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Determinants of Bioenergy Consumption in the European Continental Countries: Evidence from GMM Estimation

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ABSTRACT

This study contributes to the existing literature by examining bioenergy consumption and related factors in continental European countries (ECC). This study extends the current research through its focus on the ECC, which mainly consists of nationwide studies. This study analyses the determinants of bioenergy consumption in the ECC from 2005-2013, estimates its economic variables and evaluates the influence of each variable on bioenergy consumption and related significance level. A generalised method of moments estimator (GMM) was designed for ECC. The estimated models show that bioenergy capital input (CI) positively impacts bioenergy consumption. The most influential factor on use was the price of bioenergy (PR) followed by investment (INV), then gross domestic product (GDP). These results should be considered and used as a tool to develop legislation and policies that could benefit the bioenergy sector in ECC. The evidence shows that CI, INV, and PR have been the primary keys in improving bioenergy consumption in recent years in ECC countries. Thus, they have advanced the efficiency of bioenergy consumption.

Keywords: Bioenergy consumption, bioenergy price, capital input, gross domestic product, investment

INTRODUCTION

The World Bioenergy Association (WBA, 2014) identified Europe as a region with a high potential for growth in the bio-energy sector. The derived bio-energy from bio-waste and bio-mass sources could provide around 20% of the total energy in European countries by 2020, with 85% of the energy supplied by European counties and 15% imported from overseas. It is thought that green and sustainable energy sources could

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supply up to 45% of the EU's total energy by the end of 2030.

The consumption of bioenergy is one of the primary drivers of the European initiative to meet the aims of the National Renewable Energy Action Plan (NREAP) by the end of 2020 and to establish an accessible local renewable and sustainable energy framework (Burck et al., 2012; Geheeb, 2007; Jossart & Calderon, 2013). The bioenergy consumption in Europe can mitigate the need to import energy, regulate a dynamic trade balance, decrease fossil fuel prices, aid the development of urban areas, generate new jobs, develop knowledge and exploration, and reduce carbon output.

In 2014, the European Commission (EC) announced the new NREAP targets to be achieved by the end of 2030. The 2030 NREAP goals can play a significant role in developing European economies and increasing competition in the energy sector. If the goals are achieved, it will lower greenhouse gas (GHG) emissions by 40% compared to 1990 levels. The aims require an increase in renewable energy consumption of 27%, a reduction of fossil energy of 27%, and a 27% improvement in energy efficiency (Calderon et al., 2015; Scowcroft & Nies, 2011). This study aims to investigate the economic determinants of the bioenergy industry in continental European countries (developed and underdeveloped) during the period between 2005 and 2013.

An evaluation of the bioenergy consumption rates in European countries is essential for achieving the National Renewable Energy Action Plan (NREAP) goals by the end of 2020 (Snieskiene & Cibinskiene, 2015). Evidence shows that local demand for bioenergy output will increase from 59 Mtoe in 2005 to 135 Mtoe in 2020 due to domestic consumption (Susaeta et al., 2012). The major sectors with a high demand for bioenergy are the electricity sector which demands between 10000-kilo tonnes of oil equivalent (Ktoe) and 20000 Ktoe, and the transport sector, which requires between 14000 Ktoe and 28000 Ktoe (Clerici & Assayag, 2013). The growth in demand in the electricity sector between 2005 and 2020 was exceptionally high in Belgium, France, Germany, Italy, the Netherlands, Poland, and the UK, with predicted outgrowths of 900 Ktoe, 1500 Ktoe, 4200 Ktoe, 1700 Ktoe, 1400 Ktoe, 1200 Ktoe, and 2200 Ktoe, respectively (Junginger et al., 2011).

In Figure 1, the bio-energy output forecast supply of 0.435 Million GWh and import of 0.731 Million GWh for the EU-28 countries and by the end of 2006 was evaluated to provide approximately 1.167 Million GWh overall (Alsaleh et al., 2017). The bio-energy utilising forecast demand of 0.669 Million GWh and export but 0.628 Million GWh by the end of 2006 was estimated to be about 1.298 Million GWh in the EU-28 countries. The finding presents a shortfall in the bio-energy market by (-0.131) Million GWh in 2006.

The bio-energy output forecast supply of 0.660 Million GWh and import of 0.912 Million GWh in the EU-28 countries by the end of 2020 was foreseen to provide approximately 1.572 Million GWh overall

