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Bioenergy Intensity and Its Determinants in European Continental Countries: Evidence Using GMM Estimation

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Abstract: This study contributes to the existing literature by examining bioenergy intensity and its related factors in European continental countries (ECC). Through its focus on European continental (EC), this study extends the existing literature, which mainly covers nationwide studies. The current paper aims to investigate the variables of bioenergy intensity in the ECC during the term 2005–2013, construct its economic variables, and evaluate the volume and significance level of the impact of each variable on bioenergy intensity. To successfully achieve this analysis, a generalised method of moments estimator (GMM) was designed for ECC. The estimated models show that available bioenergy for final consumption has a positive impact on bioenergy intensity in ECC. The largest influence on bioenergy intensity was evaluated for the annual growth of Gross Domestic Product (GDP), followed by the investment and referral that the scale and construction of this economic variable should be taken into consideration and applied as a precious bioenergy regulation and policy instruments for developing bioenergy intensity and efficiency.

Keywords: bioenergy industry; bioenergy intensity; European continental countries (ECC); GMM regression

1. Introduction

1.1. Bioenergy Industry Profile

Bioenergy intensity is a measure used in macroeconomics level individually as an indicator representing the relation between the available bioenergy for final consumption and gross domestic product (GDP). Bioenergy intensity is one of the most significant indicators for monitoring the performance of European continental countries (ECC) to achieve the ambition of the national renewable energy action plan (NREAP) objectives by the end of 2030. If the country's economy becomes extra efficient in its use of bioenergy outputs and the related GDP stay persistence, then the rate of the bioenergy intensity index will fall accordingly. The bioenergy intensity can provide the ECC with information that can be used to consistently track changes in ECC bioenergy intensity over time for the entire economy, as well as for specific end-use products (bioheat, biocool, biofuel, and bioelectricity) and end-use sectors (transportation, industrial, residential, and commercial).

In 2015, the European Bioenergy Outlook and European Biomass Association's key findings referred to the primary energy production from traditional sources in the European Union (EU) decreasing from 941 million tonnes of oil equivalent (Mtoe) in 2000 to 789 million tonnes of oil equivalent (Mtoe) by the end of 2013. However, the energy outputs from renewable and sustainable sources increased by 100% from 97 million tonnes of oil equivalent (Mtoe) to 192 million tonnes of oil equivalent (Mtoe) in 2000 and 2013 respectively [1]. This demonstrates that renewable energy outputs are the most significant primary energy source, even more important than energy outputs from conventional resources such as coal, gas, and oil. As per the European Bioenergy Outlook in 2015, countries with the highest primary energy production from renewable and sustainable sources in the EU are Germany, Italy, and France, with the volume of 33 Mtoe, 23 Mtoe, and 23 Mtoe, respectively.

In spite of the reduction in total primary energy production in the EU, energy consumption increased continuously and steadily during the last several decades, which led European countries to depend mainly on energy imports to fill up the shortage of energy supply. On the one hand, European countries' total available energy for final consumption reached 1.666 Mtoe in 2013. Moreover, the overall gross elementary energy generation of fuel combination, fossil oil available for final consumption is still the most significant energy provenance with an estimated 33.4%, the natural invader with 23.2%, solid fossil fuels 17.2%, nuclear fusion 13.6%, and renewable energy with 11.8%. The share of bioenergy primary production is more than 65% of Europe's energy from green and environmentally friendly sources. The growth and development of all green and friendly energy sources together in the past five years were as significant as the development and growth of the bioenergy industry in absolute terms with an estimated 6.2 Mtoe per year.

The bioenergy industry is by far the main contributor in renewable energy sources in Europe. Bioenergy outputs provide 123 Mtoe to the primary energy generation which is roughly equal to the primary energy production from natural gas and higher than the primary energy production from oil. However, the bioenergy industry and all other renewable energy industries must be developed and growing continuously. European countries have committed to reducing CO_2 emissions with 2 °C targets through enhancing the consumption of energy from renewable and sustainable sources. EU countries import fossil fuels worth more than 1 billion euro per day, which represents an estimated 4% of EU countries' annual GDP. The dependency of European countries on the bioenergy industry will not only prevent the depletion of energy resources, but will provide a strong position from a geopolitical perspective, and support the GDP's decline.

