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# Financial Development and Bioenergy Consumption in the EU28 Region: Evidence from Panel Auto-Regressive Distributed Lag Bound Approach

**Mohd Alsaleh * and A. S. Abdul-Rahim**

Faculty of Economics and Management, Universiti Putra Malaysia, UPM Serdang, Selangor 43400, Malaysia; abrahimabsamad@gmail.com
* Correspondence: moe_saleh222@hotmail.com

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**Abstract:** This paper investigates the relationship between financial development and bio-energy consumption in the European Union (EU28) countries for the period from 1990 to 2013 through the panel autoregressive distributed lag (ARDL) approach and causality analysis. The empirical results show that financial development shows a significant positive impact, at a 1% statistical level, on bio-energy consumption for the EU28 during the studied period. In developing countries, the financial market indicator affects bio-energy consumption outgrowth positively and significantly at a 1% statistical level. For developed countries, there is a positive influence of financial institutions and financial market indicators on bio-energy consumption growth at the 1% and 10% levels, respectively. The study concludes that there is a significant relationship between the consumption of bio-energy and financial development factors. The study provides recommendations that are useful when formulating policy related to energy consumption and the promotion of bio-energy consumption. Financial development and economic outgrowth show a significant influence on the outgrowth of bio-energy consumption at a 1% statistical level.

**Keywords:** Financial institution; financial market; bio-energy consumption; autoregressive model

## 1. Introduction

In 2014, the European Union (EU-28) countries supported and funded two main projects to promote the bio-energy industry in the EU economy. The EU-28 granted $1.3 billion to 19 sustainable energy and environmental pollution mitigation initiatives [1]. Furthermore, the EU announced the start of a modern European cooperative agreement on bio-based industries (BBI), which is set to invest $4.2 billion into the bio-economy to encourage financing and investment, and promote a greener market with high competition. The plan is that the raw materials are extracted, processed, or manufactured within Europe. The funding will support 19 sustainable energy enterprises, and additional future investment will be sourced from the revenue.

Six bio-energy enterprises gained subsidies under the second allocation of funding in the EU. In Denmark, a bio-energy enterprise was granted subsidies of $45.1 million. The second and third bio-energy projects were established in Estonia and were awarded $7.93 and $28.7 million. The fourth project was in Latvia, and was given $4.48 million. The fifth bio-energy project was located in Spain and received $33.5 million. The final bio-energy project that was awarded funding was in Sweden, and they received $33.5 million in subsidies [2].

As per the European bio-energy report in 2010, the sale of $CO_2$ (carbon dioxide) allowance releases worldwide is becoming more critical in the fight against environmental pollution [3]. It is often forgotten that the allowance mechanism only takes into consideration greenhouse gas (GHG) releases and does not pertain to access and supply of green energy. The approach handles the result of trouble but does not deal with the source of the problem. The plan to decrease consumption of conventional energy and to switch to renewable green energy fixes the cause of troubles and leads to reductions in $CO_2$ emissions.

According to the AEBIOM (European Biomass Association) analyses in 2010, there are various obstacles to overcome in future bio-energy development related to regulations, legislation, and lobbying from energy companies. In 2010, AEBIOM highlighted multiple problems. One is converting the 300 Mtoe (million tonnes of oil equivalent) that the EU consumes to bio-energy by 2030. There is also concern about the disparity in access to renewable energy within the EU and how to effectively manage large-scale production. New financial development programs for the implementation of renewable energy allocated $11.5 billion to co-fund public projects that aim to amend the energy practices in housing and tertiary sectors from traditional energy to bio-energy [4].

Bio-energy outputs could be one of the leading solutions to avoid the European carbon emission tax and energy poverty [5]. Around 40% of the energy in the EU is consumed residentially or by the service industry, primarily in heating and cooling applications. Currently, about 90% of this heat consumption is sourced through conventional energy. Later, once the output cost of traditional energy products increases, this can lead to issues of energy shortages. There will no doubt be a lengthy period until the switch from fossil fuels to renewable energy is fully made [6]. The primary issue for the quick development of bio-energy products is the shortage of capital input and the lengthy payback period. This issue is further impacted by the inefficient use of EU funds used to encourage private enterprises to change their energy habits. The results could have been better considering that only 50% of the private companies successfully met the energy demand.

The European objectives for environmental pollution and energy shortages for 2030 are: a 40% decrease in $CO_2$ released compared to the 1990 amounts, a minimum 27% increase in green energy use and a minimum 27% decrease in conventional energy consumption compared with the 1990 levels. These goals assist the European countries to meet further competitiveness, access a renewable energy application and achieve their long period 2050 $CO_2$ mitigation aims. The plan shows serious action towards changing the energy market and motivating private business in a new green and environmentally friendly energy industry. The objectives are set considering economic estimations that validate how to achieve high-cost efficiency levels aligned with the low-carbon approach by the end of 2050. The price of attaining the goals does not vary from the cost paid to change the traditionally used energy applications. The initial monetary impact of low-carbon will be through switching the investments from conventional energy sources to the renewable and sustainable system [7].

