Chapter 7

BIOFUEL PRODUCTION AND ECONOMIC GLOBALIZATION NEXUS IN DEVELOPING COUNTRIES

Bilgehan TEKİN[1]
Nazlıhan TEKİN[2]

1. INTRODUCTION

Using renewable (RN) biofuel (BF)s obtained from biomass energy is a promising opportunity for issues such as protecting the environment, meeting energy (ENG) demand, and supporting sustainable ENG (Banerjee et al., 2019). At the same time, it has recently become an important source of movement for employment, investment and growth (Mena-Cervantes et al., 2023). The fact that biofuels can be obtained from renewable sources increases economic (EC) sustainability. At the same time, studies in the literature show that using environmentally harmful and cheap waste raw materials in biofuel production adds a cost-effective and eco-friendly aspect to biomass ENG in economic and environmental (EN) terms. It is stated in the literature that biofuel production reduces emissions by 20-90% compared to fossil fuels (Sheriff et al. 2020; Subramaniam and Masron, 2021). In addition, it has been emphasized that as a result of the use of biodiesel (BIO) produced with different raw materials, emissions decrease by 35-80% (depending on the type of raw material) (Subramaniam and Masron, 2021).

Among BFs, BIO is a RN fuel obtained from vegetable oils or animal fats using a short-chain alcohol in the presence of a catalyst, often by a chemical reaction called transesterification (Rodrigues et al., 2008). The chemical structure of BIO consists of monoalkyl esters containing medium-length C16-C18 fatty acid chains. It differs depending on the properties of the alcohol used during the reaction, and the most common BIO is a mixture of fatty acid methyl esters (FAME) obtained by using methanol (Branco-Vieira et al., 2017).

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[1] Assoc. Prof.,Cankiri Karatekin University, Faculty of Economics and Administrative Sciences, btekin@karatekin.edu.tr, ORCID iD: 0000-0002-4926-3317

[2] PhD, Ankara University, nazlihanyildirim@hotmail.com, ORCID iD: 0000-0003-1922-594X

BIO ranks first in the production of BF in the world and is a prevalent fuel (Fauzi et al., 2022). The first use of BIO was in the 1900s when Rudolf Diesel started a diesel engine using the fuel he produced with peanut oil (King and Wright, 2007). Later, interest in BIO increased due to the oil crisis in the 1970s. Large production facilities have begun to be established, especially in the USA and Brazil, the world's largest BIO and bioethanol producers (Sajid et al., 2021).

BIO is used as a partial or replacement for vehicle engines due to its physical and chemical properties. For this reason, it is used by blending with fossil-based diesel fuel, and the mixture ratio varies depending on the engine type (6-20% volume range according to ASTM 7467 standard for diesel engine vehicles) (Mena-Cervantes et al., 2023).

The wide usage area of BIO shows its production and consumption volume growing day by day. By 2025, the volume of global biodisel production (BP) is expected to be 41.4 Billion liters (Rouhany and Montgomery, 2019; Ali et al., 2022). It is stated in the literature that especially the USA and the European Union will have the largest volume for the production and consumption of BIO (Ali et al., 2022). However, the high costs that developing countries must bear for BF or BP may reduce the production and consumption volume (Avinash et al., 2018).

The eco-friendly, economical, sustainable and RN nature of BF production and consumption is a source of motivation for further improvements to be made in every region of the world. For this reason, it is stated in the literature that especially the continuation of economic globalization (EG) changes the nature of renewable energy consumption. EG is international EC exchange and the flow of goods, services, people, information and capital across national borders (Brady et al., 2007). Subramaniam and Masron (2021) stated that EG could be a way to increase BF use and reduce dependence on fossil fuels. EG, especially in developing countries, can solve problems such as the use of raw materials in BF production and its conversion to BF through knowledge transfer. Therefore, increased EG is critical to increasing BF consumption by supporting BF production.

In addition, EG is an indicator of EC growth based on a country's activities at the international level (Santiago et al., 2020). When this situation is evaluated from the perspective of developing countries, if the cost that must be incurred for BP can be solved by EG, it is inevitable to see EC growth. However, variables such as urbanization, carbon emissions and ENG consumption also affect this relationship. In this study, it is aimed to investigate the causality and cointegrations between EG and BP in developing countries.