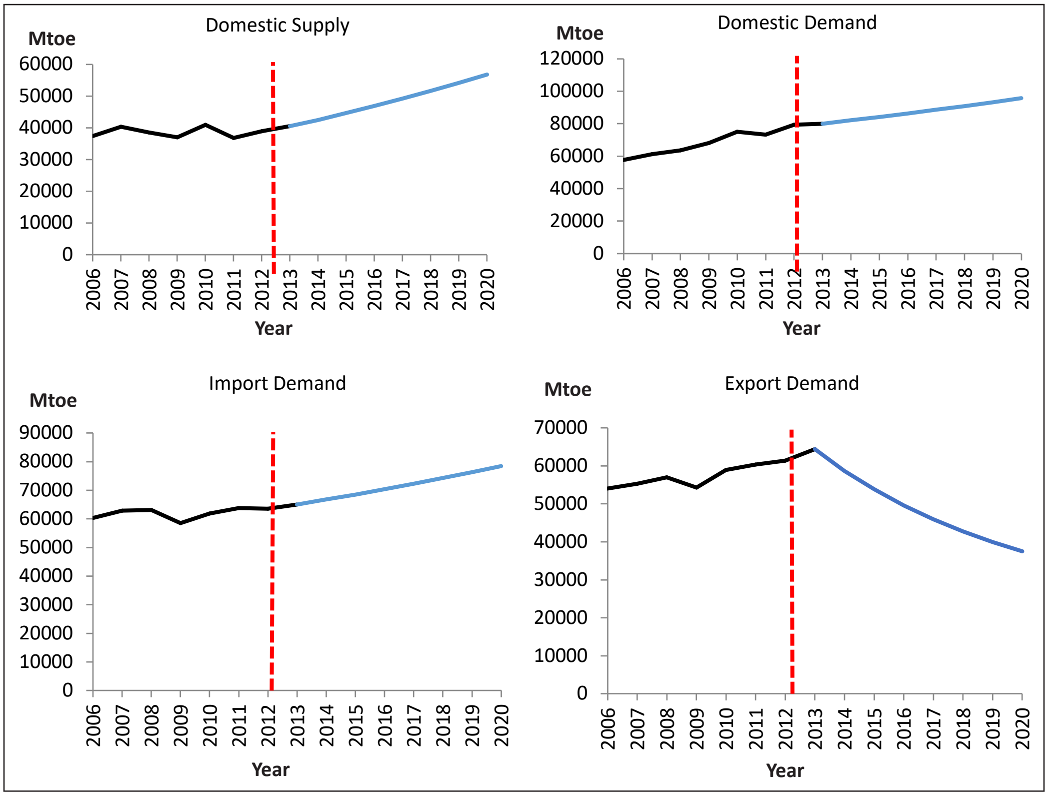

Figure 1. Forecasting results of domestic and international bioenergy markets in the EU28 region from 2014-2020

Notes. The black line referred to available data. The vertical line referred to the threshold between historical data and forecasted data.

(Figure 1). On the other hand, the bio-energy use forecast demand of 1.114 Million GWh and export of 0.436 Million GWh. By the end of 2020, demand is expected to be about 1.551 Million GWh overall. The finding presents that there will be a surplus of 0.021 Million GWh in the bio-energy market in the EU-28 region. The findings show that the bio-energy market in the EU-28 has developed from having a lack of (–0.131) Million GWh to attaining a surplus scale of 0.021 Million GWh by the end of 2020 (Alsaleh & Abdul-Rahim, 2019).

Figure 2 shows different comparisons related to the bio-energy industry development in developing members in comparison to developed members in the European region. The development level in developed members has improved sharply, unlike the development level in developing members, which has shortly increased in the European region from 2000 to 2013 (Alsaleh & Abdul-Rahim, 2019).

The significance of bioenergy consumption in European countries has been visible through reduced GHG emissions, reduced energy dependency on traditional sources, increased green GDP, and increased employment rates. Research by Calderon et al. (2015) shows that the number of

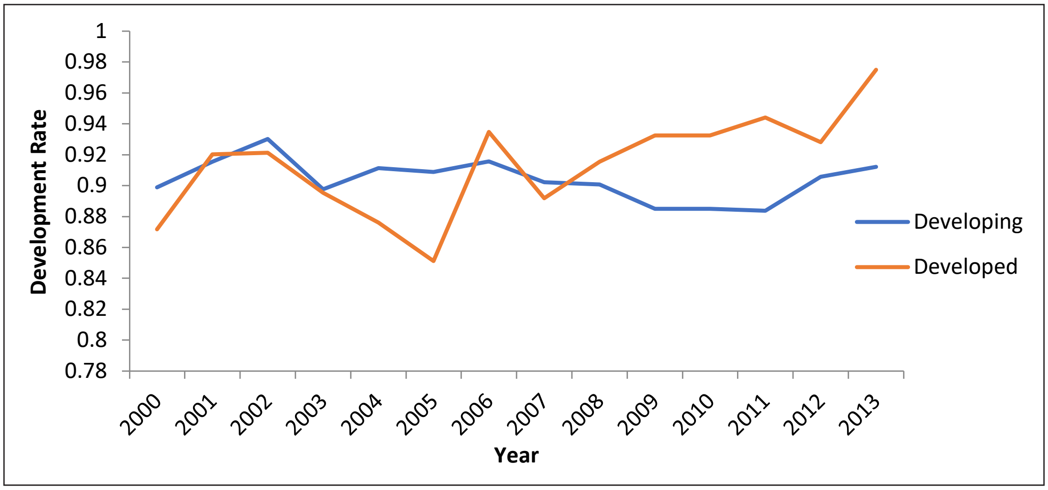

Figure 2. Comparisons of bioenergy industry development in developing and developed countries in European countries
Source: Alsaleh and Abdul-Rahim (2019)

vacancies in the European bioelectricity industry is three to six times higher than traditional energy production.

