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CONFRONTING THE BIOFUEL-CARBON EMISSIONS-BIODIVERSITY TRILEMMA IN A PANEL OF BIOFUEL CONSUMING COUNTRIES

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Abstract Since our growth, the human-made activities for better living damage the global environment. Biodiversity is no exception that damages due to massive humanization process. This study focused on the relationship between biofuels consumption, carbon dioxide emissions and biodiversity in a panel of 12 selected biofuels consuming countries for a period of 2000-2013. The study employed panel fixed effect and panel random effect model to obtain the parameter estimates. The results found that biofuels consumption and carbon dioxide emissions both damage the biodiversity in a panel of countries. The results confirm the cointegration relationship between the variables. The quest for the renewable energy fuels for human development remains the keen agenda for the policy makers, however, the war for better health and wealth always exhausts the natural environment of the world's precious natural resources that should be taken into account in the next call for alerts.
Keywords: Biofuels consumption; Biodiversity; Carbon dioxide emissions; Panel Fixed Effect; Panel Random Effect; Panel cointegration.

INTRODUCTION

Biological diversity, short biodiversity remains dependent upon the natural environment. Now a days, biofuels considered be the one of the sustainable energy around the globe, however, serious concerned has been raised on the production and consumption that have a considerable impact on the biodiversity. Biofuels are one of the energy fuels that extracted from living organisms and from the waste that living organisms produced. Biofuels considered the rich form of energy source that help to reduce the impact of climatic change across the globe (Timilsina and Mevel, 2013). This benefit ends up to the depletion of natural environment i.e., biological diversity, which suffered the lives of many small microorganisms that played an important roles in our daily lives (Danielsen et al. 2009). World Bank (2014) provides an index for measuring the biodiversity that facilitate to assess the country's biodiversity potentials from the range of 0 (no biodiversity potential) to 100 (maximum biodiversity potential.

Supporters of the biofuels argued that biofuels help to mitigate greenhouse gas emissions and air quality pollutants across the globe (example, Schneider and McCarl, 2003; Tilman et al, 2009, Demirbas, 2009 etc). The benefits of biofuels have a potential to mitigate climatic change. The risk to biodiversity outweigh the benefits of biofuels to focused on the conservation of biodiversity while formulating energy policy. Tilman et al. (2006, p. 629) argued that "Human-driven ecosystem simplification has highlighted questions about how the number of species in an ecosystem influences its functioning". In the similar lines, Tscharntke et al. (2012) argued that rapid population increase has the global concern to preserve the biodiversity across the globe.

The biodiversity preservation traces from the work of Cook et al. (1991) that examined the impact of biomass production on the US biodiversity. There are a number of studies on biofuels and biodiversity, for example Gasparatos et al (2013), Gasparatos et al. (2015), Verdade et al. (2015), etc. across the world. Gasparatos et al. (2013) emphasized the need of unified framework to synthesize environmental impacts of biofuel, while in another study, Gasparatos et al. (2015) concluded that biofuels consumption linked with the socio-economic and environmental factors such as climate change, water pollution, biodiversity loss, energy and food security etc that need for effective utilization of biofuels resources for broad-based economic growth. Verdade et al. (2015) confined that biofuels have a mitigating impact on climate change, however, expansion of biofuels crops directly impact on forest biodiversity while indirectly its impact on soil and water degradation. Rathmann et al. (2010) concluded that production of biofuels in relation with the food security need caution with handling sustainability issues. Mol (2011) argued that biofuels are one of the major factors that have a considerable reservation in the agricultural-environmental nexus across the globe. Fletcher et al. (2011) recommended some management practices that may facilitate the unsafe impact of biofuel crops on biodiversity which includes reduction in the chemical inputs, raise heterogeneity within fields, and delay harvests until bird breeding has ceased. Koh and Ghazoul (2008) concluded that biofuels consumption considered as the energy resource that may add up in to the energy stream lines with cautions of sustainability issues that face the world in near future. Ozturk (2015) confirmed the long-run association between biofuels production and sustainable indicators across the countries.

