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RETRACTED: Energy Transition, Sustainable Development Opportunities, and Carbon Emissions Mitigation: Is the Developed World Converging Toward SDGs-2030?

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The success of sustainable development heavily depends on successful energy transition toward renewable or carbon-free energy sources. This study attempted to analyze the impact of sustainable development and environmental initiatives on sustainable energy transition in selected OECD economies. For this purpose, the study generated the dataset of environment air and GHG emission, environmental-related technologies, development (gross domestic product, trade openness, and gross domestic spending on R&D) and sustainable environment (air and GHG emission and environmental-related technologies), and energy sources (renewable energy consumption, nonrenewable energy consumption, and sum of total energy consumption) of selected economies of OECD between 2000 and 2020. This study utilized dynamic panel GMM for regression analysis, and FMOLS and DOLS were applied as the robustness models. Empirical results indicated that sustainable development and a sustainable environment contribute positively to the energy transition process in OECD economies. However, these factors also negatively contribute to non-renewable energy consumption in OECD. Thus, the study's outcomes confirmed the sustainable energy transition in OECD. Therefore, this study suggested that the success of Sustainable Development Goals depends on successful energy transition.

Keywords: sustainable energy transition, carbon mitigation, sustainable development, environmental-related technologies, dynamic panel GMM

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INTRODUCTION

The Sustainable Development Goals (SDGs) are a set of 17 global objectives to serve as a "blueprint" for achieving a progressive future for all people. These objectives are interconnected with one another. The United Nations General Assembly established the Sustainable Development Goals in 2015, intending to accomplish them by 2030 (Stafford-Smith et al., 2017). They are contained in a proposal passed by the General Assembly of the United Nations termed Agenda 2030. The Sustainable Development Goals (SDGs) are the next set of goals for global development that will take the place of the Millennium Development Goals, which ended in 2015. They were produced as part of the Post-2015 Development Agenda (Patole, 2018).

Moving to alternative energy sources that produce less carbon dioxide is a constant task known as energy transition (Hordeski, 2020). In a broader sense, this shift refers to a significant structural change that occurs within an energy infrastructure concerning demand and availability. An energy shift from timber and other forms of biomass to coal, then oil, and most recently natural gas drove industrialization. Timber and other forms of biomass were its primary fuel source. Over 70% of the world's total emissions are due to the energy industry, including emissions from using energy for heating, transportation, and manufacturing (Reuters, 2019). Throughout history, there has been a correlation between an ever-increasing need for energy and the availability of alternative forms of energy. The current shift toward renewable energy is distinct from previous ones because it is being driven, in large part, by the realization that greenhouse gas emissions must be lowered to zero on a worldwide scale. Because coal and oil constitute the most significant single source of carbon emissions, the Paris Agreement of 2015 placed restrictions on the total sum that might be generated to maintain a temperature increase of fewer than 1.5 degrees Celsius (Mangano et al., 2019).

The energy system offers sustainable energy opportunities that enable the world to maintain a balanced, healthy ecology and human life. Sustainable energy includes renewable energy sources such as solar, wind, geothermal, hydro, and ocean power. As a result, energy transition is underway around the planet (Specht and Madlener, 2019). Energy transitions relate to intentional and paradigmatic shifts from the legacy energy production infrastructure and heavy consumption dependence on high-carbon nonrenewable energy sources toward a more effective low-carbon energy mix. The energy transition is also a global effort to decarbonize the energy system to reduce its carbon footprint from the energy industry and minimize the consequences of climate change (Worighi et al., 2019). Therefore, this transition method intends to incorporate renewable energy technologies into energy to replace existing energy technologies based on fossil fuels. It also includes energy-saving measures and energy efficiency improvements. While numerous projects and efforts in the field of the energy transition are now taking place locally and globally, further steps are needed to reduce carbon emissions to counteract the effects of global warming. Renewable energy and efficiency techniques can significantly reduce carbon by 90% (Pimm et al., 2021). The future of the global energy transition depends on national legislatures and regional group capacity to manage energy security, energy equity, and ecological sustainability.

Environmental technology is the application of environmental science, green chemistry, environmental monitoring, and electronic devices to monitor, model, and conserve the natural environment and resources and curb human involvement's negative impacts. Environmental technology can also be defined as the application of environmental science (Laskowski et al., 2019). The phrase also refers to technology that generates renewable energy sustainably, such as photovoltaic systems and wind farms. Environmental technologies revolve around sustainable development as their central focus. A category of electronic gadgets that might encourage the responsible administration of resources is sometimes referred to as "environmental technology," which is another use of the terminology (Čulić et al., 2021). The most effective sources of environmental technology include cleaning of water and air, treating of sewage, restoration of damaged environments, and management of solid waste.

Several member nations of the OECD have articulated lofty, long-term objectives for achieving sustainable growth, particularly concerning the transition to a climate-neutral process and the global of a circular economy. These goals are intricately intertwined with the successful implementation of COP-21 and Sustainable Development Goals for 2030 (Kinley, 2017). There is a rising awareness that the difficulties associated with the low-carbon and circular economy call for a dynamic process, which is sometimes linked to the requirement to further capitalize on the possibilities offered by globalization and the changes that go along with it. The role that urban areas play in the transformation of energy and climate change is becoming increasingly essential. Today, they are accountable for two-thirds of the world's power usage, two-thirds of the world's greenhouse gas emissions, and a significant portion of the economic activities that take place. The urbanization of Europe's population results in additional demands and opportunities for making better use of available resources. Urban regions are home to 75 percent of the continent's population (Saraswati, 2019). Cities are in an enviable position to combat global warming and, at the same time, to integrate climate resilience into their spatial planning, infrastructure, local regulations, and investments by using locally customized climate plans per existing targets. Cities will play a crucial part in transforming their building stock, mobility networks, land use, businesses and industries, and urban infrastructures such as electricity, water, and solid waste management as we move closer to the year 2050 (Ikhlayel and Nguyen, 2017). It will require significant investments, but it also has the potential to bring numerous good consequences to urban sustainability, such as an increase in the number of business opportunities in the local area, better air quality, greater public service, and increased growth and well-being. It has been established beyond a reasonable doubt that such shifts are necessary. There is an expanding field of academic research, and the idea has entered the policy debate in the European Union and the OECD. However, even though the successful completion of transitions necessitates implementation of structural adjustments at the regional and local level, there has not been a significant amount of research conducted on the distributional impact and policy consequences of transitions in general nor on the role that regions and cities play in the administration of investment in transition.

