823	1.36385	0.172	LGDPC \gg LEFP	6.15349	6.41951	0.000
LGDPC \gg LOFDI	4.59556	3.88306	0.000	LEFP \gg LGDPC	2.90639	1.13292	0.257
LNR \gg LGDPC	2.03251	-0.28983	0.771	LGDPC ² \gg LEFP	5.65196	5.60298	0.000
LGDPC \gg LNR	5.71773	5.71006	0.000	LEFP \gg LGDPC ²	2.63590	0.69255	0.586
LTO \gg LGDPC	2.78874	0.93744	0.000	LGDOF \gg LEFP	2.35106	0.22879	0.819
LGDPC \gg LTO	7.97958	9.37584	0.000	LEFP \gg LGDOF	4.20019	3.23935	0.001
LFD \gg LGDPC	2.42547	0.34851	0.727	LGDRE \gg LEFP	4.31513	3.42649	0.000
LGDPC \gg LFD	11.2462	14.6994	0.000	LEFP \gg LGDRE	3.74524	2.49866	0.012
LRE \gg LGDPC	3.24345	1.68170	0.000	LGDNR \gg LEFP	4.49715	3.72283	0.000
LGDPC \gg LRE	5.74711	5.75789	0.000	LEFP \gg LGDNR	6.17921	6.46138	0.000
LNR \gg LOFDI	1.78002	-0.70091	0.483	LGDPC \gg LGDPC ²	5.10366	4.71029	0.000
LOFDI \gg LNR	1.68547	-0.85484	0.392	LGDPC ² \gg LGDPC	5.45320	5.27938	0.000
LTO \gg LOFDI	5.01490	4.55636	0.000	LGDFD \gg LGDPC	2.87174	1.07652	0.281
LOFDI \gg LTO	1.58946	-1.01214	0.311	LGDPC \gg LGDFD	4.23946	3.30329	0.001
LFD \gg LOFDI	3.70654	2.43274	0.015	LGDRE \gg LGDPC	2.99554	1.27808	0.201
LOFDI \gg LFD	3.69370	2.41185	0.000	LGDPC \gg LGDRE	8.47357	10.1968	0.000
LRE \gg LOFDI	2.82960	1.00791	0.313	LGDNR \gg LGDPC	2.03251	-0.28983	0.771
LOFDI \gg LRE	2.09469	-0.18860	0.850	LGDPC \gg LGDNR	5.23665	4.92681	0.000
LTO \gg LNR	4.88475	4.34479	0.000	LGDFD \gg LGDPC ²	2.90932	1.13770	0.255
LNR \gg LTO	3.95379	2.83138	0.004	LGDPC ² \gg LGDFD	4.18456	3.21391	0.001
LFD \gg LNR	2.67935	0.76156	0.446	LGDRE \gg LGDPC ²	2.88343	1.09554	0.273
LNR \gg LFD	4.79228	4.19917	0.000	LGDPC ² \gg LGDRE	8.51987	10.2722	0.000
LRE \gg LNR	3.61413	2.28519	0.022	LGDNR \gg LGDPC ²	1.63252	-0.94105	0.364
LNR \gg LRE	3.38977	1.91992	0.054	LGDPC ² \gg LGDNR	1.70616	-0.82116	0.411
LFD \gg LTO	6.08131	6.28433	0.000	LGDRE \gg LGDFD	2.72991	0.84561	0.397

LTO » LFD	4.64863	3.95695	0.000	LGDFD » LGDRE	2.66702	0.74321	0346
LRE » LTO	5.40953	5.19788	0.000	LGDNR » LGDFD	1.63252	-0.94105	0.483
LTO » LRE	3.72272	2.45576	0.014	LGDFD » LGDNR	1.70616	-0.82116	0.411
LRE » LFD	3.53500	2.15366	0.031	LGDNR » LGDRE	3.26913	1.72350	0.004
LFD » LRE	5.94303	6.07137	0.000	LGDRE » LGDNR	4.01877	2.94399	0.003