Biofuels are therefore promoted globally for three interrelated objectives i.e., energy security, climate mitigation and rural development (Gasparatos et al. 2015). However, some researchers are optimistic of the prospects of biofuels in terms of the economic merits in rural areas in Asia and Africa (Vermeulen and Cotula 2010, Phalan 2009, Zhou and Thomson 2009 etc). Others researchers and international community is alarmed by the negative impacts biofuels that might cause such as biodiversity, land use change, water quality etc. (Polasky et al. 2011, Scarlat and Dallemand 2011 etc). The purpose of this study is therefore to examine the long-run relationship between biofuels consumption, carbon emissions and biodiversity in a panel of 12 biofuels consuming countries for the period of 2000-2013. There are therefore three major streams of research agenda i.e., economic growth, carbon dioxide emissions, and biodiversity that need to be address for sustainability agenda.

Biofuels are the rich energy source that helpful to increase economic gains in the competitive world. Biofuels is incorporated in most of the economic and environmental modeling for sustainable energy reforms. Lehtonen and Tykkyläinen (2009) argued that optimal use of forest resources required more labour to produce biofuel to meet energy requirements. Arndt et al. (2010) studied biofuels, poverty and economic growth in the context of Mozambique and found that investment in biofuels increases country's economic growth by 0.6% and reduction in the incidence of poverty by 6% that show pro-poor energy reforms in a country. Ajanovic (2011) studied that biofuels production especially 1st generation and 2nd generation biofuels have a considerable impact on feedstock prices, which seriously affected the global sustainability agenda. Ozturk and Bilgili (2015) investigated the long-run relationship between bioenergy and economic growth in Sub-Saharan African countries from 1980-2009. The results of the study reveal that economic growth is positively affected by the number of economic variables including biomass energy consumption, population and trade in the region. Thurlow et al. (2015) studied environmental effect that is produced by biofuels in case of Tanzania and found that biofuels help to accelerate economic and environmental gains in order to utilized unused land with the sugarcane – ethanol production. Withers et al. (2015) found that woody biomass helpful to decrease life cycle of carbon emissions relative to the conventional transportation fuel. Xiong et al. (2015) confirmed the U-shaped relationship between energy and per capita income in Kazakhstan. Azad et al. (2015) discussed the different prospects of biofuels consumption, production and used as a future investment in terms of using alternative fuel for transport in Australia. The results confirmed that biofuels helpful to mitigate environmental hazards, while it has an ability to replace conventional transportation fuel for the matter of sustained economic growth. Baral et al. (2015) discussed the importance of algal biofuel production in India by using carbon dioxide emissions from thermal power plant that helpful to reduce the environmental and power crisis nationwide to promote sustained economic growth.

Biofuels is one of the optimal strategies that significantly reduce carbon dioxide emissions from the atmosphere. Fargione et al. (2008) confined the need of biofuels production in order to reduce carbon emissions, while Achten et al. (2008) emphasized bio-diesel consumption and production for mitigating greenhouse gas emissions across the globe. Fulton et al. (2015) highlighted the importance of biofuels that fulfil future energy needs with zero carbon emissions Xu and Lin (2015) confirmed the environmental Kuznets curve hypothesis in relation with the a) urbanization and carbon emissions and b) economic growth and carbon emissions in the China's transportation sector, however, energy efficiency followed the U-shape relationship with the carbon emissions.

Blanchard et al. (2011) showed that biofuels is one of the future sustainable energy for South Africa that helps to mitigate climatic change. Phalan (2009) showed that biofuels reduces the impact of environmental pollution and provided energy security in South Asia. Sarkar et al. (2012) stresses the need of bioethanol production from agricultural wastes and found agricultural wastes are cost effect, renewable and viable solution to produced bioethanol production to meet future energy need. Santamaria and Azqueta (2015) concluded that biofuels consumption significantly decreases greenhouse gas emissions, sulphur dioxide emissions and other particulate matter emissions in Spain.

