Do Economic Globalization and Paris Climate Accord Drive Bioenergy Consumption in Developing and Developed Countries?

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Abstract

Climate change is driving the world to care about environmental sustainability, including the use of bioenergy. External factors like economic globalization and international agreements may impact the rise in bioenergy consumption. Hence, this study examines the impact of economic globalization and the Paris Climate Accord on bioenergy consumption in developing and developed countries. Economic globalization encourages developing and developed countries to use more bioenergy. One of the factors that compels both regions to employ bioenergy is a variety of ecologically friendly trade standards. In the meantime, the Paris Climate Accord only benefits the use of bioenergy in developed countries. Other factors that drive bioenergy consumption include the value-added of industry and agriculture, population growth, human development, and temperature. Meanwhile, GDP growth harms bioenergy consumption in developing countries. The study's findings are consistent with the EKC theory, where strict regulations and innovation increase environmental awareness, while economic growth without proper supervision will harm the environment.

Keywords: population, human development index, value-added, temperature, GDP

1. Introduction

The population greatly influences the total GDP and energy consumption. However, this also causes an increase in ecological demands for human activities, including housing, industry, agriculture, and ultimately environmental degradation [1]. High population density, acute poverty, and rapid industrialization are significant obstacles to sustainable development [2]. This is compounded by the fact that many countries face unique challenges, such as a heavy reliance on coal-based energy sources that cause air pollution [3]. Many parts of the world are experiencing a rapid increase in energy needs. The fastest way to meet this condition is to use fossil fuels that negatively impact the environment and human health. Countries that are particularly vulnerable to the effects of climate change would suffer greatly if this issue is neglected [4].

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A country makes a lot of effort to preserve environmental sustainability. For instance, the BRICS countries have achieved carbon neutrality of approximately 0.567% and 0.139% because of the introduction of green energy and taxes [3]. Many countries are now using bioenergy. Fuel fuels currently meet approximately 10% of the world's energy needs, accounting for 2% of the world's electricity production and a comparable portion of all the use of liquid fuels [5]. Although essential for addressing climate change and guaranteeing sustainable development, the transition to green energy faces numerous obstacles in obtaining funds, implementing effective government policies in practice, and improving material efficiency.

One way to address this issue is to implement economic globalization and international policy pressure [6]. Although the impact of economic globalization is still subject to debate because it helps importing countries ensure food security, on the other hand, it has increased interdependence between countries and contributes to environmental pollution and resource depletion [7]. Furthermore, restrictions on grain import dependence caused more changes in cereal consumption in most regions than the effects of climate change on agricultural productivity [8]. However, for the green energy transition, increased economic globalization has a positive impact on the green energy transition in developed countries such as the Republic of Korea, but some countries experience adverse effects on the transition, such as Spain, Italy, and Portugal [6].

The Paris Agreement, which encouraged countries to alter environmental laws and implement an emissions reduction plan, came into effect to slow the rate of ecological damage that is occurring on a worldwide scale. Even countries known for lack of environmental awareness are trying to adapt to the Paris Accord. For example, China has established rules to promote renewable energy sources and has set a goal to reduce carbon emissions [3]. Likewise, the Arabian Gulf Countries have committed and ratified the Paris Agreement to reduce their CO_2 emissions, improve the environment, public health, and economy. They created several scenarios to achieve this goal, with the retirement of the oldest natural gas and oil-fired power plants that reduce total emissions by 75 $MtCO_2$/year and the installation of point source capture in power plants, which would prevent emissions of around 240 $MtCO_2$/year [9].

Previous studies have analyzed the impact of economic globalization and Paris Climate Accord (PCA) in G-20 countries [1], OECD [6], or only one country [10] on bioenergy. Some studies also examine developing countries but only look at one country [3,11]. Considering this, the question arises: do economic globalization and PCA impact bioenergy consumption in developing and developed countries? This study will answer these questions by examining numerous countries and comparing developed and developing countries. In addition, this study also uses several explanatory variables: agriculture, forestry and fishing, value added; industry value added; GDP growth; population growth; previous year temperature change; and human development index.

Theoretically, this study looks at how external factors, in this case, economic globalization and international agreements, affect the attainment of environmental sustainability. The Environmental Kuznets Curve, a contemporary concept, only highlights how economic growth affects sustainability and environmental harm. This study also contributes significantly to the achievement of the Sustainable Development Goals, especially Goal 7 on Affordable and Clean Energy, Goal 12 on Responsible Consumption and Production, and Goal 13 on Climate Action.

2. Theoretical Background, Literature Review and Hypothesis

2.1. Theory

The connection between environmental degradation and economic growth is depicted by the Environmental Kuznets Curve (EKC). According to the EKC, environmental degradation is more likely to be caused by increases in economic and income [12]. This theory states that when a country's income is still low, it will prioritize raising its income above addressing issues with environmental quality. As a result of the process, environmental degradation will occur via land, water, and air pollution [13]. However, at a certain point, economic and income growth will reduce environmental degradation (turning point). This results from government regulation, environmental public awareness, technological advancements, and the transitioning to a service-based economy [13,14]. However, this scenario will be reversed as a country's population grows and its energy needs are met without considering the environment. In this study, these two phenomena are human development and population growth. One benefit of human quality development has been the rise in environmental awareness. They place a high priority on using eco-friendly energy to reduce environmental harm and assist future generations. In addition, technological progress in this study is described as the value added to various sectors in a country. Value added is obtained from the industrial and agricultural sectors, which are the economy's foundation. A country can enhance environmental circumstances, including bioenergy usage, with value added.

Using an inverted U-curve model, the EKC explains the connection between environmental degradation and economic growth. The pre-industrial economy (agriculture), the industrial economy (the shift from agriculture to industry), and the post-industrial economy (a service-based economic structure) are the three phases of this. Changes in the economic structure of urbanization and the industrial economy phase tend to cause environmental degradation. Mass manufacturing and satisfying rising consumption are the goals of this activity. Then, the shift in the economic structure from energy-based sectors to technology-based industries and services causes this to fall [12,15]. This study captures the phenomenon by including the GDP growth variable which increases environmental damage, as seen by developing countries increasing their energy consumption, whereas developed countries experience the reverse situation.