The world has changed a lot in the past few decades because of EG. This happening, characterized by countries being more connected through the exchange of goods, services, money, and information, has had important effects on different parts of the world economy. Out of all these industries, the ENG industry is an important area where globalization has caused major changes and opportunities.

The ENG industry's changes related to global connections are strongly connected to the rise and expansion of BF production. BFs are made from plants, algae, and waste materials, and they offer a good and long-lasting option instead of regular fuels made from fossils. They can help reduce greenhouse gases, make ENG more secure, and promote EC growth, especially in places with many plant or animal materials that can be used for ENG (Demirbas, 2009; World Bank, 2007). As people become more worried about climate change and want safer ways to get ENG, BFs have become an important part of the switch to new ENG sources.

The connection between the global economy and BF production is complex, always changing, and has many different aspects. Globalization has helped make it easier for countries to trade BFs and the materials needed to make them. This has helped more people have access to different kinds of ENG and reduced how much we rely on regular fuels from the ground. The worldwide market for BFs has gotten bigger, which has made the process of making, delivering, and using them more complicated.

However, the spread of the BFs industry worldwide has caused many worries for the environment and society. This has caused people to question how land is being used, if we have enough food for everyone, and if money is being shared fairly. The growth of crops like corn and soybeans for BFs has caused deforestation and changes in land use. This has led to the destruction of habitats and loss of biodiversity (Searchinger et al. , 2008). Furthermore, people worry that arable land might be used for BF crops instead of food. This could increase the cost of food and make it harder for some regions to have enough food to eat (Runge & Senauer, 2007).

This paper aims to study how EG and BF production affect each other. It will look at the EC, social, and EN aspects of this connection. The goal is to give a clear understanding of what causes globalization in the BFs industry and what effects it has. This includes looking at the viewpoints of both rich and poor countries. Additionally, this research will evaluate the possible advantages and disadvantages of EG and the sustainable production of BFs. It will use real-life examples and studies from various countries.

This paper wants to talk about how global trade and BF production are connected. The goal is to add to the conversation about using sustainable ENG and making fair trade policies. It is very important for us to understand how these two connected variables work together. This understanding will help us make decisions that promote a future with fair and long-lasting ENG for everyone.

2. CONCEPTUAL FRAMEWORK

The relationship between EG and BFs is diverse and dynamic, with both positive and negative impacts. As globalization continues to change the world EC landscape, it has played a key role in the emergence and expansion of the BFs industry. In this discussion, we consider important aspects of this relationship and draw insights from the literature. EG has facilitated cross-border trade in BFs and their raw materials, facilitating the growth of the global market for bioenergy products. This expansion has opened opportunities for countries to access alternative ENG sources and reduce their dependence on traditional fossil fuels. BFs such as BIO and bioethanol have become traded commodities in international markets with supply chains spanning continents (Sorda et al., 2010). This globalization of the BF industry has facilitated technology transfer, knowledge exchange, and investment in bioenergy production, especially in developing countries (Demirbas, 2009). While EG has led to the worldwide adoption of BF technologies, it has also raised various EN and social concerns. One of the main concerns is the land use changes associated with the production of BF feedstocks, especially in regions with abundant arable land (Searchinger et al., 2008). Conversion of forests and other natural habitats into areas for growing BF crops can lead to deforestation, habitat loss, and biodiversity loss (Gibbs et al., 2008).

Additionally, there are concerns that agricultural land may be diverted from food production to BF crops, which could impact food prices and food security in some regions (Runge and Senauer, 2007). Competition for land and resources between food production and fuel production is a contentious issue, and globalization is exacerbating this challenge by increasing demand for BFs (Timilsina and Shrestha, 2011). EG also impacts the political climate surrounding BFs. The interconnectedness of global markets has created a need for harmonized standards and regulations to ensure the sustainability and quality of BFs (Sorda et al., 2010). International agreements and frameworks, such as the renewable energy Directive in the European Union and sustainability certification systems like the Roundtable on Sustainable Biomaterials (RSB) and the Roundtable on Sustainable Palm Oil (RSPO), have emerged to address these concerns and promote responsible BF production (EIA, 2018). Globalization has accelerated the spread of BF technologies, leading to innovations and advances in bioenergy production. Knowledge sharing and cooperation between countries have facilitated BF research and development, including the development of second-generation BFs from non-food feedstocks (EIA, 2018). This has the potential to reduce the EN and social impacts associated with first-generation BFs. In summary, the relationship between EG and BFs is complex and characterized by both opportunities and challenges. While globalization has expanded the scope of BF markets and technology transfer, it has also raised concerns about EN sustainability, food security, and equitable development. Effective governance, international cooperation and sustainability standards are essential to reaping the benefits of globalization while mitigating its negative impacts on BF production and trade.