Financial development can contribute significantly to boost the private sector and to change the energy system towards a more bio-based industry. In the heating sector only, one million Euros invested in the bio-energy industry creates 55,000 jobs per year. Moreover, 30 Mtoe of electricity output from bio-energy sources creates another 120,000 jobs [8]. The significance of EU subsidies, like the territorial subsidies or projects, might be restructured particularly to boost public projects for the modification of the energy applications in the small and medium enterprises because these enterprises will contribute towards transitioning to greener energy consumption in the EU. Financial development can help the private sector to decrease fossil fuel dependency and transition towards the bio-energy industry, which has the potential to create four times more jobs than the fossil fuel industry [8].

Bio-energy outputs are more useful and need lower capital inputs. Bio-energy can encourage all primary factors of EU region outgrowth, implicating economic development, energy developments, and access for energy production [9]. Therefore, aside from the many useful ecological effects, bio-energy may also give higher socio-economic benefits for EU countries. One more significant point is that carbon dioxide neutrality is beneficial in reducing environmental pollution. The question of this paper is: does financial development affect the consumption of bio-energy positively and significantly? This paper analyses the correlation between financial development and bio-energy consumption in developing members, developed members and the EU28 region from 1990 to 2013.

Section 1 provides an overview of the bio-energy consumption–financial development hypotheses along with a focus on the empirical literature of the causal relationship between bio-energy consumption and financial development. Section 2 discusses the data, material and methodology. Section 3 gives empirical results and presents the outcome of the results. Section 4 provides conclusions.

*Empirical Review*

The sustainable energy programs, intended to replace conventional energy sectors one day, are not only economically beneficial but also provide vital ecological impacts. An early study [10], investigated the correlation between renewable energy development and financial development during 1980 and 2008 in the top 55 global economies. The study found that renewable energy projects have obvious advantages, but there were many obstacles during the development of renewable energy projects, especially the lack of financial support. A previous article [5] explored the direct correlation among financial indicators, economic development and sustainable energy use in Russia from 1990 to 2014. One study [11] analysed the correlation between energy demand and financial indicators to determine different dimensions of the financial system that were used as indicators in seven newly industrialised countries from 1971 to 2010. Other papers [12,13] empirically examined the relationship between carbon emissions, energy consumption, trade openness and financial development in Pakistan for the period 1971–2011. The results reveal a bi-directional causality correlation between energy consumption and financial development. This current paper investigates the trade intensity of the bio-energy industry in the EU28 region and related economic determinants from 1990 through 2013 [14].

Prior research [15], examined the correlation between energy demand, economic outgrowth, related energy expenses, gross fixed capital formation and various fiscal variables (available local funds, debt obligations, local credit supplied by financial industry and local credit to small and medium enterprises) in the studied sample, which included Bangladesh, India, Nepal, Pakistan and Sri Lanka from 1975 through 2011. The results show that there is a significant relationship between energy consumption, economic growth, FDI (foreign direct investment) and financial development proxies [15]. A study [16] exploring financial development and energy consumption for Saudi Arabia using annual data for the period 1971 to 2011 explains that in the long term, financial factors improve energy consumption in Saudi Arabia. An earlier study [17] examined the correlation between economic outgrowth, energy demand, fiscal improvement, foreign commercial and GHG releases during 1975 and 2011 in the case of Indonesia. The same scholar [18] found an asymmetrical correlation between energy use and economic development by integrating financial variables, capital input and labour input into a Cobb–Douglas function in India for the period from 1960 to 2015.

In addition, the scholars [19–21] investigated, in the early paper, the correlation between energy consumption and economic outgrowth by examining financial variables, global commerce and physical inputs as significant determinants of the Cobb-Douglas function from 1971 through 2011 in China. The study indicated that financial development and energy use cause (Granger) each other. Previous studies [22,23] investigated the influence of financial factors on energy use in the Arab Gulf countries, specifically, Kuwait from 1980 to 2009. The paper explained that the financial factor is one of the determinants that raised energy use in the short and long term. In a different study [24], the same researcher estimated the effect of energy demand on the macroeconomic and financial indicators in more than 18 countries from 1980 and 2008. This sample was investigated due to the reason that the financial determinants significantly affect the GDP of the selected Arab countries. The findings showed that energy use leads to these states achieving significant economic growth and financial improvement. One paper [25] analysed the correlation between financial factors and energy demand in Asian countries from 1980–2012. The findings of the panel co-integration analysis showed that there was a long period equilibrium relationship among fiscal improvement and energy demand in Asian countries.