The EKC has become an intriguing study topic, along with the strengthening of environmental degradation worldwide. Mason & Swanson [14] state that the EKC theory applies in high-income countries. This study supports the theory that the EKC in the area has an inverted U-curve over the long term. Several previous studies on the relationship between economic growth and environmental degradation also consider the impact of sectoral value-added structural changes, international trade-induced structural changes, and the effects of globalization on economic growth–environment relations [16]. The problem could be further complicated because the efficiency of strategic sectors may not always be able to reduce environmental damage [17]. In other words, environmental damage is worsening in many countries, necessitating international cooperation across sectors. Many countries have understood this and started several accords to strengthen their shared environmental concern [18]. In this study, the accord is reflected through climate agreements, especially the Paris Climate Accord, which encourages each country to do their part to lessen the adverse effects of climate change, including by using bioenergy. Furthermore, economic globalization is one of the key elements influencing bioenergy use in this study. The reason for this is that economic globalization has prompted numerous regulations and certifications to ensure that every country manufactures eco-friendly goods.

2.2. Literature review and hypothesis

One strategy to boost the use of bioenergy is to add agricultural value added. Value added demonstrates the effectiveness of technological advancement and innovation in a sector that benefits the environment. For example, producing value-added outputs from residues represents an opportunity to increase the renewable energy supply. Agricultural waste can be converted into sustainable bioenergy and biofuels (biodiesel, bioethanol, biogas, and biohydrogen) to lessen the shortage of fossil fuels and the effects of climate change. Although it can be treated, agricultural waste has been a global issue as most of it is burned or buried in the ground, polluting the air and water, and causing global warming [19]. According to a different study, using agricultural waste with a high value added can help expand its use in the food, pharmaceutical, and agricultural sectors as well as in bioenergy [20].

Hypothesis 1: agriculture, forestry, and fishing value added will increase bioenergy consumption in developing and developed countries.

Developments in the industrial sector have led to increased energy consumption [21]. This development is followed by technological advancement that promotes economic growth. However, technological advancements are responsible for the decrease in carbon emissions by using more ecologically friendly energy. On the other hand, the value added in the industry has a detrimental effect on the ecological footprint. All this happens because of the limited ability to develop and use environmentally friendly production methods and weak environmental policies [22].

Hypothesis 2: industry (including construction) value added will increase bioenergy consumption in developing and developed countries.

GDP per capita more accurately reflects the development level and the most important key factor affecting energy demand, including clean energy. Even yet, the relationship could be complicated because it will fluctuate in the short term before stabilizing once a particular GDP level is attained and sustained. In the first year, GDP per capita has no direct impact on the use of bioenergy. On the other hand, net energy production falls in the second year and then rises in the third. Long-term stabilization eventually occurs after a minor decline in the fourth year [23]. GDP growth can also be more complicated when comparing developed and developing countries. While GDP growth in developed countries can lead to a rise in the use of bioenergy, the opposite is genuine in developing countries. Alsaleh and Abdul-Rahim [24] added a positive relationship exists between GDP and the degree of cost efficiency of the bioenergy sector; the more economic growth, the greater the cost efficiency that may be achieved.

Hypothesis 3: GDP growth will increase bioenergy consumption in developed countries but decrease bioenergy consumption in developing countries.

Energy consumption is predicted to rise as the population grows since more people use energy for daily needs, including industry, transportation, and power. Hence, population growth is one of the factors contributing to environmental damage, notably higher carbon emissions, the use of harmful environmental goods, and unclean manufacturing procedures because of the growing ecological pressure in this state [3]. In developing countries, where energy infrastructure may still rely heavily on fossil fuels, this rising demand directly results in higher CO_2 emissions. Reliance on carbon-intensive energy sources may be strengthened if population growth rates surpass the expansion of sustainable energy capacity [25]. Natural resources are being depleted at an alarming rate due to population growth, endangering species and life on Earth [2].

Hypothesis 4: population growth will decrease bioenergy consumption in developing and developed countries.

Direct investment and trade openness significantly affect the long-term advantages of increasing the usage and production of bioenergy [23]. Trade openness lowers the need for conventional energy usage because trade promotes the development of green technologies [1]. Li et al. [3] argue that financial globalization increases the efficiency and sustainability of green energy and resource management. However, economic globalization has led to large-scale infrastructure development, including ports, highways, and industrial zones. Although this development is essential for economic expansion, it frequently harms the environment [26]. Economic globalizers often prioritize investment in established, low-cost energy infrastructure, such as coal or natural gas, over clean and renewable technologies [23,27]. Economic globalization drives CO_2 emissions, perhaps due to foreign trade-related carbon leakage and the self-interestedness of multinational firms [28]. Economic globalization also impacts water and bioenergy: the world's irrigation water usage will rise by 3%, while maize ethanol production will fall by 7% in 2050 [8]. This circumstance supports the pollution haven hypothesis, which holds that because labor and environmental regulations in developing countries are laxer than in developed countries, polluting firms that export to other countries are more likely to settle there to cut costs [26].

Hypothesis 5: economic globalization will decrease bioenergy consumption in developing and developed countries.

Air temperature variations affect power loads and the supply and demand for renewable energy. Reduced heating needs can be met with low-temperature energy from renewables. On the one hand, rising temperatures may eventually result in less need for heating, which is advantageous for the economy, ecology, and energy sector. On the other hand, as temperatures rise, more energy is needed for cooling, particularly during the summer. The current building services and energy systems are not yet wholly equipped to supply the growing demand for cooling sustainably. Meanwhile, the efficiency of electricity generation is negatively impacted by rising air temperatures in energy systems that conventional power plants dominate. This condition raises awareness of the use of bioenergy [29]. When linked to nature, rising temperatures and precipitation will make more wood fuel energy supplies available by the middle of this century, allowing them to replace coal [5]. It is also impossible to ignore the use of bioenergy in industry, both to meet societal demands and to try to mitigate climate change.

Hypothesis 6: previous year's temperature change will increase bioenergy consumption in developing and developed countries.

The human development index (HDI) is critical in achieving economic and societal sustainability goals since it includes the skills, knowledge, and experience individuals possess that drive innovation, productivity, and sustainable practices. Additionally, HDI will guarantee the availability of qualified personnel capable of driving the adoption and implementation of green energy solutions. The government must also provide a framework to promote green technology innovation, which includes offering tax incentives for eco-friendly products [27]. Higher HDI countries use more bioenergy to create an environmentally friendly state. For example, a 1% increase in bioenergy usage in Mediterranean countries reduces EMS CO_2 by 1.902% [30]. Countries with high HDI have gained benefits from protecting the environment, including longevity, health, and a decent standard of living [31].

Hypothesis 7: Human development index will increase bioenergy consumption in developing and developed countries.