The bioenergy industry is the primary source of available renewable energy for final consumption, accounting for 61.2% in European countries. Also, it is a significant index to scale the performance in meeting the ambitions of the national renewable energy action plan (NREAP) goals by the end of 2020. In 2014, the European commission (EC) announced the NREAP's new targets for European countries by the end of 2030. The scheduled NREAP targets to be achieved in 2030 can play a significant role in developing European countries' economic systems, energy industry competitiveness, security, and sustainability as follows: lowering greenhouse gas (GHG) emissions by 40% in comparison to 1990, increase the consumption of renewable energy sources by 27%, reducing the production of energy from conventional sources by 27%, and raising efficiency and energy savings by 27% [1].

Based on a prior study [1], European countries depend on the bioenergy industry significantly to meet the NREAP targets by 31 December 2020. However, the share of bioenergy in the gross available renewable energy for final consumption represent 91.4%, 89.2%, and 86.9% in Estonia, Poland, Hungary, and Lithuania, respectively. The highest contribution rate of natural biomass sources of available bioenergy for final consumption in 2013 was found to be 31.9%, 31.8%, and 31.6% in Latvia, Finland, and Sweden, respectively. In 2013, bioenergy available for final consumption was 105.1 Mtoe, which represents almost double the amount of bioenergy available for final consumption in 2000. An estimated 74.6% of the available biomass crops were used in the bioenergy industry to generate heat outputs of 78.4 Mtoe, bioelectricity products of 13.5 Mtoe, and biofuel outcomes of 13.1 Mtoe. The most significant share of biomass crops utilized in the bioenergy industry to produce bioheat output to the residential market was 53% and 25.5% in the industry.

The improvement of bioenergy intensity can be achieved through lowering GHG emissions, reducing energy dependency from traditional sources, creating green economic activity, and increasing the rate of employment in Europe. The same study shows that employment requirements in the bioelectricity industry in European countries is three to six folds higher than the employment requirement to produce electricity from traditional energy sources. However, the required employment in the bioenergy industry is higher in comparison to different conventional energy and renewable energy sources due to the extra stages in the generation cycle. In 2013, the bioenergy industry added economic strength in rural areas throughout European countries. Based on the European biomass association statistical report, the figure representing created employment opportunities in the bioenergy industry amounted to 494,550 jobs (64% with solid biomass, 20% with biofuels, 13% with biogas and 3% with waste) in 2013, and the economic added value was estimated at 56 billion euro.

The problem with this study is that bioenergy industry production has a shortage of industrialized fuel supply chains and continued scepticism over whether bioenergy is a sustainable source of energy, namely due to the low rate of bioenergy industry growth. However, so far, the bioenergy industry has not registered significant mass in the European energy combination. Moreover, bioenergy production has no output on minimizing unit costs, and is almost uncompetitive economically with other renewable energy outputs such as solar and wind energies in European energy markets. Following various renewable energy industries in European countries, bioenergy has dealt with serious problems because of the low price of coal imports, low CO_2 amounts in the emissions mitigation system, and the regulatory and economic reaction against renewable energy policies such as substantial reductions in government aids. It is fair to question the economic variables of the intensity of bio-energy output in European Continental members, as European countries plan to increase their renewable energy applications to meet the NREAP's by 31 December 2020.

This research gap leads to the primary questions of the study: Does the ECC region have the proper intensity to provide for the demand in its bio-energy output to achieve the 2030 goal? What are the macroeconomic and microeconomic factors of the intensity of bio-energy output? The current paper aims to investigate the intensity of bio-energy output and the determinants of bio-energy intensity in the ECC. The importance of this study is to define the intensity and pertaining factors, which would impact bio-energy output in the ECC. Moreover, this research assesses the macroeconomic and microeconomic variables of the intensity of bio-energy output in the ECC to detect factors that minimise the intensity of bio-energy outputs and discover how the intensity of bio-energy outputs may shorten bio-energy consumption required to meet the NREAP 2030 goal.

This study may contribute to early empirical bio-energy research by (1) applying various assessors with different validation tests to evaluate the data, (2) checking the intensity of bio-energy outputs between 2005 and 2013, (3) investigating the economic determinants of the intensity of the bioenergy industry in ECC countries. The findings reveal the correlation among economic variables and the intensity of bio-energy outputs in ECC countries between 2005 and 2013. Furthermore, the study's empirical findings report more profound analysis outcomes, which depend on whether the country is developing or developed (Table 1).