Another study [26] examined the long-term and short-term impacts of financial factors, economic outgrowth, export demand, import demand, capital input and energy consumption in Japan from

1970 and 2012. The findings of the study establish that in the long term, a 1% increase in the financial factor may add a significant limitation on the electricity demand by 0.24% in the case of Japan. In the short term, the paper found that a 1% increase in the financial factor led to higher pressure on electricity consumption which increased by 0.22% in the case of Japan. Another analysis [27] reported one important impact on energy demand when financial institutions and financial market elements were applied as financial variables in 53 countries from 1999 and 2008. The findings show that energy demand rises with financial improvement when financial institution factors are applied as financial determinants. Another case study [28] analysed the relation between fiscal factors and energy demand in Malaysia. Evidence suggests that financial development can reduce energy use by increasing energy efficiency. The paper explores the existence of a long run relationship among energy use, aggregate production, financial development and population in Malaysia.

Theoretically, many studies [29,30] applied various approaches to estimate the correlation between energy demand and financial outgrowth, such as panel ARDL analysis [31–33]. Several studies [12,13,15,16] used ARDL time series analysis to estimate the correlation among energy demand dependent variable and fiscal improvement indicators [17–19]. Different panel data methods were applied in various studies [15,27], such as pooled least square, the fixed effect model and the random effect model, to test the validity of the relationship between energy consumption and financial development indicators. The panel Granger causality test was used in various studies [5,22,23] to validate the correlation between energy outgrowth and financial improvement factors [24–26]. Previous studies [21,28] employed the vector error correction model (VECM), while earlier studies [13] employed techniques like the generalised method of moments (GMM) and ordinary least square (OLS) to estimate the correlation between renewable energy consumption and development of the financial system. Based on the theoretical and empirical reviewed papers, it appears that there is no previous study analysing the impact of fiscal improvement on bio-energy demand in the EU28 countries. In addition, no previous study has investigated the impact of financial development on bio-energy consumption in the EU between 1990 and 2013 using the ARDL approach. To address the knowledge gap in research, the current study uses the panel ARDL approach to estimate the relation between bio-energy consumption dependent variable and financial development indicators in the EU from 1990 to 2013.

## 2. Material and Methods

The current paper focuses on the period from 1990 and 2013 to investigate whether financial development indicators can play a main role in achieving the scheduled national renewable energy action plan (NREAP) 2020 and 2030 objectives of bioenergy consumption in the EU region. This research applies ARDL analysis to the cointegration method using Eview software (Eview9), STATA (STATA/SE 11.0), and SPSS (IBM SPSS Trials). The panel ARDL technique was selected to investigate the long-term and short-term cointegration correlations between the determinants and extract the ECM (error correction version) of the panel characteristics to identify the short-term dynamic. In addition, substitute cointegration methods were used to attain similar findings, as were the Johansen and Juselius [33] and conventional Johansen [34] methods. However, the panel autoregressive distributed lag method was preferred over cointegration because of the additional benefits it provides. Although the traditional cointegration approach assesses the long-term correlation within the system of equations in the context, the panel ARDL approach uses an individual briefed form of equation [35]. As per Equation (1), the panel ARDL approach could be used with the studied factors regardless of whether they were I(0), I(1), or both I(0) and I(1) [36]. In Equation (2), panel ARDL with various variables can include various lags, which are inapplicable using the standard cointegration test. Moreover, using panel ARDL, both long-term and short-term coefficients are provided at once [37,38]. Eventually, the ARDL approach could be applied with restricted sample data where the group of primary estimations were improved by [39]. In Equation (3), the famous production function of panel ARDL that ought to be analysed for the bounds test method is presented as the following [40]:

$$Y_{it} = \alpha_{it} + \beta_{it}' Xit + \varepsilon_{it} \quad (1)$$

$$Y_{it} = \alpha_{it} + \sum_{i=1}^{k} \delta_{ij} Y_{j,t-i} + \sum_{i=0}^{q} \beta_{it}' X_{j,t-i} + \varepsilon_{it} \quad (2)$$

$$\Delta \ln CON_{it} = \beta_1 + \sum_{i=1}^{k} a_{ij}\, \Delta \ln CON_{j,t-i} + \sum_{i=0}^{k} \beta_{ij}\, \Delta \ln GDP_{j,t-i} + \sum_{i=0}^{k} X_{ij} \Delta \ln CO_{2\, j,t-i} + \sum_{i=0}^{k} \delta_{ij} \Delta \ln FIN_{j,t-i} + \sum_{i=0}^{k} \vartheta_{ij}\, \Delta \ln CAP_{j,t-i} + \theta_1 \ln CON_{j,t-1} + \theta_2 \ln GDP_{j,t-1} + \theta_3 \ln CO_{2\, j,t-1} + \theta_4 \ln FIN_{j,t-1} + \theta_5 \ln CAP_{j,t-1} + \varepsilon_{jt} \quad (3)$$