Countries have pledged to fight to eradicate carbon footprint and greenhouse gas (GHG) emissions through the Paris Agreement, mainly using bioenergy and renewable energy sources. For instance, India has a rigorous plan to reduce its carbon footprint and has attained a 26% share of renewable energy to meet the promises made in the Paris Agreement [18]. However, as the pace of renewable energy growth approaches the Paris Agreement, there is an unforeseen consequence: costs will rise dramatically. This phenomenon can potentially slow down bioenergy use if it is not supported by strict government policies and public awareness [32].

Hypothesis 8: The Paris Climate Accord will increase bioenergy consumption in developing and developed countries.

3. Methods

3.1. Data source

This study uses panel data that combines cross-sectional and time-series data. These data were obtained from the World Bank, FAO, and KOF Globalization. This study used cross-sectional data from 74 developing and 17 developed countries, and the time-series data ranged from 1990 to 2022 (Table 1). The country samples are selected based on the data availability in each database. Many developing and developed countries cannot be used as subjects in this study as they have not released data. Meanwhile, a three-decade time frame is ideal for observing the massive determinant factors of bioenergy consumption measures.

Table 1: *List of developing and developed countries*

Developing countries			Developed countries
1. Argentina	26. Guyana	51. Panama	1. Australia
2. Bahamas	27. Haiti	52. Papua New guinea	2. Austria
3. Bangladesh	28. Honduras	53. Paraguay	3. Brunei Darussalam
4. Barbados	29. India	54. Peru	4. Cyprus
5. Belize	30. Indonesia	55. Philippines	5. Denmark
6. Benin	31. Iran	56. Russia	6. Finland
7. Bolivia	32. Iraq	57. Saint Lucia	7. France
8. Botswana	33. Jamaica	58. Saudi Arabia	8. Germany
9. Brazil	34. Jordan	59. Senegal	9. Italy
10. Bulgaria	35. Kenya	60. Sierra Leone	10. Netherland
11. Cameroon	36. Lesotho	61. South Africa	11. New Zealand
12. Chile	37. Malawi	62. Sri Lanka	12. Norway
13. China	38. Malaysia	63. Sudan	13. Republic of Korea
14. Colombia	39. Mali	64. Thailand	14. Singapore
15. Congo Republic	40. Mauritania	65. Togo	15. Sweden
16. Democratic Republic of Congo	41. Mauritius	66. Tonga	16. Switzerland
17. Dominican Republic	42. Mexico	67. Trinidad and Tobago	17. United Kingdom
18. Ecuador	43. Mongolia	68. Turkey	
19. Egypt	44. Morocco	69. Uganda	
20. El Salvador	45. Mozambique	70. Tanzania	
21. Eswatini	46. Namibia	71. Uruguay	
22. Fiji	47. Nepal	72. Vietnam	
23. Gabon	48. Nicaragua	73. Zambia	
24. Guatemala	49. Niger	74. Zimbabwe	
25. Guinea	50. Pakistan		

Based on the purpose of this study, one primary variable will be investigated: bioenergy consumption or the total bioenergy use in a country from bagasse, animal waste, biogasoline, biodiesel, biogases, bio-jet kerosene, charcoal, fuelwood, and other liquid biofuel [33]. Several explanatory variables will have an impact on this variable (Table 2): (1) agriculture, forestry, and fishing, value added is the net output of the agricultural sector after adding up all outputs and subtracting intermediate inputs in a country [34]; (2) industry (including construction), value added is the net output of the industrial sector after adding up all outputs and subtracting intermediate inputs in a country [34]; (3) GDP growth annually is the annual percentage growth rate of GDP at market prices based on constant local currency [34]; (4) population growth annually is the exponential rate of growth of the midyear population from year t-1 to t [34]; (5) economic globalization index is measured using the variables exports and imports of goods and services, capital flows, and stocks of foreign assets and liabilities [35]; (6) previous year temperature change is temperature change on land domain disseminates statistics of mean surface temperature change by country, with annual updates [33]; (7) human development index is a summary measure of human development [34]; and (8) Paris climate accord (PCA) is an international treaty on climate change that was signed in 2016 [34].

Table 2: *Variable and data source of this study*

Variable	Symbol	Source
Bioenergy consumption	BIO	FAO [33]
Agriculture, forestry, and fishing, value added (annual % growth)	AGR	World Bank [34]
Industry (including construction), value added (annual % growth)	IND	World Bank [34]
GDP growth annually (%)	GDP	World Bank [34]
Population growth annually (%)	POP	World Bank [34]
Economic globalization index	EGI	KOF Globalization [36]
Previous year temperature change (°C)	TEMP	FAO [33]
Human Development Index	HDI	World Bank [34]
Dummy Paris Climate Accord (0 = period before the agreement, 1 = period after the agreement)	PCA	World Bank [34]

3.2. Data analysis

The impact of economic globalization, PCA, and other variables on bioenergy consumption in developing countries and developed countries (i) every year (t) is assessed using the following model:

$$\begin{aligned} BIO_{it} = {} & A_0 + A_1 \log AGR_{it} + A_2 \log IND_{it} + A_3 \log GDP_{it} + A_4 \log POP_{it} \\ & + A_5 \log EGI_{it} + A_6 \log TEMP_{it} + A_7 \log HDI_{it} + D_{PCA} + \varepsilon_i \end{aligned} \tag{1}$$

Equation (1) can be written as:

$$\begin{aligned} BIO_{it} = {} & A_0 + \sum_{i=1}^{p} A_1 \log AGR_{it-1} + \sum_{i=1}^{p} A_2 \log IND_{it-1} + \sum_{i=1}^{p} A_3 \log GDP_{it-1} \\ & + \sum_{i=1}^{p} A_4 \log POP_{it-1} + \sum_{i=1}^{p} A_5 \log EGI_{it-1} + \sum_{i=1}^{p} A_6 \log TEMP_{it-1} \\ & + \sum_{i=1}^{p} A_7 \log HDI_{it-1} + D_{PCA} + \varepsilon_{it} \end{aligned} \tag{2}$$

The first step of this study is the unit root test to determine the stationarity of the variable. This test can prevent a regression model from producing "t-ratios" that do not follow a standard t-distribution and spurious regression, indicating a significant relationship between two variables when there should be none. The Levin Lin Chu (LLC) unit root test is considered in this study [37]:

$$\Delta y_t = \alpha y_{t-1} + \sum_{i=1}^{k} A_i \Delta y_{t-i} + \mu + \gamma_t + e_t \quad (3)$$

$\delta = \alpha - 1$
$\alpha =$ coefficient of y_{t-1}
$\Delta y_t =$ first difference of y_t, i.e., $y_t - y_{t-1}$

The unit root analysis results display variations across variables and models (Table 3). According to the analysis findings, the variables BIO, AGR, IND, GDP, POP, EGI, TEMP, and HDI of both developing and developed countries are significant at the level. Therefore, the variables in this study do not have stationarity issues and can analyzed at the level.