Table 1. 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 and 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

Table 1. *Cont.*

European Continental Countries			
Country	**Status**	**Country**	**Status**
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).

1.2. The Study Motivation

The reasoning behind this study is that the bioenergy industry shows one of the most capital (physical) efficient transitions from conventional energy sources such as coal to renewable and sustainable energy sources. In 2011, European countries produced more than 850 thousand Gigawatt-hours of power electricity from a solid fossil fuel including coal and lignite, which accounted for 25% of total energy production [2]. Minimizing the share of coal-fired output generation is an essential part of any decarburization plan. Biomass co-firing and coal-to-biomass are two primary strategies that show the capability to utilize the available coal factories to produce bioenergy products. This can help European countries save billions and produce competitive output in the energy markets, which does not apply to any other renewable and sustainable energy sources.

A significant transformation from traditional energy sources to green and friendly sources is happening due to various factors, such as implicating the shortage of conventional fossil fuel's domestic supply to meet the local demand of traditional fossil fuel and mitigate the emission of greenhouse gases. Moreover, the production of conventional energy from fossil fuel sources is struggling to meet domestic energy demands from conventional sources in ECC countries. Earlier studies [3,4] state that the bioenergy industry is commonly identified as the most hopeful source of renewable energy that has great potential to substitute traditional energy outputs in energy markets. This will help ECC countries to cover the quickly increasing domestic demand for energy stimulated by dramatic economic and population growth, particularly in developing countries in the ECC.

Other studies [5–7] related to the growth of the biomass and bioenergy industry have been recently carried out. However, they have concluded that the bioenergy industry's technical restrictions and limitations are considered to be two of the most significant strategies that have the potential to lead economic growth and development. Previous studies [8–10] concluded that the improvement of the supply chain determinants of the biomass and bioenergy industry has great potential for good green economic productivity, functionality, and growth associated with friendly and efficient ecological productivity. This study can investigate the intensity issue and related economic determinants based on two studies [11,12] that established an econometric technique to identify the economic variables that impact intensity of bio-energy industry in European region.

The structure of this study will constitute five main sections: 1. Introduction, 2. Literature Review, 3. Materials and Methods, 4. Results, and 5. Conclusion.

2. Literature Review

Contemporaneous papers about the intensity of the sustainable energy industry provide much information regarding the correlation among the intensity of the sustainable energy industry and the economic decomposition. Most studies report that economic determinant has had a significant impact on the intensity of the renewable energy industry. However, this section will provide an overview and background of the recent studies related to the bioenergy industry, as well as the determinants and previously used methodologies and approaches. No previous literature of the bioenergy industry provides a shared method for scaling the intensity of generations related to economic variables. Furthermore, experimental evidence on the correlation between bioenergy intensity and the related economic determinants is limited. However, the goal of this research is to build on the limitations of previous studies.

2.1. Empirical Background

According to one study [13], focusing on the case of renewable energy intensity in Italy in the early twenty-first century is highly pertinent because Italy upgraded one of the wealthiest sustainable energy programmes in the world. The study used an authentic microdata-based approach to estimate renewable energy intensity. Also, it counted through different applications of the collected panel data the correlation between renewable energy intensity and labor input between 2002 and 2009. The main outcomes of one previous research [13] are as follows: the renewable energy intensity in Italy significantly increased between 2008 and 2009, and did not affect gaining scales of labor input, the skilled labour impact outcomes when the renewable energy intensity raises.

Due to the planet's high dependency on conventional fuel and the control of its energy industry in the economy, increasing energy efficiency remains the best exercise for EU members to reduce energy intensity and to achieve its objectives set in the Copenhagen Climate Change Conference to mitigate at least 40% of CO_2 releases intensity by 31 December 2030. Numerous studies analyzed energy intensity trends and drivers in more than 40 major economies using the world-bank database. Most of the previous studies [14–18] analyzed the energy intensity indicator in different sectors and industries in the world. At this level, the studies found that despite a shift in the world's economy to more energy-intensive countries, aggregate energy efficiency improved mainly due to technological change.

Optimizing energy structure to reduce carbon intensity as an effective way to build the low-carbon city was one of the aims of the Chinese Ministry of Energy and Environment [19–23]. The high energy consumption in China has led to increasing emissions of greenhouse gases (GHG) and worsening energy shortages to meet domestic demand of the energy in China [24–28]. The fluctuations of China's energy intensity have attracted the attention of many scholars, but fewer studies consider the data quality of official input-output tables [29–34]. In China, many earlier studies investigated energy intensity and related economic determinants among the country's regions and provinces [34–39].