Based on the European biomass association statistical report, the number of people employed in the biomass industry in 2013 was 494.550 (64% solid biomass, 20% biofuels, 13% biogas, and 3% waste). The economic added value was 56 billion euros. The significance of this research is to define the consumption of bioenergy and pertaining factors that may influence the bio-energy sector growth and development in ECC. Moreover, to assess the economic variables and find the drivers, which could improve consumption rates of bioenergy and help meet the 2020 and 2030 NREAP objectives.

The bioenergy industry faces these problems: a shortage of industrialised fuel supply chains; a continued scepticism over whether bioenergy is a sustainable energy source in the long term; and the development and growth of the bioenergy industry have been low compared to the high rate of demand and consumption. However, so far, bioenergy consumption has not become a hugely significant part of the European energy combination. Moreover, it does not compete economically with other renewable energy outputs.

In this paper, there is an implicit assumption that economic determinants significantly influence bioenergy consumption in ECC. The price of bioenergy is assumed to be a significant factor in people's willingness to consume it. In addition, the researchers believe that capital input and investment significantly affect the consumption of bioenergy. Therefore, the primary questions of the research are the following: Do the ECC countries have adequate consumption of bioenergy output to achieve the 2020 and 2030 aims? What are the economic factors of the consumption of bioenergy output in ECC? This research analyses the macroeconomic and microeconomic drivers of bioenergy consumption in ECC.

The motivation of the current paper is that the bioenergy industry shows one of the most capital-efficient transitions from a conventional energy source like coal to green energy sources. In 2011, European countries consumed more than 850 thousand gigawatt-hours of electricity from solid fossil fuels such as coal and lignite, which accounted for about 25% of total energy consumption (Albani et al., 2014). Therefore, minimising the share of coal-fired output production is an essential part of any decarburisation plan. Biomass co-firing and coal-to-biomass are two powerful strategies that show the capability to utilise current coal factories to produce bioenergy products. These strategies could help European countries save billions of euros and produce competitive output in the energy markets. Unlike other renewable and sustainable energy sources.

This research contributes to the empirical bio-energy research in the following ways: (1) applying various panel data analysis estimations with different validation tests to evaluate the data, (2) check the rate of the bio-energy consumption during the period between 2005 through 2013, (3) investigate the macroeconomic and microeconomic determinants of the bio-energy output consumption in the ECC members. The authors' outcomes elaborate on the correlation among economic drivers and the bio-energy consumption in ECC between 2005 and 2013. Furthermore, the authors' empirical proof shows different analysis outcomes according to the country's development status, developing or developed (Appendix A).

Renewable energy is one of the main factors that significantly impact economic development and growth in the world. Previous work by Lin et al. (2014) examined the relationship between renewable energy consumption and economic growth in China between 1977 and 2011. The study affirmed a statistical, positive, and vital correlation between renewable energy consumption and economic growth in China (Lin et al., 2014). Another study by Bhattacharya et al. (2015) analysed the relationship between renewable energy consumption and economic growth in 38 countries between 1991 and 2012. The study found a significant positive correlation between sustainable energy use and economic output for 57% of the selected 38 members.

Bioenergy is one of the primary sources of the renewable energy industry, according to earlier researches (Dam et al., 2009; Khishtandar et al., 2016; Meyer et al., 2013; Mehrara et al., 2015; Nybakk & Lunnan, 2013; Raitano et al., 2017; Tye et al., 2011). Moreover, Chang et al. (2003) and Hu and Wang (2005) reviewed the consumption level of biomass energy in China over the past three decades. They found an enormous growth potential for biomass energy in China. Also, Arodudu et al. (2016) and Meyer and Priess (2014) studied the influence of the bio-energy sector with different criteria. The study found that improvements in decision-making and the administrative aspects of the bio-energy sector may boost economic growth and satisfy the public demand for more green energy.

Bio-wood fuel extracted from forests is one of the essential sources of biomass in European countries. A previous study by Andersen (2016) primarily refers to bio-wood fuels traded worldwide. The European Union market is the largest global producer and consumer of biomass output. In 2013, European Union members consumed 85% of all biomass production from the forestry industry.

The European Union`s use of biomass is rising quicker than the rate of manufacturing. Also, the European Union biomass imports rose from below 0.0018 billion tonnes in 2009 (BT) to over 0.0045 BT in 2012, and then over 0.006 BT in 2013, respectively. As a result, the EU bio-energy sector consumed around 0.0019 BT of biomass outputs in 2013. The traded volume of biomass outputs worldwide is forecasted to increase significantly. Presently, the European Union imports most of the consumed bio-wood fuels from countries like the United States, Canada, and Russia (Andersen, 2016).

The shortage of production in bioenergy retail can harm the trade equilibrium of bio-energy. For example, Tromborg et al. (2013) stated that the local bioenergy production from the biomass forestry natural sources in Sweden was about 0.0014 BT, while domestic demand for bioenergy from the biomass sources was evaluated at 0.0017 BT. Therefore, around 400,000 tons of biomass from natural forestry sources were imported to fill the gap between domestic consumption and bioenergy output.