Table 3: *LLC unit root test*

	Developing Countries		Developed Countries	
Variable	**Level**	**Sig.**	**Level**	**Sig.**
BIO	At level	-6.092***	At level	-3.568**
AGR	At level	-12.503***	At level	-7.044***
IND	At level	-12.072***	At level	-7.828***
GDP	At level	-11.836***	At level	-6.113***
POP	At level	-7.3116***	At level	-4.722***
EGI	At level	-9.4168***	At level	-4.285***
TEMP	At level	-11.502***	At level	-6.815***
HDI	At level	-7.7916***	At level	-5.927***

***:sig. at 0.000, **:sig. at 0.01

In this study, several pre-estimation tests must be carried out after the unit root test. Pre-estimation tests are needed to determine one of the best static panel data models: common effect, fixed effect, or random effect. The Chow test can determine whether a multiple regression function differs across two groups [38]. It determines whether each variable's intercept indicator and interaction differ. The hypothesis of the Chow test is as follows:

$H_0 : \theta_1 = \cdots = \theta_n = 0,$ pooled effect model
$H_1 : \theta_1 \neq \ldots \neq \theta_n \neq 0,$ fixed effect model

The Chow test results indicate that the p-value is lower than 0.05, suggesting that H_0 can be rejected or the model that best fits this data is probably a fixed effect model. The Hausman test is used as the initial analysis to check for a relationship between the error term and the explanatory variable [38]. The Hausman test in this study uses the Chi-square test with the hypothesis:

$H_0 : \rho = 0,$ random effect model
$H_1 : \rho \neq 0,$ fixed effect model

The Hausman test results indicate that the p-value is greater than 0.05, indicating that the Chi-square value is insignificant or H_0 cannot be rejected (Table 4). Therefore, the model that best fits this data is probably a random effect model. The Breusch Pagan test for heteroskedasticity based on a variance function or the Lagrange Multiplier (LM) test must be used to validate this further. Chi-square with the hypothesis is used in the LM test in this study, just like in the Hausman test [38]:

$H_0 : \beta_1 = \beta_n = 0,$ pooled effect model

$H_1 : \beta_1 \neq \beta_n \neq 0,$ random effect model

Since the p-value is less than 0.05, the LM test results indicate a significant Chi-square value. The random effect model is the proper model, as this result shows that H_0 is rejected. Hence, the random effect model will be used in this study based on the outcomes of all tests.

Table 4: *Test results for developing and developed countries*

Test Type	Developing Countries	Developed Countries
Chow test	6302.378*** Conclusion: FEM	929.034*** Conclusion: FEM
Hausman test	9.1226^{ns} (p-value = 0.3321) Conclusion: REM	6.6048^{ns} (p-value = 0.5798) Conclusion: REM
Lagrange Multiplier Test (Breusch-Pagan)	8645.1^{ns} (p-value < 2.2e-16) Conclusion: REM	2974.9^{ns} (p-value < 2.2e-16) Conclusion: REM
Breusch-Pagan test	112.89 (p-value < 2.2e-16) Conclusion: there is heteroskedasticity	57.249 (p-value < 1.61e-09) Conclusion: there is heteroskedasticity
Breusch-Godfrey/Wooldridge test	690.94 (p-value < 2.2e-16) Conclusion: there is autocorrelation	282.1 (p-value < 2.2e-16) Conclusion: there is autocorrelation

The multicollinearity, heteroscedasticity, and autocorrelation tests are the subsequent pre-estimation that follows the selection of the random effects model. The results of the multicollinearity test show that the variables used are free from this issue since no relationship between variables has a value of more than 0.8 (Table 5). The Breusch-Pagan test concludes that the model includes heteroscedasticity components (Table 4). The Breusch-Godfrey/Wooldridge test is used in the autocorrelation test. According to the test results, the model used in this study displays a tendency for autocorrelation. Therefore, the robust standard error of the random effect model is used in this study instead of the conventional random effect model. This model is designed to provide more reliable estimates of uncertainty in statistical models, especially heteroscedasticity or autocorrelation issues. Technically, this model will correct the OLS standard error by correcting the standard error. All regressors are divided by the weights to get a nuisance error with a constant variance (homoscedasticity) in the model [38].

This study also uses Propensity Score Matching (PSM) to explore the analysis results of the PCA dummy on bioenergy consumption. PSM can be performed with multiple phases of analysis. First, identify the control group and treatment group. Second, determine which outcomes can be quantified using an impact evaluation study. Third, ascertain the impact of the treatment on the predefined outcomes, conduct a characteristic matching procedure between the treatment group (following PCA) and the control group (before PCA) [39]:

$$ATT = E(R_1 \mid I = 1) - E(R_0 \mid I = 0) \tag{4}$$

$$ATT = E\{R_1 \mid I = 1, p(Z)\} - E\{R_0 \mid I = 0, p(Z)\} \tag{5}$$

Where ATT (Average Treatment effect of the Treated group) is the value of the impact of treatment on outcomes based on all the data used, I denotes the treatment indicator used in the study (I=0 for the control group's outcome, I=1 for the treatment group), R_0 denotes the value of the control group, R_1 denotes the value of the treatment group's outcome, and p(Z) denotes

Table 5: *Correlation matrices for developing and developed countries*

Developing Countries									
	BIO	AGR	IND	GDP	POP	EGI	TEMP	HDI	PAR
BIO	1.000								
AGR	0.031	1.000							
IND	0.066	0.063	1.000						
GDP	0.167	0.266	0.605	1.000					
POP	0.202	0.081	0.113	0.132	1.000				
EGI	-0.264	-0.060	0.005	0.012	-0.282	1.000			
TEMP	-0.012	0.030	-0.064	-0.021	-0.027	0.100	1.000		
HDI	-0.283	-0.089	-0.078	-0.062	-0.466	0.543	0.141	1.000	
PAR	0.016	-0.028	-0.099	-0.084	-0.120	0.136	0.367	0.233	1.000
Developed Countries									
	BIO	AGR	IND	GDP	POP	EGI	TEMP	HDI	PAR
BIO	1.000								
AGR	-0.049	1.000							
IND	-0.150	0.047	1.000						
GDP	-0.145	0.018	0.590	1.000					
POP	-0.462	0.038	0.135	0.138	1.000				
EGI	0.093	-0.055	-0.098	-0.093	-0.070	1.000			
TEMP	0.327	0.003	-0.088	-0.196	-0.229	0.311	1.000		
HDI	0.471	-0.033	-0.109	-0.062	-0.078	0.589	0.402	1.000	
PAR	0.087	-0.034	0.021	0.017	-0.016	0.186	0.369	0.435	1.000

the propensity score derived from the PSM analysis. The probit estimation results for the PCA dummy variable are used to determine p(Z). Two presumptions must be fulfilled for the PSM's results to be considered valid: conditional independence and overlapping [40].