It is generally agreed that countries in the OECD were the first to respond to the SDGs-2030 and that these countries effectively accepted the condition of sustainable transition (OECD DCD-CFE, 2019). For this reason, the economies of the OECD did everything they could to facilitate a sustainable energy transition toward energy sources with zero or no carbon emissions (Azevedo et al., 2021). Therefore, the analysis of the OECD energy transition based on sustainable development and a sustainable environment can be a roadmap for other countries, particularly developing economies, to achieve Sustainable Development Goals by successfully transforming their energy sources from fossil fuels to clean energy (Aldieri et al., 2021). Furthermore, it can be conducive for countries that are still in the process of transitioning their energy systems. Therefore, this study has the potential to be the pinnacle of its field, given the lack of other studies that focus on the same area of research but utilizing other parameters.

The following text outlines the sections that make up this study: the next part addresses the literature review and gap in this line of work. Following that, we included data sources for the underlying variables and the potential methodological approaches. The findings and comments based on the various outcomes are presented in the fourth section of the study. The conclusion was the last part that we included.

Literature Review

In the nexus between the community and environment, the most pressing concerns facing the globe today are environmental issues and rising temperatures (Karki et al., 2020). The primary contributors to global warming and climate change are greenhouse gas emissions, particularly carbon dioxide (Arora and Mishra, 2021). In this context, the interaction between climate change, energy production, and sustainable economic growth has caught the considerable interest of a significant number of academics as well as lawmakers. Several multiple evaluation methodologies have been utilized to examine these correlations. There is a line of inquiry in the economics literature that analyzes the connection between the expansion of the economy and the degradation of the surrounding environment (Abou Elseoud, 2015). The Environmental Kuznets Curve (EKC) theory proposes that a link in the form of an inverted U exists between various pollutants and per capita income in the economy. These studies attempt to prove this concept. In other words, environmental degradation in an economy first increases with a nation's success, but at some point, it finally declines as happiness keeps increasing. It is because of the virtuous cycle that occurs when success continues to ascend. As a result, the EKC hypothesis articulates a particular connection between development and the quality of the natural atmosphere (Chen et al., 2019). As a result of the rapid deployment of renewable energy across a lot of nations, an increasing number of research studies have been carried out to examine the influence that utilization of renewable energy has played in affecting the quality of the environment as well as the growth of the economy on a national, regional, and global scale (Kumaran et al., 2020). Studies were conducted in OECD countries to analyze the correlation between non-renewable and renewable energy sources and carbon intensity. The results of these studies support the existence of an Environmental Kuznets Curve between CO_2 emissions, providing evidence for the hypothesis that using renewable energy sources reduces dioxide emissions (Razmjoo et al., 2021).

In contrast, the utilization of non-renewable energy sources raises CO_2 emissions. Other studies have focused explicitly on the connection between the amount of energy consumed by a nation and its rate of economic expansion (Baloch et al., 2020). It explored how energy consumption, economic growth, and environmental emissions are related. The findings of these studies varied widely depending on the nation that was investigated; this disparity is due to several elements unique to each of these empirical research studies (Abbas Scholar and Sharif Chaudhry, 2017).

In contrast to the common analytical approaches discussed earlier, the most recent empirical research investigates the connection between economic expansion and the transition to renewable energy sources (Abbas et al., 2020), (Shen et al., 2021). Many researchers have concentrated their attention on how economic growth might facilitate energy transitions, while mitigating the effects of global warming (Wu et al., 2021). In recent years, there has been a growing body of research in the field of economics that studies how expanding economies influence the consumption of both renewable and non-renewable forms of energy (Wei et al., 2021), (Chaudhry et al., 2021). In addition, it is becoming increasingly common practice in the fields of environmental policy, energy policy, and innovation policy to investigate the designs of complicated policy mixes. It is a trending approach in the area of policy research and practice (Hao et al., 2021).

A move toward sustainability driven by innovation demands investments not only in diffusion but also in technological breakthroughs. In the study that has been carried out until now, scholars have often ignored how significant the changes are. If one can presume that a specific industry or technology is more or less in a stable condition, then this does not provide a difficulty (Bataille, 2017). However, this may be too restrictive for industries and economies that are now changing. It is possible to think of an innovation-led transition to sustainability requiring small equity investments in invention and innovation. At the same time, large-scale loan instruments are used to finance dissemination. The transformation of the energy sector into one that produces no carbon emissions will be driven mainly by investments in technology that use alternative fuels (Taboada et al., 2021). These will include solar photovoltaic (PV) and wind power systems that are less expensive and are supported by commercialized energy storage technologies. A successful transition to renewable energy sources also requires making strides toward decarbonizing the system (Blazquez et al., 2018).

The OECD's energy transition looks closely connected with the Sustainable Development Goals (SDGs) due to the shared objective of emission reductions. Significant investments in environmentally friendly energy technology may result from using the energy transition as a driver of economic restoration (McGraw Hill Construction, 2009). Mobilization of funds will primarily concentrate on renewable energy, hydrogen, and clean transportation, following the Sustainable Development Goal (SDG) priorities. The climate change issue will receive 30 percent of the money. The OECD's design for the infrastructure development effort could make it possible for new growth drivers to enter the market. This program primarily emphasizes the following three areas: information-based architecture, convergent infrastructure for emerging digital technologies, and innovative research and development infrastructure. Technological innovations, such as hydrogen electrolysis, present the possibility of enormous new markets for their products (Berkel et al., 2021). The widespread adoption of digital technology across economic and social spheres has the potential to boost energy efficiency and facilitate a transition toward a more sustainable model through advances in system design. According to the findings of the prior literature and other publications in the field, the transition to a cleaner energy source has been shown to have a positive impact on economic output, environment-related technology, research in R&D, trade, air, and greenhouse gas emissions, and other (non) economic factors (Pereirada, 2019). The commitment of the OECD to carbon neutrality will be a significant factor in accelerating its transition to low-carbon energy to rapidly reduce emissions across the economy and get closer to net-zero levels. Accelerating the shift toward cleaner energy sources is essential to any strategy that will achieve this objective (Pianta et al., 2021).