3. LITERATURE

Lee (2016) applied an engineering ECs analysis to assess the EC feasibility of biobutanol, biohydrogen and BP facilities. As a result of the study, it was found that biobutanol and biohydrogen can replace fossil fuels due to their EC feasibility. It was also stated that these BFs can be cost-competitive with fossil fuels under optimized conditions.

Similarly, Al-Mulali et al. (2016) examined the effect between biofuel energy consumption and EC growth in Brazil between 1980 and 2012. As a result, EC growth, biofuel energy consumption, capital, urbanization and globalization were found to be cointegrated. In the short and long run, Brazil's EC growth was boosted by biofuel energy consumption.

Koengkan (2017) investigated the relationship between BF consumption and EC growth in Brazil between 1990 and 2015. The findings show that there is a bidirectional relationship between oil consumption and EC growth, BFs and oil consumption, and BF consumption and EC growth.

Bildirici (2017) examined the relationship between EC growth, militarization, CO_2 emissions and BF consumption in Brazil, China and the US between 1985 and 2015. As a result of the study, it was determined that there is a bidirectional causality between BF consumption and EC growth and between EC growth and

CO_2 emissions.

Simionescu et al. (2019), who evaluated the impact of transportation-based BIO consumption on EC growth in the EU between 2010 and 2016, stated that BIO consumption increased EC growth, albeit very slightly, with a unidirectional relationship.

Ben Jebli & Ben Youssef (2019) examined the dynamic relationships between Brazilian per capita combustible renewable energy resources and waste (CRW) consumption, agricultural value added (AVA), carbon dioxide (CO_2) emissions and real gross domestic product (GDP) over the period covering 1980-2013. There is long-run cointegration and long-run bidirectional causality between the variables considered. Moreover, CRW consumption and AVA are found to increase EC growth. However, EC growth increases agricultural production and CRW production.

Ashani et al. (2020) applied various purification scenarios for acetone-butanol-ethanol (ABE) production using municipal solid waste (MSW) and investigated the effects on both butanol concentration and cost. The study found that ABE production from MSW can be economically feasible and has a significant impact on the ENG use in the plant with the optimized scenario technique.

Naqvi et al. (2023) investigated the impact of waste and biofuel energy production on EN degradation in 14 APEC countries from 1990 to 2017. In this research, the role of natural resources and financial development is also included. The study emphasizes that increasing BF and waste ENG production will reduce EN degradation.

Guliyev and Tatoğlu (2023) examined the relationship between renewable energy and EC growth in European countries from 1970 to 2019, and obtained significant results. Accordingly, the study shows the continuous effect of renewable energy on EC growth.

4. METHODOLOGY

Investigating the causality and cointegrations between EG and BP in developing countries using panel data is a complex research endeavour that requires a combination of various econometric techniques.

With a panel dataset consisting of 10 developing countries (Argentina, Brazil, China, Indonesia, Philippines, Poland, Romania, Thailand, Türkiye, Uruguay. These are the countries whose data is fully accessible) and 11 years of data, we have a relatively small sample size, which can limit the applicability of certain econometric techniques. In such cases, it is important to choose methods that are suitable for your data's size and characteristics. For the empirical analysis, Pedroni, Kao and Westerlund panel cointegration and Juodis, Karavias and Sarafidis (JKS) and Dumuitrescu-Hurlin causality analyses were performed. In this research, we analyze a panel dataset covering the period from 2010 to 2020, focusing on two key variables that are central to our investigation:

Economic Globalization (EG): EG measures the extent to which a country is integrated into the global economy, taking into account various dimensions, such as trade openness, capital flows, and EC interactions with the world. Data on EG were obtained from the KOF Globalization Index, a widely recognized and comprehensive measure of globalization.