The impact evaluation result is unbiased because the total percentage of bias reduction reached 94.80% in developing countries and 96.70% in developed countries (Table 6). The low number of observations on "treated: off support" following the matching process indicates that the PSM model developed in this study fulfilled the requirements for overlapping assumptions. As a result, the PSM analysis is accurate and can be used in this study.

Table 6: *Balancing test for matching based on the propensity score and its distribution*

Indicator	Developing countries	Developed countries
Mean Standardized Bias Before Matching	23.70	25.60
Mean Standardized Bias After Matching	2.64	2.78
Total % bias reduction	94.80	96.70
Distribution of propensity scores	Overlapping	Overlapping

4. Results

According to comparing conditions between developing and developed countries, developing countries utilize more bioenergy on average than developed countries (Table 7). Bioenergy sources are more abundant, varied, and reasonably priced in developing countries. The value added of agriculture, industry, and GDP growth in developing countries is also higher than in developed countries because this region is racing against time to improve its economic conditions by utilizing all of its resources. This condition is also supported by the rapid population growth of developing countries, which allows them to supply inexpensive labor. Developed countries have advantages in terms of human development and can adopt economic globalization better than developing countries. Temperature change, the study's sole environmental element, is trending downward in both regions.

Table 7: *Descriptive statistics of the variables in this study (log model)*

Variable	Mean		Standard Error	
	Developing	Developed	Developing	Developed
BIO	4.66	4.49	1.30	1.05
AGR	0.41	0.32	0.48	0.48
IND	0.57	0.28	0.48	0.43
GDP	0.52	0.33	0.40	0.37
POP	0.14	-0.20	0.36	0.39
EGI	1.67	1.87	0.10	0.07
TEMP	-0.18	-0.04	0.32	0.32
HDI	-0.24	-0.05	0.12	0.02
PCA	0.21	0.21	0.41	0.41

Source: Own elaboration (2024)

Once each variable has been described, the study employs a robust standard error of random effect model analysis to determine the factors influencing bioenergy use in developing and developed countries. The analysis's findings indicate that developing and developed countries ' adjusted R^2 values are included in the "good" category (Table 7). This suggests that the study's explanatory variable variation can explain 41.82% of the variation in bioenergy consumption in developed countries and 68.77% in developing countries. On the other hand, the F-test value indicates significance or that the explanatory factors together influence the dependent variable.

Table 8: *Robust standard error of the random effect model in this study*

Variable	Developing Countries		Developed Countries	
	Coefficient	Std Error	Coefficient	Std Error
C	4.552*** (12.481)	0.365	0.984^{ns} (0.471)	2.091
AGR	0.016$^{\cdot}$ (1.796)	0.009	-0.006^{ns} (-0.420)	0.014
IND	0.026* (2.267)	0.012	0.016^{ns} (0.504)	0.032
GDP	-0.053* (-2.104)	0.025	0.035^{ns} (0.040)	0.873
POP	0.135$^{\cdot}$ (1.789)	0.076	0.167* (2.282)	0.073
EGI	0.159* (2.223)	0.072	2.010* (2.102)	0.956
TEMP	-0.003^{ns} (-0.2115)	0.016	-0.057^{ns} (-1.611)	0.035
HDI	0.726** (2.9933)	0.243	4.099*** (4.769)	0.859
PCA	0.008^{ns} (0.452)	0.017	0.070* (2.073)	0.034
Adj. R-Squared	0.687712		0.41824	
F-stat	134.53***		410.598***	

Source: Own elaboration (2024)

***: sig. at 0.000, **: sig. at 0.01, *: sig. at 0.05, $^{\cdot}$: sig. at 0.1, ns= not significant

Economic globalization can increase bioenergy consumption (BIO) by 0.159% in developing countries and by 2.010% in developed countries (EGI). Another explanatory variable focused on this study, Dummy PAC, has a significant influence only in developed countries. Population growth (POP) and the human development index (HDI) are other explanatory variables significantly influencing both regions. An increase in POP by 1% in developing countries can increase BIO by

0.135%; an increase in POP in the same percentage can also increase BIO by 0.167% in developed countries. In the meantime, a 1% increase in HDI will benefit bio in developing (0.726%) and developed (4.099%) countries.

Several other explanatory variables significantly influence only one of the regions in this study. Increased agricultural (AGR) and industry (IND) value added only significantly affect developing countries, each of which positively influences BIO by 0.016% and 0.026%. GDP growth is the only variable that negatively influences BIO; an increase of 1% in GDP decreases bioenergy consumption by 0.053% in developing countries. The last variable in this study, TEMP, has no significant effect on BIO in developing and developed countries.

The Propensity Score Matching analysis findings are consistent with those in Table 9. PAC is only significant in developed countries but has no effect in developing countries. Following PAC's adoption, bioenergy consumption in developed countries rose by 0.067%. Although the consumption trend increased, it was relatively modest and fell short of many people's expectations.

Table 9: *Impact evaluation results of Paris Climate Accord on bioenergy consumption*

Dummy Variable	Developing Countries		Developed Countries	
	Estimate	t-stat	Estimate	t-stat
Paris Climate Accord	0.007	0.964^{ns}	0.067	6.789^{***}

Source: Own elaboration (2024)
***: significant at 0.000, ns = not significant

5. Discussion

5.1. Impact of economic globalization and Paris Accord on bioenergy consumption

Economic globalization expands international trade and investment opportunities, which support the transition to green energy. The global economy is revolutionizing by replacing capital-intensive frameworks with economically and environmentally sustainable green energy. As a result, green energy policies have gained attention from economists and scientists due to their potential to benefit the environment and economy [2]. Nowadays, several regional and global free trade agreements that promote exports also consider environmental sustainability. These agreements can facilitate the use of bioenergy to lessen the harm of different economic activities on the environment [26].