Furthermore, in 2007, Tromborg et al. (2013) found that biomass production from natural forestry sources was about 330 thousand tonnes in Finland. On the other hand, that demand was about 117 thousand tonnes. This difference shows that their output rate is significantly higher than the level of demand. In contrast to Sweden, allows for the exportation of biomass rather than importation.

Numerous studies, Hara et al. (2015), Levy and Belaid (2017), Mahalik et al. (2016), Salim et al. (2017), and Samuel et al. (2013), analysed the main determinants of energy consumption in the residential sectors around the world. On the other hand, the aim of the studies by Azam et al. (2015), Bamiro and Ogunjobi (2015), Brien and Torugsa (2011), Johnson (2016), and Tewathia (2014) is to identify the significant factors of energy consumption by taking into consideration various hypothetical obstacles related to energy consumption. Also, to analyse and compare energy consumption patterns in different countries like Japan, Nigeria, India, Greece, and China. Furthermore, to identify the significant factors that influence energy consumption and energy-saving initiatives.

Renewable and sustainable energy is a central part of the transition to a low carbon economic approach. Zhang et al. (2014) investigated the factors influencing renewable consumption. Specifically, in earlier studies, Lin et al. (2015) and Mehrara et al. (2015), the factors that influence the total renewable consumption were investigated using different data terms and econometric techniques.

The findings indicate a long-term correlation between the consumption of renewable energy and gross domestic product (GDP) per capita, a low trade openness ratio, the rate of foreign direct investment, financial development, and fossil energy consumption. Economic growth and business improvement encourage the use of renewable energy. At the same time, foreign direct investment, a low trade openness ratio, and fossil fuel lobbying activities are detrimental to renewable energy consumption.

Based on the research of Omri and Nguyen (2014), the impact of shock economic factors seems to dissipate with time. In contrast, the impact of lobbying is continuous and volatile. The finds also state a unidirectional short-term direct causality from a share of financial development to renewable energy consumption and from the use of renewable energy to the openness of trade.

According to previous work by Omri and Nguyen (2014), high economic development leads to a high rate of renewable energy consumption. People in those countries are more concerned with combating the effects of climate change and environmental degradation. Therefore, governments should implement policies that encourage renewable energy production and promote more comprehensive economic development to increase renewable energy use.

Unlike previous studies, this research examines the bioenergy consumption level in European Continental Countries (ECC). Furthermore, a regression estimation was used to analyse the influences of different economic factors on the consumption of bioenergy output in ECC. The present research concentrates on the European Continental Countries, taking into consideration varying levels of development, to investigate the rate of bioenergy consumption in the selected samples. Two different estimators were applied, GMM different and GMM system, with varying levels of robustness to check the validity of the used econometric method for the period between 2005 and 2013. No previous research used the same approach, countries, or themes as in the current study. Thus, this research is related to the development of the bio-energy sector, particularly the green energy sector. It also correlates to and expands upon previous studies.

MATERIALS AND METHOD

Regarding the panel nature of the study data, this section reviews different panel regression approaches to evaluate various econometric models. There are numerous approaches to panel regression that have been applied in these studies. However, this study has to justify the most appropriate and applicable approach. For example, the wood fuel consumption of Sub-Saharan African countries was measure in an early study by Sulaiman et al. (2017). The study applied the generalised method of moment (GMM) different and system approaches. The same author, Sulaiman et al. (2016), explored another study on the relation between wood fuel consumption and growth economies in Sub-Saharan African countries. The used the generalized method of moments system approach (GMM) and Arellano Bond Dynamic Panel GMM estimators (Mileva, 2007; Yuxiang & Chen, 2009).

Numerous studies investigated the determinants of consumption in different renewable energy industries such as bioenergy by using various econometric methods. For instance, Zhang et al. (2013, 2014) investigated the determinants of bioenergy consumption in rural China by applying different econometric regression techniques like OLS regression, Logit, and Tobit. Other studies (Bamiro & Ogunjobi, 2015); Johnson, 2016) follow the same econometric approach OLS and Multinomial Logit Regression to analyse structural determinants of energy consumption in Togo and Nigeria, respectively. Previous studies (Azam et al., 2015; Lin et al., 2015) estimated the determinants of energy and renewable energy consumption in Greece and China, respectively. The studies applied the vector error correction model (VECM) approach to carry out the regression.

Previous studies have shown that auto-regressive distributed lag (ARDL) is one of the most applied econometric methods to estimate energy consumption in China and Saudi Arabia. It was used by Mahalik et al. (2016) and Salim et al. (2017). Otherwise, different econometric approaches like the Bayesian model averaging and weighted-average least-square were applied by Mehrara et al. (2015) to investigate the determinants of renewable energy consumption among Economic Cooperation Organization (ECO) countries. Also, a study by Salim et al. (2017) estimated the impacts of human capital on energy consumption in three provinces in China by applying different econometric estimators; fully modified oriented least square (FMOLS), dummy oriented least square (DOLS), mean group (MG), dynamic fixed effect (DFE) and pooled mean group (PMG).