589

590

591 **5. Conclusions and policy recommendations**

592 Key focus of this paper is to estimate the critical determinants of economic development
593 (achieved) and its impacts on environmental degradation in CEE economies for the time of 1990-
594 2017 with annual frequency. The study firstly checks out the CD across the panel and applies the
595 second-generation panel unit root tests that consider CD accordingly. Based on the Westerlund
596 cointegration association study's endorsement, it executes AMG and CCE-MG estimators, which
597 yields a long-run relationship among indicators. Results found a positive relationship between
598 explained (LGDP) and explanatory variables (LOFDI, LTO, LFD LRE and LNR) in the light
599 of the first model. Thus, all determinants of economic development showed that they help to
600 boost economic development in CEE economies.

601 We have developed another model containing economic development and its determinants, such
602 as interaction terms of economic development with OFDI, NR, and RE consumption, which can
603 influence the environment. An inverted U-shaped association is found between the per capita
604 income and LEFP. Thus, achieved economic development is a guarantee for sustainable
605 development in CEE economies. Likewise, LGDNR, LGDFD, and LGDRE consumption reduce
606 environmental degradation. In the end, the D-H panel causality test explores the nature of the
607 relationship among study variables. Similarly, in the first model, there is bidirectional causality
608 between economic development and TO. Also, GDPC and RE consumption Granger cause each
609 other.

610 Furthermore, the feedback hypothesis is found between FD and OFDI, TO and NR income, RE
611 and NR income, FD and TO, RE and TO, and FD and RE consumption. However, one-way
612 causality is running from per capita income to OFDI, NR, and FD. Finally, TO Granger causes
613 OFDI. In the case of the second model, there exists a two-way causality between LGDNR and
614 environmental degradation. LGDRE usage and LEFP, Granger, causes each other. A feedback
615 hypothesis is found between LGDRE consumption and LGDNR. Likewise, unidirectional

616 causality is running from economic development to environmental degradation, from LEFP to
617 LGDFD, and from LGDPC to LGDFD. In the last LGDPC, Granger causes interaction term of
618 LGDNR.

619 The investigated results give some practical implications that may be imperative for policy
620 inferences. First, attention should be given to the interaction term of LGDFD in terms of the
621 industrial sector. The explicit requirements include the following main points. The proportion of
622 host economies technology seeking LGDFD should be enhanced. In the light of empirical
623 findings, a one percent rise in LGDFD will decrease environmental degradation equal to
624 0.0026% and 0.0056% for both specifications (AMG and CCE-MG), implying that in CEE
625 economies, LGDFD can produce an adverse outcome on environmental degradation. Therefore,
626 the purpose of low environmental degradation in CEE economies can be attained by regulating
627 outward foreign direct investment industry selection and increasing the proportion of technology
628 seeking outward foreign direct investment industry. The government must build favorable
629 political support and a legal climate for industries to attract competitive companies
630 internationally in foreign fields such as clean energies, new technologies, and new
631 manufacturing. By converting domestic surplus potential and extending the overseas market, it
632 can reverse the technology spillover impact of OFDI.

633 Regarding LGDRE consumption, this factor plays an imperative role in reducing the level of
634 environmental degradation. The inclusion of RE consumption at a higher rate in the energy mix
635 is recommended. When revenue grows, more budget is to be earmarked for RE-project
636 developments. On the other side, economic development can alone control pollution coupled
637 with some strict environmental measures required to ensure more sustainable NR use. Likewise,
638 in light of selected economies, the policymakers are suggested to increase the share of RE in
639 their energy mix to manage their NR efficiently and control their globalization pattern similar to
640 their current implications to establish a sustainable future. The EFP, with the increasing
641 economic growth, is an opportunity for the policymaker to spend further on RE development as
642 the energy sector is directly linked to three pillars of sustainable development (Ulucak et al.
643 2019).

644 This study has some limitations to a certain degree. First, it emphasizes the effect of achieved
645 economic development with its determinants on environmental degradation by using EFP, in

646 CEE economies, with limited possibilities to look at the impact of inward FDI and another form
647 of RE such as nuclear energy, biomass energy on economic development by HDI and
648 environmental degradation by SO₂, carbon footprint. Furthermore, this paper only deliberates the
649 selected inducing factors of geographical and development level in the analysis of heterogeneity,
650 but several other factors may affect the economic development and environmental quality and
651 can be considered by future studies.