Economic globalization can also promote environmental sustainability through technology transfer. For example, technological regulation in economic globalization can encourage the adoption of environmentally friendly practices by establishing and enforcing environmental standards [27]. The FDI can also contribute to developing and growing bioenergy infrastructure. Countries that open themselves to foreign investment have more room to install bioenergy plants and reduce environmental externalities. Many countries are competing to embrace companies with green finance that promote the use of bioenergy to gain immediate benefits without restricting the use of resources in the future [2]. Multinational companies frequently employ Corporate Social Responsibility (CSR) to promote the expansion of the bioenergy sector [28].

The Paris Climate Accord (PCA) variable gives positive results for bioenergy consumption in both regions, although it is only significant in developed countries. The PCA has increased the commitment of many countries to address climate change and adapt to its adverse impacts. These countries have implemented domestic policies that strictly improve environmental conditions.

The stringent environmental policies have been shown to drive the transition to green energy in developed countries such as the Republic of Korea. The government of the Republic of Korea offers numerous incentives to promote the use of bioenergy through infrastructure development, liberalization of bioenergy installation, development of agricultural solar energy models, and reduction of rental fees. On the other hand, an emission trading scheme is included as an extra carbon tax to limit the country's usage of energy-polluting activities [6]. At the same time, the US has put in place several measures to change its energy balance, including more domestic renewable resources, including bioenergy [32]. Government effectiveness, rule of law, regulatory quality, and voice and accountability have also been demonstrated to increase bioenergy consumption growth in Western European (WEC) countries compared to Central and Eastern European (CEEC) countries [41].

Energy consumption in developing countries tends to be high from fossil fuels. Although developing countries are making strides in renewable energy, the pace could not be sufficient to counteract emissions from traditional energy sources [25]. In addition, numerous factors contribute to the Paris Accord's inability to encourage the use of bioenergy in developing countries. The selling price is not competitive since producing bioenergy in developing countries exceeds the expected cost to comply with the Paris Agreement [32]. Bioenergy technology transfer in developing countries faces obstacles such as patents and high costs. This is exacerbated by the concentration of technological innovation in industries based on traditional energy sources, which can hamper the development of the bioenergy sector [6]. While non-renewable energies may be initially less expensive, they could have far-reaching detrimental impacts on a country's economy and social stability compared to bioenergy [2]. The most striking is the weak support for bioenergy consumption policies in developing countries. These countries still face a dilemma because bioenergy development will reduce land for food production. Significant adjustments to the food system's demand side or advancements in biotechnology are needed to simultaneously meet the demand for both food and bioenergy [42].

5.2. Impact of other factors on bioenergy consumption

Agricultural value-added (AGR) is one way to increase bioenergy consumption. In fact, if handled properly, agricultural waste can have value-added that can be reused to achieve sustainable agriculture and the environment as bioenergy [19]. Modern technology is being used in agriculture these days, and it can assist farms in lowering emissions through bioenergy and boosting yields. Industrial value-added (IND) has the same potential to raise bioenergy use as AGR. Energy consumption may have increased because of industrial developments like construction and transportation expansion [21]. However, if the development is followed by value-added, technological advancement, and human capital, it will reduce environmental damage. This results from the shift in energy use toward sustainable bioenergy [22]. Several countries have also initiated policies to make industries more environmentally conscious through action or financing. Industries value-added that benefit from unrestricted access to resources must be compelled to engage in these activities or bear such costs, which must be recognized as compromising their financial viability [43]. In addition, Aquilas et al. [11] stated that industrial performance and environmental sustainability are positively impacted by the relationship between value added and the use of bioenergy. The primary energy source for industry could eventually be bioenergy. More bioenergy will be needed as the industrial sector grows, increasing the load capacity factor and enhancing environmental sustainability. Therefore, the benefits of using bioenergy balance the harm that industry causes to the environment.

The consumption of non-renewable energy has increased due to population growth (POP) and rising food demands, which lowers soil fertility and produces pollution. Rapid POP could surpass environmental rules and infrastructure development, leading to insufficient environmental control and waste management systems. Hence, cleaner and more energy-efficient technologies are the answer to this problem [3]. The age distribution changes toward a percentage of adults who are nearly fully employed at several points in the demographic transition. By expanding comparatively lower energy use of the service sector, which typically has a lower carbon footprint than manufacturing and heavy industry, this scenario promotes higher economic productivity. Using bioenergy and greater recycling may help raise awareness and spur action to lower carbon footprints as the population expands [25].

HDI positively impacts developed countries' transition from conventional energy to green energy. High HDI countries are focused on sustainable economic growth. This indicates that progress will significantly benefit current and future generations by protecting the environment [2]. Sound policies for a sustainable environment are implemented, low-emission production is practiced, environmentally friendly agricultural goods are chosen, waste is processed (recycled), and climate-smart technological and institutional innovation is encouraged via human resource development [44]. In addition, high HDI countries will support the cost-efficiency rate of the bioenergy industry among developing countries, which is equal to that of developed countries in the case of EU28 [24]. Finland and Poland promote using and building renewable energy power plants through their tax regulation policies, premium guarantees, and quota systems [27].

GDP has reduced the use of bioenergy in developing countries. This finding is consistent with the Environmental Kuznets Curve theory, which holds that developing countries prioritize economic growth over environmental sustainability [13, 14]. Increasing GDP often correlates with growing industrialization, demand for natural resource extraction, and traditional energy consumption (such as coal, oil, and natural gas). So does the demand for fossil-fueled transportation, which is cheaper than bioenergy and rapid urbanization, leading to detrimental effects, such as high carbon emissions or the destruction of forests for construction, which lowers the number of resources available for future generations [2, 25]. Another study shows that bioenergy can not lower CO_2 emissions, so many countries are skeptical of its potential for environmental improvement and prefer to focus on economic growth [45]. Developing countries also often face unstable economic growth. This factor can impact the bioenergy industry by causing it to suffer due to low demand and production [24].

In the meantime, the analysis findings also show that GDP can increase bioenergy consumption in developed countries, although the relationship is not significant. Developed countries have recognized environmental harm and are implementing economic adaptation strategies prioritizing environmental sustainability in their growth [13, 14]. High GDP also allows residents of developed countries to use bioenergy, which may be more expensive than traditional energy. In addition, there is a positive relationship between GDP, clean production methods, and the degree of cost efficiency of the bioenergy sector in developed countries; the more economic growth, the greater clean production methods and the cost efficiency that may be achieved. Comparing high-GDP countries to those with lower GDPs, the former are more effective at lowering total production costs (labor and capital costs) and generating enough output (primary production) [24].