To combat the potentially catastrophic effects of global warming, more and more people are turning to low-emission energy technologies and transitional energy plans (Vogl et al., 2021). Within the confines of this paradigm, an analysis of low-emission pathways for 2050 on emissions, economic, and energy systems was carried out using a country-level methodology. The investigation found that effective low-emission transportation options for many economies include the growth of renewable energy sources and improvements in energy efficiency (Anderson and Rezaie, 2019). It was the case for the majority of the countries that were investigated. It is possible that if the representatives of COP-26 speed up the transformation to cleaner energy as part of a scheme for reaching a minimum carbon dioxide emissions, it could transform the world's responsibility toward the environment and could make a significant contribution directly to the growth of both the 15th meeting of the Conference of the Parties (COP15) and the 26th meeting of the Conference of the Parties COP26 (Alnuaim, 2019).

DATA AND METHODOLOGY

The datasets of sustainable development, environmental sustainability, and energy transition of OECD nations were utilized in this study. The period covered by the study was from 2000 to 2020. The research used gross domestic product (GDP_{PC}) at constant 2010USD, trade openness (EI_{GDP}) as the sum of the export and import share of the gross domestic product, and total gross domestic spending on R&D ($TGDS\_{R\&D}$) as a percent of GDP as the sustainable development factors. All of these were taken into consideration. In addition, air and greenhouse gas emissions (AGHG_pc), also known as CO_2 tons per capita, and environmental-related technologies ($E\_{r}T$), also known as environmental management, have been used as indicators of a sustainable environment. Finally, energy sources such as the sum of total energy consumption (TEC_{pc}), which is measured in kilograms of oil equivalent, renewable energy consumption (TREC), and non-renewable energy consumption (TNREC), quantify as input rations to produce energy through renewable and non-renewable energy consumption. The OECD database 2020, World development indicators 2020, and the International Energy Agency (IEA) 2020 have contributed to the compilation of the underlining indicator data collection.

The relationship between the forecasters is considered multicollinearity in a model, while its existence might adversely influence regression outcomes. Multicollinearity is detected with a variance inflation factor (VIF) in a regression model.

$$VIF = \frac{1}{1 - R_i^2}. \tag{1}$$

When two predictors in the framework are compared, VIFs can be derived from the results. Once this is performed, the values of R_i^2 can be connected to the VIF formula. On the other hand, the homogeneity test determines whether or not the slope coefficients are consistent with one another. To identify the root unit, cointegration, and test for causality, homogeneity of the pitch coefficients is required. Regarding delta and adjusted delta testing, the Pesaran and Yamagata test statistics are measured as (Hashem Pesaran and Yamagata, 2008)

$$\tilde{\Delta} = \sqrt{N}\left(\left(N^{(-1)s^-} - k\right)/2k\right) \sim x\_k\hat{2}, \tag{2}$$

$$\tilde{\Delta}\_adj = \sqrt{N}\left(\left(N^{(-1)s^-} - k\right)/v(t,k)\right) \sim N(0,1), \tag{3}$$

N specifies the cross-section size in the equations listed, S indicates the Swamy test statistic, k denotes the number of categorical variables, and v (t,k) is the default.

The major challenge with the panel dataset is cross-sectional dependency (CSD). Whether or not CSD is predominantly determined, in the CSD scenario, permitted unit root tests are employed. The Breusch & Pagan test statistics indicate considerable size displacement; we apply a cross-sectional dependence check with T < N (Breusch and Pagan, 1980). Pesaran proposes the preceding for the CSD test (Pesaran, 2004).

$$CD = \sqrt{\frac{2T}{N(N-1)}}(i = 1\sum_{i=1}^{N-1}\sum_{j=i+1}^{N}\rho_{ij}, \tag{4}$$

Equation 4 revealed no CSD for high N and less under the null hypothesis. In addition, the panel unit root of the first and second generations was used in this investigation. It presumes that individuals are independent, but *i* has an inevitable heterogeneity. The fundamental advantage of adopting panel unit root testing is that the root strength of these tests in finite samples is substantially more significant than the low power of standard unit root testing with extremely persistent deviations from balance. We used a collection of unit-root panels of the first generation because of their various features and composition (Barbieri, 2006). Their due difference is present in **Table 1**.

The Levin–Lin–Chu (LLC) analytical framework can be described as follows:

$$\Delta y_{it} = \rho y_{it} + \alpha_{0i} + \alpha_{1i}t + u_{it}, \; i = 1, 2, \ldots, N, \; t = 1, 2, \ldots, T \tag{5}$$

where a time trend ($\alpha_{1i}t$) and individual effects (α_i) are incorporated.

Im, Pesaran, and Shin (IPS):

TABLE 1 | First-generation unit root test specifications.

Test	Panel	Options	ρ under H_a	Asymptotic
IPS	unbalanced	—	panel-specific	N → ∞, T fixed, or T&N fixed
	unbalanced	trend	panel-specific	N → ∞, T fixed, or T&N fixed
	unbalanced	lags ( )	panel-specific	(T, N) $\rightarrow_{seq}$ ∞
	unbalanced	trend lags ( )	panel-specific	(T, N) $\rightarrow_{seq}$ ∞
LLC	balanced	nonconstant	common	√ N/T → 0
	balanced	—	common	√ N/T → 0
	balanced	trend	—	√ N/T → 0
Fisher-type	unbalanced	—	panel-specific	T → ∞, N finite or infinite
Hadri	balanced	—	(Not applicable)	(T, N) $\rightarrow_{seq}$ ∞
			(Not applicable)	(T, N) $\rightarrow_{seq}$ ∞

$$u_{it} = \sum_{j=1}^{\infty} \theta_{ij} u_{it-j} + \epsilon_{it}. \quad (6)$$

augmented Dickey-Fuller (ADF):

$$\Delta x_{it} = \alpha_i + \pi_{it} + \beta_i x_{i,t-1} + \sum_{j=1}^{k} \varphi_{it} \Delta x_{i,t-1} + \epsilon_{it}. \quad (7)$$

Hadri test:

$$y_{it} = \delta_{mi} d_{mt} + \varepsilon_{it}, \ m = 2, 3. \quad (8)$$

The PPF test involves fitting the regression:

$$y_i = \alpha + \rho y_{i-1} + +e_i, \quad (9)$$

where we can omit or include a trend period; two Z_p and Z_t statistics are calculated by the following formula:

$$z_t = \frac{\sqrt{(\gamma_{0,n}\rho_{n-1})}}{\sqrt{\lambda_n^2 \sigma}} - \frac{1}{2}\left(\lambda_n^2 - \gamma_{0,n}\right)\frac{n\sigma}{\lambda n \ Sn}, \quad (10)$$