The dependent variable is bioenergy consumption (CON), defined as the available energy output for final per capita consumption. The experiential formation for the current research is based on past research by Omri and Nguyen (2014), where bioenergy consumption is assumed to be determined by economic variables. The correlation among these factors and bioenergy consumption is elaborated as:

$$CON = f(GDP, INV, PR, CI) \qquad (1)$$

CON is bioenergy consumption presented in a tonne of oil equivalent (toe). It is an equation of four factors: GDP, representing the gross domestic product level and shows annual economic growth, INV represents the investment which reflects the capital formation (constant 2010 $), PR points to the domestic price of the available bioenergy output in USD Dollar, and CI refers to other factors related to capital inputs that influence bioenergy consumption (See Appendix B). For example, access to the financial development of the bioenergy industry.

Based on an earlier paper, the economic model of Omri and Nguyen (2014) was adapted by replacing renewable energy consumption as a dependent variable with bioenergy consumption. Converting the dynamic correlation in Equation 1 into panel framework and framing it in an econometric model, Equation 2 is presented as:

$$\mathrm{CON_{it}} = \alpha_{\mathrm{it}} + \delta_{\mathrm{it}}\,\mathrm{lnGDP_{it}} + \beta_{\mathrm{it}}\,\mathrm{lnINV_{it}} + \theta_{\mathrm{it}}\,\mathrm{lnPR_{it}} + \vartheta_{\mathrm{it}}\,\mathrm{lnCI_{it}} + \epsilon_{\mathrm{it}} \quad (2)$$

Where α is the constant of the model, ϵ is the error term, and i refers to every individual county in the study, t points to the running period in the econometric model, ln indicates the natural logarithm. We estimate these relationships based on a dynamic panel data model using the generalised system method of moments. This approach allows one to solve three main problems in panel data estimations: the endogeneity problem, the time-invariant country characteristics or fixed effects, and the presence of the lagged dependent variable.

Consequently, our econometric model can be framed, as shown in Equation (3). Where $\mathrm{CON_{it}}$ stands for the country`s i bioenergy consumption at time t. α_0 is the parameter to be estimated. X is a vector of core explanatory variables used to model bioenergy consumption. They include the GDP, INV, PR, and CI. μ is the country-specific effects. ε is the error term.

$$\mathrm{CON_{it}} = \alpha_0 CON_{it-1} + \sum_{j=1}^{4} \beta X_{\mathrm{it}} + \mu_{\mathrm{it}} + \epsilon_{\mathrm{it}} \quad (3)$$

$i = 1, \ldots, 50; \quad t = 2005, \ldots, 2013$

According to the essence of the data panel of the current research, the study selects a panel regression technique to estimate this study model. There are numerous econometric panel estimators available. First, however, a solid justification must be given regarding the most appropriate applied econometrics technique. Various panel regression models such as random effect, fixed effects, and pooled oriented least-square would not provide proper results in the existence of dummy variables and lagged dependent variables.

Moreover, in the presence of possible endogeneity in the independent determinants, these econometric techniques are invalid. In this case, the endogeneity comes from an uncontrolled confounding variable. This variable correlates with both the independent variable in the model and with the error term.

The estimated coefficients from these techniques will be biased with the hypothesis of sequent unlinked disruption period (Ibrahim & Law, 2014). In these circumstances, these techniques are inappropriate for the regression of this study because of the weaknesses mentioned.

These statistical issues can be defeated based on one study by Arellano and Bond (1991). They established an econometric technique called the GMM. The model manages the influences of country time-invariant, time-specific, and country-specific by employing the first difference. Arellano and Bond (1991) highly recommended the first differencing approach because it uses instrumental determinants, and the exogenous factors may perform as specialised tools.

Also, the differenced lagged of the dependent factor and other endogenous factors might be fixed, with their lags in rates, lagged 2, or further terms. This estimation is named the first difference GMM validator. Referring to Ahn and Schmidt (1995), the primary deficiency of the first difference the GMM approach is that it neglects the possible information in the level correlation, and the relationship among the first difference estimator and the levels estimator.

Furthermore, Blundell and Bond (1998) referred to the limitations of the first difference GMM approach. They stated that it could impact the validity of the applied regress. Also, they can be weak instruments in the first difference if the level determinants show stability. Arellano and Bover (1995) point out that regressing level and first difference as a GMM system method can address this weakness and limitations. According to Blundell and Bond (1998), the GMM system approach develops from the first difference GMM. It is more suitable when the time series is short, or the dependent factor is highly aligned with the autoregressive term nearing unity. Regarding the highlighted econometric points, the current research implements the GMM difference and system approaches. The first difference of the GMM approach was also applied as a validation test inspector.

According to earlier studies by Arellano and Bover (1995), the validity and reliability of the GMM approach are evaluated using various diagnostic checks related to Hansen`s diagnostic check for over defining weakness and the second-order serial relationship. Hansen`s diagnostic test investigates the overall reliability of the instruments in the regressed analysis. On the other hand, second-order serial correlation estimators can be applied to investigate the hypothesis not related to the serial correlation in the error term.