One of the more favorable approaches to achieving climate change policy aims is developing the efficiency of the energy industry, which may subsequently lead to the minimization of environmental pollution, climate change damages, and the required amount of input to generate a necessary volume of production. According to the world input-output database (WIOD), many studies analyzed the reduction of energy intensity in the European Union (EU) member countries in different periods. The modifications in energy intensity are contributed mostly in two ways: alterations in the manufacturing decomposition of an economy, and change in its energy manufacture intensities. In European countries, different studies [40–44] analyzed the decomposition and determines factors of energy intensity in various sectors such as residual, commercial, electricity, transportation, and manufacturing in European countries in recent decades [45–50].

Despite the expansion of taxation and subsidized energy preservation policies, Africa's developing countries have different obstacles to overcome to meet energy efficiency aims. Energy intensity scales increased significantly, negatively affecting the surety of the energy industry. This draws attention to a significant matter: which macroeconomic and microeconomic conditions encourage representatives to be energy aware? In Africa, many studies [31–33] analyzed the problem of energy intensity determinants based on different econometric approaches in South Africa, Nigeria, and Algeria respectively. These studies provide a solid background into the productivity of voluntary and involuntary energy tradition regulations, the privilege of ministry-conventional energy support minimizing regulation, the function of technology in energy tradition, and the function of utilization ability on the influence of gross fixed capital formation on energy intensity.

Another previous study [48] defined the impacts of economic factors of efficiency rate in the bio-energy sector for European members. The study was founded according to an analytical model related to data envelopment analysis (DEA), presenting a relationship among input variables and the rate of technological efficacy. The study investigated the possible factors of technical efficacy ratio in the bio-energy sector for the EU's 28 countries between 1990 and 2013. The findings of the study found the technical efficacy rate of the bio-energy sector in 28 EU developed members to be lower than in EU-28 developing members [12]. Various determinants: resource, annual growth of GDP, inflation rate, and interest ratio mainly influenced the technological efficacy rate of the bio-energy sector in the EU-28 developing and developed countries between 1990 and 2013.

2.2. Theoretical Background

This section reviews different studies that used a panel regression approach to evaluate various econometric models. Numerous methods to panel regression were applied in these studies. However, they had to make a detailed justification of the most appropriate and applicable approach. In the wood fuel industry of Sub-Sahara Africa country, an early study [46] applied a generalized method of moment (GMM) different from system approaches. On the other hand, the same researcher in a separate study [49] related to the wood fuel industry of Sub-Sahara African countries, implemented the generalized method of moment (GMM) system approach for five different models that relied on previous studies [42,47] using the Arellano Bond Dynamic Panel GMM estimators.

Bioenergy production efficiency has an essential function in decreasing the intensity of the bio-energy industry due to the decompositions of the intensity indicator being economical and consumption structures. To reduce the intensity indicator of renewable and non-renewable energy industries, different efficiency and productivity estimators can be used as independent variables as per the following: technological efficacy and pertaining elements (pure technological efficacy and scale efficacy), economic efficiency and related decompositions (price efficiency and technical efficiency), total factor productivity change and related decompositions (efficiency change and technological change), and efficiency change and pertaining decompositions (pure technical efficiency change and scale efficiency change) based on previous studies in the energy industry [19–21,43].

The outcome of validation tests of the rebound effect showed it could disturb the improvement of energy intensity. On the other hand, the negative influence of the technological movement of energy intensity would generate from the disturbance of the energy rebound effect. However, numerous studies [33,34,36,40,47] analyzed the problem of energy intensity determinants, relying on the oriented least square and related random and fixed effect models. Another study [32] applied Autoregressive Distributed Lag models such as augmented mean group and mean group estimation using three different channels (one, two and three) to estimate the determinants of energy intensity problems.

Unlike earlier studies, this paper estimated the intensity of the bioenergy industry in ECCs. Also, researchers employed a regression panel analysis to investigate the influences of economic determinants on the intensity rate. The present research has concentrated on EECs, taking into consideration developed members and developing members, to examine the scale of intensity in the listed members. The study employed data panel analysis (GMM different and GMM system) for different periods (2005–2013 and 2009–2013). No previous research used the methodology, region, and terms as those applied in the present analysis. However, the current paper adds mainly to the bio-energy sector specifically, the sustainable energy industry in general, and related previous studies.