Temperature changes (TEMP) have an insignificant effect on bioenergy in developing and developed countries. The rise in TEMP, which lowers the bioenergy industry's profitability, contributes to this. Because of this, the market's supply is erratic, bioenergy development is sluggish, and customers are not interested in using it [46]. Furthermore, there is skepticism in the community regarding the ability of bioenergy to withstand TEMP. People in Sweden, for instance, are extremely cautious when using bioenergy from boreal woods that are managed for productive purposes because of their ability to withstand TEMP [47].

6. Conclusion

Economic globalization is one of the variables contributing to the rise in bioenergy consumption in developed and developing countries. Various forms of trade and investment openness boost both regions' use of bioenergy. Increasing the use of bioenergy is also largely dependent on the Paris Climate Accord, although primarily in developed countries. Other factors that could increase bioenergy consumption in both regions include the human development index and population growth. The increase in the value-added of industry and agriculture is another factor driving the use of bioenergy in developing countries. The inhibiting factor for bioenergy consumption is GDP growth, although only in developing countries. In the meantime, neither region has seen a rise in the use of bioenergy due to rising temperatures.

The results of this study support the Environmental Kuznets Curve (EKC) theory, which states that economic growth will reduce the concern of developing countries for the environment. However, this study also highlights the massive efforts in developing countries to increase the value added of their economic sectors and human development, as well as the role of external factors, especially economic globalization and climate agreements, can accelerate the achievement of the next stage of EKC, which is reducing environmental damage. The same thing also happens in developed countries where external factors have increased public concern for the environment.

Some recommendations to increase bioenergy consumption include: (1) increasing commitment to economic globalization, especially requirements regarding environmentally friendly products. In fact, several regulations and requirements in economic globalization might motivate developing and developed countries to take environmental issues seriously, especially the use of bioenergy. Countries must agree on strict rules for economic globalization to continuously maintain environmental sustainability; (2) increasing compliance of developing and developed countries within the framework of the Paris Climate Accord. This agreement encourages the commitment of all countries to mitigate and adapt to climate change, one of which is using bioenergy to reduce global temperature increases. PCA must be implemented as an act in every country to facilitate the transition to bioenergy. For the development and use of bioenergy, developed countries must also offer financial assistance, subsidies, and tax incentives to developing countries; (3) increasing the human development to raise environmental concerns among all countries. Increasing education and literacy in environmentally friendly technologies is a practical step that all countries can take. This will also enhance the development of more efficient technologies in converting biomass into energy, including waste utilization; and (4) increasing the value-added of a country's agricultural and industrial sectors. Increasing value-added will ensure that a sector uses resources efficiently and obtains maximum profit. The primary activity to increase the value-added of a sector is increasing investment in research and development of bioenergy technologies and human resource training.

The main limitation of this study is that many countries have incomplete data, which prevents them from being analyzed in this study. This condition opens opportunities for future research to use more country samples if other researchers find databases with better data completeness. For example, this study makes PCA easier with dummy, without considering how countries' compliance with PCA varies. Another limitation of this study is that it does not consider regional heterogeneity, which could impact its findings. Therefore, further studies can consider analysis based on regional areas. Finally, this study can only use static panel data analysis because the variables have been significant at the level. Meanwhile, dynamic panel data analysis, such as the General Method of Moment (GMM) and System GMM, requires the variables to be stationary at the 1st difference. At the same time, both analysis methods can be used to solve several economic problems that could lead to spurious regression.

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References

[1] Ashfaq S, Liangrong S, Waqas F, Gulzar S, Mujtaba G, Nasir RM. Renewable energy and green economic growth nexus: Insights from simulated dynamic ARDL. *Gondwana Research* 2024:127:288-300.

[2] Zeng Q, Li C, Magazzino C. Impact of green energy production for sustainable economic growth and green economic recovery. *Heliyon* 2024:10:e36643.

[3] Li Y, Liu J, Li Y. Exploring the impact of renewable energy, green taxes and trade openness on carbon neutrality: New insights from BRICS countries. *Heliyon* 2024:10:e36984.

[4] Lo K. Asian energy challenges in the Asian century. *Journal of Asian Energy Studies* 2017:1:1-6.

[5] Klimenko V, Tereshin A, Mikushina O. Increase of energy potential of Russian forest resources due to climate change and CO2 fertilization. *E3S Web of Conferences* 2019:103:1-5.

[6] Aydin M, Degirmenci T, Erdem A, Sogut Y, Demirtas N. From public policy towards the green energy transition: Do economic freedom, economic globalization, environmental policy stringency, and material productivity matter? *Energy* 2024:311:133404.

[7] Wang JM, Liu Q, Hou Y, Qin W, Bai ZH, Zhang FS, et al. Impacts of international food and feed trade on nitrogen balances and nitrogen use efficiencies of food systems. *Science of the Total Environment* 2022:838:156151.

[8] Zhang Y, Waldhoff S, Wise M, Edmonds J, Patel P. Agriculture, bioenergy, and water implications of constrained cereal trade and climate change impacts. *PLoS ONE* 2023:18:1-18.

[9] Alatiq A, Aljedani W, Abussaud A, Algarni O, Pilorgé H, Wilcox J. Assessment of the carbon abatement and removal opportunities of the Arabian Gulf Countries. *Clean Energy* 2021:5:340-353.

[10] Awosusi AA, Rjoub H, Ağa M, Onyenegecha IP. An insight into the asymmetric effect of economic globalization on renewable energy in Australia: Evidence from the nonlinear ARDL approach and wavelet coherence. *Energy & Environment* 2023:35:3600-3624.

[11] Aquilas NA, Ngangnchi FH, Mbella ME. Industrialization and environmental sustainability in Africa: The moderating effects of renewable and non-renewable energy consumption. *Heliyon* 2024:10:e25681.

[12] Grossman GM, Krueger AB. Economic growth and the environment. *The Quarterly Journal of Economics* 1995:110:353-377.

[13] Galeotti M. Economic growth and the quality of the environment: Taking stock. *Environment, Development and Sustainability* 2007:9:427-454.

[14] Mason R, Swanson T. A Kuznets curve analysis of ozone-depleting substances and the impact of the Montreal Protocol. *Oxford Economic Papers* 2003:55:1-24.

[15] Dasgupta S, Laplante B, Wang H, Wheeler D. Confronting the environmental Kuznets curve. *Journal of Economic Perspectives* 2002:16:147-168.

[16] Marsiglio S, Ansuategi A, Gallastegui MC. The environmental kuznets curve and the structural change hypothesis. *Environmental and Resource Economics* 2016:63:265-288.