Biodiesel Production (BP): BP represents the annual volume of biofuel produced within a country. BP data were sourced from the United Nations (UN) statistics, providing insights into the renewable energy sector's development across nations.

These two variables were selected based on their relevance to the study's primary objective of examining the relationship between EG and BP during the specified period. The panel dataset comprises *N* individual countries or regions, enabling us to explore both cross-sectional and temporal variations in the context of EG and BP. The data underwent rigorous quality control and harmonization procedures to ensure consistency and comparability across different sources and time periods.

The inclusion of EG and BP variables allows us to assess how EC integration with the global economy may influence the growth and development of the biodiesel sector across diverse regions and nations over the last decade. These variables play a pivotal role in shaping our understanding of the intricate dynamics between globalization and renewable energy production.

The study estimates the relationship between EG and BP growth in the case of developing countries. For the proxy of biofuel production, we use biodiesel production. The long-run equation is specified as follows:

$$BP_t = f(LNEG_t) \tag{1}$$

The variables for the cointegration relationship are examined in the following step. In panel data econometrics, a number of cointegration tests have been developed, including Pedroni (2004), Pedroni (1999), Kao (1999) residual-based cointegration, and, most recently, Westerlund (2005) cointegration. Given the benefits of each test, this study used all three cointegration tests.

4.1 Pedroni Test for Panel Co-Integration

The Panel Pedroni methodology (Pedroni, 1999, 2004) extends the cointegration analysis to panel data by accounting for individual-specific heterogeneity and cross-sectional dependence. It is particularly valuable in scenarios where researchers seek to ascertain the presence of cointegration relationships across diverse entities within a panel dataset.

The basic framework of the Panel Pedroni test can be represented by the following equation:

$$yit = \alpha i + \delta it + \beta 1ix1i,t + \beta 2ix2i,t + \cdots + \beta mixmi,t + ei,t \tag{2}$$

where $t = 1, \dots\dots\dots, T; i = 1, \dots\dots\dots, N; m = 1, \dots\dots, M$ and x is expected to be . The factors αi and δi are individual and drift effects, which may be fixed at zero if needed.

The Panel Pedroni test assesses the null hypothesis of no cointegration $(\beta_i = 0)$ against the alternative hypothesis of cointegration $(\beta_i < 0)$ for each individual within the panel. It further provides options for both homogeneous and heterogeneous tests, allowing for variations in cointegration relationships across entities.

The residuals $e_{i,t}$ will be I(1), as was already mentioned, if there is no co-integration. Typically, an auxiliary regression (Equation (3)) is run on the residuals obtained from Equation (2) and tested to see if I(1) for each cross-section.

$$e_{i,t} = \rho_i t_{i-1} + u_{it} \tag{3}$$

4.2 Kao Test for Panel Co-Integration

The Panel Kao methodology (Kao, 1999) is designed to detect cointegration in panel data while considering individual-specific effects, cross-sectional dependence, and potential heterogeneity. It extends the traditional Engle-Granger cointegration test to panel settings. represents the error term. Kao (1999) suggested that (Alam et al., 2021):

$$y_{it} = \alpha_i + \beta X_{it} + e_{it} \tag{4}$$

for

$$\begin{aligned} y_{it} &= y_{it-1} + u_{i,t} \\ x_{it} &= x_{it-1} + \varepsilon_{i,t} \end{aligned} \tag{5}$$

where and . Kao then ran the pooled auxiliary regression:

$$e_{it} = \rho e_{it-1} + u_{it} \tag{6}$$

The Panel Kao test extends this basic framework to account for cointegration across the panel entities while considering potential variations in the cointegration relationship.

4.3 Westerlund Test for Panel Co-Integration

The Panel Westerlund methodology (Westerlund, 2005) offers a robust approach for cointegration analysis in panel datasets characterized by non-stationary variables and cross-sectional dependence. It extends the panel Granger causality test to cointegration settings. The null hypothesis of no cointegration is tested against the alternative hypothesis of some panels being cointegrated using the panel-specific-AR test statistic. The null hypothesis of no cointegration is tested against the alternative hypothesis, which states that all the panels are cointegrated, using the same-AR test statistic.