After appraising the above cited studies, it is clear that biological diversity seriously affected by biofuel consumption and carbon emissions. United Nations convention for conserving biological diversity is the paramount policy option to preserve our natural resources. The previous studies lack to examine the interlinkages between biofuel consumption and biodiversity in a panel of different developed and developing countries, while a few studies utilize GEF biodiversity index as a proxy for biological diversity, as conventional proxies usually used in this nexus including forest area, plant and animal species etc, which are comparatively micro in nature and bounded in nation-wide assessment. For a comparative and macro level assessment, this study is the first attempt, as per authors' belief, that used more comprehensive analysis to estimate the relationship in a diversified panel of countries. We believe that this study will contribute in an existing literature to filled it by more sophisticated and robust empirical estimation that would helpful for environmentalist and policy makers to device long-term sustainable policies to conserve biodiversity and it search for the appropriate renewable energy source for broad-based growth.

DATA SOURCE AND METHODOLOGICAL FRAMEWORK

The study examined the impact of biofuels consumption on biodiversity in the panel of twelve developed and developing countries, namely, Argentina, Austria, Brazil, Canada, China, Cuba, Czech Republic, France, Germany, India, Spain, Sweden and United States. These countries are selected due to its liberalization policies to promote sustainability agenda, as rapid economic transformation deteriorate natural environment that required appropriate energy mix to support energy demand function in a region. The data set of biofuels consumption taken from EIA (2014), while remaining variables including carbon dioxide emissions and biodiversity taken from World Development Indicators (2014). Biodiversity is measured by GEF benefits index for biodiversity (0 = no biodiversity potential to 100 = maximum), biofuels consumption is measured by thousand barrels per day, and carbon dioxide emissions is measured by million metric tons. The data range taken from 2000 – 2013 is used for evaluating the nexus between the biofuels and biodiversity in a panel of countries. The data of biodiversity is interpolated by forward and backward interpolation method in order to fill the missing gaps in the data series.

Biodiversity serves as the ‘response’ variable while biofuel consumption and carbon dioxide emissions both serve as ‘regressors’ in this study. The results hypothesized that biofuels consumption threatened the biodiversity in order to obtain fuel from animal fats, biogases, ethanol etc. Following the studies of Groom et al. (2008), Blanchard et al. (2011), Weins et al. (2011), and Verdade et al. (2015), the non-linear equation is estimated in order to examine the long-run relationship between biofuels consumption and biodiversity in the panel of countries i.e.,

$$\ln(BIOD)_{i,t} = \beta_0 + \beta_1 \ln(BF)_{i,t} + \beta_2 \ln(CARBON)_{i,t} + \varepsilon_{i,t} \quad (1)$$

Where, BIOD is biodiversity, BF is biofuels consumption, CARBON is carbon dioxide emissions, ‘i' is cross section identifiers representing 12 countries, ‘t’ is time period from 2000-2013, ‘ln’ is natural logarithm and ε is the error term.

The study employed the following panel econometric modeling for robust analysis i.e., Levin, Lin and Chu (2002) panel unit root, ADF- Fisher chi square unit root (Fisher, 1932) and Im-Pesaran-Shin (2003) unit root tests are used to analyze the stationary property of the respected variables. .These unit root test applied on each variable to find whether the variable contained the unit root problem or there is no unit root problem in the data series. If the data series found that there is no unit root problem, it implies that the given variable is stationary at level and there have no such volatility in the data series over the period of time. Alternatively, if the data series contains unit root problem, it implies that the variables are differenced stationary and it contains fluctuations over the period of time. As the economic variables changes over the time, therefore, we expect that, these variables stationary at their first difference.