In Equation (1), i = 1, . . . , n is the country index, t = 1, . . . , T is the time index and $\varepsilon_{it}$ a random disturbance term. Of course, the latter is not estimable with N = n × T data points. In Equation (2), some assumptions are usually made about the parameters, the errors and the exogeneity of the regressors, giving rise to a taxonomy of feasible models for panel data. In Equation (3), $\ln CON_{it}$ is bio-energy consumption in tonnes of oil equivalent (TOE), $\ln GDP_{it}$ is gross domestic product per capita, $\ln CO_{2\,it}$ is carbon dioxide per capita, $\ln FIN_{it}$ refers to domestic credit to private sector percentage of GDP (financial institution), and $\ln CAP_{it}$ points to domestic market capitalization percentage of GDP (financial market) (please see Table 1). Furthermore, t is time, i refers to the studied country, Δ is the 1st variation factor, and k is the ideal lag length. In this paper, financial development is decomposed into two variables; financial institutions and the financial market. This is done to recognise the effect of each financial decomposition on bio-energy consumption because both indicators influence the development of the bio-energy industry in the countries. These decompositions are less important with minor effects and involvements. Furthermore, significantly, the two indicators of financial development are used separately as independent variables to avoid the possibility of the multicollinearity issue and the reliance on less important factors with minor involvement, which may result in econometrically biased outcomes. To investigate the long-term cointegration correlation between the determinants, the below assumptions are formed:

$H_0$: $\theta_1 = \theta_2 = \theta_3 = \theta_4 = \theta_5 = 0$ (There is no cointegration).

$H_a$: $\theta_1 \neq \theta_2 \neq \theta_3 \neq \theta_4 \neq \theta_5 \neq 0$ (There is cointegration).

**Table 1.** Summary of Variables.

| Variable | Abbreviated | Data Source | Statistics | Unit |
|---|---|---|---|---|
| Bio-energy consumption | $\ln CON_{it}$ | Eurostat | Dependent Variable | Tonnes of oil equivalent (TOE) |
| Gross Domestic Product per capita | $\ln GDP_{it}$ | World Bank Datasets | Significant | Market prices (constant 2005) (billion €) |
| Carbon Dioxide per capita | $\ln CO_{2\,it}$ | Eurostat | Significant | Kilo Tonnes (KT) |
| Financial Institution | $\ln FIN_{it}$ | World Bank Datasets | Significant | % of GDP |
| Financial Market | $\ln CAP_{it}$ | | Significant | % of GDP |

The no cointegration assumption can be investigated and compared with the assumption of cointegration applying the F test, which does not have a typical allocation that relies on whether the factors involved in the model are fully I(0), fully I(1), or a combination of I(0) and I(1); the number of estimators; and either the model has a trend, intercept, or both. Keeping in mind the volume of the studied sample of this paper, which is relatively small, the analytical estimations developed by [41], which are established for the application of a small sample volume (>20). The test uses panel autoregressive distributed lag bounds, which relies on whether the factors are purely I(0), purely I(1), or a combination of I(0) and I(1). Two groups of main rates were computed; I(0) identified with lower restriction, and I(1) identified with higher restriction. If the F statistics surpass the I(1), we disapprove the null assumption and conclude that there is a cointegration correlation. If they result below the I(0), we cannot decline the null assumption, and if they result between the I(0) and I(1), a derivation cannot be generated properly. Anyhow, if a proof of a long-term correlation between the determinants results, the below long term and short term in Equations (4) and (5), the models will be estimated simultaneously:

$$\begin{aligned} \ln CON_{it} = \beta_2 + \sum_{i=1}^{k} \alpha_{i2} \ln CON_{j,t-i} + \sum_{i=0}^{k} \beta_{i2} \ln GDP_{j,t-i} + \sum_{i=0}^{k} X \\ {}_{i2} \ln CO_{2\ j,t-i} + \sum_{i=0}^{k} \delta_{i2} \ln FIN_{j,t-i} + \sum_{i=0}^{k} \vartheta_{i2} \ln CAP_{j,t-i} + \varepsilon_{it2} \end{aligned} \quad (4)$$

$$\begin{aligned} \Delta \ln CON_{it} = \beta_3 + \sum_{i=1}^{k} \alpha_{i3} \Delta \ln CON_{j,t-i} + \sum_{i=0}^{k} \beta_{i3} \Delta \ln GDP_{j,t-i} + \sum_{i=0}^{k} X_{i3} \Delta \ln CO_{2\ j,t-i} \\ + \sum_{i=0}^{k} \delta_{i3} \Delta \ln FIN_{j,t-i} + \sum_{i=0}^{k} \vartheta_{i3} \Delta \ln CAP_{j,t-i} + \gamma ECT_{j,t-i} + \varepsilon_{it3} \end{aligned} \quad (5)$$