The panel-specific-AR test statistic is given by

$$\mathrm{VR} = \sum_{i=1}^{N} \sum_{t=1}^{T} \widehat{E}_{it}^{2} \widehat{R}_{i}^{-1} \tag{7}$$

The same-AR test statistic is given by

$$\mathrm{VR} = \sum_{i=1}^{N} \sum_{t=1}^{T} \widehat{E}_{it}^{2} \left(\sum_{i=1}^{N} \widehat{R}_{i}\right)^{-1} \tag{8}$$

where $\widehat{E}_{it} = \sum_{j=1}^{t} \hat{e}_{ij}, \widehat{R}_i = \sum_{t=1}^{T} \hat{e}_{it}^2$, and $\hat{e}_{it}$ consist of the residuals from the panel-data regression model in (4). After proper standardization, the asymptotic distribution of all test statistics converges to N(0,1).

4.4 Causality Tests

The Dumitrescu and Hurlin (2012) panel causality test is a robust and widely employed method for examining Granger causality in a panel data setting. This methodology extends the traditional Granger causality test to account for cross-sectional dependence and individual heterogeneity commonly encountered in panel datasets.

Dumitrescu and Hurlin (2012) provide a designed extension to detect causality in panel data. The underlying regression is

$$y_{i,t} = \alpha_i + \sum_{k=1}^{K} \gamma_{ik} y_{i,t-k} + \sum_{k=1}^{K} \beta_{ik} x_{i,t-k} + \varepsilon_{i,t} \text{ with } i = 1, \dots, N \text{ and } t = 1, \dots, T \qquad (9)$$

where $x_{i,t}$ and $y_{i,t}$ are the observations of two stationary variables for individual in period . The coefficients are assumed to be time invariant but are permitted to vary between individuals (note the i subscripts on the coefficients). The panel must be balanced, and it is assumed that all members have the same lag order K.

Testing for significant effects of past values of x on the present value of y is the procedure to ascertain the existence of causality, as in Granger (1969). Therefore, the definition of the null hypothesis is:

$$H_0: \beta_{i1} = \cdots = \beta_{iK} = 0 \; \forall i = 1, \dots, N \qquad (10)$$

which corresponds to the absence of causality for all individuals in the panel. The DH test assumes there can be causality for some individuals but not necessarily for all. Thus, the alternative hypothesis is

$$\begin{aligned} H_1: \beta_{i1} = \cdots = \beta_{iK} = 0 \quad & \forall i = 1, \dots, N_1 \\ \beta_{i1} \neq 0 \text{ or } \dots \text{ or } \beta_{iK} \neq 0 \quad & \forall i = N_1 + 1, \dots, N \end{aligned} \qquad (11)$$

where $N_1 \in [0, N-1]$ is unknown. If $N_1 = 0$, there is causality for all individuals in the panel. must be strictly smaller than ; otherwise, there is no causality for all individuals, and reduces to .

Juodis et al. (2021) used a causality test in this manner, basing it on the bias-corrected estimator as follows;

$$y_{i,t} = \phi_{0,t} + \sum_{p=1}^{P} \phi_{p,t'} y_{1,t-p} + \sum_{p=1}^{P} \beta_{p,t} x_{i,t-p} + \varepsilon_{i,t} \tag{12}$$

It is assumed that $x_{i,t}$ is a scalar for simplicity and generality. The individual-specific influences are shown in $\phi_{0,1}$, and the heterogeneous parameters are shown in $\phi_{p,i}$. The requirement that y_i;t has the same number of delays as $x_{i,t}$ has the benefit of needing minimum computational effort when choosing lag lengths. This test allows CSD and resists homogeneous and heterogeneous alternatives. The above equation can be used to formulate the null hypothesis of non-causality from $x_{i,t}$ to $y_{1,t}$.

$$H_0: \beta_{p,s} = 0 \tag{13}$$

It is possible to conclude that $x_{i;t}$ does not Granger-cause $y_{1,t}$ if the null hypothesis is not disproved.