In this case, $\lambda_n^2 - \gamma_{0,n} = 0$, and the 2nd term disappears. $\frac{(\gamma_{0,n}}{\lambda_n^2} = 1$; thus, $\frac{\sqrt{(\gamma_{0,n}\rho_{n-1})}}{\sqrt{\lambda_n^2 \sigma}}$ reduces to $\frac{\rho_{n-1}}{\sigma}$ and $z_t = \frac{\rho_{n-1}}{\sigma}$ is the t-statistic in the standard ADF equation. The last test we have retained in our first-generation group is the Imet al. (2003) test, using a normalized t-statistical predicated on the ADF distribution progression:

$$z_{t\_bar} = \frac{\sqrt{N}\left\{t_{bar} - N^{-1}\sum_{i=1}^{N} E(t_{iT})\right\}}{\sqrt{N^{-1}\sum_{i=1}^{N} var(t_{iT})}}. \quad (11)$$

Pesaran presented a test to increase the augmented regressions of ADF by the cross-sectional average for lagged levels and the initial time series variations (Pesaran, 2007). The common factor is thus supported by the mean intersection of y_i and its lagged values. The Pesaran test uses cross-sectional ADF (CADF) statistics, as provided below:

$$\Delta y_{i,t} = \alpha_i + \beta_i y_{i,t-1} + \gamma_i \bar{y}_{t-1} + \delta_i \Delta \bar{y}_i + \varepsilon_{i,t}, \quad (12)$$

where δ_i, α_i, γ_i, and β_i are estimated using the ADF region test slope coefficients i, y_{t-1} is the average level of laggings – and Δy_i is the means of initial differences, and $\varepsilon_{i,t}$ is the terms of error.

This study used four principal cointegration tests to examine the panel's cointegration due to their abilities to tackle various situations.

Pedroni, (1999) outlines the cointegration test structure with m = 2,..., M explanatory parameters, while Pedroni. (2004) addresses the situation with only one regressor (Pedroni, 2004). The proposed regression cointegrated is

$$y_{i,t} = \mu_i + \omega_i t + \psi_i x_{i,t} + \zeta_{i,t} \ for \ t = 1, \cdots, T, \ i = 1, \cdots, N, \quad (13)$$

Again, T represents the transversal dimension of time and N. The slope coefficient and the μ_i factor for fixed effects may differ between the panelists. A particular temporal trend with a time coefficient is also presented.

Keo (1995) proposes measuring the coincidence's homogeneity by combined regression for the entity (Kao, 1999). The regression equation is determined by

$$Y_{i,t} = \alpha_i + \beta X_{i,t} + u_{i,t}, \quad (14)$$

Kao tests are based on the corresponding t-statistic (Kao, 1999).

$$t_{\bar{p}} = (\tilde{\rho} - 1)\left(\hat{s}_{\tilde{u}}^2\left(\sum_{i=1}^{N}\sum_{t=1}^{T}\tilde{u}_{i,t-1}^2\right)^{-1}\right)^{-\frac{1}{2}}, \quad (15)$$

where $\hat{s}_{\tilde{u}}^2 = N^{-1}T^{-1}\sum_{i=1}^{N}\sum_{t=1}^{T}\Delta\tilde{u}_{i,t-1}^2 \Delta\tilde{u}_{i,t-1}'$ corrected for endogeneity and serial correlation.

The Dutt & Ghosh panel cointegration (Dutt and Ghosh, 1995):

$$y_{it} = \alpha_i + A_1 y_{it-1} + - - + A_\rho y_{it-\rho} + \mu it. \quad (16)$$

The cointegration and the short-run terms can be expressed in **Equation 6** as

$$\Delta y_{it} = \alpha_i + \Pi y_{it-1} + \sum_{j=1}^{\rho} \Gamma \Delta Y_{t-j} + \mu_{it}. \quad (17)$$

Examining the dynamic impact of the model, where the set of independent variables contains the lagged dependent including dynamics to the model because without the lagged dependent, the independent indicators show the complete information which produces a pragmatic outcome *Cit*. On the other hand, in the lagged inclusion, the entire history of the independent variables with estimated influence appears; the impact of the dependant represents the effect of the latest information.

TABLE 2 | Results of the pairwise correlation matrix.

Correlation matrix

	GDP_PC	**EI_GDP**	**TGDS_R&D**	**AGHG_pc**	**E_rT**	**TEC_pc**	**TREC**	**TNREC**
GDP_PC	1.00	—	—	—	—	—	—	—
EI_GDP	0.46	1.00	—	—	—	—	—	—
TGDS_R&D	0.36	0.37	1.00	—	—	—	—	—
AGHG_pc	0.43	0.43	0.39	1.00	—	—	—	—
E_rT	0.18	0.24	0.11	0.33	1.00	—	—	—
TEC_pc	0.13	0.19	0.12	0.36	0.42	1.00	—	—
TREC	0.03	−0.01	−0.03	−0.14	−0.21	−0.19	1.00	—
TNREC	0.16	0.29	−0.08	0.24	0.24	0.27	−0.13	1.00

****, **, and * show the significance level at 1, 5, and 10% level, respectively.*
H_o: There is a correlation between the variables.
H_1: There is no correlation between the variables.

$$C_{it} = \mu_i + \beta ESG_{it} + \rho C_{it} - 1 + \varepsilon_{it} \quad (18)$$

A significant problem is brought on by the fact that the lagged dependent is generally associated with the error terms. It is the source of the difficulty. Instrumental variables are used to address difficulties of this nature. By taking the first differences in the GMM model, all of these heterogeneity-related problems were eliminated from the functional form.