[17] Nugroho AD. Impact of agricultural technical efficiency on farm-gate emission: An implementation of environmental kuznets curve in Asian developing countries. *Caraka Tani: Journal of Sustainable Agriculture* 2024:39:269-280.

[18] Krishankumar R, Pamucar D, Deveci M, Aggarwal M, Ravichandran KS. Assessment of renewable energy sources for smart cities' demand satisfaction using multi-hesitant fuzzy linguistic based choquet integral approach. *Renewable Energy* 2022:189:1428-1442.

[19] Koul B, Yakoob M, Shah MP. Agricultural waste management strategies for environmental sustainability. *Environmental Research* 2022:206: 112285.

[20] Yadav VK, Sharma AK, Gacem A, Pandit J, Wany A, Kumar A, et al. Emerging Trends in the Valorization of Agricultural Waste and Their Utilization in Agricultural, Pharmaceuticals, and Environmental Cleanup. *Waste and Biomass Valorization* 2025.

[21] Chaouali I, Ben Jebli M, Ghazouani T. Investigating the dynamic effects of service value added on CO2 emissions: Novel insights from a non-parametric approach. *Journal of Environmental Management* 2024:365:121553.

[22] Payab AH, Kautish P, Sharma R, Siddiqui A, Mehta A, Siddiqui M. Does human capital complement sustainable development goals? Evidence from leading carbon emitter countries. *Utilities Policy* 2023:81:101509.

[23] Zambrano-Monserrate MA, Soto GH, Ahakwa I, Manigandan P. Dynamic effects on modern renewable energy generation: The role of patents in clean energy technology. *Energy* 2024:311:133340.

[24] Alsaleh M, Abdul-Rahim AS. Determinants of cost efficiency of bioenergy industry: Evidence from EU28 countries. *Renewable Energy* 2018:127:746-762.

[25] Oprea SV, Georgescu IA, Bâra A. Charting the BRIC countries' connection of political stability, economic growth, demographics, renewables and CO2 emissions. *Economic Change and Restructuring* 2024:57:161.

[26] Abbas M, Yang L, Lahr ML. Globalization's effects on South Asia's carbon emissions, 1996–2019: a multidimensional panel data perspective via FGLS. *Humanities and Social Sciences Communications* 2024:11:1171.

[27] Degirmenci T, Aydin M, Cakmak BY, Yigit B. A path to cleaner energy: The nexus of technological regulations, green technological innovation, economic globalization, and human capital. *Energy* 2024:311:133316.

[28] Afroz S, Raghutla C. Do various financial resources ensure renewable energy production and environmental protection in OECD countries: modelling for insight. *Environmental Science and Pollution Research* 2024:31:58562-58580.

[29] Canales FA, Jadwiszczak P, Jurasz J, Wdowikowski M, Ciapała B, Kaźmierczak B. The impact of long-term changes in air temperature on renewable energy in Poland. *Science of the Total Environment* 2020:729:138965.

[30] Dradra Z, Abdennadher C. Modeling the effects of renewable energy on sustainable development: evidence from simultaneous equations models. *Economic Change and Restructuring* 2023:56:2111-2128.

[31] Ahmad M, Satrovic E. How do fiscal policy, technological innovation, and economic openness expedite environmental sustainability? *Gondwana Research* 2023:124:143-164.

[32] Herath N, Tyner WE. Intended and unintended consequences of US renewable energy policies. *Renewable and Sustainable Energy Reviews* 2019:115:109385.

[33] Food and Agriculture Organization of the United Nations. FAOSTAT. In: FAOSTAT [Internet]. 2024 [cited 28 Oct 2024]. Available: https://www.fao.org/faostat/en/#data

[34] World Bank. World Bank Open Data. In: World Bank Open Data [Internet]. 2024 [cited 28 Oct 2024]. Available: https://data.worldbank.org/2022:8(1):e08803.

[35] Gygli S, Haelg F, Potrafke N, Sturm JE. The KOF Globalisation Index – revisited. *Review of International Organizations* 2019:14:543-574.

[36] KOF Swiss Economic Institute. KOF Globalisation Index. 2024 [cited 28 Oct 2024]. Available: https://kof.ethz.ch/en/forecasts-and-indicators/indicators/kof-globalisation-index.html

[37] Harris RID. Testing for unit roots using the augmented Dickey-Fuller test. Some issues relating to the size, power and the lag structure of the test. *Economics Letters* 1992:38:381-386.

[38] Gujarati DN. *Basic Econometrics* 4th ed. New YorK, USA: McGraw Hill Companies, Inc; 2003.
[39] Kuss O, Blettner M, Börgermann J. Propensity Score: an Alternative Method of Analyzing Treatment Effects. *Deutsches Arzteblatt International* 2016:113:597-603.
[40] Sseguya H, Robinson DS, Mwango HR, Flock JA, Manda J, Abed R, Mruma SO. The impact of demonstration plots on improved agricultural input purchase in Tanzania: Implications for policy and practice. *Plos One* 2021:16(1):e0243896.
[41] Alsaleh M, Abdul-Rahim AS, Abdulwakil MM. The importance of worldwide governance indicators for transitions toward sustainable bioenergy industry. *Journal of Environmental Management* 2021:294:112960.
[42] Henry RC, Engström K, Olin S, Alexander P, Arneth A, Rounsevell MD. Food supply and bioenergy production within the global cropland planetary boundary. *PloS One* 2018:13(3):e0194695.
[43] Pirard R. Rethinking the role of value-added industries for invasive trees in South Africa. *International Forestry Review* 2023:25:223-243.
[44] Aydin M, Koc P, Tumay M. Investigating the environmental Kuznets curve hypothesis with recovered paper consumption, human development index, urbanization, and forest footprint. *International Journal of Environmental Science and Technology* 2023:20:9053-9064.
[45] Wang J he, Mamkhezri J, Khezri M, Karimi MS, Khan YA. Insights from European nations on the spatial impacts of renewable energy sources on CO2 emissions. *Energy Reports* 2022:8:5620-5630.
[46] Zubair AO, Alsaleh M, Abdul-Rahim AS. Evaluating the profit efficiency of bioenergy industry and its determinants in EU28 region. *International Journal of Energy Sector Management* 2021:15:678-696.
[47] Cintas O, Berndes G, Cowie AL, Egnell G, Holmström H, Ågren GI. The climate effect of increased forest bioenergy use in Sweden: Evaluation at different spatial and temporal scales. *Wiley Interdisciplinary Reviews: Energy and Environment* 2016:5:351-369.