652 **Ethical Approval and consent to participate**

653 Not applicable

654 **Consent for publication**

655 Not applicable

656 **Author Contribution**

657 **Qianxiao Zhang:** Conceptualization, Methodology, Editing original draft, **Syed Ale Raza**
658 **Shah:** Conceptualization, Methodology, Software, **Syed Asif Ali Naqvi:** Writing - original draft,
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662 **Competing Interests**

663 The authors declare that they have no competing interests.

664 **Data Availability and Materials**

665 The data will provide the corresponding author on demand.

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1041 **Appendix**

1042 **Table 10** List of selected CEE economies

Selected Region	Name of Countries
CEE Economies	Armenia, Belarus, Bulgaria, Croatia, Czech Republic, Estonia, Hungary, Latvia, Lithuania, Poland, Romania, Russia, Slovak Republic, Slovenia, Turkey, Ukraine,

1043

1044 **Table 11** Variance inflating factors

Variable	VIF		1/VIF
		Model 1	
LRE	1.29		0.776400
LNR	1.23		0.812666
LOFDI	1.19		0.838287
LFD	1.14		0.875803
LTO	1.12		0.895399
		Model 2	
LGDP	3.37		0.296735
LGDP ²	4.91		0.203665
LGDFD	1.28		0.778335
LGDNR	1.30		0.769913
LGDRE	1.95		0.513987

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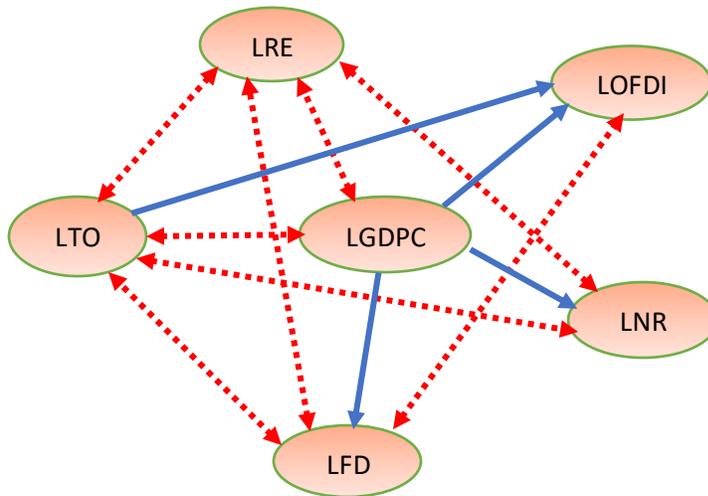
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1053 (i) Causal linkage of achieved economic development with its determinants

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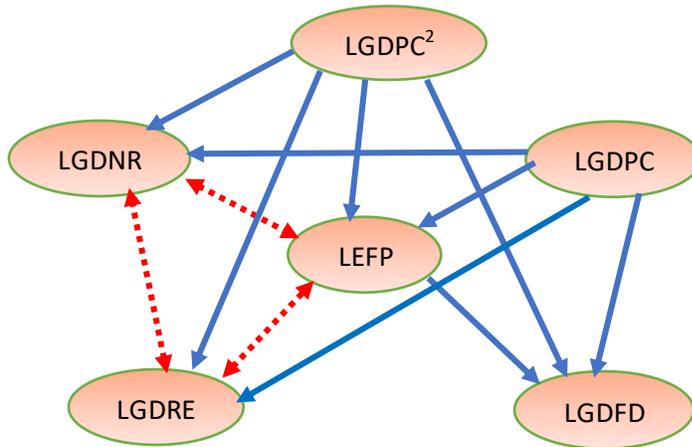
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1062 (ii) Causal linkage of economic development and ecological footprint

1063 **Note:** Unidirectional and Bidirectional causality

1064 **Fig. 2** Causal linkage of achieved economic development with its determinants

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