The error correction term (ECT) is formed as above in Equation (6). The indicator $\gamma$ points to the coefficient of the ECT in Equation (5) and can validate the quickness of changes of the determinants for assemblage to equilibrium. Moreover, the coefficient gives input regarding the long-term correlation between the determinants in Equation (6). To finalize the analyses procedure, validation tests will be applied to evaluate the accuracy and sufficiency of the evaluations. The applied data were extracted from different sources: World Development Indicators and The World Bank database from between 1990 and 2013 (24 years), according to the available data. Where real gross domestic product per capita was employed to an economic growth indicator, private credit from financial companies (financial development) and market capitalization of domestic company (financial market) were used as two proxies for financial development, bio-energy consumption was used to proxy the bio-energy industry development, and $CO_2$ per capita was used to proxy $CO_2$ emission [42].

$$\begin{aligned} ECT_{j,t} = \ln CON_{it} - \beta_2 - \sum_{i=1}^{k} \alpha_{i2} \ln CON_{j,t-i} - \sum_{i=0}^{k} \beta_{i2} \ln GDP_{j,t-i} - \sum_{i=0}^{k} X_{i2} \ln CO_{2\ j,t-i} - \\ \sum_{i=0}^{k} \delta_{i2} \ln FIN_{j,t-i} - \sum_{i=0}^{k} \vartheta_{i2} \ln CAP_{j,t-i} \end{aligned} \quad (6)$$

## 3. Results and Discussion

The results in Table 2 reveal panel unit root validation for the European members (EU28) during the period 1990 to 2013. Panel unit root analyses provide different results related to the stabilisation level of the studied period. All outcomes indicate that the selected sample is stationary and statistically important at the 1% level in the first difference and difference levels. This refers to a stable correlation among the financial development indicators and bio-energy consumption. Thus, this study analysed the relationship between the financial development proxies in the panel cointegration test. Table 3 illustrates the panel co-integration method results for European Union members from 1990 through 2013. In regard to Table 3, five of the seven tests are statistically important at the 1% scale and uphold the co-integration relationship among lnCON, $\ln CO_2$, lnFIN, and lnCAP. In other words, there is a high possibility for a co-integration correlation among the fiscal improvement indexes and bio-energy consumption in the long-term. Model 1 shows the influence of various financial and economic factors on the bio-energy consumption in European Union members from 1990 to 2013 (Table 4). To be accurate, a 1% rise in lnGDP can boost bio-energy consumption in the European Union region by 1% as estimated by PMG (pool mean group).

**Table 2.** Panel unit root test results for the European Union region in 1990–2013.

| Variable | Difference | | First Difference | |
|---|---|---|---|---|
| | LLC | IPS | LLC | IPS |
| $lnCON$ | −5.499<br>(0.000) | −10.159 ***<br>(0.000) | −3.061 ***<br>(0.000) | −8.547 ***<br>(0.000) |
| $lnGDP$ | −9.313<br>(0.000) | −9.888<br>(0.000) | −11.206<br>(0.000) | −9.864<br>(0.000) |
| $lnCO_2$ | −8.378<br>(0.000) | −10.884<br>(0.000) | −8.611<br>(0.000) | −10.739<br>(0.000) |
| $lnFIN$ | −10.006 ***<br>(0.000) | −12.835 ***<br>(0.000) | −6.836 ***<br>(0.000) | −9.458 ***<br>(0.000) |
| $lnCAP$ | −4.837 ***<br>(0.000) | −14.705<br>(0.000) | −11.775 ***<br>(0.000) | −12.465<br>(0.000) |

- Remark: *** refer importance at the 1%, scale. - Levin, Lin & Chu test (LLC), and Im, Pesaran, and Shin W-stat test (IPS). - Values in parentheses are $p$-values.

**Table 3.** Panel Co-Integration Test Results for the European Union Region in 1990–2013.

| Dependent Variable: Bio-Energy Consumption | | |
|---|---|---|
| **Variables** | **Without Trend** | **With Trend** |
| Pedroni Residual Co-integration Test<br>Alternative hypothesis: common AR coefficients. (within dimension): | | |
| Panel v-Statistic | −0.530<br>(0.702) | −0.049<br>(0.519) |
| Panel rho-Statistic | 2.155<br>(0.984) | 2.796<br>(0.997) |
| Panel PP-Statistic | −3.735 ***<br>(0.000) | −3.028 ***<br>(0.001) |
| Panel ADF-Statistic | −6.241 ***<br>(0.000) | −5.711 ***<br>(0.000) |
| Alternative hypothesis: common AR coefficients. (between dimension): | | |
| Group rho-Statistic | 4.360 | 1.000 |
| Group PP-Statistic | −3.718 *** | (0.000) |
| Group ADF-Statistic | −5.170 *** | (0.000) |

- Remark: ***, ** and * refer importance at the 1%, 5%, and 10% scales respectively. - Values in parentheses are $p$-values.