After panel unit root test, the study further proceeds towards the panel cointegration tests. There are three panel cointegration tests i.e., Pedroni's cointegration test (Pedroni, 1999), Kao residual cointegration test (Kao, 1999) and Johansen Fisher panel cointegration test (Fisher, 1932). All these tests confirmed whether the variables of the model contained any cointegration relationship between them or not. Cointegration test is important to analyze the long-run relationship between the variables. Pedroni's cointegration have four panel statistics and three group statistics, while Kao residual cointegration is based upon the ADF test on the residual. Johansen Fisher cointegration test is similar~~ly~~ like the conventional test of Johansen cointegration test of time series analysis having trace statistics and maximum eigenvalue statistics. However, Fisher cointegration test is more robust in panel setting that confirms the cointegration relationship between the variables. The study employed panel fixed effect regression and panel random effect regression for robust regressions. Both the test provides useful insights about the relationship between biofuels consumption and biodiversity in the panel of countries. Finally, the study employed Hausman test for better model specification and it is measured through chi-square statistics.

These test statistics are necessary to obtain the robust parameter estimates, as different panel unit root tests including Levin-Lin-Chu test, Im-Pesaran-Shin test and ADF – Fisher panel unit root test is used to compare the stationary results of the respective variables, while three different cointegration tests including Pedroni's cointegration, Kao residual cointegration and Fisher – Johansen cointegration tests are used to analyze the long-run relationships between the variables. Finally, the study used panel fixed effect and random effect regression technique to obtain and compare the parameter estimates for robust inferences.

RESULTS AND DISCUSSION

The study first presented the results of descriptive statistics and correlation matrix in order to assess the variables trend and correlation between the variables. Table 1 shows the descriptive statistics and correlation coefficient between biofuels consumption, carbon dioxide emissions and biodiversity in the panel of countries.

Table 1: Descriptive Statistics and Correlation Matrix

Statistics	BF	CARBON	BIOD
Mean	72.19908	1211.550	28.080
Maximum	928.0000	8127.000	100
Minimum	0.100000	25.19793	0.101
Std. Dev.	168.6589	2021.039	34.539
Skewness	3.500873	2.028680	1.107
Kurtosis	15.60290	5.742042	2.715
Observations	182	182	182

Cross sections	12	12	12
Correlation Matrix			
Variables	BF	CARBON	BIOD
BF	1		
CARBON	0.457	1	
BIOD	-0.0360	-0.0311	1

Note: BF is biofuels consumption, CARBON is carbon dioxide emissions, BIOD is biodiversity index.

The results show that biofuels consumption has a minimum value of 0.100 thousand barrels per day to maximum value of 928 thousand barrels per day with an average value of 72.199 thousand barrels per day. The standard deviation is 168.658 thousand barrels per day with a positively skewed distribution and having a considerable peak of the distribution. Carbon dioxide emissions have a mean value of 1211.550 metric tons with a minimum value of 25.197 metric tons to maximum value of 8127 metric tons. The standard deviation is 2012.039 metric tons with a kurtosis value of 5.742. Finally, biodiversity has a minimum value of 0.101 that represented no biodiversity potential to maximum value of 100 that is biodiversity potential in countries, having an average value of 28.080. In the next panel, the study shows the correlation matrix and found that there is a positive correlation between biofuels consumption and carbon dioxide emissions while there is negative and weaker relationship between biofuels consumption and biodiversity in a region. Moreover, there is a negative and low impact of biofuels consumption and carbon dioxide emissions on biodiversity in a panel of countries.

After observing the variables trend and its magnitude, one may assess the variables stationary in the given model, for this purpose, the study adopted three panel unit root test i.e., Levin, Lin and Shin, ADF – Fisher chi square panel unit root test and Im-Pesaran-Shin test. The results presented the panel unit root tests in Table 2.

Table 2: Results of Panel Unit Root Tests

Variables	Levin, Lin and Chu Unit Root		ADF – Fischer Chi Square Unit Root		Im-Pesaran-Shin Unit Root	
	Level	First Difference	Level	First Difference	Level	First Difference
BF	-1.305	-4.516*	6.851	48.217*	2.390	-3.184*
BIOD	-1.597	-13.186*	13.222	740.095*	2.680	-8.716*
CARBON	0.851	-9.303*	13.115	88.551*	2.230	-7.041*

Note: BF is biofuels consumption, CARBON is carbon dioxide emissions, BIOD is biodiversity index. * indicates 1% level of significance. The level and first difference statistics are at individual intercept.