We use the DOLS and FMOLS estimation methodologies developed by Pedroni (1999) and Pedroni (2004). It helps ensure that our results are reliable. DOLS is a versatile method that enables the cointegration of heterogeneous vectors within the given parameter. It is a parametric and normally dispersed test that regulates mistakes during reinforcing static regressors by using lead and lag values at the first differences. On the other hand, Pedroni came out with the FMOLS approach in 2004, regarded as a nonparametric estimating technique. It corrects the biases caused by OLS when endogeneity and serial correlation concerns are present among the vectors and residuals. As a result, it makes fewer assumptions. The DOLS approach can be characterized by the equation that is presented below:

$$SDgap_t = \gamma_i + EM_i^{'}\beta + d_{1t}\psi_1 \sum_{j=q}^{r} \Delta EM_{t+j}^{'}\delta + \mu_{it} \quad (19)$$

In this case, FMOLS estimation can be performed with the following equation:

$$\omega_{GM} = N^{-1}\sum_{i=1}^{N}\left[\sum_{t=1}^{T}\left(\Delta EM_{it} - EM_i^{'}\right)^2\right]^{-1}\left[\sum_{t=1}^{T}\left(EM_{it} - EM_i^{'}\right)SDgap_i^{'} - T\tau_i\right] \quad (20)$$

DOLS and FMOLS produced more reliable estimates.

RESULT ESTIMATION

The empirical outcomes of the study based on the dynamic panel GMM and other methods have been presented in this section. For this purpose, this study performed data diagnostic tests given below.

The results of the pairwise correlation matrix are presented in **Table 2**. Again, the independent variable results demonstrate no difficulty with the correlation between the independent variables in this case. As a result, we conclude that there is no association between the variables in this dataset, which leads us to reject the null hypothesis and accept the alternative hypothesis.

We have investigated whether or not there is a connection between the variables, and the results are presented in **Table 3**. The likelihood of multicollinearity occurring among the model parameters is presented as an unlikely scenario in statement 1.2. To determine this aspect, the variance inflation factors (VIFs) for each model parameter have been computed, and the test results have indicated no multicollinearity among the model parameters. With this evidence, we can get started on the empirical estimation. Furthermore, unit root results based on the six different methods presented in **Table 4** below. Outcomes of these tests confirm that dataset is stationary and there is no issue of unit root.

The findings from Pedroni (2004), Kao (1999), and the Johansen–Fisher panel cointegration tests are presented in **Table 5**. Due to the unique qualities of each of these approaches, it was necessary to perform another round of cross-verification of the cointegration process. The Pedroni test has seven cointegration panels; four are based within the dimension, while the remaining three are between sizes. Every trial begins with the assumption that the null hypothesis, which states that no two data can be integrated, is true. One of the three group statistics tests and one of the four-panel statistics tests conclude that there is cointegration, thereby rejecting the null hypothesis that there is no cointegration. However, to assert that the dataset is cointegrated, all of the panels must have statistical significance, as stipulated by the Padroni assumption.

The findings of the Kao residual panel indicate that the null no-cointegration level of 10 percent does not satisfy the majority of the requirements. The conclusions presented in **Table 5** of Pedroni's residual cointegration test are reflected in the observations made by Kao regarding the residual cointegration test. In both the Pedroni and the Kao trials, the Schwartz Information Criterion (SIC) is applied automatically to select the appropriate lag time.

The outcomes of the cointegration test for the Johansen–Fisher panel are presented in **Table 5**, as can be seen there. To find the optimal lag period, we used the Akaike Information Criterion (AIC) in conjunction with the SIC. The cointegration test is carried out with a trend-free and trend

TABLE 3 | Results of the multicollinearity test and homogeneity test.

Variance inflation factor (VIF)

	$GDP_{\_PC}$	$EI_{\_GDP}$	$TGDS_{\_R\&D}$	$AGHG_{\_pc}$	$E_{\_r}T$	$TEC_{\_pc}$	TREC	TNREC
$GDP_{\_PC}$	—	—	—	—	—	—	—	—
$EI_{\_GDP}$	1.76	—	—	—	—	—	—	—
$TGDS_{\_R\&D}$	2.41	1.15	—	—	—	—	—	—
$AGHG_{\_pc}$	1.39	2.13	1.18	—	—	—	—	—
$E_{\_r}T$	1.03	1.06	1.01	1.12	—	—	—	—
$TEC_{\_pc}$	1.02	1.04	1.01	1.15	3.10	—	—	—
TREC	1.00	1.00	1.00	1.02	1.05	1.04	—	—
TNREC	1.03	1.09	1.01	1.06	1.06	1.08	1.02	—

Pesaran, Yamagata. 2008 Test

Delta tilde	p-value	Adjusted Delta tilde	p-value					
10.951***	0.000	11.616***	0.000	—	—	—	—	—

****, **, and * show the significance level at 1, 5, and 10% level, respectively.*
H_o: There is no multicollinearity in the dataset.
H_1: There is multicollinearity in the dataset.
**** shows the significance level at 1%.*
H_o: slope coefficients are homogenous.
H_1: slope coefficients are not heterogeneous.

TABLE 4 | Results of the first-generation unit root tests.

Variables	**LLC**	**IPS**	**ADFF**	**PPF**	**Hadri**	**Z-Stat**
$GDP_{\_PC}$	−6.68***	0.90	58.84	84.72	20.93***	19.81***
	(0.00)	(0.82)	(0.90)	(0.19)	(0.00)	(0.00)
D. $GDP_{\_PC}$	−10.02***	−13.14***	314.65***	449.46***	0.93**	2.49**
	(0.00)	(0.00)	(0.00)	(0.00)	(0.01)	(0.01)
$EI_{\_GDP}$	−8.41***	−11.42***	207.46***	540.36***	18.64***	20.31***
	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)
D. $EI_{\_GDP}$	−41.34***	−25.38***	301.06***	443.45***	9.80***	9.50***
	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)
$TGDS_{\_R\&D}$	−7.38***	−2.15	129.02***	417.52***	18.73***	20.29***
	(0.00)	(0.05)	(0.00)	(0.00)	(0.00)	(0.00)
D.$TGDS_{\_R\&D}$	−8.02***	−11.34***	277.25***	493.16***	15.18***	7.15***
	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)
$AGHG_{\_pc}$	−7.99***	0.03	64.98	95.34*	21.17***	20.94***
	(0.00)	(0.51)	(0.76)	(0.05)	(0.00)	(0.00)
D. $AGHG_{\_pc}$	−14.42***	−15.89***	384.08***	584.67***	1.80**	2.19**
	(0.00)	(0.00)	(0.00)	(0.00)	(0.04)	(0.01)
$E_{\_r}T$	0.26	−2.86***	124.61***	282.65***	8.45***	7.58***
	(0.60)	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)
D. $E_{\_r}T$	−3.11***	−11.14***	311.06***	785.69***	3.56***	4.36***
	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)
$TEC_{\_pc}$	−0.27	0.50	105.10***	107.43***	16.89***	8.44***
	(0.39)	(0.69)	(0.01)	(0.01)	(0.00)	(0.00)
D. $TEC_{\_pc}$	−8.25***	−12.67***	304.90***	634.29***	1.86**	5.16***
	(0.00)	(0.00)	(0.00)	(0.00)	(0.03)	(0.00)
TREC	6.73	7.34	37.46	48.92	18.82***	11.93***
	(1.00)	(1.00)	(1.00)	(0.99)	(0.00)	(0.00)
D. TREC	−6.24***	−11.86***	310.22***	560.99***	1.53***	5.55***
	(0.00)	(0.00)	(0.00)	(0.00)	(0.06)	(0.00)
TNREC	−0.65	3.31	67.46	59.10	12.96***	9.76***
	(0.26)	(1.00)	(0.69)	(0.90)	(0.00)	(0.00)
D. TNREC	−10.29***	−11.81***	290.42***	550.85***	9.74***	7.64***
	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)