3. Methods and Materials

3.1. Empirical Model Development

The dependent factor is bio-energy intensity (EI). It is identified as the quantity of bio-energy used to produce a unit of output. According to previous studies [17,24], the bioenergy intensity indicator can be formed in Equation (1) as follows:

$$\text{Bioenergy Intenisty} = \frac{\text{Bioenergy Consumption}}{\text{Gross Domestic Product (GDP)}} \quad (1)$$

The established model for the present research will adopt the empirical frame of early studies [25] where bioenergy intensity is assumed to be determined by economic variables. The correlation between these determinants and bioenergy intensity is framed as:

$$\text{EI} = \text{f(GDP, INV, CI, CON)} \quad (2)$$

where EI bioenergy intensity status is calculated according to Equation (1), GDP represents the level of the gross domestic product showing the percentage of annual economic growth. INV represents the investment which in turn represents the capital formation (constant 2010$). CI refers to other factors related to capital (physical) inputs that could influence bioenergy intensity, and includes access to bioenergy industry plants and factories. And CON points to the available bioenergy output for final consumption per capita measured in a thousand tonnes of oil equivalent (TOE). Previous studies relied on applied models [25] by replacing energy intensity with bio-energy intensity because the bio-energy industry is the central element of the energy industry in ECC. By converting the dynamic correlation in Equation (2) into a panel framework and framing it in an econometric model, the following is produced:

$$\text{EI}_{\text{it}} = \alpha_{\text{it}} + \delta_{\text{it}} \ln\text{GDP}_{\text{it}} + \beta_{\text{it}} \ln\text{INV}_{\text{it}} + \theta_{\text{it}} \ln\text{CI}_{\text{it}} + \vartheta_{\text{it}} \ln\text{CON}_{\text{it}} + \epsilon_{\text{it}} \quad (3)$$

where α is constant of the model, ϵ is error term, and ln indicates to the natural logarithm, i refers to every individual county in the study and t points to the running period in the econometric model.

3.2. Panel Regression Technique

According to the characteristics of the data panel in this research, the study selects a panel regression approach to evaluate the study model. There are numerous econometric panel estimators in the current analysis. Studies need to build healthy and sound reasoning when it comes to the most appropriate applied econometric technique. Various panel regression estimators 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. In the case of a possible presence of endogeneity in the independent determinants, the applied econometric techniques are invalid. The estimated coefficients from these techniques will be biased with the hypothesis of serially unrelated noisy terms [24]. In these circumstances, the methods are inappropriate for the regression of this study as a result of the stated weaknesses.

These statistical issues can be defeated based on one study [11] that established an econometric technique named GMM. The GMM model can prevent the possible impacts of country time-invariant, time-specific, and country-specific by first differentiating the studied model. Applying the first difference, recommended by [11], can use instrumental determinants. The study suggested that exogenous determinants can work as specific tools. Also, the differenced lagged of the dependent factor and endogenous factors may be tooled with their lags in scales, lagging two or more terms. This method is called the first difference GMM approach. Regarding [9], the primary deficiency of the first difference GMM approach is that it neglects the possible provided information in the level correlation—also, the relationship between two estimators: first differences estimator and levels estimator.

Furthermore, Blundell and Bond [38] referred to different limitations of the first difference GMM approach that can impact the validity of the applied regress. Also, they can be weak instruments in primary difference if the scale determinants present insistence. Arellano and Bover [28] points out that a regressing scale and fundamental difference as a GMM system method can address this weakness and limitations. According to reference [38], the GMM system approach is a development over the first difference GMM, and it is suitable when the studied period is short, or the dependent factor is highly aligned with autoregressive term nearing unity. Considering all the highlighted econometric matters, the present study implements GMM difference and system approaches for the evaluation. First difference GMM approach can be applied as a validation test estimator.

According to previous studies [28,38], the GMM approach validity and reliability are evaluated using validation estimators, which relate to Hansen diagnostic estimates of over-defining weakness and the second order serial relation. The Hansen diagnostic test investigates the overall reliability of the instruments used in the regressed analysis. On the other hand, second-order serial correlation estimators can be applied to study the hypothesis related to no serial correlation in the error term.