5. FINDINGS

Table 1 shows the descriptive analysis of each of the variables used in deviations for each of the variables employed. These statistics in the form of natural logarithm of the variables. BP has a mean of 6,28477 with a standard deviation of 1,918829. EG has a minimum rate of 3.57 and 4.3 as the maximum rate, and this has 4 as the mean with 0,2 as the standard deviation. The other part of the Table 1 shows the correlation analysis among the variables. The correlation figures which is (*r=-0.5313*) between BP and EG a negative and medium-level of correlation between the variables.

Table 1: Descriptives and Correlations

Variable	Obs	Mean	Std. Dev.	Min	Max	*EcGlob*	*BIO*
lnEG	110	3.999331	.1977153	3.565198	4.299304	*1.0000*	-
BP	110	6.28477	1.918829	1.94591	9.082507	*-0.5313*	*1.0000*

The analysis begins by assessing the degree of cross-sectional dependence in the panel data. Table 2 presents the findings of the panel cross-sectional dependence test. In order to investigate cross-sectional dependence, the Pesaran CD test is used. With power enhancement from Fan et al., the Juodis ve Reese's CDw test is also used for comparison purposes. In Table 3, Pesaran and Xie's CD^* test and's CD_{w+} test are compared. The null hypothesis of cross-sectional independence is rejected for *lnBP* according to Pesaran's CD test, Fan et al.'s CD_{w+} test and is rejected for *lnEG* according to only Fan et al.'s CD_{w+} test. Therefore, it is concluded that there is a cross-sectional dependence for the only *lnBP*.

Table 2: Cross-sectional dependence tests

	CD	**CD_W**	**CD_{W+}**	**CD^***
lnBP	14.37 (0.000)	-0.18 (0.855)	103.44 (0.000)	-1.32 (0.186)
lnEG	1.06 (0.290)	-0.38 (0.703)	60.53 (0.000)	0.64 (0.523)

CD- Pesaran (2015, 2021) CD test.
CD_w - Juodis and Reese (2022) CDw test.
CD_{w+} - CDw with power enhancement from Fan et al. (2015).
CD^*- Pesaran and Xie (2022) CD test with 4 factors.

p-values in parenthesis

In order to ascertain whether the variables are stationary, this study employs two unit-root tests: the Maddala and Wu Test (MW), a first-generation test, and the CIPS unit root test, a second-generation test. Utilizing Phillips-Perron (PP) parameters, Maddala and Wu Test compute an individual regression for each panel's cross-sections before comparing the p-values for each panel's unit root. The augmented Dickey-Fuller (ADF) and the Im-Pesaran-Shin (de Oliveira and Moutinho, 2022) are two first-generation models that were combined to create the CIPS (Pesaran, 2007). Cross-sectional dependence makes it possible for the conventional first generation to arrive at an incorrect conclusion.

The Mandalla and Wu test (MW) and the Pesaran CIPS test were used to determine whether a unit root existed. Since the Mandalla and Wu test (MW) may not be accurate in the case of cross-sectional dependence, the CIPS was also used. As shown in Table 3, the *lnEG* variable is stationary at level and without trend and non-stationary at level with trend. Furthermore, *lnBP* is non-stationary at both the level with and without a trend model. In conclusion, at lag 0 and lag 1, *lnBP* is stationary at I(0) and stationary at I(1), and *lnEG* is stationary at I(1). However, the Mandala and Wu test indicates that the *lnEG* is stationary at I(0) at lag 1. Three different cointegration tests were used in this study due to the inconsistent results of the unit root tests.

Table 3: Panel unit root tests

Maddala and Wu Panel Unit Root				
	Specification without trend			
Variable	**lags**	**chi_sq**	**p-value**	
lnBP	0	21.010	0.397	
lnBP	1	8.760	0.986	
lnEG	0	26.778	0.142	
lnEG	1	34.217	0.025	
	Specification with trend			
Variable	**lags**	**chi_sq**	**p-value**	
lnBP	0	28.590	0.096	
lnBP	1	9.952	0.969	
lnEG	0	16.283	0.699	
lnEG	1	21.189	0.386	
Pesaran Panel Unit Root (CIPS)				
	Specification without trend			
Variable	**lags**	**Zt-bar**	**p-value**	**t-bar**
lnBP	0	-2.237	0.013	.
lnBP	1	-1.281	0.100	.
lnEG	0	0.897	0.815	.
lnEG	1	-0.018	0.493	.
	Specification with trend			
Variable	**lags**	**Zt-bar**	**p-value**	**t-bar**
lnBP	0	0.941	0.827	.
lnBP	1	-0.244	0.404	.
lnEG	0	3.033	0.999	.
lnEG	1	1.704	0.956	.