The results of panel unit root test indicate that biofuels consumption, biodiversity and carbon dioxide emissions all contained the unit root problems, as biofuels consumption, biodiversity and carbon emissions are non-stationary series at level, however, after taking first difference, these variables becomes stationary. The same results has been shown in all three panel unit root tests, therefore, we may safely conclude that the variables are first difference stationary and have the same order of integration - one i.e., I(1). After panel unit root analysis, the studies further precede towards the panel cointegration techniques. These statistics are presented in the Table 3 and Table 4 respectively.

Table 3: Pedroni Cointegration Test

Alternative hypothesis: common AR coefs. (within-dimension)

	Statistic	Prob.	Weighted Statistic	Prob.
Panel v-Statistic	-2.422536	0.9923	-0.746158	0.7722
Panel rho-Statistic	-4.293784	0.0000	-0.863304	0.1940
Panel PP-Statistic	-18.51386	0.0000	-5.035056	0.0000
Panel ADF-Statistic	-17.11170	0.0000	-2.320461	0.0102

Alternative hypothesis: individual AR coefs. (between-dimension)

	Statistic	Prob.
Group rho-Statistic	1.450659	0.9266
Group PP-Statistic	-4.709105	0.0000
Group ADF-Statistic	-2.875221	0.0020

The result of Pedroni' cointegration indicates the long-run cointegration relationship exists between the variables, as the number of panel statistics and group statistics confirmed the validity of cointegration relationship in the given model. The results of 'within –dimension' statistics indicates the significance statistic value of 'Panel rho', 'panel PP' and 'panel ADF' statistic; similarly, weighted statistics of 'panel PP' and 'panel ADF' also indicates the significance statistic at 1% level. In between – dimension statistics, 'group PP statistic' and 'group- ADF statistic' both significant at 1% level. Table 4 shows the test statistics of Kao residual cointegration.

Table 4: Estimates of Kao Residual Cointegration Test

	t-Statistic	Prob.
ADF	-8.391642	0.0000
Residual variance	4244022.	
HAC variance	326472.0	

The results of Kao residual cointegration shows the ADF statistics that is significant at 1% level; therefore, we may conclude that biofuels consumption, biodiversity and carbon dioxide emissions have the cointegration relationship between them. In the similar lines, the study further employed Fisher Johansen cointegration test in order to see the cointegration equations between the variables. The results are shown in Table 5.

Table 5: Result of Fisher – Johansen Cointegration Test

Trend assumption: No deterministic trend (restricted constant)
Lags interval (in first differences): 1 1
Unrestricted Cointegration Rank Test (Trace and Maximum Eigenvalue)

Hypothesized No. of CE(s)	Fisher Stat.* (from trace test)	Prob.	Fisher Stat.* (from max-eigen test)	Prob.
None	488.2	0.0000	457.6	0.0000
At most 1	52.09	0.0003	42.18	0.0059
At most 2	32.10	0.0758	32.10	0.0758

Note: * Probabilities are computed using asymptotic Chi-square distribution.

The result of Table 5 shows that there are two cointegration equations at 5 % level in the given model, as both the trace statistics and maximum eigenvalue statistics indicate that the hypothesized number of cointegration are two in number. As the study employed number of panel cointegration techniques, that one may easily seen that the variables have a long-run relationship between them, therefore, there is a considerable need to examine the long-run elasticities while controlling the country specific shocks and time invariant shocks. Table 6 presented the panel fixed effect and panel random effect regression coefficients.

Table 6: Estimates of Panel Fixed Effect and Panel Random Effect Model

Variables	**Fixed Effect**	**Random Effect**
Constant	6.184*	4.713*
Log(BF) $_{i,t}$	0.036	-0.155***
Log(CARBON) $_{i,t}$	-0.741*	-0.443*
Statistical Test		
F-Statistics	364.200*	18.156*
Hausman Test		
Chi-square Statistic	Fixed Vs Random Effect	10.294*

Note: Dependent variable: Log(BIOD). BF is biofuels consumption, CARBON is carbon dioxide emissions, BIOD is biodiversity index. * and *** indicates 1% and 10% level of significance.