4. Results and Discussion

4.1. Descriptive Statistics and Correlation Matrix Tests

To regress the primary model, this study applied two statistical validations: statistical descriptive test and relationship matrix test. The findings of the descriptive statistical analysis are laid out in Table 2. According to Table 2, the definitive statistical test shows figures related to maximum values, minimum values, standard deviation values, mean values, and observations value, the sample overall, and between the sample countries. The findings suggest that there is an essential difference between countries and between countries. The results rationalize the implementation of the panel regression approach.

Table 2. Descriptive statistics.

Variables	Observations	Mean	Standard Deviation	Min	Max
EI	450	55.037	232.806	0.0422	1870.782
GDP	450	52.607	5.666	33.017	94.04
INV	450	91.506	156.816	9.23×10^{-10}	732.9188
CON	450	791517	301,390	406.1	2.14×10^{7}
CI	450	860.250	1944.151	0.254	26,992.99

Table 3 presents the relation matrix among the used independent determinants in the current study. The findings suggest there is no evidence for a high relationship between bioenergy intensity and economic determinants. Therefore, this study can proceed with the estimation of other determinants; the scale of relationship is acceptable between and within the used variables. Overall, the analysis can be taken into consideration as a safe estimation from the multicollinearity issue.

Table 3. Correlation Matrix.

Variables	GDP	INV	CON	CI
GDP	1.000			
INV	0.2582	1.000		
CON	−0.1246	0.2250	1.000	
CI	0.1974	0.4869	−0.1479	1.000

4.2. Panel Data Analysis of Bioenergy Intensity in the ECC

Table 4 shows the findings of the regressed econometric model applying GMM difference estimators and GMM system estimators with bioenergy intensity in ECC as the dependent factor.

The identification tests used to check validity and appropriateness of this employed two different GMM approaches. For example, the Hansen-J estimator could not decline the over-defining limits, and Diff-in-Hansen estimator also could not reject the further tools needed for GMM regression. These specification tests emphasize the reliability and appropriateness of the used devices. Likewise, the serial correlation estimator declines the null hypothesis related to no first-order auto-correlation and confirms the invalid assumption associated with no second order auto-correlation. As a result, the residues of the regressed model may not include auto-correlation issues. Mainly, the lagged relied factor shows a significant and positive correlation, which refers to functionality of the applied equation.

Table 4. Estimated results of the panel GMM with the bioenergy Intensity in the ECC.

Variables	**Difference GMM**	**System GMM**
	Coefficients	**Coefficients**
GDP	0.603 * (0.073)	1.754 ** (0.014)
INV	0.106 (0.425)	0.049 ** (0.045)
CON	1.082 *** (0.000)	0.005 (0.846)
CI	0.218 (0.229)	0.061 (0.370)
Instruments	10	9
No of groups	50	50
AR1: *p*-value	0.095	0.868
AR2: *p*-value	0.756	0.940
Hansen J-test	0.510	0.883
Diff-in-Hansen test	0.271	0.048

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

As earlier stated, this study's estimation will consider GMM system approach findings. On the other hand, the GMM difference approach outcomes will be employed for validation purposes. This will shed light on the analysis and justifications of the GMM system findings all over the findings display. The coefficients of the independent determinants applied in the GMM system approaches such as annual growth of gross domestic product (GDP), available bioenergy for final consumption (CON), investment (INV), and capital input (CI) have the expected signs. The coefficients provided by the GMM different approach for the GDP variable show the same findings with the factors supplied by the GMM system approach. This indicates that the estimated results are robust.

The findings coefficient of the lagged relied factor shows positive and correlation, which approves the functional quality of the applied econometric analysis, leading to the justification of using the GMM approach. The estimated findings in Table 4 align with previous studies that bioenergy intensity rate improves with the increase of GDP rate in ECC. The estimated coefficient of bioenergy intensity in difference and system GMM regress, results that roughly increases by 1.754% and 0.603% in GDP, respectively, can drive to improve bioenergy intensity by 1%. The GMM difference and system approaches suggest that a rise in GDP rate in ECC has a strong link to a boosting bioenergy intensity. Likewise, the evaluated coefficient of bioenergy intensity in GMM system estimation shows that 0.049% increase in INV explanatory variable can lead to a boost in the bioenergy intensity by 1%. However, the robust estimator GMM different reveals that an increase of 1.082% in bioenergy CON in ECC can improve the strength of the bioenergy industry by 1%.