5.1 Panel Cointegrations Tests

Tables 4, 5, and 6 present the findings of the Kao, Pedroni, and Westerlund cointegration tests. The model's t-statistics are significant and reject the null hypothesis that there is no cointegration. As a result, the investigated countries have cointegrated EG and BP.

Table 4: Kao Cointegration Test Results		
	Statistic	***p-value***
Modified Dickey-Fuller t	2.0345	0.0209
Dickey-Fuller t	3.2141	0.0007
Augmented Dickey-Fuller t	3.5041	0.0002
Unadjusted Modified Dickey-Fuller t	2.0308	0.0211
Unadjusted Dickey-Fuller t	3.2079	0.0007

Table 5: Pedroni Cointegration Test Results		
	Statistic	***p-value***
Modified Philips-Perron t	2.4529	0.0071
Philips-Perron t	.	.
Augmented Dickey-Fuller t	3.4943	0.0002

Table 6: Westerlund Cointegration Test Results		
H_0: *No cointegration;* H_A: *All panels are cointegrated*	***Statistic***	***p-value***
Variance ratio	2.2991	0.0107

The panel fully modified OLS is used after the cointegration between the variables has been established, and the results are shown in Table 6. The findings show that a 1% increase in EG growth will result in a 2.31% increase in BP. The increase in BP growth by 1% will decrease the level of EG 0.13%.

Table 7: FMOLS Long Run parameter estimates				
Independent Variable	***Coefficient***	***Std. Error***	***t-Statistic***	***Prob.***
lnEG	2.304350	1.151098	2.001870	0.0487
lnBP	-0.126405	0.039581	-3.193566	0.0019

5.2 Panel Causality Tests

The causality nexus was investigated using the Granger non-causality tests proposed by Juodis, Karavias, and Sarafidis in 2021 and the Dumitrescu-Hurlin (2012) tests (Table 8). Lopez and Weber (2017) suggested that the Dumitrescu and Hurlin test could be expanded to use Bayesian information criteria (BIC) and generate accurate p-values using the bootstrap method. However, because their test statistic can only be theoretically justified when T is significantly less than N (Xiao et al. 2021). The Granger non-ausality test proposed by Juodis, Karavias, and Sarafidis (2021), which uses a polled estimator with a faster convergence rate, has a number of advantages over existing causality methods. This test, which is based on the Half Panel Jackknife (HPJ) bias-corrected pooled estimator and the Wald test statistic, is applicable to models with both heterogeneous and homogeneous coefficients (Glavaski et al. , 2022).

The JKS Causality test results show that EG Granger cause of BP. The negative z-score and the associated p-value of 0.033 indicate statistical significance, meaning that there is evidence to support the hypothesis that changes in EG precede changes in BP. The result also indicates that BP Granger causes EG. The positive z-score and the very low p-value of 0.000 signify strong statistical significance. This suggests that changes in BP lead to changes in EG and that this relationship is statistically robust. The coefficient of 36.6868 provides an estimate of the strength of the causal effect. In summary, the JKS Causality test reveals a bidirectional causal relationship between EG and BP, with each variable Granger causing the other. The Dumitrescu-Hurlin Causality test results indicate that there is a statistically significant causal relationship running from BP to EG, but there is no evidence of causality in the reverse direction, from EG to BP.

Table 8: Juodis, Karavias & Sarafidis (2021) and Dumitrescu & Hurlin (2012) Causality Tests

	HPJ Wald Test	**Std. Err.**	**z**	**P> lzl**	**[95% Conf.**	**Interval]**
lnEG → lnBP	4.5247	.2465183	-2.13	0.033	-1.007542	-.0412087
lnBP → lnEG	36.6868	.0074256	6.06	0.000	.0304226	.0595304

Dumitrescu & Hurlin (2012) Test Results

	W-bar	**Z-bar**	**p-value**
lnBP → lnEG	1.8974	2.0066	0.0448
	W-bar	**Z-bar**	**p-value**
lnEG → lnBP	0.8464	-0.3435	0.7312