The results show that carbon dioxide emissions have a significant and negative relationship with the biodiversity, as the coefficient value in terms of elasticity indicates that if there is one percent increase in the carbon dioxide emissions, biodiversity decreases by 0.741 percentage points. This reflects the less elasticity relationship between the variables, as the coefficient value less than the unity. On the other hand, the impact of biofuels consumption on biodiversity remains an insignificant in case of fixed effect regression model; therefore, we may remains silent on the nature of relationship between them. However, this results doesn't imply that biofuels consumption does not have any impact on biodiversity, as in case of random effect regression, the relationship between biofuels consumption and biodiversity is visible i.e., there is a significant and negative relationship between biofuels consumption and biodiversity in the panel of selected countries. The results indicate that, if there is one percent increase in biofuels consumption and carbon emissions in random effect regression, the biodiversity decreases by 0.155% and 0.443% respectively. The results conclude that biodiversity is affected from biofuels consumption and carbon dioxide emissions in a panel of selected countries. The results imply that biodiversity is affected through human made activities, like biofuels consumption and its first to fourth generation. The first generation biofuels mainly produced by animal fats, biogases, ethanol etc., second generation biofuels produced from non-food crops, wood chips etc, third generation produced by algae and cellulosic breakdown in the fourth generation biofuels. These biofuels generation significantly threatened to the biodiversity that remains the big challenge to the policy makers in order to protect the natural bonanza across the countries.

The overall results indicate that biodiversity is affected by biofuels consumption and carbon dioxide emissions in the panel of selected countries. This is the time to wake up and device sustainable and long-term policies to protect the natural bonanza for the world's precious inhabitants that have a considerable role in our health and wealth. The results are inline with the previous studies of Wiens et al. (2011), Phalan (2009), Groom et al (2008), Eggers et al. (2009), Blanchard et al. (2011), Zaman et al. (2016), Titeux et al. (2016) etc. Weins et al. (2011) argued that biofuels production have a minimum carbon debt and do not required marginal land for biofuel production, however, conservation of biodiversity is subjected to the global sustainable agenda, which required serious attention while allocated land for biofuel production. Phalan (2009) discussed environmental and social aspects of biofuels in view of land-use, technological advancement and food security, and concluded that biofuels have attached sustainability issue that need optimal utilization of land-use with technological up gradation to meet the challenges of food security across the countries. Groom et al. (2008) emphasized the need of "biodiversity-friendly biofuels" for certifying sustainability issue with low carbon debt while Eggers et al. (2009) considered biofuels as a potential threat to the biodiversity loss. Blanchard et al. (2011), Zaman et al. (2016), and Titeux et al. (2016), all these studies confined the role of biofuels in order to assess its environmental affects in a diversified panel of countries and they are generally concluded that biofuels production and consumption have a visible environmental affects to land-use, food security, water resources, climate change and biodiversity loss.

CONCLUSIONS

The objective of the study is to examine the impact of biofuels consumption on biodiversity in the panel of twelve selected biofuels consuming countries, over the period of 2000-2013. The study argued the key question that is, does the biofuels consumption damage the biodiversity? In order to give the conclusive remarks, the study employed different panel techniques including panel unit root tests, panel cointegration tests, panel fixed effect and panel random effect models. The results show that biofuels consumption damages the biodiversity in the panel random effect model. The study further includes carbon dioxide emissions in the biofuel-biodiversity nexus in order to minimize the biased of the single variable case. The results show that carbon dioxide emissions also deteriorate the natural environment in the panel of selected countries. On the basis of key findings, we may conclude that Biofuels consumption affected the natural environment across the globe, as the results of the study indicated that biofuel consumption decreases the GEF biodiversity index, therefore, the policy makers should have to reconsider their energy fuels portfolios in order to prevent the natural inhabitants that played their ecological role in their destinations. There is a high time to think and reconsider the policies of biodiversity in order to meet the challenges of sustainable development across the globe.

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