**Table 4.** Summary of the panel regression model 1 for the European Union region during 1990–2013.

| Model 1. Panel Data Analysis Estimation for European Union Region 1990–2013 | | | | | | |
|---|---|---|---|---|---|---|
| **Variables** | **Panel PMG** | | **Panel MG** | | **Panel DFE** | |
| | **Coefficient** | **Probability** | **Coefficient** | **Probability** | **Coefficient** | **Probability** |
| $lnGDP$ | 1.018 *** | (0.000) | 0.138 | (0.945) | 1.119 *** | (0.000) |
| $lnCO_2$ | −1.022 *** | (0.000) | 0.438 | (0.818) | −1.104 ** | (0.044) |
| $lnFIN$ | 0.394 *** | (0.000) | 2.045 | (0.284) | 1.149 | (0.388) |
| $lnCAP$ | 0.103 *** | (0.000) | −0.089 | (0.741) | 0.050 | (0.558) |
| Hausman MG test | 6.19 (0.185) | | | | | |

- Remark: ***, ** and * refer importance at the 1%, 5%, and 10% scales respectively. - Values in parentheses are $p$-values.

Moreover, a 1% increase in lnFIN can support a 0.39% improvement in bio-energy consumption as estimated by PMG. Furthermore, a 1% decrease in $lnCO_2$ can lead to a 1% increase in bio-energy consumption in the EU-28 region. Finally, a 1% increase in lnCAP will drive a 10% rise in bio-energy consumption in the EU28 region as shown by PMG.

In the current study, the next test evaluates the short-term and long-term variables through the pooled mean group (PMG), mean group (MG), and dynamic or difference fixed effect (DFE) tests. In Table 3, Model 1 illustrates the findings for the European Union during the period between 1990 and 2013, applying various panel methods: PMG, MG and DFE. As the p-value of the Hausman test is statistically insignificant, the long-run PMG estimator is more appropriate. Based on the findings of the PMG estimator, the coefficients for lnGDP, lnFIN and lnCAP have positive relationships and are significant at the 1% statistical level with bio-energy consumption. The coefficient of the $lnCO_2$ findings has a negative relationship and is significant at a 1% statistical level with bio-energy consumption (see Table 4).

In Table 5, Model 2 explains the findings for developed members in the European Union using different estimators: PMG, MG and DFE. Since the p-value of the Hausman test is statistically significant at a 1% level, the short-run MG estimator is more suitable. The coefficient of lnGDP and lnCAP shows positive and significant correlations, at the levels of 1% and 10%, respectively, with the bio-energy consumption dependent variable. Model 2 shows the impact of different financial and economic factors on the bio-energy consumption in developed members of the European Union for the period between 1990 through 2013 (Table 5). To be accurate, a 1% increase in lnGDP can lead to 3% development in the bio-energy consumption in developed members of the European Union as estimated by MG. Furthermore, a 1% rise in lnCAP can cause a 0.24% improvement in the bio-energy consumption as estimated by MG.

**Table 5.** Summary of Panel Regression Model 2 for Developed Members during 1990–2013.

| **Model 2. Panel Data Analysis Estimation for Developed Members 1990–2013** | | | | | | |
|---|---|---|---|---|---|---|
| **Variables** | **Panel PMG** | | **Panel MG** | | **Panel DFE** | |
| | **Coefficient** | **Probability** | **Coefficient** | **Probability** | **Coefficient** | **Probability** |
| lnGDP | 3.137 *** | (0.000) | 3.464 *** | (0.000) | 8.808 | (0.120) |
| $lnCO_2$ | −5.458 *** | (0.000) | −2.228 | (0.185) | −0.929 | (0.682) |
| lnFIN | 0.112 | (0.646) | 1.173 | (0.558) | 0.437 | (0.638) |
| lnCAP | 0.118 | (0.236) | 0.242 * | (0.087) | 0.128 | 0.838) |
| Hausman | 13.72 | | | | | |
| MG test | (0.008) | | | | | |

- Remark: ***, ** and * indicate significance at the 1%, 5%, and 10% scales respectively. - Values in parentheses are *p*-values.

Model 3 illustrates the findings of developing members located in the European Union region between 1990 and 2013 (please see Table 6), applying various panel estimators: PMG, MG, and DFE. Since the p-value of the Hausman test is statistically insignificant, the long-run PMG estimator is more appropriate. The coefficient of $lnCO_2$ has a negative and statistically significant correlation with the bio-energy consumption at a 1% scale. The finding shows that lnFIN, lnCAP and lnGDP have positive and statistically significant correlations, at the 1% level, with bio-energy consumption in developing members of the European Union between 1990 and 2013 (please see Table 6). Model 3 analysed the effect of the financial determinants on the bio-energy consumption in developing members of the European Union between 1990 and 2013 (Table 6). Significantly, a 1% rise in lnGDP leads to a 1% rise in bio-energy consumption in developing members as shown by PMG. Also, a 1% enhancement in lnFIN can lead to a 0.38% enhancement in the bio-energy consumption as estimated by PMG. In addition, a 1% shortening in lnCAP causes a 0.10% rise in bio-energy consumption in developed members of the European Union as estimated by PMG. Finally, a 1% shortening in $lnCO_2$ leads to a 0.87% increase in bio-energy consumption in developing members as estimated by PMG.