6. CONCLUSION

The observed relationship between economic globalization and the production of biofuels emphasizes a mutually beneficial and long-lasting relationship. This reciprocal relationship shows that changes in the landscape of biofuel production are sparked by the acceleration of economic globalization, and vice versa, changes in the patterns of biofuel production have an impact on the course of economic globalization. The temporal scope of this dynamic relationship investigation covered the years 2010 through 2020. Economic globalization and the production of biofuels in the chosen countries are mutually dependent and exhibit inextricable links, according to the identification of bidirectional causality. Particularly, as economic globalization accelerates, it is likely to reduce biofuel production within the target countries. Increased international trade that results from increased economic globalization makes the world market more fiercely competitive. Because biofuel production uses a lot of resources, some countries might strategically shift their attention away from it in search of more lucrative economic opportunities.

On the other hand, the production of biofuels helps to increase the resilience and interconnectedness of the world economy. Increased employment opportunities and higher profits for farmers and biofuel producers are two ways that expanding biofuel production promotes economic growth. Additionally, it increases economic security by reducing reliance on fossil fuels and diversifying energy sources.

Governments may develop policies to strengthen the competitiveness of the biofuel industry on the global stage in response to the negative impact of energy management on the production of biofuels. Financial incentives, research support, innovation promotion, and trade agreements are a few examples of such policies. A nation's economic diversity and revenue flow can be strengthened by biofuel production, making it a tempting option for nations looking to gain economic clout. However, a thorough analysis of the effects on the environment and the sustainability issues related to the production of biofuels is still necessary.

The ongoing interaction between the production of biofuels and economic globalization needs to be acknowledged by developing countries. This complex relationship suggests that changes in one area may eventually have long-term effects on the other. A significant opportunity for emerging economies is provided by the production of biofuels, which has the potential to have a positive impact on economic globalization. The creation of jobs, income, and economic growth can all be sparked by investments in and support for the biofuel production industry.

However, it is critical to recognize any negative effects that may result from the nexus of globalization of the economy and the production of biofuels. Due diligence should be put into determining how developing nations' biofuel production industries will be impacted by trade liberalization and increased global competition. A biofuel production paradigm that is in line with environmental sustainability and long-term viability is especially important for less developed countries. This calls for careful land management, environmental protection, and eco-friendly biofuel production, along with a steadfast commitment to ensuring that people have access to food and that their communities' social structures are preserved.

Developing countries can use biofuel production to improve the security of their energy supply by using different energy sources and decreasing their reliance on fossil fuels. The idea that biofuel production can help make the world more connected and boost the economy suggests that biofuel productions can be a way to bring in different types of businesses and make more money. Policymakers can find ways to support the sector and ensure it can continue in the long run. Developing countries must pay close attention to the enviromental effects of biofuel production. Developing countries should actively join in talks about international trade to get good conditions for their biofuel production exports. Creating trade agreements that support sustainable practices can be helpful for both the biofuel production industry and the growth of the global economy. Developing countries may need help getting the latest biofuel production technology and creating the skills to do it themselves. When different countries work together and share what they know, it can help them share and transfer new technology. Developing countries can encourage foreign and domestic investment in the biofuel production industry by creating a good business environment, offering benefits, and making clear rules and regulations.

To put it simply, the information suggests that biofuel production can help developing countries grow their economies and become more involved in global economy. However, it is important for them to think carefully about how their actions affect the environment, sustainability, and how global competition may change things. Creating a well-rounded plan that considers financial and enviromental objectives is important for these countries to gain the advantages of producing biofuel productions.

The results could impact the important issues that the countries studied focus on. For example, they might have to ensure that biofuel production is sustainable while still promoting economic globalization. During trade talks between countries, they may request better conditions for their biofuel production exports and also think about how trade agreements may affect their biofuel production industry. Policymakers might focus on biofuel production to keep their energy sources safe and to help with climate change. They know that biofuel production can help reduce greenhouse gases and give us different options for energy. It is important to highlight that understanding these results should be done carefully and about the specific situation. The particular plans and ways of doing things followed by each of the studied countries, along with their economic and political situations, will decide how these discoveries are put into practice. Furthermore, it is important to think carefully about how biofuel production is made and its effects on the environment when making and following policies.

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