Table 5 contains results of the influence of the economic determinants of the dependent variable bio-energy intensity in ECC developing countries. The specification tests' outcomes for both difference and system GMM assessors favored the assessed outcomes. The result of the coefficient related to the lagged relied factor shows a statistical positive and significant relationship, it approves the functional quality of the approach, and it can support the implementation of the GMM system approach. The findings suggest that GDP shows a positive correlation as predicted previously. In particular, an increase of 0.50% and 2.11% in GDP as resulted by GMM difference approach and GMM system approach respectively, can lead to evolvement in bioenergy intensity by 1%. This outcome explains the previous statement that GDP may have a positive impact on bio-energy intensity in ECC developing countries. The regressed coefficients of independent determinants provided by the GMM difference approach present somewhat different findings in comparison to the factors of independent determinants presented by the GMM system approach. The robust estimator GMM difference shows an increase in CON by 0.99%, which can evolve the intensity of bioenergy industry by 1%. However, the coefficient of the GDP shows the same statistical importance level and sign. It suggests that the results obtained from the GMM difference estimator may support it as a robust test.

Table 5. Estimated results of the panel GMM with the bioenergy intensity in the ECC developing countries.

Variables	Difference GMM	System GMM
	Coefficients	Coefficients
GDP	0.500 * (0.061)	2.11 *** (0.006)
INV	0.216 (0.167)	0.054 (0.107)
CON	0.996 *** (0.000)	0.005 (0.933)
CI	0.074 (0.586)	0.061 (0.248)
Instruments	10	9
No of groups	32	32
AR1: *p*-value	0.059	0.107
AR2: *p*-value	0.866	0.147
Hansen J-test	0.291	0.895
Diff-in-Hansen test	0.450	0.056

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

According to Table 6, the outcomes detect that GDP has decisive and statistical importance when it comes to bioenergy intensity in ECC developed countries. To be precise, the increases of 083% and 1.161% in GDP as depicted by difference and system GMM assessors, respectively, can lead to the upgrade of bioenergy intensity by 1%. This outcome suggests that the correlation between the GDP and bio-energy intensity in ECC developed countries is more than that of ECC developing countries. The robust regressor difference GMM results demonstrate an increase in the economic determinants CON and CI by 1.022% and 0.168%, suggesting it can promote the intensity of bioenergy industry by 1% in the developed countries model. It is important to highlight that the three regressed models in Tables 4–6 have met the expectation of the applied specification tests.

Table 6. Estimated results of the panel GMM with the bioenergy intensity in the ECC developed countries.

Variables	Difference GMM	System GMM
	Coefficients	Coefficients
GDP	0.083 (0.550)	1.161 * (0.068)
INV	0.073 (0.400)	0.087 (0.337)
CON	1.022 *** (0.000)	0.004 (0.938)
CI	0.168 ** (0.033)	0.043 (0.179)
Instruments	10	9
No of groups	18	18
AR1: *p*-value	0.451	0.009
AR2: *p*-value	0.598	0.399
Hansen J-test	0.695	0.611
Diff-in-Hansen test	0.134	0.856

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

4.3. The Economic Determinants of Bioenergy Intensity in the ECC

Bioenergy intensity can be defined theoretically based on previous studies [19–25,32] as the bioenergy consumption per unit GDP, and is considered the most widely used measure of bioenergy efficiency. On the one hand, the high bioenergy intensity indicates a high cost of converting bioenergy output into GDP. On the other hand, low bioenergy intensity indicates a lower cost of converting bioenergy output into GDP. However, high bioenergy intensity means high industrial output as a portion of GDP. However, countries with low bioenergy intensity signify a labor-intensive economy. The domestic economy has developed rapidly, and the growth of GDP has significantly affected the bioenergy intensity in ECC. Therefore, there is a positive correlation between GDP and EI in the ECC. A strong economic foundation and inadequate investment in the ECC make the relationship between investment and bioenergy intensity significant.