**Table 6.** Summary of Panel Regression Model 3 for Developing Members during 1990–2013.

| **Model 3. Panel Data Analysis Estimation for Developing Members 1990–2013** | | | | | | |
|---|---|---|---|---|---|---|
| **Variables** | **Panel PMG** | | **Panel MG** | | **Panel DFE** | |
| | **Coefficient** | **Probability** | **Coefficient** | **Probability** | **Coefficient** | **Probability** |
| lnGDP | 1.053 *** | (0.000) | 1.144 *** | (0.000) | 0.805 *** | (0.002) |
| $\ln CO_2$ | −0.875*** | (0.000) | −0.194 | (0.845) | −1.025 | (0.106) |
| lnFIN | 0.389 *** | (0.000) | 0.135 | (0.631) | 0.032 | (0.852) |
| lnCAP | 0.107 *** | (0.000) | 0.142 | (0.144) | 0.120 | (0.162) |
| Hausman | 2.67 | | | | | |
| MG Test | (0.615) | | | | | |

- Remark: ***, ** and * refer importance at the 1%, 5%, and 10% scales respectively. - Values in parentheses are *p*-values.

Table 7 indicates the results of the heterogeneous panel causal direction investigation for the European Union region, developed members, and developing members in the European Union from 1990 through 2013. The results of the panel heterogeneous causality test were developed by an early study [43]. In regard to the causal direction test findings, there is a two-trend causal direction relationship in the European Union members among lnCON and $\ln CO_2$. There are one-trend causality correlations in the European Union members from lnCON to lnGDP, from lnCON to lnFIN, and from lnCON to lnCAP. In EU28 developed countries, there are one-trend causality relationships from lnCON to lnGDP, from lnCON to $\ln CO_2$, and from lnCON to lnFIN. In EU28 developing countries, there are one-trend causality relationships from lnGDP to lnCON, from lnCON to lnFIN, and from lnCON to lnCAP. Lastly, these results encourage growth, feedback, and naturalised assumptions between financial development and bio-energy consumption growth in the EU-28 from 1990 to 2013.

**Table 7.** Summary of panel causality analysis for the European Union region from 1990–2013.

| **Heterogeneous Panel Causality Analysis for European Union Region from 1990 through 2013** | | | | | | |
|---|---|---|---|---|---|---|
| **Variables** | **European Union Region** | | **Developed Members** | | **Developing Members** | |
| | **Wald stat** | **(Prob.)** | **Wald stat** | **(Prob.)** | **Wald stat** | **(Prob.)** |
| lnGDP→lnCON | 2.619 | (3.657) | 3.195 | (2.154) | 1.955 * | 0.075 |
| lnCON→lnGDP | 4.216 *** | (0.000) | 4.895 *** | (0.000) | 3.425 | 1.066 |
| $\ln CO_2$→lnCON | 2.006 *** | (0.005) | 1.635 | (0.235) | 1.575 | 0.328 |
| lnCON→$\ln CO_2$ | 7.265 *** | (0.000) | 8.800 *** | (0.000) | 3.758 | 2.088 |
| lnFIN→lnCON | 1.229 | (0.714) | 1.727 | (0.163) | 0.655 | 0.337 |
| lnCON→lnFIN | 2.243 *** | (0.000) | 2.278 *** | (0.008) | 2.203 ** | 0.021 |
| lnCAP→lnCON | 1.549 | (0.175) | 1.317 | (0.640) | 1.816 | 0.137 |
| lnCON→lnCAP | 1.776 ** | (0.039) | 1.034 | (0.861) | 2.632*** | 0.001 |

- Remark: ***, ** and * refer importance at the 1 %, 5 %, and 10 % scales respectively. - Values in parentheses are *p*-values.

The results in Models 1 and 3 show that the financial institution proxies have a positive and statistically significant relationship with bio-energy consumption at a 1% scale. This result is in line with previous studies [23–27], which show that analyses of financial institution coefficients are predicted to be positive and that the increase of financial institution development results in an increase in bio-energy consumption. In the long run, there are one-trend causality relationships between financial institutions and bio-energy consumption in the European Union region, developing members and developed members (Table 7). The model shows that the effect of lnGDP is positive and statistically significant at a 1% level in Models 1, 2, and 3. This is aligned with a previous study [17,43], where the coefficients of the lnGDP suggest importance and positive correlations result. In addition, a rise in lnGDP of the European Union members is predicted to develop bio-energy consumption. There is a one-trend causality relationship from bio-energy consumption to lnGDP in the European Union zone and developed members of the European Union (see Table 7). In addition, there is a one-trend causality relationship from lnGDP to bio-energy consumption in the developing members of the European Union (see Table 7).