RESULTS

Before regressing the primary model, illustrative statistics and the relationship matrix were applied as preliminary tests. Table 1 elaborates the findings of the illustrative statistics and includes figures related to maximum, minimum, standard deviation, mean, and observations values, overall the studied sample and between the investigated samples for different countries.

Table 1
Illustrative statistics

Variable	Observations	Mean	Std. Dev.	Min	Max
CON	249	-0.000	0.239	-1.300	1.068
GDP	250	-9.716	1.010	-11.857	-7.327
INV	250	-2.417	3.985	-6.597	20.700
PR	250	1.774	2.068	-3.999	6.979
CI	250	-4.870	2.590	-9.324	1.203

The findings show interesting differences within countries and between countries. The results rationalise the implementation of the panel regression approach.

Table 2 presents the relation matrix among the independent determinants in the current study. The findings show there is no evidence for a high relationship between bioenergy consumption and the economic determinants. Therefore, this study can proceed with the estimation. For other determinants, the scale of relationship is acceptable between and within the used variables. Essentially, this analysis can be considered a safe estimation that is free from problems of multicollinearity.

Table 2
Correlation matrix

	GDP	INV	PR	CI
GDP	1.000			
INV	0.252	1.000		
PR	0.045	0.028	1.000	
CI	0.256	0.776	0.021	1.000

Tables 3, 4 and 5, show the findings of the regressed econometric model applying GMM system estimator and GMM difference estimator with bioenergy consumption in ECC as the dependent factor. The identification tests were applied to check the validity and appropriateness of the two GMM approaches. For example, the Hansen-J estimator could not decline the over-defining limits, nor could the Diff-in-Hansen estimator decline the additional tools needed for GMM regression. These specifications tests emphasise the reliability and appropriateness of the used tools.

Likewise, the serial correlation estimator declines the null hypothesis related to no autocorrelation of first-order and confirms the invalid assumption related to no autocorrelation of second-order. As a result, the residues of the regressed model may not include autocorrelation issues. Essentially, the lagged dependent factor shows a significant and positive correlation; this refers to the functional of the applied econometric approach.

Table 3
Estimated results of the panel GMM with the bioenergy consumption in the ECC

	System GMM	Difference GMM
	Coefficients	Coefficients
GDP	0.000 (0.904)	0.002 (0.608)
INV	0.000 (0.279)	0.007 (0.652)
PR	-0.006** (0.038)	-0.000 (0.981)
CI	0.001 (0.648)	0.009 (0.138)
Instruments	9	11
No of groups	50	50
AR2: p-value	0.155	0.495
Hansen J-test	0.233	0.244
Diff-in-Hansen test	0.672	0.224

Notes: ***indicates significant at 1%, **indicates significant at 5%, *indicates significant at 10%. Parenthesis are the standard errors.

Table 4
Estimated results of the panel GMM with the bioenergy intensity in the ECC developing countries

	System GMM	Difference GMM
	Coefficients	Coefficients
GDP	0.014 (0.381)	0.002 (0.336)
INV	0.007** (0.019)	0.007 (0.620)
PR	- 0.003 (0.488)	-0.000 (0.731)
CI	0.019** (0.023)	0.007 (0.175)
Instruments	8	11
No of groups	32	32
AR2: p-value	0.630	0.455
Hansen J-test	0.657	0.978
Diff-in-Hansen test	0.245	0.118

Notes: ***indicates significant at 1%, **indicates significant at 5%, *indicates significant at 10%. Parenthesis are the standard errors.

As per the previous statement in the method section, this paper's estimation of will mainly consider the GMM system approach findings. Also, the GMM difference approach outcomes are employed as a validation test.

This research provides justifications for the GMM system and difference findings and the coefficients of the independent determinants such as investment (INV) in ECC developing (Table 4) and ECC developed countries (Table 5); bioenergy price (PR) in ECC overall (Table 3) and ECC developed countries (Table 5); and capital input (CI) in ECC developing (Table 4) and ECC developed countries (Table 5).

Importantly, the findings coefficient of the lagged dependent factor shows a significant and positive correlation, which approves the functional quality of the applied econometric analysis leading to justify the implementation of a GMM approach. The estimated findings in Table 3 follow earlier expectations that bioenergy consumption rate increase with the increase of GDP, INV, and CI, and rates in ECC. Also, bioenergy consumption levels increase with the decrease of PR in ECC. The two GMM regressors show that an increase in GDP, INV and CI, and rates in ECC are strongly linked with increased bioenergy consumption. The estimated coefficient of bioenergy consumption in the GMM system regress suggests that a decrease of approximately 0.6% in PR can increase the bioenergy consumption by 1%.