****, **, and * show the significance level at 1, 5, and 10% level, respectively. The bracket shows the probability value, and "D" represents the 1st difference condition.*
H 0: the panel is nonstationarity.
H 0: Panel is stationarity.

TABLE 5 | Results of the Padroni, Keo, and Fisher cointegration test.

Padroni residual cointegration test					
	(Within-dimension)	Statistic	Prob	Weighted statistic	Prob
	Panel v-Statistic	7.26***	0.00	0.36	0.36
	Panel rho-Statistic	5.21	1.00	4.43	1.00
	Panel PP-Statistic	5.28	1.00	−1.85**	0.03
	Panel ADF-Statistic	5.05	1.00	−0.58	0.28
		(Between-dimension)	Statistic	Prob	
		Group rho-Statistic	6.68	1.00	
		Group PP-Statistic	−1.52*	0.05	
		Group ADF-Statistic	0.73	0.77	
Results of the Kao Test			Kao t-stat	Prob	—
—	—	ADF	1.50*	0.05	—
Results of Johansen–Fisher panel cointegration test					
Null Hypothesis	Fisher Stat.*(Trace Test)	Prob	Fisher Stat.*(Max Eigen Value)	—	Prob
CE = 0	1112.00***	0.00	560.60***	—	0.00
CE ≤ 1	507.10***	0.00	280.20***	—	0.00
CE < 2	279.90***	0.00	161.60***	—	0.00
CE < 3	167.40***	0.00	114.60***	—	0.00
CE < 4	110.70***	0.00	93.18*	—	0.05
CE < 5	112.60***	0.00	112.60***	—	0.00

****, **, and * show the significance level at 1, 5, and 10% level, respectively.*
H 0: There is no cointegration in the panel.
H 1: There is cointegration in the panel.

TABLE 6 | Results of the cross-sectional dependency test.

Variables	Breusch-pagan LM	Pesaran Scaled LM	Bias-Corrected Scaled LM	Pesaran CD
$GDP_{\_PC}$	4975.87***	118.09***	117.45***	20.02***
$EI_{\_GDP}$	17101.74***	450.34***	449.70***	129.84***
$TGDS_{\_R\&D}$	16396.43***	431.01***	430.37***	126.79***
$AGHG_{\_pc}$	17034.35***	448.49***	447.85***	129.86***
$E_{\_r}T$	6645.94***	163.85***	163.21***	42.91***
$TEC_{\_pc}$	6539.10***	160.92***	160.28***	30.92***
TREC	1643.60***	26.79***	26.15***	7.38***
TNREC	18582.83***	490.92***	490.28***	136.21***

**** shows the significance level at 1%.*
H_o: There is no cross-section dependency.
H_1: There is the cross-sectional dependency.

constant as the dependent variable. Based on the highest statistical value, we conclude that in the null hypothesis that there is no cointegration should be accepted. The results of trace statistics also assist in the discovery of maximum self-value statistics where there is a contradiction between r = 0 and r = 1, respectively, in the direction of null hypotheses.

The cross-sectional dependence in the model is examined first as a starting point for the panel data analysis, and the results of this examination are presented in **Table 6**. There is abundant proof that the panelists are subject to cross-sectional dependencies in their work. Therefore, dependence on panel data leads to production of misleading results and decreases the estimator's efficiency when using first-generation estimation approaches because the majority of these nations are important trading partners with several different bilateral and multilateral arrangements and because a portion of the energy imports is utilized in manufacturing the final products that are intended for international trade. At the one percent significance level, both tests' null hypotheses are incorrect, which verifies the presence of cross-sectional dependency.

TABLE 7 | Long-run results of the dynamic panel GMM estimator.

	$TEC_{\_pc}$	TREC	TNREC
$lnGDP_{\_PC}$	0.963** (0.048)	0.814** (0.050)	–.616*** (0.044)
$lnE_{\_r}T$	0.590*** (0.009)	0.368*** (0.000)	−0.125*** (0.005)
$lnEI_{\_GDP}$	0.362** (0.045)	0.303** (0.004)	−0.369** (0.049)
$lnTGDS_{\_R\&D}$	0.122* (0.059)	0.101*** (0.000)	−0.640* (0.057)
$lnAGHG_{\_pc}$	0.865*** (0.006)	−0.753** (0.050)	0.159** (0.025)

According to the long-run results of GMM in **Table 7**, $GDP_{\_PC}$ contributes positively and statistically significantly (at 5%) to $TEC_{\_pc}$ and TRCE, while negatively contributing to TNREC, respectively. This outcome indicates that there is one unit change in the GDP of the selected OECD countries, contributing 9.63% in total energy consumption, 8.14% in

TABLE 8 | Results of robustness based on FMOLS and DOLS.