The outcomes illustrate that the influence of the financial market index on the bio-energy consumption is positive and statistically important, at 1%, 10% and 1% scales, in Models 1, 2, 3, respectively. This is aligned with the previous study [28], where the financial market improvements affect energy use. Therefore, there is a positive linkage between energy use and fiscal market improvement. There is a one-trend causality relationship from bio-energy consumption to financial capital in the European Union zone and developing members of the European Union region (Table 7). The outcomes explain that the influence of ln$CO_2$ on the bio-energy consumption is negative and statistically important, at the 1% scales, in Models 1 and 3. This is aligned with past research [43], where renewable energy consumption mitigates $CO_2$ emissions. Therefore, there is a negative correlation between renewable energy consumption and $CO_2$ emissions. In the long-run, there is a two-trend causality relationship between $CO_2$ emission and bio-energy consumption in the EU-28 region. However, there is only one trend causality relationship from bio-energy consumption to $CO_2$ in the EU28 developed members (see Table 7). The limitation of the study is that there was not sufficient data available for the independent variables during the period between 2014 and 2018.

## 4. Conclusions

In recent decades, there has been an increase in problems related to energy production, environmental pollution and restricted access to the conventional energy approach, which have led to conversion from traditional energy to a green energy approach. Bio-energy output is the main source of sustainable energy nominated at the top of the list as the solution to achieve the national renewable energy action plan (NREAP) objectives by the end of 2030. In regard to the conclusions of the ARDL estimation in Models 1 and 3, there is a positive and important relationship between bio-energy consumption and dependent variables (economic growth and financial institutions and the financial market) in the EU-28 region. In contrast, there is a significant and negative relationship between $CO_2$ emission and bio-energy consumption in the European Union region and developing members of the European Union. In Model 2, developed countries show that there is a positive and significant relationship between bio-energy consumption and independent variables (economic growth and the financial market). Based on the findings of the causal direction estimation among lnGDP and bio-energy consumption, it is concluded that a one-trend assumption relationship from lnCON to lnGDP is suggested by the three studied models. Therefore, neutrality assumption is effective in the European Union region, and developed and developing members of the European Union. In regard to the findings of the causal direction estimation among financial institutions and bio-energy consumption, the authors concluded that a one-trend causal direction relationship is effective in the European Union region, and developing and developed members. Referring to the findings of the causal direction estimation among the financial market and bio-energy consumption, the authors concluded that a one-trend causal direction relationship is effective in the European Union region and developing members.

As for the correlation between the financial improvement index and economic outgrowth, the findings suggest that taking the panel causal direction analysis into consideration is highly significant. A positive impact of the financial institution does influence bio-energy consumption in the EU28 region and EU28 developing countries, but not in developed countries. In such conditions, it is recommended that the financial regulation committee in developed members of the European Union might give further attention to both the public financial institutions and listed private financial institutions to upgrade their investments in efficient bio-energy firms. From a political point of view, the authors highly recommend that the decision makers in developed members of the European Union wisely investigate the effective allocation of monetary resources considering different limitations of bio-energy consumption and business performance to maximise the positive output on bio-energy consumption outgrowth. This implicates that useful credits utilised by both the users and the investors will add to bio-energy consumption in the EU28 countries. EU28 region countries could benefit from a two-pronged policy to promote financial institution improvement in developed countries and continue the present system of financial institution improvement in developing countries.

On the other hand, a positive impact of the financial market does affect bio-energy consumption in the European Union region, and developed and developing members in the European Union. The underlying implication is that the existence of proper domestic investment and foreign direct investment (FDI) in the EU28 brings both superior technology and knowledge, which lead to well-developed and flexible financial markets. The emerging financial market in developing countries enhances participation by consumers and businesses, promotes economic activity, and boosts green energy consumption. Therefore, developed financial markets can increase investment through lending capital-input to the bio-energy section, and offering debt and equity financing to bio-energy enterprises. High motivation should be put into funding new bio-energy projects and investing in other renewable and eco–friendly energy efficiency approaches like long-term energy integration and high-efficiency resources. Nonfulfillment in the short term of the green energy requirements would not help achieve the two visions of the NREAP objectives by 2020 and 2030. It is possible that the economies could remain massively invested in conventional energy and experience the harmful results of high GHG releases. As a long-term aim, a financial improvement master plan would be the primary objective for an effective bio-energy infrastructure and would eventually lead to high efficiency rates in all bio-energy sectors.

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