Following a previous study [25], this particular study takes the annual growth of GDP as one of the main explanatory variables. Table 4 shows the regressed outcomes of the panel GMM system with bioenergy intensity in the ECC. The findings of the study reveal that the GDP determinant has a positive and vital influence on bioenergy intensity at the 5% statistical level. Also, Table 5 shows the impact of economic determinants on bio-energy intensity in the ECC developing members that apply the panel GMM approach. The findings suggest that GDP rate determinant has a significant and positive impact on bio-energy intensity in ECC developing members at the statistical level of 1%. Table 6 shows the result of the influence of economic factors on the bio-energy intensity level in the ECC developed members using the panel GMM estimator. The results indicate that the GDP variable has a significant and positive influence on the intensity of bio-energy in developed countries at a statistical scale of 10%.

The next explanatory variable is an investment which has a primary role in developing the bioenergy industry and significantly improving bioenergy intensity. To meet scheduled NREAP targets by the end of 2030, European governments executed an economic motivation regulation that leads to a quick enhance in capital investment. Thus, substantial and significant agreements of bio-energy intensive outputs were consumed. However, the rapid increase of bioenergy intensity investments and their high added-value led to a large improvement in bioenergy intensity. In line with previous studies [21,22,36], which highlighted the impact of investment determinants on the power of the energy industry, Table 4 shows that the investment determinant has statistical importance and positive impact on the intensity of the bioenergy industry at the statistical level of 5%. The limitations of this study are related to sample sizes and the insufficiency of reliable data, as well as the lack of previous research on the topic. Future studies can investigate the impact of bio-energy intensity on the consumption of the bio-energy industry in the EU region, developing, and developed countries between 1990 and 2018.

5. Conclusions and Recommendation

The current study estimates the determinants are boosting developments of bioenergy intensity in the ECC between 2005 and 2013, and takes into consideration environmental pollution regulation and economic disturbance. The GMM approach succeeded in finding the economic determinants of bio-energy intensity in the developing and developed members of the ECC. The impacts of factors like GDP, investment, physical input, and consumption on bioenergy intensity were also assessed. The outcomes of the investigation are precise. Take material information as an example. This research could not detect a significant impact of the physical input on overall bio-energy intensity. An elevated rate of physical input has a noticeably rising influence on the decomposition constructional bio-energy effect outputs. However, the bio-energy outputs intensity effect decreases in capital input.

Bioenergy intensity is a significant index of continual improvement and is therefore of specific benefit to research. In neither hypothesis nor exercise is there scientific evidence and professional acceptance of the independent variables that impact bioenergy intensity, or on the trend and solidity of their impact. The current research aims to investigate bioenergy intensity in the ECC and to analyse the economic variables with a pertaining effect on bioenergy intensity, specifically the available bioenergy for final consumption, GDP, investment and capital input. The study relies on panel data analysis between 2005 and 2013, where the estimation factors are regressed by the GMM system estimator and the GMM difference estimator with further consideration to the GMM system.

It was established that investment and GDP have a positive impact on bioenergy intensity. The most significant influence on bioenergy intensity, in terms of solidity and explanatory power, was assessed for GDP, while the other economic variables have lower significance. This finding includes GDP among these variables could be taken into consideration as a valuable bioenergy policy tool for developing bioenergy effectiveness, particularly in the developing and developed countries of the ECC. Therefore, results from this study offer objective regulation and policy inclusions for increasing bioenergy technical efficiency in the ECC. Decision makers should give more consideration to a combination of policies rather than an individual system in separation.

The evidence suggests that investment has been a primary key in developing bioenergy intensity in recent years in ECC countries. Due to continuously enhancing the efficiency of bioenergy outputs, it will be fundamental to adopt other countries' experiences that have achieved fast development in achieving this aim. Many types of research about the macroeconomic and microeconomic determinants of the bioenergy intensity have specific restrictions and obstacles that should be taken into consideration. The primary limitation of the data availability, due to the chosen variable of bioenergy intensity studies in an empirical analysis, relies on a persistent time series for an adequate long term: the more complete the data, the more efficient and functional the measurement of bioenergy intensity.

Appointing the economic variables that influence bioenergy intensity adds to the knowledge about this phenomenon as a highly significant index of sustainable improvement. Bioenergy intensity developments are taking place significantly fast, but not soon enough to achieve the planet's bioenergy deficiencies. Significant mitigation in bio-energy intensity, 35%–40%, may be implemented in 2005 through to 2030. Due to the predicted quick economic outgrowth, these developments in bio-energy intensity may not limit the outgrowth of bio-energy consumption with its pertaining advantages to the climate and steadiness of the EU's economy.

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