	FMOLS Estimator			DOLS Estimator		
	TEC_$_{pc}$	TREC	TNREC	TEC_$_{pc}$	TREC	TNREC
lnGDP_$_{PC}$	0.353** (0.042)	0.567** (0.050)	−0.369*** (0.000)	0.735** (0.051)	0.4752** (0.049)	−0.1587** (0.055)
lnE_$_r$T	0.954** (0.058)	0.951*** (0.000)	−0.715** (0.050)	0.314** (0.052)	0.684*** (0.000)	−0.418** (0.051)
lnEI_$_{GDP}$	0.205** (0.051)	0.393*** (0.000)	−0.535* (0.058)	0.571** (0.044)	0.564*** (0.000)	−0.322*** (0.000)
lnTGDS_$_{R\&D}$	0.310*** (0.000)	0.415** (0.049)	−0.201*** (0.000)	0.041*** (0.047)	0.901*** (0.000)	−0.188** (0.051)
lnAGHG_$_{pc}$	0.344*** (0.000)	−0.136** (0.049)	0.905*** (0.000)	0.792** (0.035)	0.641*** (0.000)	0.721** (0.024)

****, **, and * show the significance level at 1, 5, and 10% level, respectively.*

renewable energy consumption, and -6.16% in total nonrenewable energy consumption. Environmental-related technology (E_$_r$T) is significant at a 1% level with a negative sign for all energy sources. A one-unit change in E_$_r$T contributed 59.0% to total energy sources and 36.8% to renewable energy. However, E_$_r$T contributed -12.5% with negative slope. The trade openness (EI_GDP) impact on energy sources in OECD economies shows positive and statistically significant (5% level) for total energy sources and total renewable energy sources, while negatively related to total nonrenewable energy sources. The coefficient value of the trade openness (EI_$_{GDP}$) indicates that one-unit change can variate 36.2% in TEC_$_{pc}$, 30.3% in TREC, and -36.9% in TNREC. The empirical outcomes of the total gross domestic spending on R&D (TGDS_$_{R\&D}$) suggest statistical significance at a 1% level for TREC and a 10% level for TEC_$_{pc}$ and TNREC. It shows the 10.01% variation in TREC due to one unit change in TGDS_$_{R\&D}$, 12.2% TEC_$_{pc}$ and -64.0% change in TNREC. Finally, the empirical results of air and GHG emission (AGHG_pc) show a 1% level of significance for TEC_$_{pc}$ and 5% significance for TREC and TNREC. Here, the coefficient of TREC hold negative relation with AGHG_$_{pc}$, indicating that a unit change in this factor can be the source of -75.3% change in renewable energy consumption. Furthermore, this parameter positively correlated with total and nonrenewable energy consumption. This parameter shows 86.5% variation in TEC_$_{pc}$ and 15.9% in TNREC. Outcomes of the empirical analysis show that based on the underline parameter of sustainable development and environment, OECD economies are successfully moving toward sustainable energy transition.

After careful methodological application of dynamic panel GMM, we applied FMOLS and DOLS to verify the robustness of the model mentioned above. The outcomes of robustness are presented in **Table 8**.

This study used FMOLS and DOLS further to investigate the consistency of the results obtained by the estimators listed in **Table 8**, which displays the findings obtained from both the FMOLS and the DOLS. These findings lend their support, with enthusiasm, to the conclusions drawn from the dynamic panel GMM. The GDP_$_{PC}$ coefficients are positive in both estimators (FMOLS and DOLS) for TEC_$_{pc}$ and TREC, TNREC; however, there is a bit of variance in the significance levels of each of these coefficients. It has been found that E_$_r$T, EI_$_{GDP}$, and TGDS_$_{R\&D}$ all have the same sign for their respective coefficients. The prior estimator did not distinguish these results in any way (dynamic panel GMM).

In conclusion, the findings also follow the same pattern for AGHG_pc; yet, the significant levels of TREC and negative for TNREC are distinct. The findings lend credence to the assertions made by the dynamic panel GMM that GDP_$_{PC}$, E_$_r$T, EI_$_{GDP}$, and TGDS_$_{R\&D}$ all positively contribute to TEC_$_{pc}$ and TREC. However, the role that these indications play for TNREC is not a positive one. The AGHG_$_{pc}$ parameter has a good impact on TEC_$_{pc}$ and TNREC but negatively on TREC.

DISCUSSION

This study attempted to conduct an empirical analysis of the relationship between sustainable development, sustainable environment, and the transition to sustainable energy in a number of countries that are members of the OECD throughout the period between 2000 and 2020. In these OECD nations, the outcomes of the total energy consumption (TEC_$_{pc}$) and renewable energy consumption (TREC) suggest a positive association with the gross domestic product (GDP_$_{PC}$), which indicates a positive relationship with the GDP_$_{PC}$. However, GDP_$_{PC}$ is now negatively affecting the total use of nonrenewable energy sources (TNREC). The reasoning behind these results is connected to the idea that OECD economies have finished the transition phase of the EKC, where green economic growth has become the first choice for economic development (Lau et al., 2019). It is because green income activity has become the primary option for economic development.

Furthermore, the use of filthy and carbon-based energy sources has become less popular due to a desire for environmentally friendly financial practices, stringent environmental rules and regulations, and obligations regarding COP-26 of the Glasgow United Kingdom agreement. Consequently, the overall energy consumption demonstrates a positive trend with GDP PC but a negative trend with TNREC. This concept has also been validated by more recent research, which demonstrated that industrialized economies have lower energy intensity and are less polluting when their income levels approach a level of GDP per capita than those of the more mature OECD states in earlier decades did during the same period (del Pilar Parra O. et al., 2017). Furthermore, according to a study conducted by Salari et al., nations within the OECD that are negatively impacted by the consumption of nonrenewable and renewable energy play a supporting role in the economic growth of around 28 countries within the OECD (Salari et al., 2021). del Pilar Parra found that there is a two-way causal relationship between GDP per capita and energy use per capita for OECD data (del Pilar Parra O et al., 2017).

The variable known as environmental-related technologies ($E\_{r}T$) has a negative correlation with TNREC and a positive correlation with TEC_{pc} and TREC. Although the ($E\_{r}T$) concept has only recently gained traction in these economies, it has rapidly evolved into a vital instrument for reducing carbon emissions and promoting renewable energy sources. Additionally, it has assisted in the enhancement of the utilization of renewable sources of energy. For example, del Pilar Parra et al. concluded that environmental-related technologies negatively affect CO_2 emissions (del Pilar Parra O et al., 2017). Similarly, Gasparatos et al. concluded that nonrenewable environmental-related technologies are an effective instrument for transitioning to renewable energy in the economy of the OECD (Gasparatos et al., 2017).