Table 4 contains the results showing the economic determinants' influence on the dependent variable bio-energy consumption in ECC developing countries. The specification checks' outcomes for both system and difference GMM regressors favoured the analysed findings. The result of the coefficient related to the lagged dependent factor shows a significant positive relationship. The findings also show that INV and CI have a significant positive correlation as predicted. The GMM system approach shows that an increase of 0.07% and 0.01% in INV and CI, respectively,

Table 5
Estimated results of the panel GMM with the bioenergy consumption in the ECC developed countries

	System GMM	Difference GMM
	Coefficients	Coefficients
GDP	0.020 (0.209)	0.067 (0.649)
INV	0.003 (0.353)	0.052* (0.059)
PR	-0.008*** (0.002)	-0.001 (0.787)
CI	0.007*** (0.004)	0.045*** (0.005)
Instruments	9	11
No of groups	18	18
AR2: p-value	0.260	0.685
Hansen J-test	0.476	0.661
Diff-in-Hansen test	0.391	0.442

Notes: ***indicates significant at 1%, **indicates significant at 5%, *indicates significant at 10%. Parenthesis are the standard errors.

can lead to a 1% increase in bioenergy consumption.

Thus, the determinants INV and CI have a positive and vital impact on bioenergy consumption in ECC developing countries. The regressed coefficients of independent determinants provided by the GMM system provide somewhat similar findings compared to the coefficients of independent determinants presented by the GMM difference approach. The robust estimator GMM difference shows that increases in GDP, INV, and CI increase the consumption of bioenergy output.

However, the coefficients of the GDP, INV and CI, remain similar in both the GMM difference and GMM system. Therefore, the results obtained from the GMM difference estimator are considered to be a robust test. Furthermore, the estimated coefficient of bioenergy PR in GMM difference and GMM system regress suggests that a decrease in PR increases in bioenergy consumption.

From Table 5, the GMM system and GMM difference results depict that CI positively and significantly impacts bioenergy consumption in ECC developed countries. To be precise, the increase of 0.7% in CI, as shown by the GMM system estimator can increase bioenergy consumption by 1%. On the other hand, the finding of Table 5 shows that PR has a negative and significant impact on bioenergy consumption in ECC-developed countries. To be specific, the decrease of 0.7% in PR as shown by the GMM system estimator, can increase bioenergy consumption by 1%.

This result indicates that the impact of INV and PR bioenergy consumption in ECC developed countries is higher than that of ECC developing countries. The regressors GMM shows that an increase in the economic determinant INV and CI by 0.05% and 0.04%, respectively, can increase the consumption of the bioenergy industry by 1% in the developed countries model. It is essential to highlight that the three investigated models in Table 3, Table 4, and Table 5 succeeded in the applied specification tests.

DISCUSSION

Bioenergy consumption is defined as per unit capita in previous studies (Lin et al., 2014; Mahalik et al., 2016; Omri & Nguyen, 2014).Tt is the most widely used measurement of socio-economic development. High bioenergy consumption indicates a significant improvement in the sustainable energy industry in the region. In comparison, nominal use of bioenergy shows a lower sustainability level of the energy industry in the area. Furthermore, substantial bioenergy consumption means higher civilisation in society. In contrast, areas with low bioenergy consumption represent limitations or a lack of development in the socio-economic-political sphere.

Following a previous study by Omri and Nguyen (2014), determinant PR is assumed to be the primary explanatory variable. Table 3 evaluated the findings of the panel GMM system with the bioenergy consumption in the ECC, and the findings reveal that PR has a significant negative influence on bioenergy consumption at the statistical level of 5%.

Table 4 estimation results explain that PR has a negative impact on bioenergy consumption. Also, the study results showed in Table 5 illustrating that the PR independent variable has a negative and significant effect on bioenergy consumption at the 1% statistical level.

In line with research by Mehrara et al. (2015), Table 4 shows the impact of economic factors on bio-energy consumption in the ECC developing members applying the panel GMM system approach. The findings show that the INV determinant has a significant positive impact on bioenergy consumption in ECC developing countries at the statistical level of 5%. Furthermore, Table 3 shows that INV positively correlates with bioenergy consumption level in the ECC countries using the panel GMM system approach. Finally, Table 5 shows that the INV variable positively relates to bioenergy consumption level in the ECC developed countries.

In line with an earlier study by Lin et al. (2014), Table 5 reveals the influence of economic factors on the bio-energy consumption level in the ECC developed countries using the panel GMM system estimator. Table 5 results indicate that the CI variable has a significant positive impact on the consumption level of bioenergy in developed countries at a statistical level of 1%. On the other hand, the finding of Table 4 indicates that the CI variable has a significant favourable influence on the consumption level of bioenergy in developing countries at the statistical level of 5%. However, Table 3 shows a positive relationship between the CI and bioenergy consumption in EEC countries.

The following explanatory variable is GDP, which plays a large part in increasing bioenergy consumption and improving the bioenergy industry (Alsaleh et al., 2016). To meet the scheduled NREAP targets by the end of 2030, European governments implemented an economic stimulus policy that led to the rapid development in the bioenergy industry. As a result, many large projects related to bioenergy development were implemented to increase production. Also, the rapid increase in GDP can add value and lead to significant increases in bioenergy production. In line with previous studies (Azam et al., 2015; Samuel et al., 2013), which highlighted the impact of GDP determinant on renewable energy consumption, Table 4 and Table 5 showed that the GDP determinant has a positive effect on the consumption of bioenergy.