Total domestic spending on research and development ($TGDS\_{R\&D}$) is an indicator of positive technical innovation that contributes to the production of renewable energy (TREC) and total energy consumption (TEC_{pc}). Both the study by Murad et al. and the study by Horbach et al. brought attention to the influence that $TGDS\_{R\&D}$ has on the surrounding environment (Murad et al., 2019) and (Horbach et al., 2012). On the other hand, it has turned into a net contributor to the consumption of nonrenewable sources of energy (TNREC) in the economies of the OECD. This concept lends a great deal of weight to the argument that innovation has already begun to boost the use of renewable energy sources. The same findings were discovered by Liddle and Huntington, (2021) about the worldwide dissemination of energy technologies, which lessens reliance on fossil fuels. For instance, a calculation using a piece of paper and a pencil anticipated that non-OECD countries would reduce their usage of fossil fuels by approximately 30 percent. It was based on the climatic footprint of many developing countries.

According to Matei's findings, research and development (R&D) funding should be invested in potentially renewable technologies and related infrastructure networks to make renewable energy sources more affordable than fossil fuels. Additionally, regional collaboration and development between countries should be supported to improve clean energy efficiency (Matei, 2018), in contrast to the findings of Yigitcanlar et al. who found that technological innovation does have positive externalities in the case of economies that are members of the OECD. It is because Yigitcanlar et al. based their research on the next eleven countries undergoing development (Yigitcanlar et al., 2021).

There is a negative correlation between the total renewable energy consumption usage TREC and the air and GHG emission ($AGHG\_{pc}$). Still, there is a positive association between these two variables and total energy consumption (TEC_{pc}) and total nonrenewable energy consumption (TNREC). Based on these findings, it appears that $AGHG\_{pc}$ plays a role in achieving the Sustainable Development Goals of reducing the consumption of polluting energy in the economies of the OECD. For instance, Sumarno et al. discovered that $AGHG\_{pc}$ directly contributes to the growth of renewable energy, which in turn leads to improving the health sector (Sumarno et al., 2020). The same conclusion can also be drawn from Sumarno et al. (2020), which presents the data.

Trade openness (EI_{GDP}) is associated with a positive sign for total energy consumption (TEC_{pc}) and total renewable energy consumption (TREC). In contrast, it is associated with a negative sign for total energy (TREC) and total nonrenewable energy consumption (TNREC). It is because the economies of the OECD could be highly reliant on the export and import of various commodities. These findings have also been uncovered by a variety of investigations conducted in recent years.

Nevertheless, the most significant contribution to developing renewable energy sources is the fact that it makes a good contribution to the process of developing renewable energy sources. It is occurring as a result of the emphasis placed by the manufacturing sectors of the economies that make up the OECD on the use of clean energy sources that do not produce carbon dioxide. As a result, it is anticipated that over time, the share of green energy, also known as renewable energy, will grow faster than the share of polluting energy, and the ultimate impact of trade openness will shift toward playing a supportive role for the transition to a safe and green energy source.

Within the context of a sustainable energy transition, this study investigates the significance of sustainable development and environmental sustainability. This strategy can analyze the shift in energy sources and their link with a variety of macroeconomic indicators and preventative instruments in an effective manner. On the other hand, if we could categorize the independent variables according to industry, it could achieve more fruitful results. For instance, the results of increased trade openness are confusing because it is impossible to determine the true impact of various export and import industries. Therefore, future research needs to consider the distinct roles played by multiple variables to narrow down the effect of this phenomenon on numerous forms of energy. For instance, the findings of researchers on the relationship between energy efficiency and greenhouse gas emissions per capita show that progress in fixed capital energy usage, structural changes determined by industry share in the national economy, and innovation related to the development and implementation of high technologies can all be important factors. Moreover, these factors are all related to energy conservation.

CONCLUSION

This study investigates the relationship between sustainable development and environmental sustainability throughout the transition to sustainable energy. To achieve this goal, a dataset covering the years 2000–2020 and comprising chosen nations from the OECD was generated. This research utilized dynamic panel GMM as the primary estimator, while FMOLS and DOLS were used to determine the robustness of the study's findings.

The findings of this empirical investigation suggest that all of the independent variables (gross domestic product, trade openness, gross domestic spending on research and development, and environmental-related technologies), except for air and greenhouse gas emissions, have a positive impact on total energy consumption and total renewable energy consumption, while total non-energy consumption is negatively associated with these variables. In this context, air and GHG emissions positively impact total and non-renewable energy consumption while negatively impacting total renewable energy consumption. According to our research findings, OECD economies are receiving favorable assistance from sustainable economic development and environmentally sustainable conditions to transition to a new energy source successfully. These findings show that decision-makers should conceive and establish effective support policies to attract investment in innovative renewable energy technology. One policy solution that can be implemented is to assist the development of renewable energy technology in achieving the overarching objective of transitioning to a sustainable energy system. The fundamental program of the development routes of a variety of non-fossil fuel activities is to meet the policy aim, which is further concretized in a set of policy targets and tools, when they embrace this policy strategy. To realize the new kind of creating an enabling environment, administrative reform will be necessary on both the global and international levels of authority. It is essential to have coherence in managing high-quality strategies for sustainable and resilient investment and innovation. That being the case, a specialized function is required to guarantee that investment methods are compatible with long-term expansion.

The International Energy Agency (IEA) suggests increasing collaboration and coordination framework of national climate and energy schemes as well as working on incorporating the energy market, increasing cross-border trade, and developing stronger signals from the price of carbon. All of these ideas are included in their respective proposals. In addition, there are several apparent linkages between the transition to a sustainable energy source, the creation of new jobs, and improvements in health. For example, pollution caused by the combustion of fossil fuels claims people's lives at an earlier age each year, while also increasing the risk of diseases affecting the respiratory system. On the other hand, environmental and social ratings have remained stable, resulting in increased returns, and using renewable energy technology may benefit both the environment and human health.

DATA AVAILABILITY STATEMENT

The original contributions presented in the study are included in the article/Supplementary Material; further inquiries can be directed to the corresponding author.

AUTHOR CONTRIBUTIONS

The conceptualization was performed by YL; methodology was formed by SA; software and validation were performed by WY and RK; formal analysis was performed by SA; investigation and resources were performed by YL; data curation was performed by RK; writing—original draft preparation was carried out by YL, SA, WY, and RK; writing—review and editing was carried out by SA, WY, and RK; visualization was carried out by WY; supervision was carried out by YL.

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