CONCLUSION

This research investigates the determinants that influenced the bioenergy industry and the bioenergy consumption in the European Continental Countries between 2005 and 2013. In the first section of this research, the economic drivers of bioenergy consumption are investigated. The GMM approach succeeds in determining the economic factors that affect bioenergy consumption in the developing and developed members of the ECC. Next, the impact of factors like GDP, investment, price, and capital input on bioenergy consumption is investigated.

In the case of GDP, there is no substantial impact on aggregate bioenergy consumption. However, a strong GDP influences the efficacy of the bio-energy sector (Alsaleh et al., 2016). Considering the development and competition between ECC countries, attention to bioenergy storage will significantly be restricted through a bioenergy efficiency approach with limited interest in the need to reduce bioenergy use with amendments in consumption and production methods. Therefore, the venture is that the gains in bioenergy efficiency are stabilised by raising consumption (the so-called Jevon's Effect). This effect will resume as long as consumption approaches are not seriously considered and economic development takes precedence.

It was established that INV and CI positively influence on the consumption of bioenergy output in developing countries and developed countries in ECC (Tables 4 and 5). The most significant influence on bioenergy consumption, was CI in all terms of solidity and explanatory power. At the same time, the economic variable that had a lower significance than was estimated was INV. The findings suggest that PR should be used as a valuable tool to develop the bioenergy industry and increase adoption, particularly in ECC.

The results from the study give objective regulation and policy recommendations for increasing the efficacy of bioenergy consumption in the ECC. However, decision-makers should consider a combination or framework of policies rather than individual policies in isolation. Sustainable bioenergy resources can improve efficiency by maximising greenhouse gas reduction, optimising bioenergy contribution to the security of energy supply, avoiding competition with food, feed, and fibre, and applying performance-based incentives for bioenergy proportional to the benefits delivered and demonstrated.

The evidence shows that CI, INV, and PR have been the primary keys in increasing bioenergy consumption in recent years in ECC countries. It is because they have advanced the efficiency of bioenergy consumption. Countries with less-developed bioenergy sectors should adopt the most successful strategies from other countries to expand their bioenergy industries. Many pieces of research about the macroeconomic and microeconomic determinants of bioenergy consumption have specific restrictions and obstacles that should be considered. The primary limitation of the data availability of bioenergy consumption studies in an empirical analysis relies on a persistence time series for an acceptable long term. Also, more complete data allows for more efficient and functional measurement of bioenergy consumption.

Identifying the economic variables that influence bioenergy consumption adds to the knowledge about the topic, which is a highly significant index of sustainable improvement. Bioenergy consumption increment is happening surprisingly quickly, but not fast enough to meet the world's bioenergy challenges. Significant consumption increases of around 20-27% are expected between 2020 and 2030. However, because of expected rapid economic growth, these improvements in bioenergy consumption will not stop the growth and development of the bioenergy industry, with its associated benefits to the environment and the stability of the world economy.

COMPLIANCE WITH ETHICAL STANDARDS

Conflict of interest: The authors declare that they have no conflict of interest.

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APPENDICES

Appendix A

List of the European Continental countries

European Continental Countries			
Country	**Status**	**Country**	**Status**
Albania	Developing	Austria	Developed
Andorra	Developing	Belgium	Developed
Armenia	Developing	Denmark	Developed
Azerbaijan	Developing	Finland	Developed
Belarus	Developing	France	Developed
Bosnia & Herzegovina	Developing	Germany	Developed
Bulgaria	Developing	Greece	Developed
Croatia	Developing	Iceland	Developed
Cyprus	Developing	Ireland	Developed
Czech Republic	Developing	Italy	Developed
Estonia	Developing	Luxembourg	Developed
Georgia	Developing	Netherlands	Developed
Hungary	Developing	Norway	Developed
Kazakhstan	Developing	Portugal	Developed
Kosovo	Developing	Spain	Developed
Latvia	Developing	Sweden	Developed
Liechtenstein	Developing	Switzerland	Developed
Lithuania	Developing	United Kingdom	Developed
Macedonia	Developing	Russia	Developing
Malta	Developing	San Marino	Developing
Moldova	Developing	Serbia	Developing
Monaco	Developing	Slovakia	Developing
Montenegro	Developing	Slovenia	Developing
Poland	Developing	Turkey	Developing
Romania	Developing	Ukraine	Developing

Source: Countries of the World Official Website (www.countries-ofthe-world.com)

Appendix B

Summary of variables

Variable	Abbreviated	Data Source	Unit
Bio-energy consumption	$\ln CON_{it}$	Eurostat	Tonnes of oil equivalent (TOE)
Gross Domestic Product per capita	$\ln GDP_{it}$	World Bank Datasets	Market prices (constant 2005) (billion €)
Investment	$\ln INV_{it}$	World Bank Datasets	Gross Fixed Capital Formation (Constant 2010 $)
Bioenergy Price	$\ln PR_{it}$	Eurostat	USD ($)
Capital Input	$\ln CI_{it}$	Eurostat	Fixed Assets Input (Constant 2010 $)